



AAMS

Annals of the Academy of Medicine, Singapore

MCI(P) 041/11/2014

VOLUME 44

NUMBER 5

FREE PAPERS

MAY 2015



Reproduced with permission from:
Pearl Gan

*"The butterfly counts not months but moments,
and has time enough."*

Rabindranath Tagore (1861–1941)
Indian poet

CONTENTS

Editorial

155 **MERS-CoV: Where Are We Now?**

[Claire Thomas](#)

Original Articles

157 **Long-term Outcomes of Medical Therapy Versus Coronary Revascularisation in Patients with Intermediate Stenoses Guided by Pressure Wire**

[Hongyu Shi](#), [Chi Hang Lee](#), [Mark YY Chan](#), et al

164 **Prevalence of Chronic Kidney Disease in Adults with Type 2 Diabetes Mellitus**

[Serena KM Low](#), [Chee Fang Sum](#), [Lee Ying Yeoh](#), et al

172 **Academic Medicine Education Institute (AM-EI): Transforming the Educational Culture of Health Professionals**

[Sok Hong Goh](#), [Kok Hian Tan](#), [Robert K Kamei](#), et al

178 **Is the Apprehension Test Sufficient for the Diagnosis of Anterior Shoulder Instability in Young Patients without Magnetic Resonance Imaging (MRI)?**

[Krishna Kumar](#), [Milindu Makandura](#), et al

Please see inside Contents for the full list of articles.

Professional Medical Congress Organisation for Professionals....



ACADEMY OF MEDICINE, SINGAPORE – YOUR PARTNER IN MEDICAL EVENTS

Academy of Medicine, Singapore (AMS) is a professional institution of medical and dental specialists devoted to advancing the art and science of medicine in Singapore by promoting and maintaining the highest professional standards of competence and ethical integrity, thereby providing the highest quality of patient care for the people in Singapore.

The Academy organises congresses and scientific meetings to enhance the continuing professional development of specialists in Singapore including the Singapore-Malaysia Congress of Medicine biennially.

The Professional Medical Congress Organisation (PMCO) department is an integral arm which specialises in medical conference management and provides professional conference management for any scientific meetings organized by any medical societies, charities and associations.

Our PMCO unit is led by an experienced team of people with event management qualifications and experiences to ensure that each event is well managed and delivered professionally. To date, AMS has organized and managed over 200 national and regional events that include trade exhibitions.

- Secretariat services
- Accounts management
- Venue management
- Event conceptualization and planning
- Website design services, with online registration system
- Marketing, publicity and publication
- Speakers' & delegates' management
- Abstract & exhibition management
- On-site event management & support

Contact us at

Academy of Medicine, Singapore
PCO Services, 81 Kim Keat Road #12-00, NKF Centre, Singapore 328836
Tel: (65) 6593 7882 Email: events@ams.edu.sg Website: www.ams.edu.sg

MERS-CoV: Where Are We Now?

Claire Thomas, ¹MRCP, FRCPath, DPhil (OXON)

Prior to 2002, coronaviruses were known mainly for causing mild human upper respiratory tract infections (URTIs) and enteric and respiratory infections in many animals. However, their full pathogenic potential was only realised when an outbreak of severe pneumonia with a high fatality rate occurred in southern China, and they were identified as a coronavirus—severe acute respiratory syndrome (SARS).

By dint of international cooperation, enhanced international and local infection control, the outbreak and the virus were contained but not without a significant loss of life and lessons learnt.

Outbreaks caused by coronaviruses were then quiescent, until summer 2012, when an Egyptian virologist¹ identified a novel coronavirus from a 49-year-old man with severe pneumonia from Jeddah, Saudi Arabia. What was unique was that the doctor had posted his findings on the World Health Organization's (WHO) ProMED-mail, a rapid and effective way of disseminating information on emerging infections and outbreaks. This sixth human coronavirus became known as the Middle East respiratory syndrome coronavirus (MERS-CoV), sequenced by the Erasmus Medical Centre and found to be a beta coronavirus with sequence homology to bat coronaviruses.

Global spread was quick by dint of air travel and medical tourism; in September 2012, the same type of coronavirus, with a near identical sequence, was isolated from a patient with severe respiratory illness who had been transferred from the Middle East to London, United Kingdom. Retrospectively, an outbreak of severe pneumonia in healthcare workers in a hospital at Zarqa, Jordan, in April 2012, was shown to be likely caused by the MERS-CoV.²

With MERS-CoV, the response of the Saudi local authorities was rapid and collaborative—they invited a WHO team, consisting of expertise from abroad and Singapore, to work with them.

Epidemiologically, MERS-CoV has been found in the Middle East, with cases originating from Jordan, Saudi

Arabia, Qatar, Lebanon, Yemen, and the United Arab Emirates.

As of 18 November 2014, there have been a total of 806 laboratory confirmed cases of MERS-CoV infection including 343 deaths, 449 recovered and 14 currently active cases in Saudi Arabia, with up to 900 possible cases currently reported worldwide. The case fatality rate is 42.5% (ProMED-mail), higher than SARs.

Most patients present with a severe acute respiratory condition that requires hospitalisation. It is also possible for subclinical MERS to occur; research has shown that up to 20% of cases show no signs of active infection but have MERS-CoV antibodies in their blood. Like SARS, it is postulated that there has been zoonotic spread, with an animal reservoir being likely. Recent studies have pointed to camel contact (milk, excretions, meat) being a risk factor, with transmission in 1 case via camel saliva/nasal excretions, but human cases have occurred with no such epidemiological links. The same virus was found in camels and their Saudi farmer who died of MERS in November 2013.³ A recent study showed that dromedary camels infected with MERS-CoV developed mild upper respiratory tract symptoms, but shed large quantities of virus from the upper respiratory tract.⁴ There does appear to be links with bat coronavirus, as similar viruses have been found in European and Ghana bats, but they have not as yet been confirmed as a reservoir.

Although person-to-person transmission was thought to be low,⁵ the number of healthcare workers becoming infected, subsequent to nursing infected patients, has been notable, as have cases within household contacts. A recent study of 26 index patients with MERS-CoV infection and their 280 household contacts, showed a rate of secondary transmission of 5%.⁶ Hence, it is paramount that when a case is suspect, respiratory and contact precautions are adhered to.

The current advice from the Singapore Ministry of Health, working with the Islamic Religious Council of Singapore (MUIS) to Haj and Umrah pilgrims and travellers from

¹Department of Infectious Diseases, Singapore General Hospital

Address for Correspondence: Dr Claire Thomas, Department of Infectious Diseases, Singapore General Hospital, Academic Block, 3rd Floor, Singapore 169608.
Email: claire.p.thomas@sgh.com.sg

Singapore, is to avoid contact with camels and camel products, and to seek medical advice if they become unwell with fever or URTI, within 2 weeks of returning from the region. All emergency departments here have clear risk assessment and management policies for suspected MERS-CoV cases developed from the SARS days and influenza outbreak of 2009; to date, all cases screened have been negative by dint of rapid PCR-based testing.

These cases have put an added pressure on isolation facilities which were expanded after SARs in preparation for future pandemics. But we must continue to be on high alert with this emerging virus; the death of a returning pilgrim in April 2014 in Malaysia, was very close to home. The concern also is that MERS-CoV has the potential to mutate into a strain that does transmit more effectively from person-to-person, so complacency is not an option.

Unlike SARS, the outbreak is ongoing, with cases continuing to be identified in the Middle East and in returning travellers throughout the world. We are all still at risk from MERS-CoV and must remain vigilant. Singapore is a major port and global transport hub, with tourism both medical and otherwise, that bring in a steady influx of visitors from the Middle East.

Post-SARS, the 2009 *H1N1* flu pandemic, and now MERS-CoV, local and international ongoing surveillance and network systems have been set up as well as universal information technology access to rapid alert systems, allowing infection professionals in the field autonomy to alert the international community to emerging pathogens or new disease trends. The expansion of the Internet worldwide has been a huge step forward in combating disease and in emergency planning.

The key thing is to know that there is a problem, understand the potential threat, and to make immediate action plans based on current knowledge of the likely spread of the disease. Mathematical models and socioeconomic models are important in predicting how diseases may spread but nothing is as important as early communication and cooperation.

As Sun Tzu said, “If you know your enemies and know yourself, you will not be imperiled in a hundred battles... if you do not know your enemies nor yourself, you will be imperiled in every single battle.” With the MERS-CoV pandemic, we are alert and prepared, but we must continue to maintain vigilance, as Singapore and the world have done since the outbreak of SARS 11 years ago.

REFERENCES

1. Zaki AM, Van Boheemen S, Bestebroer TM, Osterhaus AD, Fouchier RA. Isolation of a novel coronavirus from a man with pneumonia in Saudi Arabia. *N Engl J Med* 2012;367:1814-20.
2. European Centre for Disease Prevention and Control. Communicable Disease Threats Report, Week 18, 29 April - 5 May 2012. Severe respiratory disease of unknown origin - Jordan - outbreak in ICU [Internet]. Stockholm: European Centre for Disease Prevention and Control; 2012. Available at: <http://www.ecdc.europa.eu/en/publications/Publications/CDTR%20online%20version%204%20May%202012.pdf>. Accessed
3. Azhar EI, El-Kafrawy SA, Farraj SA, Hassan AM, Al-Saeed MS, Hashem AM, et al. Evidence for camel-to-human transmission of MERS coronavirus. *N Engl J Med* 2014;370:2499-505.
4. Adney DR, van Doremalen N, Brown VR, Bushmaker T, Scott D, de Wit E, et al. Replication and shedding of MERS-CoV in upper respiratory tract of inoculated dromedary camels. *Emerg Infect Dis* 2014;20:1999-2005.
5. World Health Organization. Novel coronavirus infection – update [Internet]. Geneva: World Health Organization; 2013. Available at: http://www.who.int/csr/don/2013_02_13/en/. Accessed
6. Drosten C1, Meyer B, Müller MA, Corman VM, Al-Masri M, Hossain R, et al. Transmission of MERS-coronavirus in household contacts. *N Engl J Med* 2014;371:828-35.

MERS-CoV: Where Are We Now?

Claire Thomas, ¹MRCP, FRCPath, DPhil (OXON)

Prior to 2002, coronaviruses were known mainly for causing mild human upper respiratory tract infections (URTIs) and enteric and respiratory infections in many animals. However, their full pathogenic potential was only realised when an outbreak of severe pneumonia with a high fatality rate occurred in southern China, and they were identified to be a coronavirus—severe acute respiratory syndrome (SARS).

By dint of international cooperation, enhanced international and local infection control, the outbreak and the virus were contained but not without a significant loss of life and lessons learnt.

Outbreaks caused by coronaviruses were then quiescent, until summer 2012, when an Egyptian virologist¹ identified a novel coronavirus from a 49-year-old man with severe pneumonia from Jeddah, Saudi Arabia. What was unique was that the doctor had posted his findings on the World Health Organization's (WHO) ProMED-mail, a rapid and effective way of disseminating information on emerging infections and outbreaks. This sixth human coronavirus became known as the Middle East respiratory syndrome coronavirus (MERS-CoV), sequenced by the Erasmus Medical Centre and found to be a beta coronavirus with sequence homology to bat coronaviruses.

Global spread was quick by dint of air travel and medical tourism; in September 2012, the same type of coronavirus, with a near identical sequence, was isolated from a patient with severe respiratory illness who had been transferred from the Middle East to London, United Kingdom. Retrospectively, an outbreak of severe pneumonia in healthcare workers in a hospital at Zarqa, Jordan, in April 2012, was shown to be likely caused by the MERS-CoV.²

With MERS-CoV, the response of the Saudi local authorities was rapid and collaborative—they invited a WHO team, consisting of expertise from abroad and Singapore, to work with them.

Epidemiologically, MERS-CoV has been found in the Middle East, with cases originating from Jordan, Saudi

Arabia, Qatar, Lebanon, Yemen, and the United Arab Emirates.

As of 18 November 2014, there have been a total of 806 laboratory confirmed cases of MERS-CoV infection including 343 deaths, 449 recovered and 14 currently active cases in Saudi Arabia, with up to 900 possible cases currently reported worldwide. The case fatality rate is 42.5% (ProMED-mail), higher than SARs.

Most patients present with a severe acute respiratory condition that requires hospitalisation. It is also possible for subclinical MERS to occur; research has shown that up to 20% of cases show no signs of active infection but have MERS-CoV antibodies in their blood. Like SARS, it is postulated that there has been zoonotic spread, with an animal reservoir being likely. Recent studies have pointed to camel contact (milk, excretions, meat) being a risk factor, with transmission in 1 case via camel saliva/nasal excretions, but human cases have occurred with no such epidemiological links. The same virus was found in camels and their Saudi farmer who died of MERS in November 2013.³ A recent study showed that dromedary camels infected with MERS-CoV developed mild upper respiratory tract symptoms, but shed large quantities of virus from the upper respiratory tract.⁴ There does appear to be links with bat coronavirus, as similar viruses have been found in European and Ghana bats, but they have not as yet been confirmed as a reservoir.

Although person-to-person transmission was thought to be low,⁵ the number of healthcare workers becoming infected, subsequent to nursing infected patients, has been notable, as have cases within household contacts. A recent study of 26 index patients with MERS-CoV infection and their 280 household contacts, showed a rate of secondary transmission of 5%.⁶ Hence, it is paramount that when a case is suspect, respiratory and contact precautions are adhered to.

The current advice from the Singapore Ministry of Health, working with the Islamic Religious Council of Singapore (MUIS) to Haj and Umrah pilgrims and travellers from

¹Department of Infectious Diseases, Singapore General Hospital

Address for Correspondence: Dr Claire Thomas, Department of Infectious Diseases, Singapore General Hospital, Academic Block, 3rd Floor, Singapore 169608.
Email: claire.p.thomas@sgh.com.sg

Singapore, is to avoid contact with camels and camel products, and to seek medical advice if they become unwell with fever or URTI, within 2 weeks of returning from the region. All emergency departments here have clear risk assessment and management policies for suspected MERS-CoV cases developed from the SARS days and influenza outbreak of 2009; to date, all cases screened have been negative by dint of rapid polymerase chain reaction (PCR)-based testing.

These cases have put an added pressure on isolation facilities which were expanded after SARs in preparation for future pandemics. But we must continue to be on high alert with this emerging virus; the death of a returning pilgrim in April 2014 in Malaysia, was very close to home. The concern also is that MERS-CoV has the potential to mutate into a strain that does transmit more effectively from person-to-person, so complacency is not an option.

Unlike SARS, the outbreak is ongoing, with cases continuing to be identified in the Middle East and in returning travellers throughout the world. We are all still at risk from MERS-CoV and must remain vigilant. Singapore is a major port and global transport hub, with tourism both medical and otherwise, that bring in a steady influx of visitors from the Middle East.

Post-SARS, the 2009 *H1N1* flu pandemic, and now MERS-CoV, local and international ongoing surveillance and network systems have been set up as well as universal information technology access to rapid alert systems, allowing infection professionals in the field autonomy to alert the international community to emerging pathogens or new disease trends. The expansion of the Internet worldwide has been a huge step forward in combating disease and in emergency planning.

The key thing is to know that there is a problem, understand the potential threat, and to make immediate action plans based on current knowledge of the likely spread of the disease. Mathematical models and socioeconomic models are important in predicting how diseases may spread but nothing is as important as early communication and cooperation.

As Sun Tzu said, “If you know your enemies and know yourself, you will not be imperiled in a hundred battles... if you do not know your enemies nor yourself, you will be imperiled in every single battle.” With the MERS-CoV pandemic, we are alert and prepared, but we must continue to maintain vigilance, as Singapore and the world have done since the outbreak of SARS 11 years ago.

REFERENCES

1. Zaki AM, Van Boheemen S, Bestebroer TM, Osterhaus AD, Fouchier RA. Isolation of a novel coronavirus from a man with pneumonia in Saudi Arabia. *N Engl J Med* 2012;367:1814-20.
2. European Centre for Disease Prevention and Control. Communicable Disease Threats Report, Week 18, 29 April - 5 May 2012. Severe respiratory disease of unknown origin - Jordan - outbreak in ICU [Internet]. Stockholm: European Centre for Disease Prevention and Control; 2012. Available at: <http://www.ecdc.europa.eu/en/publications/Publications/CDTR%20online%20version%204%20May%202012.pdf>. Accessed November 2014.
3. Azhar EI, El-Kafrawy SA, Farraj SA, Hassan AM, Al-Saeed MS, Hashem AM, et al. Evidence for camel-to-human transmission of MERS coronavirus. *N Engl J Med* 2014;370:2499-505.
4. Adney DR, van Doremalen N, Brown VR, Bushmaker T, Scott D, de Wit E, et al. Replication and shedding of MERS-CoV in upper respiratory tract of inoculated dromedary camels. *Emerg Infect Dis* 2014;20:1999-2005.
5. World Health Organization. Novel coronavirus infection – update [Internet]. Geneva: World Health Organization; 2013. Available at: http://www.who.int/csr/don/2013_02_13/en/. Accessed November 2014.
6. Drosten C1, Meyer B, Müller MA, Corman VM, Al-Masri M, Hossain R, et al. Transmission of MERS-coronavirus in household contacts. *N Engl J Med* 2014;371:828-35.

MERS-CoV: Where Are We Now?

Claire Thomas, ¹*MRCP, FRCPath, DPhil (OXON)*

Prior to 2002, coronaviruses were known mainly for causing mild human upper respiratory tract infections (URTIs) and enteric and respiratory infections in many animals. However, their full pathogenic potential was only realised when an outbreak of severe pneumonia with a high fatality rate occurred in southern China, and they were identified to be a coronavirus—severe acute respiratory syndrome (SARS).

By dint of international cooperation, enhanced international and local infection control, the outbreak and the virus were contained but not without a significant loss of life and lessons learnt.

Outbreaks caused by coronaviruses were then quiescent, until summer 2012, when an Egyptian virologist¹ identified a novel coronavirus from a 49-year-old man with severe pneumonia from Jeddah, Saudi Arabia. What was unique was that the doctor had posted his findings on the World Health Organization's (WHO) ProMED-mail, a rapid and effective way of disseminating information on emerging infections and outbreaks. This sixth human coronavirus became known as the Middle East respiratory syndrome coronavirus (MERS-CoV), sequenced by the Erasmus Medical Centre and found to be a beta coronavirus with sequence homology to bat coronaviruses.

Global spread was quick by dint of air travel and medical tourism; in September 2012, the same type of coronavirus, with a near identical sequence, was isolated from a patient with severe respiratory illness who had been transferred from the Middle East to London, United Kingdom. Retrospectively, an outbreak of severe pneumonia in healthcare workers in a hospital at Zarqa, Jordan, in April 2012, was shown to be likely caused by the MERS-CoV.²

With MERS-CoV, the response of the Saudi local authorities was rapid and collaborative—they invited a WHO team, consisting of expertise from abroad and Singapore, to work with them.

Epidemiologically, MERS-CoV has been found in the Middle East, with cases originating from Jordan, Saudi

Arabia, Qatar, Lebanon, Yemen, and the United Arab Emirates.

As of 18 November 2014, there have been a total of 806 laboratory confirmed cases of MERS-CoV infection including 343 deaths, 449 recovered and 14 currently active cases in Saudi Arabia, with up to 900 possible cases currently reported worldwide. The case fatality rate is 42.5% (ProMED-mail), higher than SARs.

Most patients present with a severe acute respiratory condition that requires hospitalisation. It is also possible for subclinical MERS to occur; research has shown that up to 20% of cases show no signs of active infection but have MERS-CoV antibodies in their blood. Like SARS, it is postulated that there has been zoonotic spread, with an animal reservoir being likely. Recent studies have pointed to camel contact (milk, excretions, meat) being a risk factor, with transmission in 1 case via camel saliva/nasal excretions, but human cases have occurred with no such epidemiological links. The same virus was found in camels and their Saudi farmer who died of MERS in November 2013.³ A recent study showed that dromedary camels infected with MERS-CoV developed mild upper respiratory tract symptoms, but shed large quantities of virus from the upper respiratory tract.⁴ There does appear to be links with bat coronavirus, as similar viruses have been found in European and Ghana bats, but they have not as yet been confirmed as a reservoir.

Although person-to-person transmission was thought to be low,⁵ the number of healthcare workers becoming infected, subsequent to nursing infected patients, has been notable, as have cases within household contacts. A recent study of 26 index patients with MERS-CoV infection and their 280 household contacts, showed a rate of secondary transmission of 5%.⁶ Hence, it is paramount that when a case is suspect, respiratory and contact precautions are adhered to.

The current advice from the Singapore Ministry of Health, working with the Islamic Religious Council of Singapore (MUIS) to Haj and Umrah pilgrims and travellers from

¹Department of Infectious Diseases, Singapore General Hospital

Address for Correspondence: Dr Claire Thomas, Department of Infectious Diseases, Singapore General Hospital, Academic Block, 3rd Floor, Singapore 169608.
Email: claire.p.thomas@sgh.com.sg

Singapore, is to avoid contact with camels and camel products, and to seek medical advice if they become unwell with fever or URTI, within 2 weeks of returning from the region. All emergency departments here have clear risk assessment and management policies for suspected MERS-CoV cases developed from the SARS days and influenza outbreak of 2009; to date, all cases screened have been negative by dint of rapid polymerase chain reaction (PCR)-based testing.

These cases have put an added pressure on isolation facilities which were expanded after SARs in preparation for future pandemics. But we must continue to be on high alert with this emerging virus; the death of a returning pilgrim in April 2014 in Malaysia, was very close to home. The concern also is that MERS-CoV has the potential to mutate into a strain that does transmit more effectively from person-to-person, so complacency is not an option.

Unlike SARS, the outbreak is ongoing, with cases continuing to be identified in the Middle East and in returning travellers throughout the world. We are all still at risk from MERS-CoV and must remain vigilant. Singapore is a major port and global transport hub, with tourism both medical and otherwise, that bring in a steady influx of visitors from the Middle East.

Post-SARS, the 2009 *H1N1* flu pandemic, and now MERS-CoV, local and international ongoing surveillance and network systems have been set up as well as universal information technology access to rapid alert systems, allowing infection professionals in the field autonomy to alert the international community to emerging pathogens or new disease trends. The expansion of the Internet worldwide has been a huge step forward in combating disease and in emergency planning.

The key thing is to know that there is a problem, understand the potential threat, and to make immediate action plans based on current knowledge of the likely spread of the disease. Mathematical models and socioeconomic models are important in predicting how diseases may spread but nothing is as important as early communication and cooperation.

As Sun Tzu said, “If you know your enemies and know yourself, you will not be imperiled in a hundred battles... if you do not know your enemies nor yourself, you will be imperiled in every single battle.” With the MERS-CoV pandemic, we are alert and prepared, but we must continue to maintain vigilance, as Singapore and the world have done since the outbreak of SARS 12 years ago.

REFERENCES

1. Zaki AM, Van Boheemen S, Bestebroer TM, Osterhaus AD, Fouchier RA. Isolation of a novel coronavirus from a man with pneumonia in Saudi Arabia. *N Engl J Med* 2012;367:1814-20.
2. European Centre for Disease Prevention and Control. Communicable Disease Threats Report, Week 18, 29 April - 5 May 2012. Severe respiratory disease of unknown origin - Jordan - outbreak in ICU [Internet]. Stockholm: European Centre for Disease Prevention and Control; 2012. Available at: <http://www.ecdc.europa.eu/en/publications/Publications/CDTR%20online%20version%204%20May%202012.pdf>. Accessed 1 November 2014.
3. Azhar EI, El-Kafrawy SA, Farraj SA, Hassan AM, Al-Saeed MS, Hashem AM, et al. Evidence for camel-to-human transmission of MERS coronavirus. *N Engl J Med* 2014;370:2499-505.
4. Adney DR, van Doremalen N, Brown VR, Bushmaker T, Scott D, de Wit E, et al. Replication and shedding of MERS-CoV in upper respiratory tract of inoculated dromedary camels. *Emerg Infect Dis* 2014;20:1999-2005.
5. World Health Organization. Novel coronavirus infection – update [Internet]. Geneva: World Health Organization; 2013. Available at: http://www.who.int/csr/don/2013_02_13/en/. Accessed 1 November 2014.
6. Drosten C1, Meyer B, Müller MA, Corman VM, Al-Masri M, Hossain R, et al. Transmission of MERS-coronavirus in household contacts. *N Engl J Med* 2014;371:828-35.

MERS-CoV: Where Are We Now?

Claire Thomas, ¹MRCP, FRCPath, DPhil (OXON)

Prior to 2002, coronaviruses were known mainly for causing mild human upper respiratory tract infections (URTIs) and enteric and respiratory infections in many animals. However, their full pathogenic potential was only realised when an outbreak of severe pneumonia with a high fatality rate occurred in southern China, and they were identified to be a coronavirus—severe acute respiratory syndrome (SARS).

By dint of international cooperation, enhanced international and local infection control, the outbreak and the virus were contained but not without a significant loss of life and lessons learnt.

Outbreaks caused by coronaviruses were then quiescent, until summer 2012, when an Egyptian virologist¹ identified a novel coronavirus from a 49-year-old man with severe pneumonia from Jeddah, Saudi Arabia. What was unique was that the doctor had posted his findings on the World Health Organization's (WHO) ProMED-mail, a rapid and effective way of disseminating information on emerging infections and outbreaks. This sixth human coronavirus became known as the Middle East respiratory syndrome coronavirus (MERS-CoV), sequenced by the Erasmus Medical Centre and found to be a beta coronavirus with sequence homology to bat coronaviruses.

Global spread was quick by dint of air travel and medical tourism; in September 2012, the same type of coronavirus, with a near identical sequence, was isolated from a patient with severe respiratory illness who had been transferred from the Middle East to London, United Kingdom. Retrospectively, an outbreak of severe pneumonia in healthcare workers in a hospital at Zarqa, Jordan, in April 2012, was shown to be likely caused by the MERS-CoV.²

With MERS-CoV, the response of the Saudi local authorities was rapid and collaborative—they invited a WHO team, consisting of expertise from abroad and Singapore, to work with them.

Epidemiologically, MERS-CoV has been found in the Middle East, with cases originating from Jordan, Saudi

Arabia, Qatar, Lebanon, Yemen, and the United Arab Emirates.

As of 18 November 2014, there have been a total of 806 laboratory confirmed cases of MERS-CoV infection including 343 deaths, 449 recovered and 14 currently active cases in Saudi Arabia, with up to 900 possible cases currently reported worldwide. The case fatality rate is 42.5% (ProMED-mail), higher than SARs.

Most patients present with a severe acute respiratory condition that requires hospitalisation. It is also possible for subclinical MERS to occur; research has shown that up to 20% of cases show no signs of active infection but have MERS-CoV antibodies in their blood. Like SARS, it is postulated that there has been zoonotic spread, with an animal reservoir being likely. Recent studies have pointed to camel contact (milk, excretions, meat) being a risk factor, with transmission in 1 case via camel saliva/nasal excretions, but human cases have occurred with no such epidemiological links. The same virus was found in camels and their Saudi farmer who died of MERS in November 2013.³ A recent study showed that dromedary camels infected with MERS-CoV developed mild upper respiratory tract symptoms, but shed large quantities of virus from the upper respiratory tract.⁴ There does appear to be links with bat coronavirus, as similar viruses have been found in European and Ghana bats, but they have not as yet been confirmed as a reservoir.

Although person-to-person transmission was thought to be low,⁵ the number of healthcare workers becoming infected, subsequent to nursing infected patients, has been notable, as have cases within household contacts. A recent study of 26 index patients with MERS-CoV infection and their 280 household contacts, showed a rate of secondary transmission of 5%.⁶ Hence, it is paramount that when a case is suspect, respiratory and contact precautions are adhered to.

The current advice from the Singapore Ministry of Health, working with the Islamic Religious Council of Singapore (MUIS) to Haj and Umrah pilgrims and travellers from

¹Department of Infectious Diseases, Singapore General Hospital

Address for Correspondence: Dr Claire Thomas, Department of Infectious Diseases, Singapore General Hospital, Academic Block, 3rd Floor, Singapore 169608.
Email: claire.p.thomas@sgh.com.sg

Singapore, is to avoid contact with camels and camel products, and to seek medical advice if they become unwell with fever or URTI, within 2 weeks of returning from the region. All emergency departments here have clear risk assessment and management policies for suspected MERS-CoV cases developed from the SARS days and influenza outbreak of 2009; to date, all cases screened have been negative by dint of rapid polymerase chain reaction (PCR)-based testing.

These cases have put an added pressure on isolation facilities which were expanded after SARs in preparation for future pandemics. But we must continue to be on high alert with this emerging virus; the death of a returning pilgrim in April 2014 in Malaysia, was very close to home. The concern also is that MERS-CoV has the potential to mutate into a strain that does transmit more effectively from person-to-person, so complacency is not an option.

Unlike SARS, the outbreak is ongoing, with cases continuing to be identified in the Middle East and in returning travellers throughout the world. We are all still at risk from MERS-CoV and must remain vigilant. Singapore is a major port and global transport hub, with tourism both medical and otherwise, that bring in a steady influx of visitors from the Middle East.

Post-SARS, the 2009 *H1N1* flu pandemic, and now MERS-CoV, local and international ongoing surveillance and network systems have been set up as well as universal information technology access to rapid alert systems, allowing infection professionals in the field autonomy to alert the international community to emerging pathogens or new disease trends. The expansion of the Internet worldwide has been a huge step forward in combating disease and in emergency planning.

The key thing is to know that there is a problem, understand the potential threat, and to make immediate action plans based on current knowledge of the likely spread of the disease. Mathematical models and socioeconomic models are important in predicting how diseases may spread but nothing is as important as early communication and cooperation.

As Sun Tzu said, “If you know your enemies and know yourself, you will not be imperiled in a hundred battles... if you do not know your enemies nor yourself, you will be imperiled in every single battle.” With the MERS-CoV pandemic, we are alert and prepared, but we must continue to maintain vigilance, as Singapore and the world have done since the outbreak of SARS 12 years ago.

REFERENCES

1. Zaki AM, Van Boheemen S, Bestebroer TM, Osterhaus AD, Fouchier RA. Isolation of a novel coronavirus from a man with pneumonia in Saudi Arabia. *N Engl J Med* 2012;367:1814-20.
2. European Centre for Disease Prevention and Control. Communicable Disease Threats Report, Week 18, 29 April - 5 May 2012. Severe respiratory disease of unknown origin - Jordan - outbreak in ICU [Internet]. Stockholm: European Centre for Disease Prevention and Control; 2012. Available at: <http://www.ecdc.europa.eu/en/publications/Publications/CDTR%20online%20version%204%20May%202012.pdf>. Accessed 1 November 2014.
3. Azhar EI, El-Kafrawy SA, Farraj SA, Hassan AM, Al-Saeed MS, Hashem AM, et al. Evidence for camel-to-human transmission of MERS coronavirus. *N Engl J Med* 2014;370:2499-505.
4. Adney DR, van Doremalen N, Brown VR, Bushmaker T, Scott D, de Wit E, et al. Replication and shedding of MERS-CoV in upper respiratory tract of inoculated dromedary camels. *Emerg Infect Dis* 2014;20:1999-2005.
5. World Health Organization. Novel coronavirus infection – update [Internet]. Geneva: World Health Organization; 2013. Available at: http://www.who.int/csr/don/2013_02_13/en/. Accessed 1 November 2014.
6. Drosten C1, Meyer B, Müller MA, Corman VM, Al-Masri M, Hossain R, et al. Transmission of MERS-coronavirus in household contacts. *N Engl J Med* 2014;371:828-35.

Addendum

Since this review was written, South Korea is experiencing an outbreak of MERS-CoV, wherein a returning traveller from the Middle East was not initially recognised as being potentially infectious, and this resulted in onward transmission in the healthcare setting and beyond, to local countries. This outbreak emphasises the need to remain vigilant, especially as cases are still occurring in the Middle East, with the potential rapid onward spread.

27-Gauge Vitrectomy for Primary Rhegmatogenous Retinal Detachment: Is it Feasible?

Dear Editor,

Pars plana vitrectomy (PPV) using the 27-gauge transconjunctival approach is the last frontier of small gauge vitrectomy. Only 1 paper has been published so far describing the use of 27-gauge vitrectomy in a limited number of cases, including epiretinal membranes, idiopathic macular holes, diabetic vitreous haemorrhages, a vitreous biopsy for presumed vitreoretinal lymphoma and a focal diabetic retinal detachment.¹ The use of 27-gauge vitrectomy systems, although innovative and efficient thanks to the high cut rate and vacuum, has met with some skepticism for the treatment of rhegmatogenous retinal detachments (RRD).² The main concerns are related to the stiffness of the light and vitrectomy probe, the ability of adequately removing the vitreous gel throughout such small probe, and the time required to perform a full vitrectomy. Furthermore, there is concern for potential postoperative hypotony due to the loss of tamponade, recognised as a major complication in eyes treated for RRD.³

We report our experience using a 27-gauge vitrectomy system for repair of primary RRD.

Surgical Technique

A phakic 45-year-old myopic man presented with a macula-off RRD with a large (2 o'clock hours) horseshoe retinal tear from 1 to 3 o'clock hours and smaller retinal tears in the upper quadrant of his right eye. The preoperative best-corrected visual acuity (BCVA) was hand motion (Fig. 1).

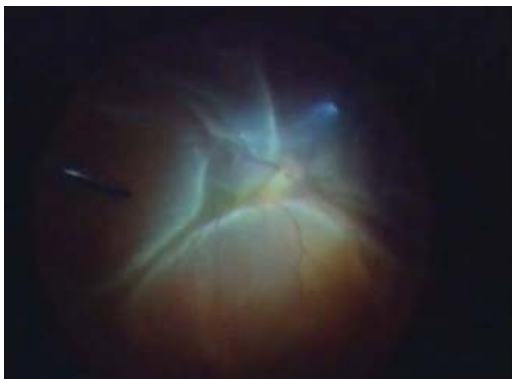


Fig. 1. Intraoperative view of total rhegmatogenous retinal detachment.

Surgery was performed under retrobulbar block with a 27-gauge transconjunctival sutureless vitrector using a 1-step system (Synergetics, USA Inc., O'Fallon, MO). The conjunctiva was displaced and 30° angled incisions were made through conjunctiva and sclera at 4 mm from the limbus (Fig. 2). The surgical parameters were the following: fixed cut rate to 2500, proportional vacuum from 150 mmHg to 500 mmHg, intraocular pressure (IOP) at 30 mmHg. A core vitrectomy was performed and the posterior hyaloid was detached and removed. During vitrectomy, the vitreous base was thoroughly trimmed with transcleral indentation with the help of the assistant surgeon (Fig. 3). The retinal periphery was inspected for retinal breaks, and any break found was treated with cryotherapy and with endolaser photocoagulation. There was no evidence of iatrogenic damage. Air-fluid exchange was then performed with humidified air. At the end of the surgical procedure, air-gas mixture (C3F8 12%) was injected. The overall surgical time for vitreous removal was 15 minutes.

The surgeon had no difficulty going throughout the different phases of the surgery, including trimming of the peripheral vitreous in a phakic eye and the air-fluid exchange. The lens was not touched during the procedure.

On the first postoperative day, the eye presented a complete gas filling (gas meniscus was not visible at indirect ophthalmoscopy examination). The IOP was 14 mmHg, ocular hypotony (IOP $\leq$ 6 mmHg) was not recorded in any of the follow-up visits. Retinal reattachment was achieved since the first follow-up and it remained stable



Fig. 2. Intraoperative 27-gauge vitrectomy trocars and infusion line.



Fig. 3. Intraoperative peripheral vitreous base trimming of the big horseshoe break.

at 1- to 3-month visits, as reported by optical coherence tomography (OCT) scan (Fig. 4). At the first month, the BCVA was 0.3 and progressively improved to 0.45 in the third month control with -5.50 spherical correction. At 3 months, an initial cortical cataract was also noted. No complications were recorded.

Discussion

As reported in the literature, the main benefits of small gauge vitrectomy are decreased inflammation and enhanced visual recovery, whereas these techniques do not seem to offer any advantage in terms of anatomical outcomes over 27-gauge vitrectomy.⁴

The main complications reported for 25-gauge and 23-gauge vitrectomy are postoperative hypotony and an increased risk for exogenous endophthalmitis, mainly due to the leakage of sclerotomies.³ The patient did not complain about any postoperative pain, and despite of a macula-off RRD, he gradually achieved functional and anatomical improvement. The OCT showed an interruption of both the external limiting membrane and the IS/OS junction, which progressively healed in the following visits. This is considered a good prognostic factor for potential functional recovery, as we have previously demonstrated.⁵

The advantage of 27-gauge vitrectomy is the decreased risk of leakage and the reduced traction on the retina due to the smaller port of the cutter. With the parameters used in this case, the flow rate was still satisfactory for the surgeon, but we believe that the increase of the vacuum over 600 mmHg and the cut rate could have further advantage in terms of safety, stability of vitreous cavity and speed of vitreous removal.

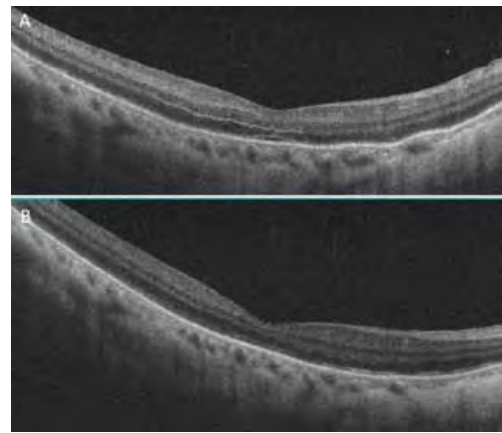


Fig. 4. OCT images. A) At month 1, interruption of both of the external limiting membrane (ELM) and IS/OS band. B) At month 3 with integrity of the ELM and restoration of the IS/OS band.

In our opinion, the main limit of 27-gauge instruments is the access to the peripheral retina, where the retinal tears are usually located. The reduced stiffness of the light pipe and of the cutter probe increase the difficulty of rotating the eye.

Conclusion

To the best of our knowledge, this is the first published report of a RRD operated with a 27-gauge calibre. We found it possible and easily feasible to perform a 27-gauge vitrectomy for primary RRD. We are currently performing a randomised trial on a large number of patients comparing 25-gauge versus 27-gauge PPV for primary RRD, in order to assess the risks and complications for this promising mini-invasive surgical approach.

The latest generation of the 27-gauge vitrectomy probe offers a new approach in inducing less traction with high flow instrumentation, keeping the safety of small gauge vitrectomy and the efficiency of small gauge techniques intact. The 27-gauge system has, at the same time, a high speed cutting rate and a smaller diameter compared with previous systems. This means reduced outflow and tractions, resulting in a safer peripheral shaving and a better fluidic stability, which are important in RRD working with a mobile retina. The 27-gauge takes a faster and smaller “vitreous bite” due to the high vacuum settings, allowing an adequate flow rate during the vitreous removal. Another advantage of a smaller calibre is the reduced risk for postoperative vitreous incarceration, avoiding further tractional phenomena and increased infection risk. In the near future, a different blade motion of the cutter probe will influence its kinetic energy, reducing the acceleration and fluid turbulence.⁶

REFERENCES

1. Oshima Y, Wakabayashi T, Sato T, Ohji M, Tano Y. A 27-gauge instrument system for transconjunctival sutureless microincision vitrectomy surgery. *Ophthalmology* 2010;117:93-102.
2. Lewis H. Sutureless microincision vitrectomy surgery: unclear benefit, uncertain safety. *Am J Ophthalmol* 2007;144:613-5.
3. Romano MR, Das R, Groenwald C, Stappeler T, Marticorena J, Valldeperas X, et al. Primary 23-gauge sutureless vitrectomy for rhegmatogenous retinal detachment. *Indian J Ophthalmol* 2012;60:29-33.
4. Ibarra MS, Hermel M, Prenner JL, Hassan TS. Longer-term outcomes of transconjunctival sutureless 25-gauge vitrectomy. *Am J Ophthalmol* 2005;139:831-6.
5. Romano MR, Vinciguerra P, Radice P, Scialdone A, Valldeperas X, Romano V, et al. Outer retinal layers. *Ophthalmology* 2011;118:1006.
6. Rossi T, Querzoli G, Angelini G, Malvasi C, Iossa M, Placentino L, et al. Fluid dynamics of vitrectomy probes. *Retina* 2014;34:558-67.

Mario R Romano, ¹MD, PhD, Jose L Vallejo-Garcia, ¹MD,
Fabrizio Scotti, ^{1,2}MD, Paolo Vinciguerra, ¹MD

¹Department of Ophthalmology, Humanitas Clinical and Research Center, Rozzano, Milan, Italy

²Department of Ophthalmology, Humanitas Gavazzeni Hospital, Bergamo, Italy

Address for Correspondence: Dr Mario R Romano, Humanitas Clinical and Research Center, Via Manzoni 56, 20089, Rozzano (Milan), Italy.
Email: mario.romano.md@gmail.com

27-Gauge Vitrectomy for Primary Rhegmatogenous Retinal Detachment: Is it Feasible?

Dear Editor,

Pars plana vitrectomy (PPV) using the 27-gauge transconjunctival approach is the last frontier of small gauge vitrectomy. Only 1 paper has been published so far describing the use of 27-gauge vitrectomy in a limited number of cases, including epiretinal membranes, idiopathic macular holes, diabetic vitreous haemorrhages, a vitreous biopsy for presumed vitreoretinal lymphoma and a focal diabetic retinal detachment.¹ The use of 27-gauge vitrectomy systems, although innovative and efficient thanks to the high cut rate and vacuum, has met with some skepticism for the treatment of rhegmatogenous retinal detachments (RRD).² The main concerns are related to the stiffness of the light and vitrectomy probe, the ability of adequately removing the vitreous gel throughout such small probe, and the time required to perform a full vitrectomy. Furthermore, there is concern for potential postoperative hypotony due to the loss of tamponade, recognised as a major complication in eyes treated for RRD.³

We report our experience using a 27-gauge vitrectomy system for repair of primary RRD.

Surgical Technique

A phakic 45-year-old myopic man presented with a macula-off RRD with a large (2 o'clock hours) horseshoe retinal tear from 1 to 3 o'clock hours and smaller retinal tears in the upper quadrant of his right eye. The preoperative best-corrected visual acuity (BCVA) was hand motion (Fig. 1).

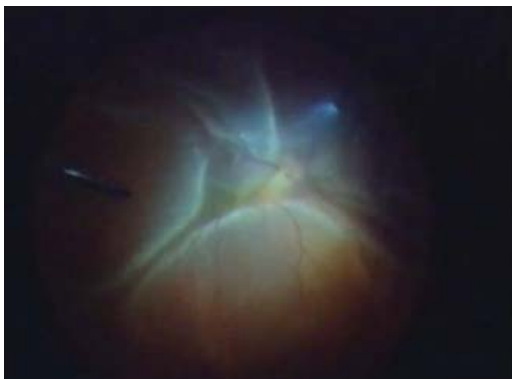


Fig. 1. Intraoperative view of total rhegmatogenous retinal detachment.

Surgery was performed under retrobulbar block with a 27-gauge transconjunctival sutureless vitrector using a 1-step system (Synergetics, USA Inc., O'Fallon, MO). The conjunctiva was displaced and 30° angled incisions were made through conjunctiva and sclera at 4 mm from the limbus (Fig. 2). The surgical parameters were the following: fixed cut rate to 2500, proportional vacuum from 150 mmHg to 500 mmHg, intraocular pressure (IOP) at 30 mmHg. A core vitrectomy was performed and the posterior hyaloid was detached and removed. During vitrectomy, the vitreous base was thoroughly trimmed with transcleral indentation with the help of the assistant surgeon (Fig. 3). The retinal periphery was inspected for retinal breaks, and any break found was treated with cryotherapy and with endolaser photocoagulation. There was no evidence of iatrogenic damage. Air-fluid exchange was then performed with humidified air. At the end of the surgical procedure, air-gas mixture (C3F8 12%) was injected. The overall surgical time for vitreous removal was 15 minutes.

The surgeon had no difficulty going throughout the different phases of the surgery, including trimming of the peripheral vitreous in a phakic eye and the air-fluid exchange. The lens was not touched during the procedure.

On the first postoperative day, the eye presented a complete gas filling (gas meniscus was not visible at indirect ophthalmoscopy examination). The IOP was 14 mmHg, ocular hypotony (IOP $\leq$ 6 mmHg) was not recorded in any of the follow-up visits. Retinal reattachment was achieved since the first follow-up and it remained stable



Fig. 2. Intraoperative 27-gauge vitrectomy trocars and infusion line.



Fig. 3. Intraoperative peripheral vitreous base trimming of the big horseshoe break.

at 1- to 3-month visits, as reported by optical coherence tomography (OCT) scan (Fig. 4). At the first month, the BCVA was 0.3 and progressively improved to 0.45 in the third month control with -5.50 spherical correction. At 3 months, an initial cortical cataract was also noted. No complications were recorded.

Discussion

As reported in the literature, the main benefits of small gauge vitrectomy are decreased inflammation and enhanced visual recovery, whereas these techniques do not seem to offer any advantage in terms of anatomical outcomes over 27-gauge vitrectomy.⁴

The main complications reported for 25-gauge and 23-gauge vitrectomy are postoperative hypotony and an increased risk for exogenous endophthalmitis, mainly due to the leakage of sclerotomies.³ The patient did not complain about any postoperative pain, and despite of a macula-off RRD, he gradually achieved functional and anatomical improvement. The OCT showed an interruption of both the external limiting membrane and the inner segment/outer segment junction (IS/OS) or ellipsoid zone, which progressively healed in the following visits. This is considered a good prognostic factor for potential functional recovery, as we have previously demonstrated.⁵

The advantage of 27-gauge vitrectomy is the decreased risk of leakage and the reduced traction on the retina due to the smaller port of the cutter. With the parameters used in this case, the flow rate was still satisfactory for the surgeon, but we believe that the increase of the vacuum over 600 mmHg and the cut rate could have further advantage in terms of safety, stability of vitreous cavity and speed of

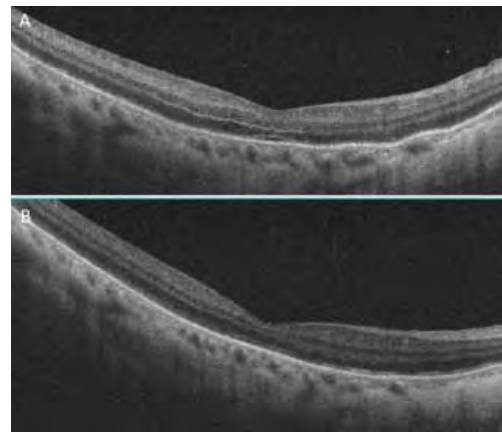


Fig. 4. OCT images. A) At month 1, interruption of both of the external limiting membrane (ELM) and inner segment/outer segment junction (IS/OS) band. B) At month 3 with integrity of the ELM and restoration of the IS/OS band.

vitreous removal.

In our opinion, the main limit of 27-gauge instruments is the access to the peripheral retina, where the retinal tears are usually located. The reduced stiffness of the light pipe and of the cutter probe increase the difficulty of rotating the eye.

Conclusion

To the best of our knowledge, this is the first published report of a RRD operated with a 27-gauge calibre. We found it possible and easily feasible to perform a 27-gauge vitrectomy for primary RRD. We are currently performing a randomised trial on a large number of patients comparing 25-gauge versus 27-gauge PPV for primary RRD, in order to assess the risks and complications for this promising mini-invasive surgical approach.

The latest generation of the 27-gauge vitrectomy probe offers a new approach in inducing less traction with high flow instrumentation, keeping the safety of small gauge vitrectomy and the efficiency of small gauge techniques intact. The 27-gauge system has, at the same time, a high speed cutting rate and a smaller diameter compared with previous systems. This means reduced outflow and tractions, resulting in a safer peripheral shaving and a better fluidic stability, which are important in RRD working with a mobile retina. The 27-gauge takes a faster and smaller “vitreous bite” due to the high vacuum settings, allowing an adequate flow rate during the vitreous removal. Another advantage of a smaller calibre is the reduced risk for postoperative vitreous incarceration, avoiding further tractional phenomena and increased infection risk. In the near future, a different blade motion of the cutter probe will influence its kinetic energy, reducing the acceleration and fluid turbulence.⁶

REFERENCES

1. Oshima Y, Wakabayashi T, Sato T, Ohji M, Tano Y. A 27-gauge instrument system for transconjunctival sutureless microincision vitrectomy surgery. *Ophthalmology* 2010;117:93-102.
2. Lewis H. Sutureless microincision vitrectomy surgery: unclear benefit, uncertain safety. *Am J Ophthalmol* 2007;144:613-5.
3. Romano MR, Das R, Groenwald C, Stappeler T, Marticorena J, Valldeperas X, et al. Primary 23-gauge sutureless vitrectomy for rhegmatogenous retinal detachment. *Indian J Ophthalmol* 2012;60:29-33.
4. Ibarra MS, Hermel M, Prenner JL, Hassan TS. Longer-term outcomes of transconjunctival sutureless 25-gauge vitrectomy. *Am J Ophthalmol* 2005;139:831-6.
5. Romano MR, Vinciguerra P, Radice P, Scialdone A, Valldeperas X, Romano V, et al. Outer retinal layers. *Ophthalmology* 2011;118:1006.
6. Rossi T, Querzoli G, Angelini G, Malvasi C, Iossa M, Placentino L, et al. Fluid dynamics of vitrectomy probes. *Retina* 2014;34:558-67.

Mario R Romano, ¹*MD, PhD*, Jose L Vallejo-Garcia, ¹*MD*,
Fabrizio Scotti, ^{1,2}*MD*, Paolo Vinciguerra, ¹*MD*

¹Department of Ophthalmology, Humanitas Clinical and Research Center, Rozzano, Milan, Italy

²Department of Ophthalmology, Humanitas Gavazzeni Hospital, Bergamo, Italy

Address for Correspondence: Dr Mario R Romano, Humanitas Clinical and Research Center, Via Manzoni 56, 20089, Rozzano (Milan), Italy.
Email: mario.romano.md@gmail.com

Single-level Anterior Corpectomy with Fusion versus 2-level Anterior Cervical Decompression with Fusion: A Prospective Controlled Study with 2-year Follow-up Using Cages for Fusion

Dear Editor,

Anterior cervical discectomy and fusion (ACDF) and anterior cervical corpectomy and fusion (ACCF) are performed for decompression of the spine when the primary compressive pathology lies anterior to the spinal cord – prolapsed intervertebral discs (PID), ossified posterior longitudinal ligament (OPLL), spondylosis, spondylodiscitis and retropulsion of fractured bony fragments. More specifically, ACDF is preferred for discal and retrodiscal pathology, whereas ACCF is indicated for retrovertebral pathology such as OPLL. When 2 consecutive levels of fusion are required, some authors have proposed the feasibility of ACCF to achieve a single-level fusion rather than 2-level fusion. Current literature shows similar clinical outcomes between the 2 methods.^{1,2} It is noted, however, that the fusion methods were heterogeneous in some studies when they were studying only 2 consecutive levels of fusion. Other studies compared ACCF versus ACDF with varied levels of fusion within each arm. We hypothesise that by using cages for both ACCF and ACDF, we would be able to better compare the intermediate term results and complications of 1-level ACCF versus 2-level ACDF.

Materials and Methods

This is a prospective case controlled study of 28 patients, 14 in each arm, with a minimum follow-up of 2 years. Ethical approval was sought from the institutional ethics committee. We reviewed prospectively collected data of all patients who underwent 2-level ACDF and 1-level ACCF by the senior author from 2007 to 2009. Twenty-eight consecutive patients with various pathologies amenable to anterior decompression were included. These patients were match-paired based on age, gender and levels of fusion.

The parameters recorded and analysed included patient demographics, presence of preoperative myelopathy, intraoperative details (duration of operation, level of operation, types and sizes of implant and bone grafts, somatosensory evoked potentials (SSEP) and motor evoked potentials (MEP) signal changes, complications), postoperative details (drop in haemoglobin, length of hospitalisation, and time to return to work), postoperative radiological findings (fusion, correction of kyphosis), functional scores ((visual analogue scale (VAS), neck

disability index (NDI), EuroQOL-5 dimensions (EQ-5D health score and EQ-5D index)), and surgery-related complications.

Functional scores were obtained during standard follow-up visits at 6 months, 1 year, and 2 years. Fusion rates based on the Bridwell grading system and degree of lordosis for the fused segments were recorded based on the interpretation of anteroposterior and lateral projections of the cervical spine obtained at the 2-year follow-up visit by 2 independent spine surgeons. The lordosis of the fused vertebral segments were measured using lines on Radweb software placed on the superior endplate and the inferior endplate of the fused vertebral segments. All patients were followed up for a minimum duration of 24 months.

Results

There were 28 patients reviewed, with 14 patients in each arm (ACCF versus ACDF). The mean age for ACCF was 58.5 years and 56.5 years for ACDF. The range of follow-up was between 24 months to 40 months, with a mean of 26.8 months. There was no lost to follow-up at the 24-month period for all patients. The male to female ratio was 6:1 (12:2) for both groups.

In the ACCF group, 3 patients had C4 corpectomy and fusion, 8 had C5 corpectomy and fusion, and 3 had C6 corpectomy and fusion. Similarly, the ACDF group had 3 patients with C3/4 and C4/5 fusion, 8 with C4/5 and C5/6 fusion, and 3 with C5/6 and C6/7 fusion. Comparable number of patients displayed myelopathic features preoperatively (11 in the ACCF group and 12 in the ACDF group). The functional scores preoperatively were similar in both groups.

All patients had PID requiring anterior decompression. The ACCF group had 6 patients with ossified posterior longitudinal ligament, 3 patients with hard and calcified sequestered discs, 3 patients with burst fractures with bony retropulsion, 1 patient with kyphotic deformity, and 1 patient with retrolisthesis requiring corpectomy.

Implants used in the ACCF group included 11 Harms cages (Depuy Spine, Raynham, MA) and 3 Pyramesh cages (Medtronic Sofamor Danek, Memphis, TN); 9 SlimLoc plates (Depuy Spine, Raynham, MA), 3 Atlantis plates (Medtronic Sofamor Danek, Memphis, TN), 1 CSLP

Table 1. Results

	ACCF	ACDF	P Value
Type of implants	11 Harms	9 Bengal	NA
	9 Slimloc	7 Slimloc	
	3 Atlantis	3 Atlantis	
	1 CSLP	2 CSLP	
	1 Eagle	1 Eagle	
	3 Pyramesh	2 Cervios	
		1 Orion	
		3 Solis	
Type of grafts	11 local	1 local with chronos	
	3 iliac	12 iliac	
		1 DBX®	
Duration of surgery (mins)			
(median) (SD)	148.5 (35.97)	165 (30.49)	
(mean)	158.58	155.93	1.000
Cage height (mm) (SD)	13 (0.86)	5.75 (0.85)	NA
Intraoperative events			
Excess bleeding	3	1	0.298
Intraoperative SSEP improvement	2	4	0.324
Intraoperative MEP improvement	2	3	0.500
Haemoglobin drop (SD)	0.95 (1.43)	0.85 (0.84)	0.490
Length of hospitalisation (days) (SD)	4 (9.88)	3.5 (9.97)	0.591
Return to work (days) (SD)	67 (42.51)	66 (48.46)	0.808
Fusion rates (at 2 years) (SD)	3 (0.579)	1 (0.363)	<0.001
Restoration of lordosis (deg) (SD)	-0.25 (8.54)	0 (3.68)	0.025
Postoperative surgical complications			
Cage subsidence	4	0	
Screw migration/cutout	3	0	
Screw in disc space	1	0	0.004
Implant breakage	0	0	
Adjacent level fractures	0	0	
Residual numbness	1	1	

ACCF: Anterior cervical corpectomy and fusion; ACDF: Anterior cervical discectomy and fusion; CSLP: Cervical spine locking plate; MEP: Motor evoked potentials; NA: Not applicable; SSEP: Somatosensory evoked potentials; SD: Standard deviation

plate (Synthes Spine, West Chester, PA), and 1 Eagle plate (Depuy Spine, Raynham, MA). In the ACDF group, there were 9 Bengal cages (Depuy Spine, Raynham, MA), 3 Solis Cages (Stryker Spine, Kalamazoo, MI), and 2 Cervios cages (Synthes Spine, West Chester, PA); 7 SlimLoc plates (Depuy Spine, Raynham, MA), 3 Atlantis plates (Medtronic Sofamor Danek, Memphis, TN), 2 CSLP plates (Synthes Spine, West Chester, PA), 1 Eagle plate (Depuy Spine, Raynham, MA), and 1 Orion plate (Medtronic Sofamor Danek, Memphis, TN). With regards to the bone grafts, the ACCF group had 11 patients with local grafts and 3 with anterior iliac crest grafts. The ACDF group had 12 patients with anterior iliac crest grafts, 1 with local graft and Chronos (Synthes Spine,

West Chester, PA), and 1 with demineralised bone matrix DBX (Synthes Spine, West Chester, PA).

The comparison of factors between ACCF and ACDF are shown in Table 1. At 2-year follow-up, there is no significant difference in operative times, bleeding rate, SSEP/MEP improvement, length of hospitalisation, return to work, and postoperative functional scores (based on VAS, NDI, EQ-5D health score and index) ($P > 0.05$). ACDF is superior in fusion rate ($P < 0.001$) and restoration of lordosis ($P = 0.025$). ACCF has more instrumentation and graft-related complications ($P = 0.004$).

One patient had residual C8 dermatomal numbness in

the ACDF group. In the ACCF group, 4 patients had cage subsidence, 3 had screw loosening resulting in migration and cutout, 1 had screw inserted into the disc space, and 1 had persistent neck pain not better with surgery requiring another magnetic resonance imaging (MRI) 1 year after surgery. The MRI did not show any worsening of spondylotic changes. Of those patients who had screw loosening, 1 patient (7%) had backing out of the anterior plate occurring 34 days after operation and requiring revision surgery. He underwent revision of anterior cervical plating with the instrumentation extending till C7 vertebra distally.

Discussion

There are numerous studies that compared ACDF and ACCF in treating multilevel cervical spondylotic myelopathy, with conflicting evidence.¹⁻⁵ Our study was able to standardise the use of cages for both ACCF and ACDF to compare the 2-year results and complications between this 2 surgical methods. Limitations of our study include a lack of randomisation of patients, lack of trauma cases and a short-term follow-up. Implant differences include different cages being used and different bone grafting techniques. Fusion was also not confirmed via computed tomography (CT) scans in our study. Based on our study, ACDF should be the procedure of choice for anterior decompression of 2-level cervical disease in view of better fusion rate, better restoration of lordosis, and less instrumentation and graft-related complications.

REFERENCES

1. Guo Q, Bi X, Ni B, Lu X, Chen J, Yang J, et al. Outcomes of three anterior decompression and fusion techniques in the treatment of three-level cervical spondylosis. *Eur Spine J* 2011;20:1539-44.
2. Uribe JS, Sangala JR, Duckworth EA, Vale FL. Comparison between anterior cervical discectomy fusion and cervical corpectomy fusion using titanium cages for reconstruction: analysis of outcome and long-term follow-up. *Eur Spine J* 2009;18:654-62.
3. Oh MC, Zhang HY, Park JY, Kim KS. Two-level anterior cervical discectomy versus one-level corpectomy in cervical spondylotic myelopathy. *Spine (Phila Pa 1976)* 2009;34:692-6.
4. Jiang SD, Jiang LS, Dai LY. Anterior cervical discectomy and fusion versus anterior cervical corpectomy and fusion for multilevel cervical spondylosis: a systematic review. *Arch Orthop Trauma Surg* 2012;132:155-61.
5. Lian XF, Xu JG, Zeng BF, Zhou W, Kong WQ, Hou TS. Noncontiguous anterior decompression and fusion for multilevel cervical spondylotic myelopathy: a prospective randomized control clinical study. *Eur Spine J* 2010;19:713-9.

Hwee Weng Hey,¹ *MMED (Orth), FRCS(Ed) (Orth), MCl (Sing)*, Keng Lin Wong,¹ *MRCs (Ed)*, Ai Sha Long,¹ *MRCs (Ed)*, Hwan Tak Hee,² *FRCS (Ed, Glas), FAMS (Ortho)*

¹Department of Orthopaedic Surgery, University Orthopaedic, Hand and Reconstructive Microsurgery Cluster, National University Health System, Singapore

²Pinnacle Spine and Scoliosis Centre, Singapore

Acknowledgement

The authors would like to acknowledge the following individuals: Ms Heng Wee May and Ms Low Jia Ying Elaine for their help in the collection of data.

Address for Correspondence: Dr Hey Hwee Weng Dennis, Department of Orthopaedic Surgery, National University Hospital Singapore, 1E Kent Ridge Road, Singapore 119228.

Email: hweeweng@gmail.com

Single-level Anterior Corpectomy with Fusion versus 2-level Anterior Cervical Decompression with Fusion: A Prospective Controlled Study with 2-year Follow-up Using Cages for Fusion

Dear Editor,

Anterior cervical discectomy and fusion (ACDF) and anterior cervical corpectomy and fusion (ACCF) are performed for decompression of the spine when the primary compressive pathology lies anterior to the spinal cord – prolapsed intervertebral discs (PID), ossified posterior longitudinal ligament (OPLL), spondylodiscitis and retropulsion of fractured bony fragments. More specifically, ACDF is preferred for discal and retrodiscal pathology, whereas ACCF is indicated for retrovertebral pathology. When 2 consecutive levels of fusion are required, some authors have proposed the feasibility of ACCF to achieve 2 fusion surfaces rather than 4 fusion surfaces. Current literature shows similar clinical outcomes between the 2 methods.^{1,2} It is noted, however, that the fusion methods were heterogeneous in some studies when they were studying only 2 consecutive levels of fusion. Other studies compared ACCF versus ACDF with varied levels of fusion within each arm. We hypothesise that by using cages for both ACCF and ACDF in this matched-paired study, we would be able to better compare the intermediate term results and complications of 1-level ACCF versus 2-level ACDF.

Materials and Methods

This is a prospective case controlled study of 28 patients, 14 in each arm, with a minimum follow-up of 2 years. Ethical approval was sought from the institutional ethics committee. We reviewed prospectively collected data of all patients who underwent 2-level ACDF and 1-level ACCF by the senior author from 2007 to 2009. Twenty-eight consecutive patients with various pathologies amenable to anterior decompression were included. These patients were match-paired based on age, gender and levels of fusion.

The parameters recorded and analysed included patient demographics, presence of preoperative myelopathy, intraoperative details (duration of operation, level of operation, types and sizes of implant and bone grafts, somatosensory evoked potentials (SSEP) and motor evoked potentials (MEP) signal changes, complications), postoperative details (drop in haemoglobin, length of hospitalisation, and time to return to work), postoperative radiological findings (fusion, correction of kyphosis), functional scores ((visual analogue scale (VAS), neck

disability index (NDI), EuroQOL-5 dimensions (EQ-5D health score and EQ-5D index)), and surgery-related complications.

Functional scores were obtained during standard follow-up visits at 6 months, 1 year, and 2 years. Fusion rates based on the Bridwell grading system and degree of lordosis for the fused segments were recorded based on the interpretation of anteroposterior and lateral projections of the cervical spine obtained at the 2-year follow-up visit by 2 independent spine surgeons. The lordosis of the fused vertebral segments were measured using lines on Radweb software placed on the superior endplate and the inferior endplate of the fused vertebral segments. All patients were followed up for a minimum duration of 24 months.

Results

There were 28 patients reviewed, with 14 patients in each arm (ACCF versus ACDF). The mean age for ACCF was 58.5 years and 56.5 years for ACDF. The range of follow-up was between 24 months to 40 months, with a mean of 26.8 months. There was no lost to follow-up at the 24-month period for all patients. The male to female ratio was 6:1 (12:2) for both groups.

In the ACCF group, 3 patients had C4 corpectomy and fusion, 8 had C5 corpectomy and fusion, and 3 had C6 corpectomy and fusion. Similarly, the ACDF group had 3 patients with C3/4 and C4/5 fusion, 8 with C4/5 and C5/6 fusion, and 3 with C5/6 and C6/7 fusion. Comparable number of patients displayed myelopathic features preoperatively (11 in the ACCF group and 12 in the ACDF group). The functional scores preoperatively were similar in both groups.

All patients had PID requiring anterior decompression. The ACCF group had 6 patients with ossified posterior longitudinal ligament, 3 patients with hard and calcified sequestered discs, 3 patients with burst fractures with bony retropulsion, 1 patient with kyphotic deformity, and 1 patient with retrolisthesis requiring corpectomy.

Implants used in the ACCF group included 11 Harms cages (Depuy Spine, Raynham, MA) and 3 Pyramesh cages (Medtronic Sofamor Danek, Memphis, TN); 9 SlimLoc plates (Depuy Spine, Raynham, MA), 3 Atlantis plates (Medtronic Sofamor Danek, Memphis, TN), 1 CSLP

Table 1. Results

	ACCF	ACDF	P Value
Type of implants	11 Harms	9 Bengal	NA
	9 Slimloc	7 Slimloc	
	3 Atlantis	3 Atlantis	
	1 CSLP	2 CSLP	
	1 Eagle	1 Eagle	
	3 Pyramesh	2 Cervios	
		1 Orion	
		3 Solis	
Type of grafts	11 local	1 local with chronos	
	3 iliac	12 iliac	
		1 DBX®	
Duration of surgery (mins)			
(median) (SD)	148.5 (35.97)	165 (30.49)	
(mean)	158.58	155.93	1.000
Cage height (mm) (SD)	13 (0.86)	5.75 (0.85)	NA
Intraoperative events			
Excess bleeding	3	1	0.298
Intraoperative SSEP improvement	2	4	0.324
Intraoperative MEP improvement	2	3	0.500
Haemoglobin drop (SD)	0.95 (1.43)	0.85 (0.84)	0.490
Length of hospitalisation (days) (SD)	4 (9.88)	3.5 (9.97)	0.591
Return to work (days) (SD)	67 (42.51)	66 (48.46)	0.808
Fusion rates (at 2 years) (SD)	1 (0.363)	3 (0.579)	<0.001
Restoration of lordosis (deg) (SD)	0 (3.68)	-0.025 (8.54)	0.025
Postoperative surgical complications			
Cage subsidence	4	0	
Screw migration/cutout	3	0	
Screw in disc space	1	0	0.004
Implant breakage	0	0	
Adjacent level fractures	0	0	
Residual numbness	1	1	

ACCF: Anterior cervical corpectomy and fusion; ACDF: Anterior cervical discectomy and fusion; CSLP: Cervical spine locking plate; MEP: Motor evoked potentials; NA: Not applicable; SSEP: Somatosensory evoked potentials; SD: Standard deviation

plate (Synthes Spine, West Chester, PA), and 1 Eagle plate (Depuy Spine, Raynham, MA). In the ACDF group, there were 9 Bengal cages (Depuy Spine, Raynham, MA), 3 Solis Cages (Stryker Spine, Kalamazoo, MI), and 2 Cervios cages (Synthes Spine, West Chester, PA); 7 SlimLoc plates (Depuy Spine, Raynham, MA), 3 Atlantis plates (Medtronic Sofamor Danek, Memphis, TN), 2 CSLP plates (Synthes Spine, West Chester, PA), 1 Eagle plate (Depuy Spine, Raynham, MA), and 1 Orion plate (Medtronic Sofamor Danek, Memphis, TN). With regards to the bone grafts, the ACCF group had 11 patients with local grafts and 3 with anterior iliac crest grafts. The ACDF group had 12 patients with anterior iliac crest grafts, 1 with local graft and Chronos (Synthes Spine,

West Chester, PA), and 1 with demineralised bone matrix DBX (Synthes Spine, West Chester, PA).

The comparison of factors between ACCF and ACDF are shown in Table 1. At 2-year follow-up, there is no significant difference in operative times, bleeding rate, SSEP/MEP improvement, length of hospitalisation, return to work, and postoperative functional scores (based on VAS, NDI, EQ-5D health score and index) ($P > 0.05$). ACDF is superior in fusion rate ($P < 0.001$) and restoration of lordosis ($P = 0.025$). ACCF has more instrumentation and graft-related complications ($P = 0.004$).

One patient had residual C8 dermatomal numbness in

the ACDF group. In the ACCF group, 4 patients had cage subsidence, 3 had screw loosening resulting in migration and cutout, 1 had screw inserted into the disc space, and 1 had persistent neck pain not better with surgery requiring another magnetic resonance imaging (MRI) 1 year after surgery. The MRI did not show any worsening of spondylotic changes. Of those patients who had screw loosening, 1 patient (7%) had backing out of the anterior plate occurring 34 days after operation and requiring revision surgery. He underwent revision of anterior cervical plating with the instrumentation extending till C7 vertebra distally.

Discussion

There are numerous studies that compared ACDF and ACCF in treating multilevel cervical spondylotic myelopathy, with conflicting evidence.¹⁻⁵ Our study was able to standardise the use of cages for both ACCF and ACDF to compare the 2-year results and complications between this 2 surgical methods. Limitations of our study include a lack of randomisation of patients, lack of trauma cases and a short-term follow-up. Implant differences include different cages being used and different bone grafting techniques. Fusion was also not confirmed via computed tomography (CT) scans in our study. Based on our study, ACDF should be the procedure of choice for anterior decompression of 2-level cervical disease in view of better fusion rate, better restoration of lordosis, and less instrumentation and graft-related complications.

REFERENCES

1. Guo Q, Bi X, Ni B, Lu X, Chen J, Yang J, et al. Outcomes of three anterior decompression and fusion techniques in the treatment of three-level cervical spondylosis. *Eur Spine J* 2011;20:1539-44.
2. Uribe JS, Sangala JR, Duckworth EA, Vale FL. Comparison between anterior cervical discectomy fusion and cervical corpectomy fusion using titanium cages for reconstruction: analysis of outcome and long-term follow-up. *Eur Spine J* 2009;18:654-62.
3. Oh MC, Zhang HY, Park JY, Kim KS. Two-level anterior cervical discectomy versus one-level corpectomy in cervical spondylotic myelopathy. *Spine (Phila Pa 1976)* 2009;34:692-6.
4. Jiang SD, Jiang LS, Dai LY. Anterior cervical discectomy and fusion versus anterior cervical corpectomy and fusion for multilevel cervical spondylosis: a systematic review. *Arch Orthop Trauma Surg* 2012;132:155-61.
5. Lian XF, Xu JG, Zeng BF, Zhou W, Kong WQ, Hou TS. Noncontiguous anterior decompression and fusion for multilevel cervical spondylotic myelopathy: a prospective randomized control clinical study. *Eur Spine J* 2010;19:713-9.

Hwee Weng Hey,¹ *MMED (Orth), FRCS(Ed) (Orth), MCl (Sing)*, Keng Lin Wong,¹ *MRCs (Ed)*, Ai Sha Long,¹ *MRCs (Ed)*, Hwan Tak Hee,² *FRCS (Ed, Glas), FAMS (Ortho)*

¹Department of Orthopaedic Surgery, University Orthopaedic, Hand and Reconstructive Microsurgery Cluster, National University Health System, Singapore

²Pinnacle Spine and Scoliosis Centre, Singapore

Acknowledgement

The authors would like to acknowledge the following individuals: Ms Heng Wee May and Ms Low Jia Ying Elaine for their help in the collection of data.

Address for Correspondence: Dr Hey Hwee Weng Dennis, Department of Orthopaedic Surgery, National University Hospital Singapore, 1E Kent Ridge Road, Singapore 119228.
Email: dennis_hey@nuhs.edu.sg

Use of the Sole Flap to Convert an Above Knee Amputation to a Below Knee Amputation in Trauma

Dear Editor,

An amputation is often a better option in patients with severe lower limb trauma when the prognosis of a limb salvage procedure is not ideal. It also minimises morbidity and mortality.¹ The level of amputation is determined by the zone of injury and availability of soft tissue cover beyond the level of bone amputation. This means that patients with severe segmental injuries involving the leg often end up with an above knee amputation (AKA) or through knee amputation (TKA) instead of below knee amputation (BKA).

We report 3 cases involving the use of sole flaps (2 free flaps and 1 pedicle flap) in segmental crush injuries to convert a potential AKA/TKA to a BKA by providing adequate cover for a below knee stump. The approach allows for knee joint salvage and increased stump length. Although the use of sole flaps to achieve better soft tissue cover in BKAs have been reported,²⁻⁸ the authors revisit this subject with a series of 3 case reports, and discuss the merits of the procedure and its effect on patient outcome in the short- and long-term.

Case 1

A 42-year-old female pillion rider was involved in a road traffic accident. She sustained a Gustilo grade 3C distal right tibia fracture and a segmental fibula fracture, with degloving injury involving extensive soft tissue and neurovascular injury (Fig. 1A). The ankle and foot remained attached via thin strands of skin and soft tissue. The distal posterior tibial and anterior tibial neurovascular bundles were severed. The decision to perform a BKA was made in view of extensive tissue injury and loss.

Wound debridement was done and free sole flap from the amputated foot was harvested based on the posterior tibial artery. The donor vessels (posterior tibial artery with 2 venae comitantes) were anastomosed with the recipient vessels (anterior tibial artery with associated venae comitantes), and an additional vein (long saphenous vein) was anastomosed with posterior tibial vein. The tibial nerve was repaired to its proximal stump. Intact medial gastrocnemius muscle was rotated medially to provide muscle cover to the anteromedial aspect of the BKA stump (Fig. 1B). The patient subsequently underwent further wound debridement



Fig. 1. A 42-year-old female was involved in a road traffic accident. A) Extensive soft tissue damage of right leg. B) Postoperative image of the limb with sole flap.

of the stump and split thickness skin grafting to the wound. The flap healed well and she was discharged 52 days after reconstructive surgery.

Postdischarge, she was fitted with a prosthesis and was able to ambulate with crutches. At 9-month follow-up, she reported paresthesia at the sole flap and tenderness at the lateral aspect of the stump. At 24-month follow-up, paresthesia and tenderness persisted. Excision of sural nerve neuroma and trimming of fibula prominence were done. At 30-month follow-up, no paresthesia or stump tenderness was noted. The patient was able to ambulate independently with prosthesis, with a normal range of motion of the knee.

Case 2

A 44-year-old male passenger of a lorry was involved in a road traffic accident. He sustained a complete traumatic amputation of his left leg, through the midshaft of the tibia and fibula, with extensive segmental soft tissue loss. However, there was minimal soft tissue damage of the left foot.

A decision for a BKA was made in view of the segmental defect with gross contamination and an intermittent period of hypotension during resuscitation. A fasciocutaneous free flap was harvested from the left foot based on the posterior tibial artery and 2 associated venae comitantes (Fig. 2A). The flap was then inset to the BKA stump, with the donor vessels and nerves anastomosed to their corresponding proximal

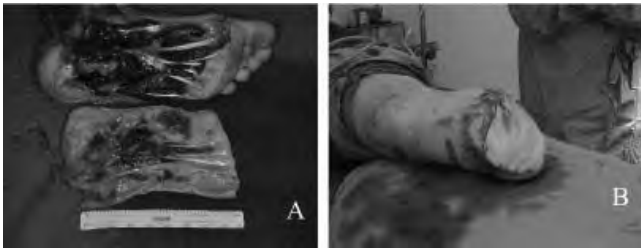


Fig. 2. A 44-year-old male was involved in a road traffic accident. A) Fasciocutaneous free flap harvested based on posterior tibial artery. B) Postoperative image of the limb.

stumps. Fascia of gastrocnemius and a full thickness skin graft were also used to provide adequate soft tissue cover (Fig. 2B). The patient subsequently underwent further wound debridement and flap haemostasis in view of recurrent bleeding postoperatively. He was discharged 21 days after the reconstructive surgery, with the flap healing well.

At 3-month follow-up, the patient was accommodating well to the prosthesis. However, a small necrotic area over the stump was noted, which healed spontaneously. At 8-month follow-up, he had occasional serous fluid discharge, which healed with conservative treatment. At 4-year follow-up, the patient was ambulating unassisted with prosthesis and was able to walk up and down the stairs well. He had full range of motion of the knee and the stump had decreased in size with no pressure ulcers.

Case 3

A 31-year-old male construction worker was at worksite when a car hit him. He sustained bilateral leg injuries and left iliac crest fracture.

The left leg sustained comminuted tibial and fibula fractures (Gustilo grade 3B) with extensive soft tissue loss. After initial wound debridement and external fixation, hemisoleus and medial gastrocnemius flaps were used to provide soft tissue coverage for an initial limb salvage attempt. However, the left leg developed wound infection with multi-resistant *Acinobacter baumannii*. Wound debridement was performed and a decision was made for a BKA. A pedicle sole flap, based on the intact posterior tibial vessels and tibial nerve (Fig. 3A), and a split thickness skin graft were used to cover the stump. The patient tolerated the operation well with no complications.

The right leg sustained a Gustilo grade 3A tibia fracture. Wound debridement was performed and the fracture was temporarily stabilised with an external fixator. Two days later, minimally invasive plating osteosynthesis (MIPO) of the tibia was done as a definitive treatment. The right tibia and left iliac bone subsequently healed without complications.

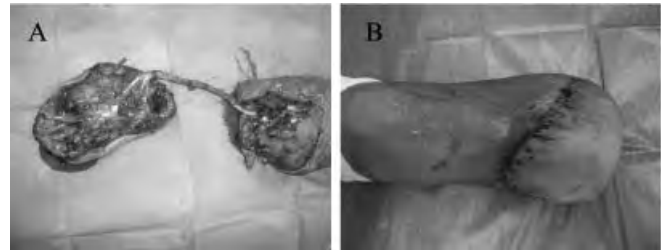


Fig.3. A 31-year-old male was hit by a car. A) Image of the pedicle sole flap harvested based on intact posterior tibial vessels and tibial nerve. B) Image of the operated limb 1 week after the surgery.

The flap remained viable and healed well (Fig. 3B). At postoperative day 10, patient returned to his native country and was lost to follow-up.

Discussion

Although there are potential benefits for limb salvage, there are problems with multiple procedures, prolonged recovery, and sometimes, poor outcome despite all the best efforts. Amputation is a single-stage procedure with quick healing that enables the patient to get back his functional level with a prosthesis, and is an attractive option. However, with severe crush injuries around the proximal or midtibial level, surgeons often have to resort to an AKA/TKA, which has definite disadvantages over a BKA.

The amputation level is an important factor that determines the patient's functional outcome.⁹ A BKA allows for a higher rehabilitation potential and ambulation level.¹⁰ Patients with BKA also require lower energy consumption during ambulation.¹¹ Preservation of the knee joint and tibial length provides increased proprioception and improved mechanical advantage of a prosthesis, thereby improving the gait.⁷

In a segmental injury of the leg, while the intervening bone and soft tissue segment is damaged, the foot is usually spared. This provides the option of harvesting a fasciocutaneous flap of the sole or instep, which may include part of dorsal skin of the foot if necessary, based on the posterior tibial vessels to provide soft tissue cover for the stump. This may be done either as a free or pedicle flap. The tibial nerve should be preserved if it is intact, or repaired to the proximal stump to achieve a sensate flap. This approach enables a BKA to be done in cases that would otherwise have required an AKA/TKA.

In cases with intact tibial neurovascular bundle to the foot, a pedicle sole flap could be raised (Case 3). Care must be taken to ensure that the long intervening segment of the posterior tibial vessels do not kink as the flap is inset, but to be coiled gently into an area that is not subjected to pressure. Should there be a problem with the long pedicle,

this can be converted into a free flap by excising the excess length. In cases where the posterior neurovascular bundle is severed or crushed, free flap is done with anastomosis to the corresponding components in the proximal stump (Cases 1 and 2).

The use of a sole flap provides a well vascularised soft tissue cover, which heals primarily and can serve as a good cushion for weight-bearing, offering pressure absorption and dispersion properties that increase tolerance to constant ambulation load.⁸ In addition, a sole flap with an intact tibial nerve (Case 3) provides a sensate weight-bearing tissue, reducing the risk of ulceration. If the tibial nerve was severed in trauma, nerve anastomosis can be performed to provide at least partial sensation (Cases 1 and 2).

The use of a sole flap does have its disadvantages. Increased surgery time and surgical risk may make it unsuitable for patients who are medically unstable or unfit. Most significant is the need for surgeons with specialised expertise, including microsurgery, supported by the appropriate infrastructure. This is especially so for free flaps, which may not be suitable in places without such resources.

Conclusion

Patients with segmental crush injuries of the leg with severe soft tissue damage may be better treated with a BKA with stump coverage using a sole flap, instead of an AKA/TKA. Though orthopaedic surgeons primarily manage these injuries, the option of a BKA with a sole flap should be kept in mind. Hence, an early referral to a reconstructive microsurgeon would be beneficial. Close collaboration in the management of such difficult injuries would ensure the best possible outcome for patients.

6. Januszkiewicz JS, Mehrotra ON, Brown GE. Calcaneal fillet flap: a new osteocutaneous free tissue transfer for emergency salvage of traumatic below-knee amputation stumps. *Plast Reconstr Surg* 1996;98:538-41.
7. Sanders WE. Amputation after tibial fracture: preservation of length by use of a neurovascular island (fillet) flap of the foot. A brief note. *J Bone Joint Surg Am* 1989;71:435-7.
8. Stiebel M, Lee C, Fontes R. Calcaneal fillet of sole flap: durable coverage of the traumatic amputation stump. *J Trauma* 2000;49:960-3.
9. MacKenzie EJ, Bosse MJ, Castillo RC, Smith DG, Webb LX, Kellam JF, et al. Functional outcomes following trauma-related lower-extremity amputation. *J Bone Joint Surg Am* 2004;86-A:1636-45.
10. Volpicelli LJ, Chambers RB, Wagner FW Jr. Ambulation levels of bilateral lower-extremity amputees. Analysis of one hundred and three cases. *J Bone Joint Surg Am* 1983;65:599-605.
11. Gonzalez EG, Corcoran PJ, Reyes RL. Energy expenditure in below-knee amputees: correlation with stump length. *Arch Phys Med Rehabil* 1974;55:111-9.

REFERENCES

1. Harris AM, Althausen PL, Kellam J, Bosse MJ, Castillo R; Lower Extremity Assessment Project (LEAP) Study Group. Complications following limb-threatening lower extremity trauma. *J Orthop Trauma* 2009;23:1-6.
2. Ghali S, Harris PA, Khan U, Pearse M, Nanchahal J. Leg length preservation with pedicled fillet of foot flaps after traumatic amputations. *Plast Reconstr Surg* 2005;115:498-505.
3. Chiang YC, Wei FC, Wang JW, Chen WS. Reconstruction of below-knee stump using the salvaged foot fillet flap. *Plast Reconstr Surg* 1995;96:731-8.
4. Frykman GK, Jobe CM. Amputation salvage with microvascular free flap from the amputated extremity. *J Trauma* 1987;27:326-9.
5. Jupiter JB, Tsai TM, Kleinert HE. Salvage replantation of lower limb amputations. *Plast Reconstr Surg* 1982;69:1-8.

Faisal Johandi,¹ Zhihao Tang,² MBBS, MRCS (Edin),
Sandeep Jacob Sebastian,³ MBBS, FAMS (Hand Surgery),
Winston YC Chew,⁴ MBBS (Singapore), MMed (Surgery), FAMS (Ortho)

¹Yong Loo Lin School of Medicine, National University of Singapore, Singapore

²Department of Orthopaedic Surgery, Tan Tock Seng Hospital, Singapore

³Department of Hand and Reconstructive Microsurgery, National University Hospital, Singapore

⁴Department of Orthopaedic Surgery, Tan Tock Seng Hospital, Singapore

Address for Correspondence: Mr Faisal Johandi, Tan Tock Seng Hospital, 11 Jalan Tan Tock Seng, Singapore 308433.

Email: faisaljohandi@yahoo.com

Use of the Sole Flap to Convert an Above Knee Amputation to a Below Knee Amputation in Trauma

Dear Editor,

An amputation is often a better option in patients with severe lower limb trauma when the prognosis of a limb salvage procedure is not ideal. It also minimises morbidity and mortality.¹ The level of amputation is determined by the zone of injury and availability of soft tissue cover beyond the level of bone amputation. This means that patients with severe segmental injuries involving the leg often end up with an above knee amputation (AKA) or through knee amputation (TKA) instead of below knee amputation (BKA).

We report 3 cases involving the use of sole flaps (2 free flaps and 1 pedicle flap) in segmental crush injuries to convert a potential AKA/TKA to a BKA by providing adequate cover for a below knee stump. The approach allows for knee joint salvage and increased stump length. Although the use of sole flaps to achieve better soft tissue cover in BKAs have been reported,²⁻⁸ the authors revisit this subject with a series of 3 case reports, and discuss the merits of the procedure and its effect on patient outcome in the short- and long-term.

Case 1

A 42-year-old female pillion rider was involved in a road traffic accident. She sustained a Gustilo grade 3C distal right tibia fracture and a segmental fibula fracture, with degloving injury involving extensive soft tissue and neurovascular injury (Fig. 1A). The ankle and foot remained attached via thin strands of skin and soft tissue. The distal posterior tibial and anterior tibial neurovascular bundles were severed. The decision to perform a BKA was made in view of extensive tissue injury and loss.

Wound debridement was done and free sole flap from the amputated foot was harvested based on the posterior tibial artery. The donor vessels (posterior tibial artery with 2 venae comitantes) were anastomosed with the recipient vessels (anterior tibial artery with associated venae comitantes), and an additional vein (long saphenous vein) was anastomosed with posterior tibial vein. The tibial nerve was repaired to its proximal stump. Intact medial gastrocnemius muscle was rotated medially to provide muscle cover to the anteromedial aspect of the BKA stump (Fig. 1B). The patient subsequently underwent further wound debridement



Fig. 1. A 42-year-old female was involved in a road traffic accident. A) Extensive soft tissue damage of right leg. B) Postoperative image of the limb with sole flap.

of the stump and split thickness skin grafting to the wound. The flap healed well and she was discharged 52 days after reconstructive surgery.

Postdischarge, she was fitted with a prosthesis and was able to ambulate with crutches. At 9-month follow-up, she reported paresthesia at the sole flap and tenderness at the lateral aspect of the stump. At 24-month follow-up, paresthesia and tenderness persisted. Excision of sural nerve neuroma and trimming of fibula prominence were done. At 30-month follow-up, no paresthesia or stump tenderness was noted. The patient was able to ambulate independently with prosthesis, with a normal range of motion of the knee.

Case 2

A 44-year-old male passenger of a lorry was involved in a road traffic accident. He sustained a complete traumatic amputation of his left leg, through the midshaft of the tibia and fibula, with extensive segmental soft tissue loss. However, there was minimal soft tissue damage of the left foot.

A decision for a BKA was made in view of the segmental defect with gross contamination and an intermittent period of hypotension during resuscitation. A fasciocutaneous free flap was harvested from the left foot based on the posterior tibial artery and 2 associated venae comitantes (Fig. 2A). The flap was then inset to the BKA stump, with the donor vessels and nerves anastomosed to their corresponding proximal

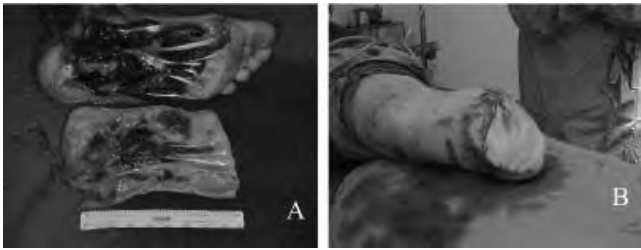


Fig. 2. A 44-year-old male was involved in a road traffic accident. A) Fasciocutaneous free flap harvested based on posterior tibial artery. B) Postoperative image of the limb.

stumps. Fascia of gastrocnemius and a full thickness skin graft were also used to provide adequate soft tissue cover (Fig. 2B). The patient subsequently underwent further wound debridement and flap haemostasis in view of recurrent bleeding postoperatively. He was discharged 21 days after the reconstructive surgery, with the flap healing well.

At 3-month follow-up, the patient was accommodating well to the prosthesis. However, a small necrotic area over the stump was noted, which healed spontaneously. At 8-month follow-up, he had occasional serous fluid discharge, which healed with conservative treatment. At 4-year follow-up, the patient was ambulating unassisted with prosthesis and was able to walk up and down the stairs well. He had full range of motion of the knee and the stump had decreased in size with no pressure ulcers.

Case 3

A 31-year-old male construction worker was at worksite when a car hit him. He sustained bilateral leg injuries and left iliac crest fracture.

The left leg sustained comminuted tibial and fibula fractures (Gustilo grade 3B) with extensive soft tissue loss. After initial wound debridement and external fixation, hemisoleus and medial gastrocnemius flaps were used to provide soft tissue coverage for an initial limb salvage attempt. However, the left leg developed wound infection with multi-resistant *Acinobacter baumannii*. Wound debridement was performed and a decision was made for a BKA. A pedicle sole flap, based on the intact posterior tibial vessels and tibial nerve (Fig. 3A), and a split thickness skin graft were used to cover the stump. The patient tolerated the operation well with no complications.

The right leg sustained a Gustilo grade 3A tibia fracture. Wound debridement was performed and the fracture was temporarily stabilised with an external fixator. Two days later, minimally invasive plating osteosynthesis (MIPO) of the tibia was done as a definitive treatment. The right tibia and left iliac bone subsequently healed without complications.

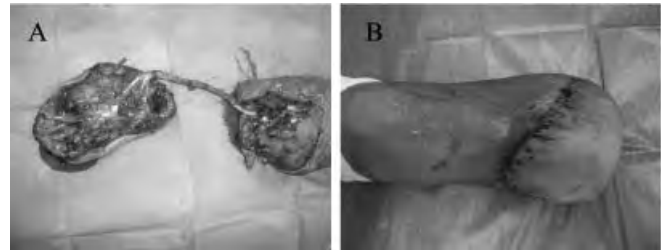


Fig.3. A 31-year-old male was hit by a car. A) Image of the pedicle sole flap harvested based on intact posterior tibial vessels and tibial nerve. B) Image of the operated limb 1 week after the surgery.

The flap remained viable and healed well (Fig. 3B). At postoperative day 10, patient returned to his native country and was lost to follow-up.

Discussion

Although there are potential benefits for limb salvage, there are problems with multiple procedures, prolonged recovery, and sometimes, poor outcome despite all the best efforts. Amputation is a single-stage procedure with quick healing that enables the patient to get back his functional level with a prosthesis, and is an attractive option. However, with severe crush injuries around the proximal or midtibial level, surgeons often have to resort to an AKA/TKA, which has definite disadvantages over a BKA.

The amputation level is an important factor that determines the patient's functional outcome.⁹ A BKA allows for a higher rehabilitation potential and ambulation level.¹⁰ Patients with BKA also require lower energy consumption during ambulation.¹¹ Preservation of the knee joint and tibial length provides increased proprioception and improved mechanical advantage of a prosthesis, thereby improving the gait.⁷

In a segmental injury of the leg, while the intervening bone and soft tissue segment is damaged, the foot is usually spared. This provides the option of harvesting a fasciocutaneous flap of the sole or instep, which may include part of dorsal skin of the foot if necessary, based on the posterior tibial vessels to provide soft tissue cover for the stump. This may be done either as a free or pedicle flap. The tibial nerve should be preserved if it is intact, or repaired to the proximal stump to achieve a sensate flap. This approach enables a BKA to be done in cases that would otherwise have required an AKA/TKA.

In cases with intact tibial neurovascular bundle to the foot, a pedicle sole flap could be raised (Case 3). Care must be taken to ensure that the long intervening segment of the posterior tibial vessels do not kink as the flap is inset, but to be coiled gently into an area that is not subjected to pressure. Should there be a problem with the long pedicle,

this can be converted into a free flap by excising the excess length. In cases where the posterior neurovascular bundle is severed or crushed, free flap is done with anastomosis to the corresponding components in the proximal stump (Cases 1 and 2).

The use of a sole flap provides a well vascularised soft tissue cover, which heals primarily and can serve as a good cushion for weight-bearing, offering pressure absorption and dispersion properties that increase tolerance to constant ambulation load.⁸ In addition, a sole flap with an intact tibial nerve (Case 3) provides a sensate weight-bearing tissue, reducing the risk of ulceration. If the tibial nerve was severed in trauma, nerve anastomosis can be performed to provide at least partial sensation (Cases 1 and 2).

The use of a sole flap does have its disadvantages. Increased surgery time and surgical risk may make it unsuitable for patients who are medically unstable or unfit. Most significant is the need for surgeons with specialised expertise, including microsurgery, supported by the appropriate infrastructure. This is especially so for free flaps, which may not be suitable in places without such resources.

Conclusion

Patients with segmental crush injuries of the leg with severe soft tissue damage may be better treated with a BKA with stump coverage using a sole flap, instead of an AKA/TKA. Though orthopaedic surgeons primarily manage these injuries, the option of a BKA with a sole flap should be kept in mind. Hence, an early referral to a reconstructive microsurgeon would be beneficial. Close collaboration in the management of such difficult injuries would ensure the best possible outcome for patients.

6. Januszkiewicz JS, Mehrotra ON, Brown GE. Calcaneal fillet flap: a new osteocutaneous free tissue transfer for emergency salvage of traumatic below-knee amputation stumps. *Plast Reconstr Surg* 1996;98:538-41.
7. Sanders WE. Amputation after tibial fracture: preservation of length by use of a neurovascular island (fillet) flap of the foot. A brief note. *J Bone Joint Surg Am* 1989;71:435-7.
8. Stiebel M, Lee C, Fontes R. Calcaneal fillet of sole flap: durable coverage of the traumatic amputation stump. *J Trauma* 2000;49:960-3.
9. MacKenzie EJ, Bosse MJ, Castillo RC, Smith DG, Webb LX, Kellam JF, et al. Functional outcomes following trauma-related lower-extremity amputation. *J Bone Joint Surg Am* 2004;86-A:1636-45.
10. Volpicelli LJ, Chambers RB, Wagner FW Jr. Ambulation levels of bilateral lower-extremity amputees. Analysis of one hundred and three cases. *J Bone Joint Surg Am* 1983;65:599-605.
11. Gonzalez EG, Corcoran PJ, Reyes RL. Energy expenditure in below-knee amputees: correlation with stump length. *Arch Phys Med Rehabil* 1974;55:111-9.

REFERENCES

1. Harris AM, Althausen PL, Kellam J, Bosse MJ, Castillo R; Lower Extremity Assessment Project (LEAP) Study Group. Complications following limb-threatening lower extremity trauma. *J Orthop Trauma* 2009;23:1-6.
2. Ghali S, Harris PA, Khan U, Pearse M, Nanchahal J. Leg length preservation with pedicled fillet of foot flaps after traumatic amputations. *Plast Reconstr Surg* 2005;115:498-505.
3. Chiang YC, Wei FC, Wang JW, Chen WS. Reconstruction of below-knee stump using the salvaged foot fillet flap. *Plast Reconstr Surg* 1995;96:731-8.
4. Frykman GK, Jobe CM. Amputation salvage with microvascular free flap from the amputated extremity. *J Trauma* 1987;27:326-9.
5. Jupiter JB, Tsai TM, Kleinert HE. Salvage replantation of lower limb amputations. *Plast Reconstr Surg* 1982;69:1-8.

Faisal Johandi, ¹MBBS, Zhihao Tang, ²MBBS, MRCS (Edin),
Sandeep Jacob Sebastin, ³MBBS, FAMS (Hand Surgery),
Winston YC Chew, ²MBBS (Singapore), MMed (Surgery), FAMS (Ortho)

¹Yong Loo Lin School of Medicine, National University of Singapore, Singapore

²Department of Orthopaedic Surgery, Tan Tock Seng Hospital, Singapore

³Department of Hand and Reconstructive Microsurgery, National University Hospital, Singapore

Address for Correspondence: Dr Faisal Johandi, Level 11, NUHS Tower Block, 1E Kent Ridge Road, Singapore 119228.

Email: faisaljohandi@yahoo.com

Use of the Sole Flap to Convert an Above Knee Amputation to a Below Knee Amputation in Trauma

Dear Editor,

An amputation is often a better option in patients with severe lower limb trauma when the prognosis of a limb salvage procedure is not ideal. It also minimises morbidity and mortality.¹ The level of amputation is determined by the zone of injury and availability of soft tissue cover beyond the level of bone amputation. This means that patients with severe segmental injuries involving the leg often end up with an above knee amputation (AKA) or through knee amputation (TKA) instead of below knee amputation (BKA).

We report 3 cases involving the use of sole flaps (2 free flaps and 1 pedicle flap) in segmental crush injuries to convert a potential AKA/TKA to a BKA by providing adequate cover for a below knee stump. The approach allows for knee joint salvage and increased stump length. Although the use of sole flaps to achieve better soft tissue cover in BKAs have been reported,²⁻⁸ the authors revisit this subject with a series of 3 case reports, and discuss the merits of the procedure and its effect on patient outcome in the short- and long-term.

Case 1

A 42-year-old female pillion rider was involved in a road traffic accident. She sustained a Gustilo grade 3C distal right tibia fracture and a segmental fibula fracture, with degloving injury involving extensive soft tissue and neurovascular injury (Fig. 1A). The ankle and foot remained attached via thin strands of skin and soft tissue. The distal posterior tibial and anterior tibial neurovascular bundles were severed. The decision to perform a BKA was made in view of extensive tissue injury and loss.

Wound debridement was done and free sole flap from the amputated foot was harvested based on the posterior tibial artery. The donor vessels (posterior tibial artery with 2 venae comitantes) were anastomosed with the recipient vessels (anterior tibial artery with associated venae comitantes), and an additional vein (long saphenous vein) was anastomosed with posterior tibial vein. The tibial nerve was repaired to its proximal stump. Intact medial gastrocnemius muscle was rotated medially to provide muscle cover to the anteromedial aspect of the BKA stump (Fig. 1B). The patient subsequently underwent further wound debridement

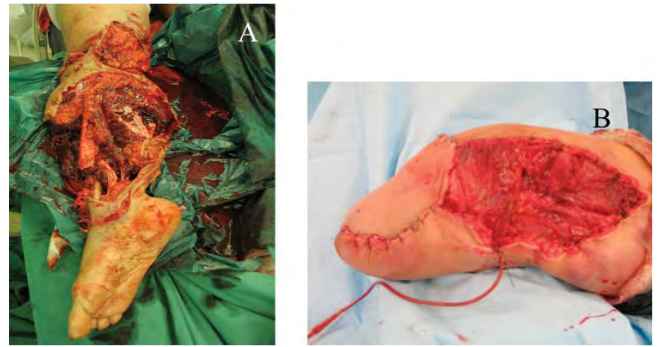


Fig. 1. A 42-year-old female was involved in a road traffic accident. A) Extensive soft tissue damage of right leg. B) Postoperative image of the limb with sole flap.

of the stump and split thickness skin grafting to the wound. The flap healed well and she was discharged 52 days after reconstructive surgery.

Postdischarge, she was fitted with a prosthesis and was able to ambulate with crutches. At 9-month follow-up, she reported paresthesia at the sole flap and tenderness at the lateral aspect of the stump. At 24-month follow-up, paresthesia and tenderness persisted. Excision of sural nerve neuroma and trimming of fibula prominence were done. At 30-month follow-up, no paresthesia or stump tenderness was noted. The patient was able to ambulate independently with prosthesis, with a normal range of motion of the knee.

Case 2

A 44-year-old male passenger of a lorry was involved in a road traffic accident. He sustained a complete traumatic amputation of his left leg, through the midshaft of the tibia and fibula, with extensive segmental soft tissue loss. However, there was minimal soft tissue damage of the left foot.

A decision for a BKA was made in view of the segmental defect with gross contamination and an intermittent period of hypotension during resuscitation. A fasciocutaneous free flap was harvested from the left foot based on the posterior tibial artery and 2 associated venae comitantes (Fig. 2A). The flap was then inset to the BKA stump, with the donor vessels and nerves anastomosed to their corresponding proximal



Fig. 2. A 44-year-old male was involved in a road traffic accident. A) Fasciocutaneous free flap harvested based on posterior tibial artery. B) Postoperative image of the limb.

stumps. Fascia of gastrocnemius and a full thickness skin graft were also used to provide adequate soft tissue cover (Fig. 2B). The patient subsequently underwent further wound debridement and flap haemostasis in view of recurrent bleeding postoperatively. He was discharged 21 days after the reconstructive surgery, with the flap healing well.

At 3-month follow-up, the patient was accommodating well to the prosthesis. However, a small necrotic area over the stump was noted, which healed spontaneously. At 8-month follow-up, he had occasional serous fluid discharge, which healed with conservative treatment. At 4-year follow-up, the patient was ambulating unassisted with prosthesis and was able to walk up and down the stairs well. He had full range of motion of the knee and the stump had decreased in size with no pressure ulcers.

Case 3

A 31-year-old male construction worker was at worksite when a car hit him. He sustained bilateral leg injuries and left iliac crest fracture.

The left leg sustained comminuted tibial and fibula fractures (Gustilo grade 3B) with extensive soft tissue loss. After initial wound debridement and external fixation, hemisoleus and medial gastrocnemius flaps were used to provide soft tissue coverage for an initial limb salvage attempt. However, the left leg developed wound infection with multi-resistant *Acinobacter baumannii*. Wound debridement was performed and a decision was made for a BKA. A pedicle sole flap, based on the intact posterior tibial vessels and tibial nerve (Fig. 3A), and a split thickness skin graft were used to cover the stump. The patient tolerated the operation well with no complications.

The right leg sustained a Gustilo grade 3A tibia fracture. Wound debridement was performed and the fracture was temporarily stabilised with an external fixator. Two days later, minimally invasive plating osteosynthesis (MIPO) of the tibia was done as a definitive treatment. The right tibia and left iliac bone subsequently healed without complications.

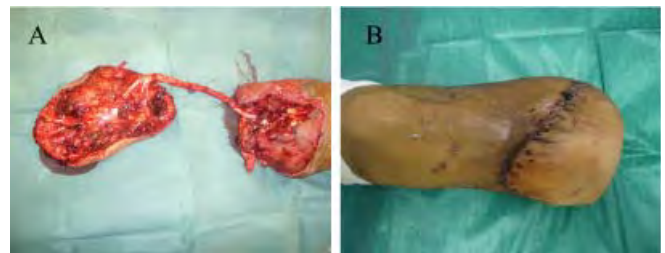


Fig.3. A 31-year-old male was hit by a car. A) Image of the pedicle sole flap harvested based on intact posterior tibial vessels and tibial nerve. B) Image of the operated limb 1 week after the surgery.

The flap remained viable and healed well (Fig. 3B). At postoperative day 10, patient returned to his native country and was lost to follow-up.

Discussion

Although there are potential benefits for limb salvage, there are problems with multiple procedures, prolonged recovery, and sometimes, poor outcome despite all the best efforts. Amputation is a single-stage procedure with quick healing that enables the patient to get back his functional level with a prosthesis, and is an attractive option. However, with severe crush injuries around the proximal or midtibial level, surgeons often have to resort to an AKA/TKA, which has definite disadvantages over a BKA.

The amputation level is an important factor that determines the patient's functional outcome.⁹ A BKA allows for a higher rehabilitation potential and ambulation level.¹⁰ Patients with BKA also require lower energy consumption during ambulation.¹¹ Preservation of the knee joint and tibial length provides increased proprioception and improved mechanical advantage of a prosthesis, thereby improving the gait.⁷

In a segmental injury of the leg, while the intervening bone and soft tissue segment is damaged, the foot is usually spared. This provides the option of harvesting a fasciocutaneous flap of the sole or instep, which may include part of dorsal skin of the foot if necessary, based on the posterior tibial vessels to provide soft tissue cover for the stump. This may be done either as a free or pedicle flap. The tibial nerve should be preserved if it is intact, or repaired to the proximal stump to achieve a sensate flap. This approach enables a BKA to be done in cases that would otherwise have required an AKA/TKA.

In cases with intact tibial neurovascular bundle to the foot, a pedicle sole flap could be raised (Case 3). Care must be taken to ensure that the long intervening segment of the posterior tibial vessels do not kink as the flap is inset, but to be coiled gently into an area that is not subjected to pressure. Should there be a problem with the long pedicle,

this can be converted into a free flap by excising the excess length. In cases where the posterior neurovascular bundle is severed or crushed, free flap is done with anastomosis to the corresponding components in the proximal stump (Cases 1 and 2).

The use of a sole flap provides a well vascularised soft tissue cover, which heals primarily and can serve as a good cushion for weight-bearing, offering pressure absorption and dispersion properties that increase tolerance to constant ambulation load.⁸ In addition, a sole flap with an intact tibial nerve (Case 3) provides a sensate weight-bearing tissue, reducing the risk of ulceration. If the tibial nerve was severed in trauma, nerve anastomosis can be performed to provide at least partial sensation (Cases 1 and 2).

The use of a sole flap does have its disadvantages. Increased surgery time and surgical risk may make it unsuitable for patients who are medically unstable or unfit. Most significant is the need for surgeons with specialised expertise, including microsurgery, supported by the appropriate infrastructure. This is especially so for free flaps, which may not be suitable in places without such resources.

Conclusion

Patients with segmental crush injuries of the leg with severe soft tissue damage may be better treated with a BKA with stump coverage using a sole flap, instead of an AKA/TKA. Though orthopaedic surgeons primarily manage these injuries, the option of a BKA with a sole flap should be kept in mind. Hence, an early referral to a reconstructive microsurgeon would be beneficial. Close collaboration in the management of such difficult injuries would ensure the best possible outcome for patients.

REFERENCES

- Harris AM, Althausen PL, Kellam J, Bosse MJ, Castillo R; Lower Extremity Assessment Project (LEAP) Study Group. Complications following limb-threatening lower extremity trauma. *J Orthop Trauma* 2009;23:1-6.
- Ghali S, Harris PA, Khan U, Pearse M, Nanchahal J. Leg length preservation with pedicled fillet of foot flaps after traumatic amputations. *Plast Reconstr Surg* 2005;115:498-505.
- Chiang YC, Wei FC, Wang JW, Chen WS. Reconstruction of below-knee stump using the salvaged foot fillet flap. *Plast Reconstr Surg* 1995;96:731-8.
- Frykman GK, Jobe CM. Amputation salvage with microvascular free flap from the amputated extremity. *J Trauma* 1987;27:326-9.
- Jupiter JB, Tsai TM, Kleinert HE. Salvage replantation of lower limb amputations. *Plast Reconstr Surg* 1982;69:1-8.
- Januszkiewicz JS, Mehrotra ON, Brown GE. Calcaneal fillet flap: a new osteocutaneous free tissue transfer for emergency salvage of traumatic below-knee amputation stumps. *Plast Reconstr Surg* 1996;98:538-41.
- Sanders WE. Amputation after tibial fracture: preservation of length by use of a neurovascular island (fillet) flap of the foot. A brief note. *J Bone Joint Surg Am* 1989;71:435-7.
- Stiebel M, Lee C, Fontes R. Calcaneal fillet of sole flap: durable coverage of the traumatic amputation stump. *J Trauma* 2000;49:960-3.
- MacKenzie EJ, Bosse MJ, Castillo RC, Smith DG, Webb LX, Kellam JF, et al. Functional outcomes following trauma-related lower-extremity amputation. *J Bone Joint Surg Am* 2004;86-A:1636-45.
- Volpicelli LJ, Chambers RB, Wagner FW Jr. Ambulation levels of bilateral lower-extremity amputees. Analysis of one hundred and three cases. *J Bone Joint Surg Am* 1983;65:599-605.
- Gonzalez EG, Corcoran PJ, Reyes RL. Energy expenditure in below-knee amputees: correlation with stump length. *Arch Phys Med Rehabil* 1974;55:111-9.

Faisal Johandi, ¹MBBS, Zhihao Tang, ²MBBS, MRCS (Edin),
Sandeep Jacob Sebastian, ³MBBS, FAMS (Hand Surgery),
Winston YC Chew, ²MBBS (S'pore), MMed (Surgery), FAMS (Ortho)

¹Yong Loo Lin School of Medicine, National University of Singapore, Singapore

²Department of Orthopaedic Surgery, Tan Tock Seng Hospital, Singapore

³Department of Hand and Reconstructive Microsurgery, National University Hospital, Singapore

Address for Correspondence: Dr Faisal Johandi, Level 11, NUHS Tower Block, 1E Kent Ridge Road, Singapore 119228.

Email: faisaljohandi@yahoo.com

Long-term Outcomes of Medical Therapy Versus Coronary Revascularisation in Patients with Intermediate Stenoses Guided by Pressure Wire

Hongyu Shi, ^{1MD}, Chi Hang Lee, ^{2MD}, Mark YY Chan, ^{2MD}, Adrian F Low, ^{2MD}, Swee Guan Teo, ^{2MD}, Koo Hui Chan, ^{2MD}, Rishi Sethi, ^{2MD}, Arthur Mark Richards, ^{2MD}, Huay Cheem Tan, ^{2MD}

Abstract

Introduction: This study aimed to examine the long-term clinical outcomes of coronary fractional flow reserve (FFR)-guided percutaneous coronary intervention (PCI) in a real-world population in an Asian tertiary centre. **Materials and Methods:** All patients who underwent FFR measurement for intermediate coronary lesions in our centre from June 2002 to December 2009 were enrolled. A threshold of FFR ≤ 0.75 was used for revascularisation. All the patients were prospectively followed-up for major adverse cardiac events (MACE) of death, myocardial infarction (MI), target vessel revascularisation (TVR) and stent thrombosis. **Results:** Based on FFR measurement, 368 (57%) patients were treated medically while 278 (43%) underwent revascularisation. At a mean follow-up duration of 29.7 ± 16 months, 53 (14.4%) patients in the medical therapy group and 32 (11.5%) patients in the revascularised group experienced MACE ($P = 0.282$). There were no statistical differences in all the clinical endpoints between the 2 groups. **Conclusion:** Medical therapy based on FFR measurement is associated with low incidences of MACE at long-term follow-up.

Ann Acad Med Singapore 2015;44:xx-xx

Key words: Fractional flow reserve, Major adverse cardiac events, Percutaneous coronary intervention

Introduction

Although coronary angiography has been used as the “gold standard” imaging technique for the diagnosis of coronary artery disease, it is essentially a lumenogram that offers no information on the functional significance of a coronary lesion. It is difficult to define the haemodynamic significance of a stenosis from the angiogram, especially in intermediate lesions (diameter stenosis of 50% to 70%).¹

Fractional flow reserve (FFR), defined as the ratio of pressure in the stenotic artery to the pressure in the same artery in the theoretical absence of stenosis, is a specific index for epicardial stenosis. A FFR value of 0.75 means that the stenotic vessel provides only 75% of the normal expected flow in the theoretical absence of stenosis. A FFR value of <0.75 is taken as a cutoff for ischaemia in

many studies.² It is the only functional index that has been validated against gold standard non-invasive functional tests such as stress echocardiography and single-photon emission computed tomography (SPECT).³⁻⁷

Several clinical randomised control trials, such as DEFER trial and FAME trial, have demonstrated significant superiority in percutaneous coronary intervention (PCI) guided by FFR when compared with angiography.^{8,9} However, the role of FFR measurement in the real world is not clear. Therefore, we decided to perform a retrospective analysis based on data extracted from National University Hospital (NUH) cardiovascular database to evaluate the long-term clinical outcomes of medical therapy versus revascularisation in patients with intermediate lesions guided by pressure wire.

¹Department of Cardiology, Shanghai Chest Hospital, People's Republic of China

²The Cardiac Department, National University Heart Centre and Yong Loo Lin School of Medicine, National University of Singapore, Singapore

Address for Correspondence: A/Prof Huay Cheem Tan, The Cardiac Department, National University Heart Centre and Yong Loo Lin School of Medicine, National University of Singapore, Singapore.

Email: huay_cheem_tan@nuhs.edu.sg

Materials and Methods

Study Patients

Patients who underwent coronary angiography and FFR measurement for intermediate coronary artery stenoses (defined visually as between 50% to 75%) at NUH, Singapore, between 2002 and 2009 were enrolled in this retrospective study. Patients with ST segment elevated myocardial infarction (MI) within 1 week after the coronary angiography were excluded.

Procedure and Antiplatelet Regimen

Percutaneous coronary angiogram was performed in accordance with standard techniques, and the intermediate lesion was determined visually by the operator. FFR was measured with Radi wire and PressureWire™ Certus FFR Measurement System (St Jude Medical, USA) positioned distally across the stenosis. Following initial pressure wire calibration and equalisation, intracoronary glyceryl trinitrate was administered to eliminate vasospasm. Maximal hyperaemia was achieved through intracoronary administration of papaverine or adenosine. Intracoronary papaverine has a duration effect of 45 seconds.¹⁰ Patients with FFR measurement of >0.75 were treated medically while those with $\text{FFR} \leq 0.75$ were revascularised. All patients receiving PCI were pretreated with clopidogrel and aspirin. A loading dose of 300 mg of clopidogrel was administered if the patient had not been pretreated. After the procedure, dual antiplatelet therapy for at least 1 year for drug eluting stent and 1 month for bare metal stent (BMS), followed by aspirin (100 mg/d to 300 mg/d) indefinitely were administered. Cardiac enzymes and 12-lead electrocardiogram (ECG) were determined routinely after the interventions.

Definitions and Follow-up

A major adverse cardiac event (MACE) was defined as the occurrence of death, MI, or need for a new revascularisation procedure. MI was defined by an increase in creatine kinase-MB fraction of more than 3 times the upper limit of normal. Stent thrombosis was defined as angiographic documentation of thrombotic stent occlusion associated with a clinical event, an unexplained sudden cardiac death, or MI not clearly attributable to another coronary lesion.

Clinical follow-up was obtained through hospital records, clinic visits and telephone phone calls.

Statistical Analysis

Categorical variables were presented as frequencies (percentages) and were compared with chi-square statistics or, when appropriate, Fischer's exact test. Continuous

variables were presented as mean $\pm$ standard deviation and compared with Student's t-test. Survival of MACE and each component were estimated using the Kaplan-Meier method, and the difference between the 2 survival curves were compared with the log rank test. Cox proportional hazards multiple regression models were used to estimate association between medical therapy versus revascularisation on long-term outcomes, after adjusting for other patient characteristics that were significantly different between groups. A *P* value of less than 0.05 was considered statistically significant, and all statistical tests were 2-tailed. Statistical analyses were performed with SPSS 13.0 (SPSS, Inc, Chicago, Illinois).

Results

Baseline Clinical Characteristics

A total of 646 patients with 812 intermediate lesions were included in this study. All of them received FFR measurement during cardiac catheterisation. In the group with FFR of more than 0.75 ($n = 360$), 347 patients (96.3%) were treated with medical therapy. Among those with an $\text{FFR} \leq 0.75$ ($n = 386$), 249 patients (87.1 %) were treated with revascularisation. There was a crossover of subjects in the 2 groups that did not go with the conventional algorithm because of the operators' decision. These included 21 patients with lesions of FFR more than 0.75 who crossed over to revascularisation, among which 9 patients had intravascular ultrasound (IVUS) examination which showed minimum lumen area (MLA) of less than 3 mm², and 12 patients had documented ischaemia on stress echocardiogram or myocardial SPECT imaging. Twenty-nine patients who had lesions with $\text{FFR} \leq 0.75$ were treated medically due to unsuitability for PCI and patients' wishes. PCI was performed in 255 patients (91.7%) with the details shown in Figure 1.

The baseline characteristics for the 2 groups were largely similar, except that the revascularised group had higher prevalence of hypertension and previous history of MI. Most patients presented with stable angina (Table 1).

Angiographic and Procedural Characteristics

Multivessel coronary artery disease accounted for two-thirds of revascularised patients, which was significantly higher than that in the medical therapy group. There was no significant difference in the lesion location between the 2 groups. More than half of the lesions were located in the left anterior descending artery. Left main artery and graft disease made up only a small percentage of the cohort (Table 2).

There was similar use of IVUS in both groups. Quantitative coronary analysis (QCA) showed higher diameter stenosis

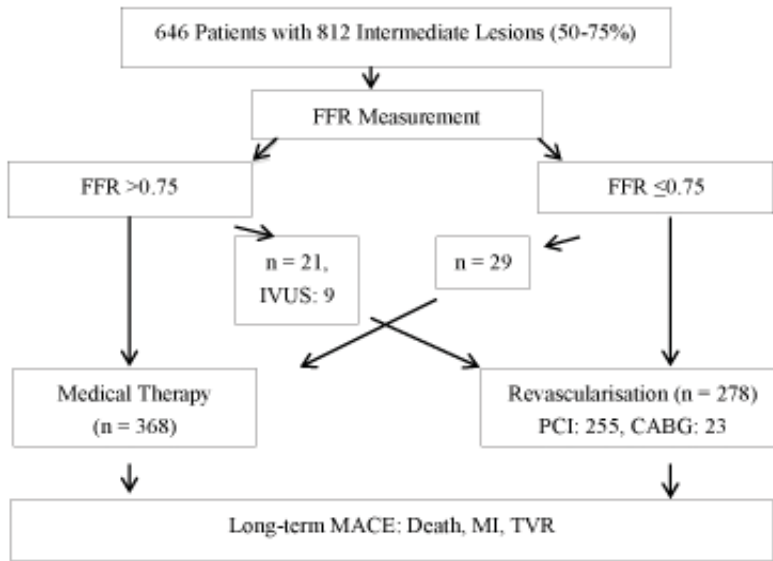


Fig. 1. Flow chart of the study. FFR: Fractional flow reserve; CABG: Coronary artery bypass grafting; PCI: Percutaneous coronary intervention; IVUS: Intravascular ultrasound; MACE: Major adverse cardiac event; MI: Myocardial infarction; TVR: Target vessel revascularisation

Table 1. Baseline Clinical Characteristics of the Study Patients

	Medical Therapy (n = 368)	Revascularisation (n = 278)	P Value
Age (years)	59.2 ± 10.4	57.0 ± 10.5†	0.008
Male (%)	273 (74.2)	234 (84.2)†	0.003
Ethnic group			0.454
Chinese, n (%)	238 (64.7)	192 (69.1)	
Indian, n (%)	60 (16.3)	42 (15.1)	
Malay, n (%)	53 (14.4)	37 (13.9)	
Others, n (%)	17 (4.6)	7 (2.5)	
Current smoker, n (%)	98 (26.6)	79 (28.4)	0.656
Hypertension, n (%)	255 (69.3)	169 (60.8)*	0.030
Diabetes, n (%)	144 (39.1)	104 (37.4)	0.683
Hyperlipidaemia, n (%)	271 (73.6)	211 (75.9)	0.524
Family history, n (%)	28 (7.6)	26 (9.4)	0.474
Previous MI, n (%)	46 (12.5)	58 (20.9)†	0.005
Previous PCI, n (%)	113 (30.7)	105 (37.7)	0.060
Indication of angiogram			0.940
Stable angina, n (%)	289 (78.6)	219 (78.7)	
NSTE-ACS, n (%)	79 (21.4)	59 (21.3)	
LVEF <50%, n (%)	68 (18.5)	54 (19.4)	0.762
Medicines			
Aspirin, n (%)	324 (88.0)	264 (95.0)†	0.002
Clopidogrel, n (%)	203 (55.2)	272 (97.8)†	0.000
Statins, n (%)	310 (84.2)	263 (94.6)†	0.000
ACEI or ARB, n (%)	196 (53.3)	167 (60.1)	0.093
Beta blockers, n (%)	269 (73.1)	221 (79.5)	0.064

ACEI: Angiotensin-converting enzyme inhibitor; ARB: Angiotensin receptor blocker; BMI: Body mass index; LVEF: Left ventricle ejection fraction; MI: Myocardial infarction; NSTE-ACS: Non-ST segment elevated acute coronary syndrome; PCI: Percutaneous coronary intervention

*P <0.05

†P <0.01

Table 2. Angiographic and Procedural Characteristics of Study Patients

	Medical Therapy (n = 368)	Revascularisation (n = 278)	P Value
Number of diseased vessel, n (%)			0.015
1	165 (44.8)	94 (33.8)*	
2	133 (36.1)	115 (41.4)	
3	70 (19.0)	69 (24.8)	
Location			0.067
LM, n (%)	20 (4.7)	11 (2.8)	
LAD, n (%)	254 (59.8)	262 (67.7)	
LCX, n (%)	66 (15.5)	39 (10.1)	
RCA, n (%)	79 (18.6)	71 (18.3)	
Grafts, n (%)	6 (1.4)	4 (1.0)	
IVUS use, n (%)	34 (9.2)	25 (9.0)	1.000
QCA measurement			
Diameter stenosis (%)	51.8 ± 11.4	70.5 ± 11.8†	0.000
Reference diameter (mm)	3.09 ± 2.67	2.72 ± 0.56	0.091
Lesion length (mm)	14.7 ± 9.3	21.4 ± 10.7†	0.000
Percentage of BMS (%)	NA	91 (32.7)	

BMS: Bare metal stent; IVUS: Intravascular ultrasound; LAD: Left anterior descending artery; LCX: Left circumflex artery; LM: Left main; QCA: Quantitative coronary angiography; RCA: Right coronary artery

* $P < 0.05$

† $P < 0.01$

and longer lesion length in the revascularised group. BMS was used in one-third of this patient cohort.

In-hospital and Long-term Results

One in-hospital cardiac death occurred in the medical therapy group and another in the revascularised group. There were no non-cardiac death, MI and repeat revascularisation before the patients were discharged from the hospital.

At a mean follow-up duration of 29.7 ± 16 months, there were no observed differences in the incidence of death, target vessel revascularisation (TVR), MI, and overall MACE rate (Table 3). The overall MACE rate was 14.4% in the medical therapy group and 11.5% in the revascularisation patients. The Kaplan-Meier analysis showed a similar MACE-free survival and survival rates between the 2 groups (Fig. 2). Likewise, there were no significant differences in the rates of TVR and MI between the 2 groups.

After adjustment for baseline characteristics in a Cox multivariable model, there were no significant differences in long-term outcomes between medical therapy and revascularisation guided by FFR measurement (Table 4).

Discussion

This retrospective study showed that patients treated with medical therapy based on FFR measurement of intermediate

coronary lesions resulted in acceptable long-term outcomes with a low incidence of TVR and MACE events.

Our study had a MACE event of 14.4% in the medical therapy group and 11.5% in the revascularised group, which was comparable with published studies.^{8,9,10-14} Notably, there were more complex lesions in the revascularised group than in the medical therapy group, with a higher portion of multivessel disease, higher diameter stenosis, smaller reference vessel diameter and more diffuse lesions, which might have presented higher risk in this patient group to some extent. The results indicated that aggressive intervention with revascularisation is reasonable in intermediate lesions with haemodynamic significance.

For those patients with FFR more than 0.75, which indicated the presence of a functionally insignificant stenosis, the residual cardiac risks were still a challenge. The PROSPECT study showed that the cardiac event risk caused by non-culprit lesions with diameter stenosis of $32.3\% \pm 20.6\%$ is high at 11.4%, after 3.4 years of follow-up.¹⁵ More aggressive medical therapy is still recommended in this patient group.

In our study, the medical therapy group had reasonable long-term outcomes when compared with the revascularisation group. Although recent studies had used a new threshold of FFR < 0.80 as the level for recommendation for revascularisation, our work was done during the early

Table 3. Long-term Outcomes of Study Patients

	Medical Therapy (n = 368)	Revascularisation (n = 278)	P Value
Death (%)	7 (1.9)	9 (3.2)	0.314
Cardiac death	4 (1.1)	4 (1.4)	0.731
Target vessel revascularisation (%)	35 (9.5)	21 (7.6)	0.232
MI (%)	30 (8.1)	22 (8.0)	0.891
Thrombosis (%)	2 (0.5)	6 (2.2)*	0.021
MACE (%)	53 (14.4)	32 (11.5)	0.282

MACE: Major adverse cardiac event; MI: Myocardial infarction

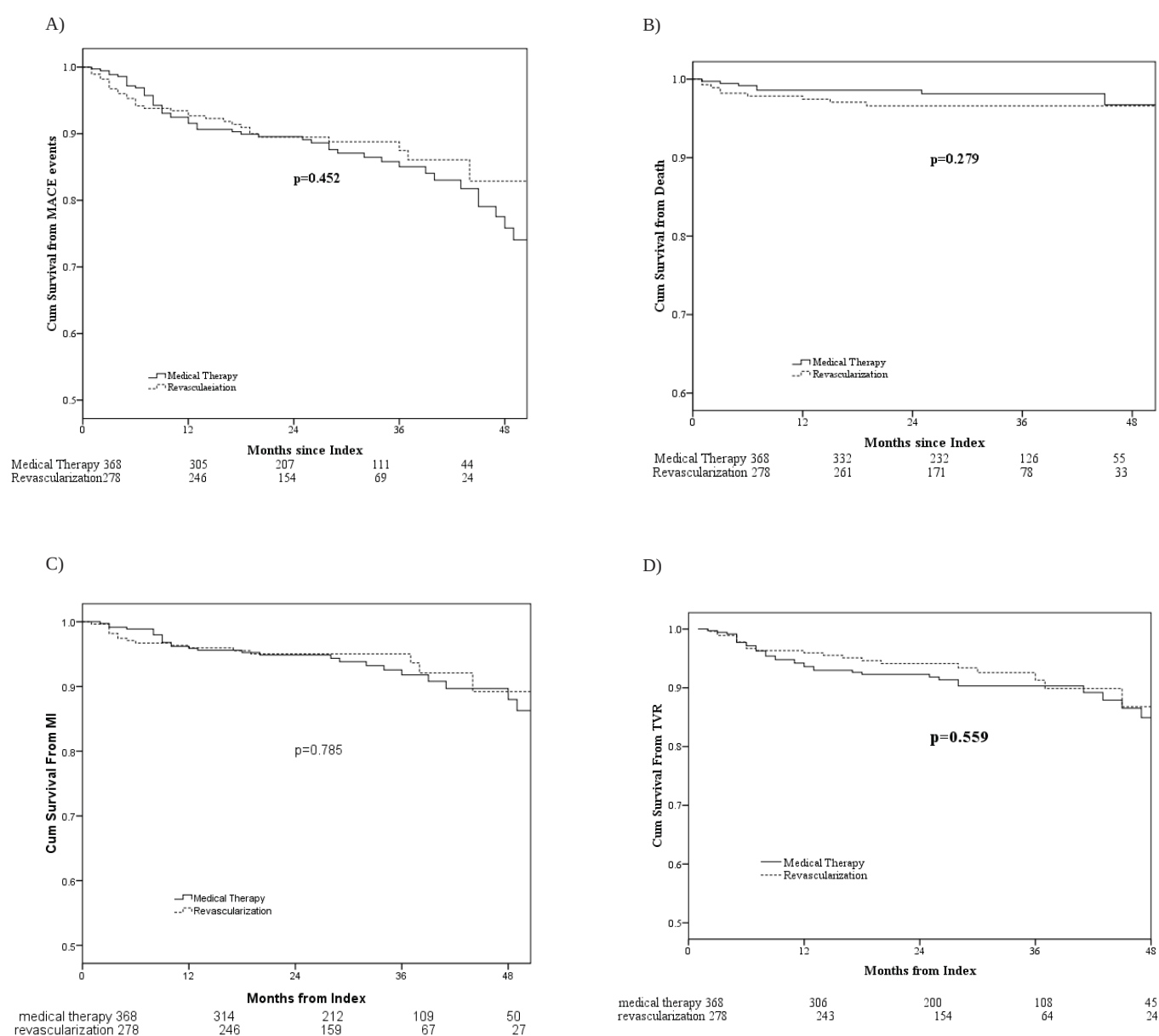
* $P < 0.05$ 

Fig. 2. Kaplan-Meier estimates of the time to cardiac events related to the target vessel during an average follow-up of 29 months for the medical therapy group and the revascularisation group (A, B, C, D).

Table 4. Cox Multivariable Models for Determinants of Outcome Events

Events	Adjusted HR*	95% CI	P Value
FFR-guided PCI vs medical therapy			
Death	2.162	0.794 – 5.891	0.132
Cardiac death	1.689	0.412 – 6.917	0.466
Target vessel revascularisation	0.760	0.431 – 1.340	0.343
MI	0.897	0.470 – 1.710	0.741
Thrombosis	2.801	0.443 – 17.709	0.274
MACE	0.861	0.544 – 1.362	0.522

CI: Confidential interval; FFR: Fractional flow reserve; HR: Hazard ratio; MACE: Major adverse cardiac events; MI: Myocardial infarction

*Adjusted for age, sex, smoker, diabetes, hypertension, hyperlipidaemia, family history, prior myocardial infarction, prior PCI indication.

period of 2002 to 2009 when FFR ≤ 0.75 was still used as the cutoff for haemodynamic significance. Our results indicated that the deferral of revascularisation in patients with FFR more than 0.75 was safe. More than 85% patients were free of MACE events at follow-up at 29 months, which implied potential cost saving from the obviation of initial PCI procedures.

In our study, IVUS was used in about 10% of the patients, and 9 patients with FFR more than 0.75 were revascularised according to IVUS findings. IVUS can provide more information about the coronary plaque than angiography alone, although several studies have revealed only a moderate correlation between minimal lesion diameter on IVUS and FFR. The correlation was dependent on the lesion location, reference vessel diameter and lesion length.¹⁶⁻¹⁸ A recent study suggested that both FFR-guided and IVUS-guided PCI strategies were associated with favourable outcomes for intermediate coronary lesions, and no significant difference was noted between both strategies.¹⁹ However, FFR-guided PCI reduced the need for revascularisation in many situations, with potential reduction of MACE event and cost of therapy. Li et al from the Mayo Clinic reported a comparative study using coronary angiography alone versus FFR for decision-making on PCI in daily practice. His results suggested that a FFR-guided strategy was associated with a favourable long-term outcome,²⁰ in corroboration with our findings. However in that study, the follow-up MACE event rate was high at 50%, compared with our medically treated MACE rate of 15%. There are several potential explanations. Firstly, our study had a shorter follow up duration of 29.7 months compared with theirs at 50.9 month. Secondly, the mortality rate in Li's study was especially high at 21% in the FFR-guided group and 32% in the angiography guided group, which counted for about half of the MACE events. This may be explained by the higher inherent risk among the patient cohort studied, which included 25% patients with previous

MI history and prior PCI in 40%.

There are several limitations to our study. This is a single centre study with a limited sample size. However, the study population comprised several Asian ethnic groups and is still one of the largest clinical studies focusing on the use of FFR in intermediate coronary lesions in an Asian setting.

Secondly, some patients were treated with BMS in this study. Whether a more widespread use of drug eluting stents will give better clinical results in intermediate coronary lesions is unknown. Moreover, there was a crossover rate of about 10% in the study groups, based on the operators' discretion following clinical assessment, consideration of anatomic feasibility for intervention, and after IVUS interrogation.

Conclusion

This retrospective study indicated that FFR-guided medical treatment of intermediate coronary lesions is feasible and associated with low incidences of TVR and MACE at long-term follow-up. Our findings corroborate with published data that FFR-guided strategy in treatment of patients with intermediate coronary artery disease reduces the need for intervention and has significant cost-saving implication in real world practice.

REFERENCES

1. Fischer JJ, Samady H, McPherson JA, Sarembock IJ, Powers ER, Gimple LW, et al. Comparison between visual assessment and quantitative angiography versus fractional flow reserve for native coronary narrowings of moderate severity. *Am J Cardiol* 2002;90:210-5.
2. Pijls NHJ, De Bruyne B, Peels K, Van Der Voort PH, Bonnier HJ, et al. Measurement of fractional flow reserve to assess the functional severity of coronary-artery stenoses. *New Engl J Med* 1996;334:1703-8.
3. Förster S, Rieber J, Ubleis C, Weiss M, Bartenstein P, Cumming P, et al. Tc-99m sestamibi single photon emission computed tomography for guiding percutaneous coronary intervention in patients with multivessel disease: a comparison with quantitative coronary angiography and fractional flow reserve. *Int J Cardiovasc Imaging* 2010;26:203-13.
4. Jung PH, Rieber J, Störk S, Hoyer C, Erhardt I, Nowotny A, et al. Effect of contrast application on interpretability and diagnostic value of dobutamine stress echocardiography in patients with intermediate coronary lesions: comparison with myocardial fractional flow reserve. *Eur Heart J* 2008;29:2536-43.
5. Hacker M, Rieber J, Schmid R, Lafougere C, Tausig A, Theisen K, et al. Comparison of Tc-99m sestamibi SPECT with fractional flow reserve in patients with intermediate coronary artery stenoses. *J Nucl Cardiol* 2005;12:645-54.
6. Rieber J, Jung P, Erhardt I, Koenig A, Hacker M, Schiele TM, et al. Comparison of pressure measurement, dobutamine contrast stress echocardiography and SPECT for the evaluation of intermediate coronary stenoses. The COMPRESS trial. *Int J Cardiovasc Intervent* 2004;6:142-7.
7. Matsuo H, Watanabe S, Kadosaki T, Yamaki T, Tanaka S, Miyata S, et al. Validation of collateral fractional flow reserve by myocardial perfusion imaging. *Circulation* 2002;105:1060-5.
8. Pijls NH, van Schaardenburgh P, Manoharan G, Boersma E, Bech JW, van't Veer M, et al. Percutaneous coronary intervention of functionally nonsignificant stenosis: 5-year follow-up of the DEFER Study. *J Am Coll Cardiol* 2007;49:2105-11.
9. Pijls NH, Fearon WF, Tonino PA, Siebert U, Ikeno F, Bornschein B, et al. Fractional flow reserve versus angiography for guiding percutaneous coronary intervention in patients with multivessel coronary artery disease: 2-year follow-up of the FAME (Fractional Flow Reserve versus Angiography for Multivessel Evaluation) study. *J Am Coll Cardiol* 2010;56:177-84.
10. Tanaka H, Chikamori T, Tanaka N, Hida S, Shindo N, Igarashi Y, et al. A flow-limiting stenosis is the major determinant of exercise-induced myocardial stunning in patients with coronary artery disease. *J Cardiol* 2010;55:337-44.
11. Oud N, Marques KM, Bronzwaer JG, Brinckman S, Allaart CP, de Cock CC, et al. Patients with coronary stenosis and a fractional flow reserve of ≥ 0.75 measured in daily practice at the VU University Medical Center. *Neth Heart J* 2010;18:402-7.
12. Legallery P, Schiele F, Seronde MF, Meneveau N, Wei H, Didier K, et al. One-year outcome of patients submitted to routine fractional flow reserve assessment to determine the need for angioplasty. *Eur Heart J* 2005;26:2623-9.
13. Muller O, Mangiacapra F, Ntalianis A, Verhamme KM, Trana C, Hamilos M, et al. Long-term follow-up after fractional flow reserve-guided treatment strategy in patients with an isolated proximal left anterior descending coronary artery stenosis. *JACC Cardiovasc Interv* 2011;4:1175-82.
14. Tonino PA, De Bruyne B, Pijls NH, Siebert U, Ikeno F, van't Veer M, et al. Fractional flow reserve versus angiography for guiding percutaneous coronary intervention. *N Engl J Med* 2009;360:213-24.
15. Stone GW, Maehara A, Lansky AJ, de Bruyne B, Cristea E, Mintz GS, et al. A prospective natural-history study of coronary atherosclerosis. *N Engl J Med* 2011;364:226-35.
16. Koo BK, Yang HM, Doh JH, Choe H, Lee SY, Yoon CH, et al. Optimal intravascular ultrasound criteria and their accuracy for defining the functional significance of intermediate coronary stenoses of different locations. *JACC Cardiovasc Interv* 2011;4:803-11.
17. Ben-Dor I, Torguson R, Gaglia MA Jr, Gonzalez MA, Maluenda G, Bui AB, et al. Correlation between fractional flow reserve and intravascular ultrasound lumen area in intermediate coronary artery stenosis. *EuroIntervention* 2011;7:225-33.
18. Takagi A, Tsurumi Y, Ishii Y, Suzuki K, Kawana M, Kasanuki H. Clinical potential of intravascular ultrasound for physiological assessment of coronary stenosis: relationship between quantitative ultrasound tomography and pressure-derived fractional flow reserve. *Circulation* 1999;100:250-5.
19. Nam CW, Yoon HJ, Cho YK, Park HS, Kim H, Hur SH, et al. Outcomes of percutaneous coronary intervention in intermediate coronary artery disease: fractional flow reserve-guided versus intravascular ultrasound-guided. *JACC Cardiovasc Interv* 2010;3:812-7.
20. Li J, Elrashidi MY, Flammer AJ, Lennon RJ, Bell MR, Holmes DR, et al. Long-term outcomes of fractional flow reserve-guided vs. angiography-guided percutaneous coronary intervention in contemporary practice. *Eur Heart J* 2013;34:1375-83.

Long-term Outcomes of Medical Therapy Versus Coronary Revascularisation in Patients with Intermediate Stenoses Guided by Pressure Wire

Hongyu Shi, ^{1MD}, Chi Hang Lee, ^{2MD}, Mark YY Chan, ^{2MD}, Adrian F Low, ^{2MD}, Swee Guan Teo, ^{2MD}, Koo Hui Chan, ^{2MD}, Rishi Sethi, ^{2MD}, Arthur Mark Richards, ^{2MD}, Huay Cheem Tan, ^{2MD}

Abstract

Introduction: This study aimed to examine the long-term clinical outcomes of coronary fractional flow reserve (FFR)-guided percutaneous coronary intervention (PCI) in a real-world population in an Asian tertiary centre. **Materials and Methods:** All patients who underwent FFR measurement for intermediate coronary lesions in our centre from June 2002 to December 2009 were enrolled. A threshold of FFR ≤ 0.75 was used for revascularisation. All the patients were prospectively followed-up for major adverse cardiac events (MACE) of death, myocardial infarction (MI), target vessel revascularisation (TVR) and stent thrombosis. **Results:** Based on FFR measurement, 368 (57%) patients were treated medically while 278 (43%) underwent revascularisation. At a mean follow-up duration of 29.7 ± 16 months, 53 (14.4%) patients in the medical therapy group and 32 (11.5%) patients in the revascularised group experienced MACE ($P = 0.282$). There were no statistical differences in all the clinical endpoints between the 2 groups. **Conclusion:** Medical therapy based on FFR measurement is associated with low incidences of MACE at long-term follow-up.

Ann Acad Med Singapore 2015;44:xx-xx

Key words: Fractional flow reserve, Major adverse cardiac events, Percutaneous coronary intervention

Introduction

Although coronary angiography has been used as the “gold standard” imaging technique for the diagnosis of coronary artery disease, it is essentially a lumenogram that offers no information on the functional significance of a coronary lesion. It is difficult to define the haemodynamic significance of a stenosis from the angiogram, especially in intermediate lesions (diameter stenosis of 50% to 70%).¹

Fractional flow reserve (FFR), defined as the ratio of pressure in the stenotic artery to the pressure in the same artery in the theoretical absence of stenosis, is a specific index for epicardial stenosis. A FFR value of 0.75 means that the stenotic vessel provides only 75% of the normal expected flow in the theoretical absence of stenosis. A FFR value of <0.75 is taken as a cutoff for ischaemia in

many studies.² It is the only functional index that has been validated against gold standard non-invasive functional tests such as stress echocardiography and single-photon emission computed tomography (SPECT).³⁻⁷

Several clinical randomised control trials, such as DEFER trial and FAME trial, have demonstrated significant superiority in percutaneous coronary intervention (PCI) guided by FFR when compared with angiography.^{8,9} However, the role of FFR measurement in the real world is not clear. Therefore, we decided to perform a retrospective analysis based on data extracted from National University Hospital (NUH) cardiovascular database to evaluate the long-term clinical outcomes of medical therapy versus revascularisation in patients with intermediate lesions guided by pressure wire.

¹Department of Cardiology, Shanghai Chest Hospital, People's Republic of China

²The Cardiac Department, National University Heart Centre and Yong Loo Lin School of Medicine, National University of Singapore, Singapore

Address for Correspondence: A/Prof Huay Cheem Tan, National University Heart Centre, Singapore 1E Kent Ridge Road, NUHS Tower Block, Level 9 Singapore 119228.

Email: huay_cheem_tan@nuhs.edu.sg

Materials and Methods

Study Patients

Patients who underwent coronary angiography and FFR measurement for intermediate coronary artery stenoses (defined visually as between 50% to 75%) at NUH, Singapore, between 2002 and 2009 were enrolled in this retrospective study. Patients with ST segment elevation myocardial infarction (MI) within 1 week after the coronary angiography were excluded.

Procedure and Antiplatelet Regimen

Percutaneous coronary angiogram was performed in accordance with standard techniques, and the intermediate lesion was determined visually by the operator. FFR was measured with Radi wire and PressureWire™ Certus FFR Measurement System (St Jude Medical, USA) positioned distally across the stenosis. Following initial pressure wire calibration and equalisation, intracoronary glyceryl trinitrate was administered to eliminate vasospasm. Maximal hyperaemia was achieved through intracoronary administration of papaverine or adenosine. Intracoronary papaverine has a duration effect of 45 seconds.¹⁰ Patients with FFR measurement of >0.75 were treated medically while those with $\text{FFR} \leq 0.75$ were revascularised. All patients receiving PCI were pretreated with clopidogrel and aspirin. A loading dose of 300 mg of clopidogrel was administered if the patient had not been pretreated. After the procedure, dual antiplatelet therapy for at least 1 year for drug eluting stent and 1 month for bare metal stent (BMS), followed by aspirin (100 mg/d to 300 mg/d) indefinitely were administered. Cardiac enzymes and 12-lead electrocardiogram (ECG) were determined routinely after the interventions.

Definitions and Follow-up

A major adverse cardiac event (MACE) was defined as the occurrence of death, MI, or need for a new revascularisation procedure. MI was defined by an increase in creatine kinase-MB fraction of more than 3 times the upper limit of normal. Stent thrombosis was defined as angiographic documentation of thrombotic stent occlusion associated with a clinical event, an unexplained sudden cardiac death, or MI not clearly attributable to another coronary lesion.

Clinical follow-up was obtained through hospital records, clinic visits and telephone phone calls.

Statistical Analysis

Categorical variables were presented as frequencies (percentages) and were compared with chi-square statistics or, when appropriate, Fischer's exact test. Continuous

variables were presented as mean $\pm$ standard deviation and compared with Student's t-test. Survival of MACE and each component were estimated using the Kaplan-Meier method, and the difference between the 2 survival curves were compared with the log rank test. Cox proportional hazards multiple regression models were used to estimate association between medical therapy versus revascularisation on long-term outcomes, after adjusting for other patient characteristics that were significantly different between groups. A *P* value of less than 0.05 was considered statistically significant, and all statistical tests were 2-tailed. Statistical analyses were performed with SPSS 13.0 (SPSS, Inc, Chicago, Illinois).

Results

Baseline Clinical Characteristics

A total of 646 patients with 812 intermediate lesions were included in this study. All of them received FFR measurement during cardiac catheterisation. In the group with FFR of more than 0.75 ($n = 360$), 347 patients (96.3%) were treated with medical therapy. Among those with an $\text{FFR} \leq 0.75$ ($n = 386$), 249 patients (87.1 %) were treated with revascularisation. There was a crossover of subjects in the 2 groups that did not go with the conventional algorithm because of the operators' decision. These included 21 patients with lesions of FFR more than 0.75 who crossed over to revascularisation, among which 9 patients had intravascular ultrasound (IVUS) examination which showed minimum lumen area (MLA) of less than 3 mm², and 12 patients had documented ischaemia on stress echocardiogram or myocardial SPECT imaging. Twenty-nine patients who had lesions with $\text{FFR} \leq 0.75$ were treated medically due to unsuitability for PCI and patients' wishes. PCI was performed in 255 patients (91.7%) with the details shown in Figure 1.

The baseline characteristics for the 2 groups were largely similar, except that the revascularised group had higher prevalence of hypertension and previous history of MI. Most patients presented with stable angina (Table 1).

Angiographic and Procedural Characteristics

Multivessel coronary artery disease accounted for two-thirds of revascularised patients, which was significantly higher than that in the medical therapy group. There was no significant difference in the lesion location between the 2 groups. More than half of the lesions were located in the left anterior descending artery. Left main artery and graft disease made up only a small percentage of the cohort (Table 2).

There was similar use of IVUS in both groups. Quantitative coronary analysis (QCA) showed higher diameter stenosis

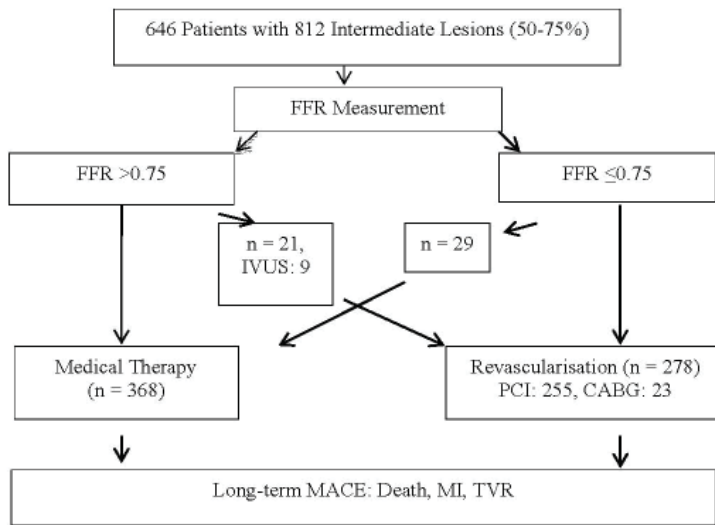


Fig. 1. Flow chart of the study. FFR: Fractional flow reserve; CABG: Coronary artery bypass grafting; PCI: Percutaneous coronary intervention; IVUS: Intravascular ultrasound; MACE: Major adverse cardiac event; MI: Myocardial infarction; TVR: Target vessel revascularisation

Table 1. Baseline Clinical Characteristics of the Study Patients

	Medical Therapy (n = 368)	Revascularisation (n = 278)	P Value
Age (years)	59.2 ± 10.4	57.0 ± 10.5†	0.008
Male (%)	273 (74.2)	234 (84.2)†	0.003
Ethnic group			0.454
Chinese, n (%)	238 (64.7)	192 (69.1)	
Indian, n (%)	60 (16.3)	42 (15.1)	
Malay, n (%)	53 (14.4)	37 (13.9)	
Others, n (%)	17 (4.6)	7 (2.5)	
Current smoker, n (%)	98 (26.6)	79 (28.4)	0.656
Hypertension, n (%)	255 (69.3)	169 (60.8)*	0.030
Diabetes, n (%)	144 (39.1)	104 (37.4)	0.683
Hyperlipidaemia, n (%)	271 (73.6)	211 (75.9)	0.524
Family history, n (%)	28 (7.6)	26 (9.4)	0.474
Previous MI, n (%)	46 (12.5)	58 (20.9)†	0.005
Previous PCI, n (%)	113 (30.7)	105 (37.7)	0.060
Indication of angiogram			0.940
Stable angina, n (%)	289 (78.6)	219 (78.7)	
NSTE-ACS, n (%)	79 (21.4)	59 (21.3)	
LVEF <50%, n (%)	68 (18.5)	54 (19.4)	0.762
Medicines			
Aspirin, n (%)	324 (88.0)	264 (95.0)†	0.002
Clopidogrel, n (%)	203 (55.2)	272 (97.8)†	0.000
Statins, n (%)	310 (84.2)	263 (94.6)†	0.000
ACEI or ARB, n (%)	196 (53.3)	167 (60.1)	0.093
Beta blockers, n (%)	269 (73.1)	221 (79.5)	0.064

ACEI: Angiotensin-converting enzyme inhibitor; ARB: Angiotensin receptor blocker; BMI: Body mass index; LVEF: Left ventricle ejection fraction; MI: Myocardial infarction; NSTE-ACS: Non-ST segment elevated acute coronary syndrome; PCI: Percutaneous coronary intervention

*P < 0.05

†P < 0.01

Table 2. Angiographic and Procedural Characteristics of Study Patients

	Medical Therapy (n = 368)	Revascularisation (n = 278)	P Value
Number of diseased vessel, n (%)			0.015
1	165 (44.8)	94 (33.8)*	
2	133 (36.1)	115 (41.4)	
3	70 (19.0)	69 (24.8)	
Location			0.067
LM, n (%)	20 (4.7)	11 (2.8)	
LAD, n (%)	254 (59.8)	262 (67.7)	
LCX, n (%)	66 (15.5)	39 (10.1)	
RCA, n (%)	79 (18.6)	71 (18.3)	
Grafts, n (%)	6 (1.4)	4 (1.0)	
IVUS use, n (%)	34 (9.2)	25 (9.0)	1.000
QCA measurement			
Diameter stenosis (%)	51.8 ± 11.4	70.5 ± 11.8†	0.000
Reference diameter (mm)	3.09 ± 2.67	2.72 ± 0.56	0.091
Lesion length (mm)	14.7 ± 9.3	21.4 ± 10.7†	0.000
Percentage of BMS (%)	NA	91 (32.7)	

BMS: Bare metal stent; IVUS: Intravascular ultrasound; LAD: Left anterior descending artery; LCX: Left circumflex artery; LM: Left main; QCA: Quantitative coronary angiography; RCA: Right coronary artery

* $P < 0.05$

† $P < 0.01$

and longer lesion length in the revascularised group. BMS was used in one-third of this patient cohort.

In-hospital and Long-term Results

One in-hospital cardiac death occurred in the medical therapy group and another in the revascularised group. There were no non-cardiac death, MI and repeat revascularisation before the patients were discharged from the hospital.

At a mean follow-up duration of 29.7 ± 16 months, there were no observed differences in the incidence of death, target vessel revascularisation (TVR), MI, and overall MACE rate (Table 3). The overall MACE rate was 14.4% in the medical therapy group and 11.5% in the revascularisation patients. The Kaplan-Meier analysis showed a similar MACE-free survival and survival rates between the 2 groups (Fig. 2). Likewise, there were no significant differences in the rates of TVR and MI between the 2 groups.

After adjustment for baseline characteristics in a Cox multivariable model, there were no significant differences in long-term outcomes between medical therapy and revascularisation guided by FFR measurement (Table 4).

Discussion

This retrospective study showed that patients treated with medical therapy based on FFR measurement of intermediate

coronary lesions resulted in acceptable long-term outcomes with a low incidence of TVR and MACE events.

Our study had a MACE event of 14.4% in the medical therapy group and 11.5% in the revascularised group, which was comparable with published studies.^{8,9,10-14} Notably, there were more complex lesions in the revascularised group than in the medical therapy group, with a higher proportion of multivessel disease, higher diameter stenosis, smaller reference vessel diameter and more diffuse lesions, which might have presented higher risk in this patient group to some extent. The results indicated that aggressive intervention with revascularisation is reasonable in intermediate lesions with haemodynamic significance.

For those patients with FFR more than 0.75, which indicated the presence of a functionally insignificant stenosis, the residual cardiac risks were still a challenge. The PROSPECT study showed that the cardiac event risk caused by non-culprit lesions with mean diameter stenosis of $32.3\% \pm 20.6\%$ is high at 11.4%, after 3.4 years of follow-up.¹⁵ More aggressive medical therapy is still recommended in this patient group.

In our study, the medical therapy group had reasonable long-term outcomes when compared with the revascularisation group. Although recent studies had used a new threshold of FFR < 0.8 as the level for recommendation for revascularisation, our work was done during the early

Table 3. Long-term Outcomes of Study Patients

	Medical Therapy (n = 368)	Revascularisation (n = 278)	P Value
Death (%)	7 (1.9)	9 (3.2)	0.314
Cardiac death	4 (1.1)	4 (1.4)	0.731
Target vessel revascularisation (%)	35 (9.5)	21 (7.6)	0.232
MI (%)	30 (8.1)	22 (8.0)	0.891
Thrombosis (%)	2 (0.5)	6 (2.2)*	0.021
MACE (%)	53 (14.4)	32 (11.5)	0.282

MACE: Major adverse cardiac event; MI: Myocardial infarction

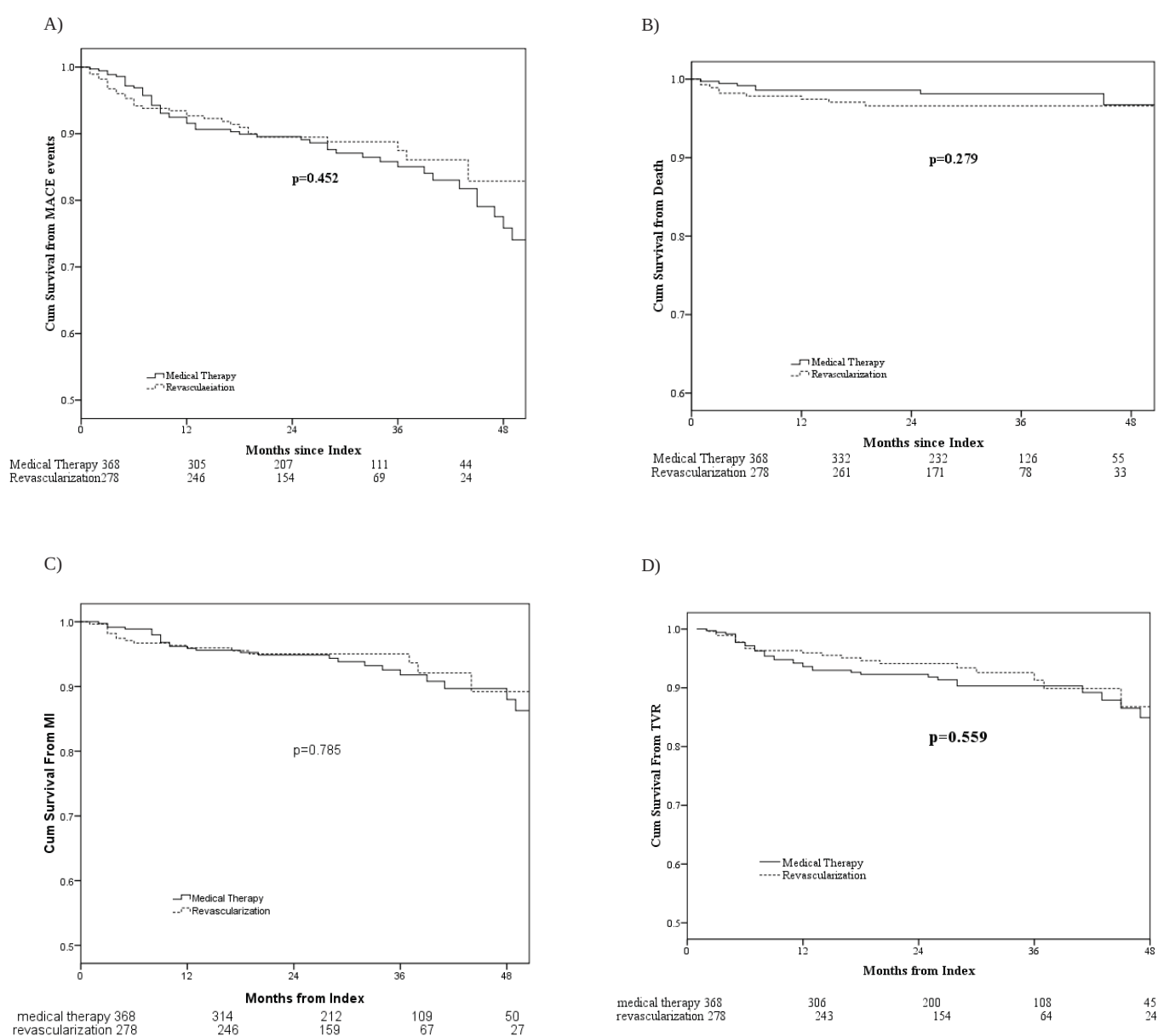
* $P < 0.05$ 

Fig. 2. Kaplan-Meier estimates of the time to cardiac events related to the target vessel during an average follow-up of 29 months for the medical therapy group and the revascularisation group (A, B, C, D).

Table 4. Cox Multivariable Models for Determinants of Outcome Events

Events	Adjusted HR*	95% CI	P Value
FFR-guided PCI vs medical therapy			
Death	2.162	0.794 – 5.891	0.132
Cardiac death	1.689	0.412 – 6.917	0.466
Target vessel revascularisation	0.760	0.431 – 1.340	0.343
MI	0.897	0.470 – 1.710	0.741
Thrombosis	2.801	0.443 – 17.709	0.274
MACE	0.861	0.544 – 1.362	0.522

CI: Confidential interval; FFR: Fractional flow reserve; HR: Hazard ratio; MACE: Major adverse cardiac events; MI: Myocardial infarction

*Adjusted for age, sex, smoker, diabetes, hypertension, hyperlipidaemia, family history, prior myocardial infarction, prior PCI indication.

period of 2002 to 2009 when FFR ≤ 0.75 was still used as the cutoff for haemodynamic significance. Our results indicated that the deferral of revascularisation in patients with FFR more than 0.75 was safe. More than 85% patients were free of MACE events at follow-up at 29 months, which implied potential cost saving from the obviation of initial PCI procedures.

In our study, IVUS was used in about 10% of the patients, and 9 patients with FFR more than 0.75 were revascularised according to IVUS findings. IVUS can provide more information about the coronary plaque than angiography alone, although several studies have revealed only a moderate correlation between minimal lesion diameter on IVUS and FFR. The correlation was dependent on the lesion location, reference vessel diameter and lesion length.¹⁶⁻¹⁸ A recent study suggested that both FFR-guided and IVUS-guided PCI strategies were associated with favourable outcomes for intermediate coronary lesions, and no significant difference was noted between both strategies.¹⁹ However, FFR-guided PCI reduced the need for revascularisation in many situations, with potential reduction of MACE event and cost of therapy. Li et al from the Mayo Clinic reported a comparative study using coronary angiography alone versus FFR for decision-making on PCI in daily practice. His results suggested that a FFR-guided strategy was associated with a favourable long-term outcome,²⁰ in corroboration with our findings. However in that study, the follow-up MACE event rate was high at 50%, compared with our medically treated MACE rate of 15%. There are several potential explanations. Firstly, our study had a shorter follow up duration of 29.7 months compared with theirs at 50.9 month. Secondly, the mortality rate in Li's study was especially high at 21% in the FFR-guided group and 32% in the angiography guided group, which counted for about half of the MACE events. This may be explained by the higher inherent risk among the patient cohort studied, which included 25% patients with previous

MI history and prior PCI in 40%.

There are several limitations to our study. This is a single centre study with a limited sample size. However, the study population comprised several Asian ethnic groups and is still one of the largest clinical studies focusing on the use of FFR in intermediate coronary lesions in an Asian setting.

Secondly, some patients were treated with BMS in this study. Whether a more widespread use of drug eluting stents will give better clinical results in intermediate coronary lesions is unknown. Moreover, there was a crossover rate of about 10% in the study groups, based on the operators' discretion following clinical assessment, consideration of anatomic feasibility for intervention, and after IVUS interrogation.

Conclusion

This retrospective study indicated that FFR-guided medical treatment of intermediate coronary lesions is feasible and associated with low incidences of TVR and MACE at long-term follow-up. Our findings corroborate with published data that FFR-guided strategy in treatment of patients with intermediate coronary artery disease reduces the need for intervention and has significant cost-saving implication in real world practice.

REFERENCES

1. Fischer JJ, Samady H, McPherson JA, Sarembock IJ, Powers ER, Gimple LW, et al. Comparison between visual assessment and quantitative angiography versus fractional flow reserve for native coronary narrowings of moderate severity. *Am J Cardiol* 2002;90:210-5.
2. Pijls NHJ, De Bruyne B, Peels K, Van Der Voort PH, Bonnier HJ, et al. Measurement of fractional flow reserve to assess the functional severity of coronary-artery stenoses. *New Engl J Med* 1996;334:1703-8.
3. Förster S, Rieber J, Ubleis C, Weiss M, Bartenstein P, Cumming P, et al. Tc-99m sestamibi single photon emission computed tomography for guiding percutaneous coronary intervention in patients with multivessel disease: a comparison with quantitative coronary angiography and fractional flow reserve. *Int J Cardiovasc Imaging* 2010;26:203-13.
4. Jung PH, Rieber J, Störk S, Hoyer C, Erhardt I, Nowotny A, et al. Effect of contrast application on interpretability and diagnostic value of dobutamine stress echocardiography in patients with intermediate coronary lesions: comparison with myocardial fractional flow reserve. *Eur Heart J* 2008;29:2536-43.
5. Hacker M, Rieber J, Schmid R, Lafougere C, Tausig A, Theisen K, et al. Comparison of Tc-99m sestamibi SPECT with fractional flow reserve in patients with intermediate coronary artery stenoses. *J Nucl Cardiol* 2005;12:645-54.
6. Rieber J, Jung P, Erhard I, Koenig A, Hacker M, Schiele TM, et al. Comparison of pressure measurement, dobutamine contrast stress echocardiography and SPECT for the evaluation of intermediate coronary stenoses. The COMPRESS trial. *Int J Cardiovasc Intervent* 2004;6:142-7.
7. Matsuo H, Watanabe S, Kadosaki T, Yamaki T, Tanaka S, Miyata S, et al. Validation of collateral fractional flow reserve by myocardial perfusion imaging. *Circulation* 2002;105:1060-5.
8. Pijls NH, van Schaardenburgh P, Manoharan G, Boersma E, Bech JW, van't Veer M, et al. Percutaneous coronary intervention of functionally nonsignificant stenosis: 5-year follow-up of the DEFER Study. *J Am Coll Cardiol* 2007;49:2105-11.
9. Pijls NH, Fearon WF, Tonino PA, Siebert U, Ikeno F, Bornschein B, et al. Fractional flow reserve versus angiography for guiding percutaneous coronary intervention in patients with multivessel coronary artery disease: 2-year follow-up of the FAME (Fractional Flow Reserve versus Angiography for Multivessel Evaluation) study. *J Am Coll Cardiol* 2010;56:177-84.
10. Tanaka H, Chikamori T, Tanaka N, Hida S, Shindo N, Igarashi Y, et al. A flow-limiting stenosis is the major determinant of exercise-induced myocardial stunning in patients with coronary artery disease. *J Cardiol* 2010;55:337-44.
11. Oud N, Marques KM, Bronzwaer JG, Brinckman S, Allaart CP, de Cock CC, et al. Patients with coronary stenosis and a fractional flow reserve of ≥ 0.75 measured in daily practice at the VU University Medical Center. *Neth Heart J* 2010;18:402-7.
12. Legallery P, Schiele F, Seronde MF, Meneveau N, Wei H, Didier K, et al. One-year outcome of patients submitted to routine fractional flow reserve assessment to determine the need for angioplasty. *Eur Heart J* 2005;26:2623-9.
13. Muller O, Mangiacapra F, Ntalianis A, Verhamme KM, Trana C, Hamilos M, et al. Long-term follow-up after fractional flow reserve-guided treatment strategy in patients with an isolated proximal left anterior descending coronary artery stenosis. *JACC Cardiovasc Interv* 2011;4:1175-82.
14. Tonino PA, De Bruyne B, Pijls NH, Siebert U, Ikeno F, van't Veer M, et al. Fractional flow reserve versus angiography for guiding percutaneous coronary intervention. *N Engl J Med* 2009;360:213-24.
15. Stone GW, Maehara A, Lansky AJ, de Bruyne B, Cristea E, Mintz GS, et al. A prospective natural-history study of coronary atherosclerosis. *N Engl J Med* 2011;364:226-35.
16. Koo BK, Yang HM, Doh JH, Choe H, Lee SY, Yoon CH, et al. Optimal intravascular ultrasound criteria and their accuracy for defining the functional significance of intermediate coronary stenoses of different locations. *JACC Cardiovasc Interv* 2011;4:803-11.
17. Ben-Dor I, Torguson R, Gaglia MA Jr, Gonzalez MA, Maluenda G, Bui AB, et al. Correlation between fractional flow reserve and intravascular ultrasound lumen area in intermediate coronary artery stenosis. *EuroIntervention* 2011;7:225-33.
18. Takagi A, Tsurumi Y, Ishii Y, Suzuki K, Kawana M, Kasanuki H. Clinical potential of intravascular ultrasound for physiological assessment of coronary stenosis: relationship between quantitative ultrasound tomography and pressure-derived fractional flow reserve. *Circulation* 1999;100:250-5.
19. Nam CW, Yoon HJ, Cho YK, Park HS, Kim H, Hur SH, et al. Outcomes of percutaneous coronary intervention in intermediate coronary artery disease: fractional flow reserve-guided versus intravascular ultrasound-guided. *JACC Cardiovasc Interv* 2010;3:812-7.
20. Li J, Elrashidi MY, Flammar AJ, Lennon RJ, Bell MR, Holmes DR, et al. Long-term outcomes of fractional flow reserve-guided vs. angiography-guided percutaneous coronary intervention in contemporary practice. *Eur Heart J* 2013;34:1375-83.

Prevalence of Chronic Kidney Disease in Singaporean Adults with Type 2 Diabetes Mellitus

Serena Low,¹ MBBS, MSc (Public Health), Chee Fang Sum,² FRCPI, FRCPE, FACP, Lee Ying Yeoh,³ MD, MRCP, Subramaniam Tavintharan,⁴ FAMS, FRCP, MCI, Xiao Wei Ng,⁴ PhD (Food Science), Simon BM Lee,⁵ MBBS, M Med (Family Med), MCFP, Wern Ee Tang,⁶ MBBS, M Med (Family Med), FCFP, Su Chi Lim,² MBBS, MRCP, PhD

Abstract

Introduction: Diabetes mellitus (DM) is a major cause of chronic kidney disease (CKD). The epidemiology of CKD secondary to type 2 DM (T2DM) (i.e. diabetic nephropathy (DN)) has not been well studied in Singapore, a multi-ethnic Asian population. We aimed to determine the prevalence of CKD in adult patients with T2DM. **Materials and Methods:** We conducted a cross-sectional study on patients (n = 1861) aged 21 to 89 years with T2DM who had attended the DM centre of a single acute care public hospital or a primary care polyclinic between August 2011 and November 2013. Demographic and clinical data were obtained from patients using a standard questionnaire. Spot urine and fasting blood samples were sent to an accredited hospital laboratory for urinary albumin, serum creatinine, HbA1c and lipid measurement. CKD was defined and classified using the 2012 Kidney Disease: Improving Global Outcomes (KDIGO) guidelines and classification. **Results:** The distribution by risk of adverse CKD outcomes was: low risk, 47%; moderate risk, 27.2%; high risk, 12.8%; and very high risk, 13%. The prevalence of CKD in patients with T2DM was 53%. Variables significantly associated with CKD include neuropathy, blood pressure $\geq 140/80$ mmHg, triglycerides ≥ 1.7 mmol, body mass index, duration of diabetes, HbA1c $\geq 8\%$, age, cardiovascular disease, and proliferative retinopathy. **Conclusion:** CKD was highly prevalent among patients with T2DM in Singapore. Several risk factors for CKD are well recognised and amenable to intervention. Routine rigorous screening for DN and enhanced programme for global risk factors reduction will be critical to stem the tide of DN.

Ann Acad Med Singapore 2015;44:xx-xx

Key words: Albuminuria, Renal impairment, Risk factors

Introduction

According to the National Health Survey, the percentage of Singapore residents with diabetes mellitus (DM) aged between 18 and 69 years has risen from 8.2% in 2004 to 11.3% in 2010.^{1,2} DM can lead to a myriad of long-term health complications such as coronary heart disease, kidney failure and stroke.³ Of note, DM is a major cause of kidney failure.⁴ There is a rising trend of end-stage renal disease (ESRD) due to DM. The proportion of diabetics among new ESRD patients increased from 48.2% in 1999 to 63.5% in 2011.⁵ The problem of kidney failure arising from DM will be of even more concern as DM prevalence increases.

There are guidelines⁶⁻⁸ to facilitate detection and

appropriate management of patients with chronic kidney disease (CKD). The Kidney Disease: Improving Global Outcomes (KDIGO) 2012 clinical practice guideline for the evaluation and management of CKD has recently updated the original 2002 version with enhanced classification of CKD. This includes adding the cause and categories of albuminuria besides glomerular filtration rate (GFR) in the assessment, and refining GFR category 3 into 3a and 3b. The risk categorisation of CKD is reflected in the yearly rate of decline in renal function, e.g. GFR drop of ≤ 1 mL/min/1.73m²/year in subjects with low risk of CKD progression and ≥ 4 mL/min/1.73m²/year in those with high risk of CKD progression.⁶ It will be useful to

¹Clinical Services, Khoo Teck Puat Hospital, Singapore

²Diabetes Centre, Khoo Teck Puat Hospital, Singapore

³Department of Medicine, Khoo Teck Puat Hospital, Singapore

⁴Clinical Research Unit, Khoo Teck Puat Hospital, Singapore

⁵Yishun Polyclinic, Singapore

⁶National Healthcare Group Polyclinics, Singapore

Address for Correspondence: Dr Serena Low, Research Laboratory, Basement 1, Khoo Teck Puat Hospital, 90 Yishun Central, Singapore 768828.

Email: low.serena.km@alexandrahealth.com.sg

understand the prevalence of the CKD based on the revised categories. Furthermore, information on the burden of CKD in DM patients in Singapore is limited although there has been extensive research on this group internationally.⁹⁻¹⁵ There were a few studies that examined the status of renal function among patients with diabetes in Singapore.¹⁶⁻¹⁸ For example, the Diabcare-Singapore 1998 study revealed abnormal levels of urinary protein (>500 mg/24 hours) in 16%, microalbuminuria in 36% and raised serum creatinine in 3% of the patients tested in 22 diabetes clinics from general hospitals and primary healthcare centres.¹⁵ While these studies have shed light on the renal status in terms of albuminuria and elevated creatinine, little is known about CKD prevalence among patients with DM using the KDIGO revised guidelines. We therefore undertook a study to determine the prevalence of CKD as well as its associated factors in patients with Type 2 DM (T2DM). We hope to establish a baseline profile for the risk of CKD outcome with the findings in order to develop future prevention and management strategies tailored to patients with T2DM.

Materials and Methods

Study Design

This is a cross-sectional study involving 1861 adult patients aged between 21 and 89 years with T2DM who attended the DM centre or a primary care polyclinic in the northern region of Singapore between August 2011 and November 2013. The polyclinics in Singapore provide medical care for acute and chronic conditions, medical examination, screening and other services. The DM centre is a one-stop centre located in Khoo Teck Puat Hospital (KTPH) for people with DM in the northern region of Singapore. It manages patients with DM with more complications that require a higher level of holistic care. The study was approved by the National Healthcare Group Domain Specific Review Board in Singapore and all patients signed written informed consent.

The exclusion criteria were as follows: T1DM, pregnancy, active inflammation, cancer, on non-steroid anti-inflammatory drugs (NSAIDs) on the day of the assessment, on oral steroids equivalent to >5 mg/day of prednisolone, fasting glucose <4.5 mmol or >15 mmol, HbA1c >12%, inability to give informed consent and insertion of pacemaker or any device that may be affected by electric current.

Measurement

Data on demographics, vascular risk factors, diabetic complications and medications were extracted from a standard questionnaire answered by all patients. Blood pressure was measured by trained nurses using a standard

electronic sphygmomanometer. The measurement was done on the arm of the subject with an appropriate cuff in the sitting position, and an average of 3 readings was taken. High blood pressure (BP) was deemed as systolic blood pressure ≥ 140 mmHg and/or diastolic blood pressure ≥ 80 mmHg, taking reference from the 2014 American Diabetes Association (ADA) recommendations.¹⁹ Ankle pressure was measured after a 5-minute rest in supine position with a standardised Doppler ultrasonic device. Ankle brachial index (ABI) was calculated as the ratio of the higher of the 2 systolic pressures at the ankle to the higher of the right and left brachial artery pressures. Peripheral artery disease (PAD) was defined as present if the lower ABI ≤ 0.9 .^{20,21} Neuropathy was assessed using a neurothesiometer for vibration and a 5.07 (10 g) monofilament on non-calloused plantar sites for light touch. For monofilament assessment in the foot, the test is considered abnormal if a patient fails to feel at least 3 out of 10 sites. For neurothesiometer readings, a mean of 3 values greater than 25 volts indicates that the patient is at risk, and the test is considered as abnormal. Neuropathy was defined as the presence of an abnormal finding in monofilament or neurothesiometer testing. Retinopathy was ascertained from patients' medical record. If this was absent, the patient was asked for the information through questionnaire.

Spot urine creatinine was obtained along with spot urine albumin and serum creatinine. An average reading for a maximum of 3 tests was obtained. Blood samples for HbA1c and lipids were also taken from the patients. The spot urine and blood samples were sent to the hospital laboratory accredited by the College of the American Pathologists (CAP) for measurement. The following assays or methods were used for measurement: Roche cobas® c501 immunoturbidimetric assay for urinary albumin; Roche cobas® c501 enzymatic colorimetric test for serum creatinine, total cholesterol (TC), low-density lipoprotein cholesterol (LDL-cholesterol), high-density lipoprotein cholesterol (HDL-cholesterol) and triglycerides (TG); and monoclonal antibody agglutination reaction using Siemens DCA Vantage® analyser for glycated haemoglobin (HbA1c). Lipid abnormalities were considered as follows: LDL-cholesterol ≥ 2.6 mmol/L (high LDL-cholesterol); HDL-cholesterol ≤ 1 mmol/L in men or ≤ 1.3 mmol/L in women (low HDL-cholesterol); TC ≥ 5.2 mmol/L (high TC); and TG ≥ 1.7 mmol/L (high TG), taking references from the 2014 ADA recommendations.¹⁹

The Modification of Diet in Renal Disease (MDRD) formula was used to calculate the estimated GFR (eGFR).²² We are aware of another equation—the Chronic Kidney Disease Epidemiology (CKD-EPI) collaboration equations—formulated for the general population (i.e. not limited to T2DM). We have decided to adopt the MDRD

formula given the wealth of publications based on this equation. The KDIGO 2012 CKD guidelines defined albuminuria categories as normal or mildly increased, moderately increased and severely increased for urinary albumin to creatinine ratio (ACR) values of <30 mg/g, 30 to 300 mg/g and >300 mg/g respectively. In the KDIGO 2012 CKD Guidelines, CKD was defined by the presence of decreased GFR <60 mL/min per 1.73 m² or kidney damage as indicated by ACR ≥30 mg/g or other markers for more than 3 months.⁶ As we were unable to ascertain if the above abnormalities persisted for more than 3 months, we defined CKD as GFR <60 mL/min per 1.73 m² or ACR ≥30 mg/g in our study.

Statistical Analysis

Categorical data were expressed as number (percentage) and continuous data as means ± standard deviation (SD) unless otherwise stated. Differences in patient characteristics, risk factors, medications and complications among categories of risk for CKD outcomes (low, moderate and high/very high risk) were studied using chi-square test for categorical variables, and one-way ANOVA or Kruskal Wallis for continuous variables where appropriate. Logistic regression was used to estimate the odds ratio (OR) for the association between patient characteristics and CKD. Variables were subsequently included in the age-adjusted multivariable logistic regression if $P < 0.1$ in the bivariate logistic regression. Statistical significance is taken at $P < 0.05$. Statistical analysis was performed using STATA version 13 (STATA Corporation, College Station, Texas).

Results

Table 1 shows the baseline characteristics of the 1861 patients with T2DM as follows: mean age, 57.5 ± 10.7 years; 50.1% males; duration of diabetes, 10 years (4 years to 16 years), mean body mass index (BMI), 27.7 ± 5.2 kg/m²; mean HbA1c, 7.5% (6.8% to 8.5%); 46.6% with BP ≥140/80 mmHg; 17.1% with high TC; 51.5% with high LDL-cholesterol; 37.9% with low HDL-cholesterol; and 35.9% with high TG.

The distribution by risk for outcome of CKD was as follows: low risk, 47%; moderate risk, 27.2%; high risk, 12.8%; and very high risk, 13%. Of the 1861 patients, 53% had CKD, 21.4% had GFR <60 mL/min per 1.73 m² and 48% had ACR ≥30 mg/g. Figure 1 shows the distribution by GFR and albuminuria categories.

The characteristics of patients by CKD risk categories are shown in Table 1. Patients with moderate or high/very high risk of CKD tended to be older, of Malay ethnicity, had longer duration of diabetes, with higher BMI, HbA1c ≥8%, BP ≥140/80 mmHg, low HDL cholesterol, and high

TG ($P < 0.001$ for all).

Compared to the low risk for CKD group, the moderate and high/very high risk groups had higher proportions of use of insulin, aspirin, angiotensin-converting enzyme (ACE) inhibitor or angiotensin II receptor blocker (ARB) and statins ($P < 0.001$ for all). In terms of complications, patients in the moderate and high/very high risk groups were more likely to have proliferative retinopathy, neuropathy and CVD (which includes heart attack, blockade of arteries, balloon angioplasty of blocked artery of the heart, bypass operation, stroke or PAD ($P < 0.001$ for all)).

Risk Factors for CKD

The significant risk factors in the multivariable model were neuropathy (OR 3.64, 95% CI, 1.99 to 6.65); BP ≥140/80 mmHg (OR 2.45, 95% CI, 1.86 to 3.23), TG ≥1.7 mmol/L (OR 1.77, 95% CI, 1.3 to 2.4), BMI (OR 1.07, 95% CI, 1.04 to 1.1); duration of DM (OR 1.05, 95% CI, 1.03 to 1.07), HbA1c ≥9% (OR 1.8, 95% CI, 1.16 to 2.78), age (OR 1.02, 95% CI, 1 to 1.03), HbA1c 8% to <9% (OR 1.57, 95% CI, 1.06 to 2.34); CVD (OR 1.45, 95% CI, 1.02 to 2.05) and proliferative retinopathy (OR 1.79, 95% CI, 1 to 3.2) (Table 2).

Discussion

The prevalence of CKD among T2DM, defined as ACR ≥30 mg/g or GFR <60 mL/min per 1.73 m², was reported to range from 27.9% to 77% in other countries.⁹⁻¹⁵ The wide variation in the burden of CKD in these studies could be due to differences in CKD definition or patient profiles such as ethnicity and healthcare setting, i.e. primary care catchment versus hospital care. In our study, 53% of T2DM patients had CKD as defined by KDIGO. The higher prevalence of CKD in our study population as compared to most of the earlier studies could be attributed to the more advanced cases managed in KTPH DM Centre (i.e. referral bias to a secondary hospital). It may also reflect the high (and rising) burden of diabetes in an urbanised society like Singapore—our latest national health survey suggested that approximately 11.3% of the adult population had diabetes.² Although it is likely that most of the CKD is secondary to DM, we do not know the proportion of individuals whose CKD can be attributable to other causes such as hypertension, IgA nephropathy and chronic glomerulonephritis. Other possible reasons for the relatively high prevalence of CKD in our study populations include: Asian's ethnic related susceptibility to diabetic nephropathy;²³ seniority of study population and age-dependent eGFR formula;²⁴ high burden of atherosclerosis and arterial calcification.²⁵ Nonetheless, the high prevalence of CKD in our study constitutes a significant public health concern as it not only

Table 1. Characteristics of Patients by CKD Risk Categories (Low, Moderate and High/Very High)

Characteristics	All* (n = 1861)	Low Risk* (n = 875)	Moderate Risk* (n = 506)	High/Very High Risk* (n = 480)	P Value
Age (years)	57.5 ± 10.7	55.8 ± 10.8	57.6 ± 10.4	60.5 ± 10.3	<0.001
Gender					
Male	932 (50.1)	428 (48.9)	240 (47.4)	264 (55)	0.038
Ethnic group					<0.001
Chinese	950 (51.1)	464 (53)	236 (46.6)	250 (52.1)	
Malay	427 (22.9)	152 (17.4)	135 (26.7)	140 (29.2)	
Indian	428 (23)	228 (26.1)	120 (23.7)	80 (16.7)	
Others	56 (3)	31 (3.5)	15 (3)	10 (2.1)	
Duration of diabetes (years)	10.0 (4 – 16)	7.0 (3 – 12)	10.0 (4 – 16.5)	15.0 (9 – 20)	0.0001
Control of Risk Factors					
Smoking history					0.012
Never	1570 (84.6)	755 (86.3)	422 (83.7)	393 (82.4)	
Ex-smoker	131 (7.1)	54 (6.2)	29 (5.8)	48 (10.1)	
Current smoker	155 (8.4)	66 (7.5)	53 (10.5)	36 (7.6)	
Body mass index (kg/m ²)	27.7 ± 5.2	27.1 ± 4.9	28.4 ± 5.5	28.2 ± 5.2	<0.001
Waist circumference (cm)	95.3 (88.1 – 104.5)	93.6 (87.1 – 103.1)	96.8 (89.1 – 106.7)	96.5 (88.4 – 104.2)	0.0006
HbA1c (%)	7.5 (6.8 – 8.5)	7.2 (6.7 – 8.2)	7.6 (6.9 – 8.7)	8 (7.1 – 9)	0.0001
HbA1c group					<0.001
<7%	575 (30.9)	334 (38.2)	140 (27.7)	101 (21)	
7% to <8%	588 (31.6)	292 (33.4)	157 (31)	139 (29)	
8% to <9%	365 (19.6)	135 (15.4)	111 (21.9)	119 (24.8)	
≥9%	333 (17.9)	114 (13)	98 (19.4)	121 (25.2)	
Systolic BP (mmHg)	139 (127 – 152)	133 (123 – 146)	141 (130 – 153)	149 (136 – 164)	0.0001
Diastolic BP (mmHg)	79.1 ± 9.6	77.9 ± 8.8	80.6 ± 9.6	79.7 ± 10.7	<0.001
BP ≥140/80 mmHg	568 (46.6)	198 (33.8)	179 (53.9)	191 (63.5)	<0.001
Total cholesterol# (mmol/L)	4.3 (3.8 – 4.9)	4.3 (3.8 – 4.9)	4.3 (3.8 – 4.9)	4.4 (3.8 – 5)	0.189
Total cholesterol ≥5.2 mmol/L#	318 (17.1)	131 (15)	91 (18)	96 (20)	0.05
HDL cholesterol in men (mmol/L)	1.2 (1 – 1.3)	1.2 (1 – 1.4)	1.2 (1 – 1.3)	1.1 (0.9 – 1.3)	0.0125
HDL cholesterol in women (mmol/L)	1.4 (1.2 – 1.6)	1.4 (1.2 – 1.6)	1.3 (1.1 – 1.6)	1.3 (1.1 – 1.5)	0.0001
HDL cholesterol ≤1 mmol/L in men or ≤1.3 mmol/L in women	704 (37.9)	288 (32.9)	209 (41.3)	207 (43.2)	<0.001
LDL cholesterol (mmol/L)	2.6 (2.2 – 3.2)	2.6 (2.2 – 3.2)	2.6 (2.2 – 3.2)	2.7 (2.2 – 3.3)	0.547
LDL cholesterol ≥2.6 mmol/L#	957 (51.5)	444 (50.7)	256 (50.6)	257 (53.7)	0.534
Triglycerides (mmol/L)	1.4 (1 – 2)	1.3 (1 – 1.8)	1.4 (1.1 – 1.9)	1.7 (1.2 – 2.3)	0.0001
Triglycerides ≥1.7 mmol/L#	668 (35.9)	239 (27.3)	187 (37)	242 (50.5)	<0.001

BP: Blood pressure; CKD: Chronic kidney disease; CVD: Cardiovascular disease; HDL: High-density lipoprotein; LDL: Low-density lipoprotein; PAD: Peripheral artery disease

*Categorical variables were expressed as numbers (%). Continuous variables were expressed as mean ± SD for normally distributed variables or median (25% and 75% quartile) for non-normally distributed variables.

Table 1. Characteristics of Patients by CKD Risk Categories (Low, Moderate and High/Very High) (Con't)

Characteristics	All* (n = 1861)	Low Risk* (n = 875)	Moderate Risk* (n = 506)	High/Very High Risk* (n = 480)	P Value
Medications					
Use of insulin	536 (29)	155 (17.8)	138 (27.4)	243 (51.1)	<0.001
Use of aspirin	427 (23.1)	130 (14.9)	114 (22.8)	183 (38.4)	<0.001
Use of ace-inhibitor or angiotensin receptor blocker	1105 (59.5)	355 (40.6)	359 (71.1)	391 (81.8)	<0.001
Use of statins	1507 (81.2)	672 (77)	415 (82.3)	420 (87.9)	<0.001
Complications					
Retinopathy					<0.001
Normal	1284 (71.7)	669 (79.6)	366 (75.8)	249 (53.1)	
Non-proliferative	327 (18.3)	138 (16.4)	77 (15.9)	112 (23.9)	
Proliferative	181 (10.1)	33 (3.9)	40 (8.3)	108 (23)	
PAD	250 (14.4)	80 (9.7)	69 (14.6)	101 (23.2)	<0.001
Neuropathy	171 (9.6)	30 (3.6)	35 (7.2)	106 (23.7)	<0.001
PAD and neuropathy	46 (2.6)	5 (0.6)	8 (1.6)	33 (7.3)	<0.001
Heart attack	32 (3.6)	5 (1.2)	9 (3.6)	18 (8.2)	<0.001
Blockade of arteries to the heart	84 (9.7)	25 (6.3)	27 (11)	32 (14.6)	0.003
Balloon angioplasty of blocked artery of the heart	49 (5.6)	16 (3.9)	15 (6)	18 (8.1)	0.084
Bypass operation	42 (4.8)	12 (2.9)	17 (6.8)	13 (5.9)	0.051
Stroke	29 (3.3)	8 (2)	9 (3.6)	12 (5.4)	0.062
CVD	356 (20)	117 (13.9)	106 (22.1)	133 (29.2)	<0.001

BP: Blood pressure; CKD: Chronic kidney disease; CVD: Cardiovascular disease; HDL: High-density lipoprotein; LDL: Low-density lipoprotein; PAD: Peripheral artery disease

*Categorical variables were expressed as numbers (%). Continuous variables were expressed as mean $\pm$ SD for normally distributed variables or median (25% and 75% quartile) for non-normally distributed variables.

				Persistent Albuminuria Categories			Total
				A1	A2	A3	
				Normal to Mildly Increased <30 mg/g n (%)	Moderately Increased 30 – 300 mg/g n (%)	Severely Increased >300 mg/g n (%)	
GFR Categories (ml/min per 1.73 m ²)	G1	Normal or high	≥ 90	469 (25.2)	256 (13.8)	55 (3.0)	780 (41.9)
	G2	Mildly decreased	60 – 89	406 (21.8)	188 (10.1)	88 (4.7)	682 (36.7)
	G3a	Mildly to moderately decreased	45 – 59	62 (3.3)	68 (3.7)	49 (2.6)	179 (9.6)
	G3b	Moderately to severely decreased	30 – 44	28 (1.5)	53 (2.9)	37 (2.0)	118 (6.3)
	G4	Severely decreased	15 – 29	3 (0.2)	19 (1.0)	48 (2.6)	70 (3.8)
	G5	Kidney failure	≤ 15	0 (0.0)	1 (0.1)	31 (1.7)	32 (1.7)
			Total	968 (52.0)	585 (31.4)	308 (16.6)	1861 (100.0)

Figure 1. Distribution by GFR and albuminuria categories (n = 1861)
Classification is based on KDIGO 2012 Clinical Practice Guidelines for the Evaluation and Management of Chronic Kidney Disease.⁶
GFR: Glomerular filtration rate

Table 2. Factors Associated with CKD Status

Characteristics	OR (95% CI) P Value	
	Bivariate	Multivariable*
Age (per year)	1.03 (1.02 – 1.04) <0.001	1.02 (1 – 1.03) 0.016
Male vs female	1.09 (0.91 – 1.31) 0.343	
Duration of diabetes (per year)	1.06 (1.05 – 1.07) <0.001	1.05 (1.03 – 1.07) <0.001
Chinese vs others	1.3 (0.76 – 2.23) 0.344	1.14 (0.48 – 2.73) 0.769
Malays vs others	2.24 (1.28 – 3.94) 0.005	1.5 (0.61 – 3.7) 0.374
Indians vs others	1.09 (0.62 – 1.9) 0.769	0.78 (0.32 – 1.92) 0.591
Ex-smoker vs non-smoker	1.32 (0.92 – 1.9) 0.131	
Current smoker vs non-smoker	1.25 (0.9 – 1.74) 0.191	
Body mass index (per kg/m ²)	1.05 (1.03 – 1.07) <0.001	1.07 (1.04 – 1.1) <0.001
HbA1c 7% to <8% vs HbA1c <7%	1.4 (1.11 – 1.77) 0.004	1.04 (0.73 – 1.47) 0.835
HbA1c 8% to <9% vs HbA1c <7%	2.36 (1.8 – 3.09) <0.001	1.57 (1.06 – 2.34) 0.025
HbA1c ≥9% vs HbA1c <7%	2.66 (2.01 – 3.52) <0.001	1.8 (1.16 – 2.78) 0.008
BP ≥140/80 mmHg	2.76 (2.18 – 3.48) <0.001	2.45 (1.86 – 3.23) <0.001
Total cholesterol ≥5.2 mmol/L	1.33 (1.04 – 1.7) 0.021	1.02 (0.7 – 1.5) 0.908
HDL cholesterol ≤1 mmol/L in men or ≤1.3 mmol/L in women	1.49 (1.23 – 1.8) <0.001	1.25 (0.92 – 1.68) 0.153
LDL cholesterol ≥2.6 mmol/L	1.05 (0.88 – 1.27) 0.564	
Triglycerides ≥1.7 mmol/L	2.05 (1.69 – 2.5) <0.001	1.77 (1.3 – 2.4) <0.001
Non-proliferative retinopathy vs normal	1.5 (1.17 – 1.9) 0.001	0.93 (0.64 – 1.35) 0.703
Proliferative retinopathy vs normal	4.88 (3.29 – 7.23) <0.001	1.79 (1 – 3.2) 0.049
Neuropathy	4.81 (3.21 – 7.22) <0.001	3.64 (1.99 – 6.65) <0.001
CVD	2.13 (1.67 – 2.72) <0.001	1.45 (1.02 – 2.05) 0.039

CKD: Chronic kidney disease; CVD: Cardiovascular disease; HDL: High-density lipoprotein; LDL: Low-density lipoprotein

*The multivariable model includes age, ethnic group, duration of diabetes, BMI, HbA1c group, BP ≥140/80 mmHg, total cholesterol ≥5.2 mmol/L, HDL cholesterol ≤1 mmol/L in men or ≤1.3 mmol/L in women, triglycerides ≥1.7 mmol/L, history of retinopathy, history of neuropathy, and history of CVD.

heralds the rise of ESRD, but also an in-tandem rise in other closely associated comorbidities such as cardiovascular diseases. This may contribute to the rising cost of health care for serious chronic conditions in Singapore. It also highlights the importance of routine rigorous screening for CKD and subsequently aggressive intervention to retard renal progression. In corollary, relevant health education targeting T2DM patients, their families and care providers will be vital.²⁴

Our study has demonstrated that serious comorbidities such as neuropathy, cardiovascular disease and proliferative retinopathy are highly prevalent among individuals with CKD (Table 2). Of note, a study in Japan showed that diabetic micro and macroangiopathies were more prevalent in the later stages of both GFR and albuminuria.¹⁵ Therefore, simultaneous screening for these comorbidities should be carefully considered and acted upon when clinically indicated. Our data reiterated that major traditional risk factors (e.g. smoking, hyperglycaemia, dyslipidaemia and hypertension) are associated with CKD. These risk factors

are likely to be causal because several landmark clinical trials have provided strong evidence to suggest that diligent control of these risk factors can retard renal progression as well as ameliorate the risk for cardiovascular disease.^{26–28} Therefore, our data reminded us of the need to strengthen our diabetes care programme to meet the rising challenge of CKD.

Our study shows that only 30.9% of patients had met the target of HbA1c <7% and 53.4% had BP <140/80 mmHg. The lipid targets were achieved in more than 60% of patients, with the exception of LDL-cholesterol where 48.5% met the target of <2.6 mmol/L. Our results on treatment targets are comparable with findings from other countries. The National Healthcare Quality Report from the US shows that the proportions of adults aged 40 and above with diagnosed DM who achieved HbA1c <7% and BP <140/80 mmHg were 52% and 65% respectively,²⁹ whereas the 2011 to 2012 National Diabetes Audit report from the UK showed that proportions of patients in England and Wales who achieved HbA1c <6.5% and <7.5%, BP

<140/80 mmHg and cholesterol <5 mmol/L were 24.7%, 62.7%, 48.1% and 77% respectively.³⁰ Therefore, it is important to continue to strive towards optimising risk factor management among our T2DM population. Having said so, we are cognisant of the possibility that not meeting the traditionally recommended glycaemic target of HbA1c <7% may reflect the evolving paradigm shift in clinical practice guidelines, which recommend less intensive glycaemic control in population with heavy comorbidities such as CKD or CVD because of the paradoxical increase in mortality that is probably related to treatment-associated severe hypoglycaemia.¹⁹

There are limitations in our study. Firstly, the cross-sectional design of our study precludes any causal inference between CKD and their risk factors. Secondly, it is possible for misclassification on retinopathy to occur when the information was obtained from questionnaire. Another limitation was that our study was confined to only patients with T2DM in the polyclinics and diabetes centre in a local hospital, and hence the findings cannot be generalised to the general diabetes patient population, including those with T1DM.

To the best of our knowledge, this is the first study on the prevalence of CKD and its risk outcomes in patients with T2DM using the recent KDOQI 2012 criteria in Singapore. The findings have established the baseline profile of CKD prevalence and CKD risks amongst patients with T2DM for future management and prevention strategies. They will help clinicians appreciate the magnitude of CKD among patients with T2DM and exercise vigilance in diabetes care, especially in those known risk factors. It is hoped that our study will provide impetus for further research on renal complications in DM patients so as to improve clinical outcomes.

Conclusion

CKD is highly prevalent among patients with T2DM in Singapore. Several risk factors for CKD are well elucidated and amenable to interventions. Our data suggest substantial unmet challenges of CKD risk factors among T2DM population. Therefore, routine screening for renal impairment and enhanced programme for global risk factors reduction is important to stem the tide of CKD in T2DM.

Acknowledgement

The authors would like to thank Dr Tan Hwee Huan for her comments on the manuscript. The study was funded by National Medical Research Council, Program Project Grant (NMRC/PPG/AH(KTPH)/2011).

REFERENCES

1. Ministry of Health, Singapore. National Health Survey 2004. Singapore, Ministry of Health, 2005.
2. Ministry of Health, Singapore. National Health Survey 2010. Singapore, Ministry of Health, 2011.
3. Health Promotion Board, Singapore. Information paper on diabetes in Singapore. Singapore, Health Promotion Board, 2011.
4. Vathsala A. Twenty-five facts about kidney disease in Singapore: in remembrance of World Kidney Day. *Ann Acad Med Singapore* 2007;36:157-60.
5. Health Promotion Board, Singapore. Trends of end stage renal disease in Singapore. Singapore, Health Promotion Board, 2013.
6. Kidney Disease: Improving Global Outcomes (KDIGO) CKD Work Group. KDIGO 2012 clinical practice guideline for the evaluation and management of chronic kidney disease. *Kidney Int Suppl* 2013;3:1-150.
7. The Renal Association. Detection, monitoring and care of patients with CKD [Internet]. Hampshire: the Renal Association; 2011. Available at: <http://www.renal.org/guidelines/clinical-practice-guidelines-committee#sthash.GN5rsYnj.dpbs>. Accessed 20 February 2014.
8. Levin A, Hemmelgarn B, Culeton B, Tobe S, McFarlane P, Ruzicka M, et al. Guidelines for the management of chronic kidney disease. *CMAJ* 2008;179:1154-62.
9. Rodriguez-Poncelas A, Garre-Olmo J, Franch-Nadal J, Diez-Espino J, Mundet-Tuduri X, Barrot-De la Puente J, et al. Prevalence of chronic kidney disease in patients with type 2 diabetes in Spain: PERCEDIME2 study. *BMC Nephrol* 2013;14:46.
10. Jia W, Gao X, Pang C, Hou X, Bao Y, Liu W, et al. Prevalence and risk factors of albuminuria and chronic kidney disease in Chinese population with type 2 diabetes and impaired glucose regulation: Shanghai diabetic complications study (SHDCS). *Nephrol Dial Transplant* 2009;24:3724-31.
11. Lou QL, Ouyang XJ, Gu LB, Mo YZ, Ma R, Nan J, et al. Chronic kidney disease and associated cardiovascular risk factors in Chinese with type 2 diabetes. *Diabetes Metab J* 2012;36:433-42.
12. Coll-de-Tuero G, Mata-Cases M, Rodriguez-Poncelas A, Pepió JM, Roura P, Benito B, et al. Chronic kidney disease in the type 2 diabetic patients: prevalence and associated variables in a random sample of 2642 patients of a Mediterranean area. *BMC Nephrol* 2012;13:87.
13. de Boer IH, Rue TC, Hall YN, Heagerty PJ, Weiss NS, Himmelfarb J. Temporal trends in the prevalence of diabetic kidney disease in the United States. *JAMA* 2011;305:2532-9.
14. Thomas MC, Weekes AJ, Broadley OJ, Cooper ME, Mathew TH. The burden of chronic kidney disease in Australian patients with type 2 diabetes (the NEFRON study). *Med J Aust* 2006;185:140-4.
15. Ito H, Oshikiri K, Mifune M, Abe M, Antoku S, Takeuchi Y, et al. The usefulness of the revised classification for chronic kidney disease by the KDIGO for determining the frequency of diabetic micro- and macroangiopathies in Japanese patients with type 2 diabetes mellitus. *J Diabetes Complications* 2012;26:286-90.
16. Lee WR, Lim HS, Thai AC, Chew WL, Emmanuel S, Goh LG, et al. A window on the current status of diabetes mellitus in Singapore – the Diabcare-Singapore 1998 study. *Singapore Med J* 2001;42:501-7.
17. Lee WR, Emmanuel S, Lim HS, Thai AC, Chew WL, Goh LG, et al. The status of diabetes mellitus in primary care institution and restructured hospitals in Singapore. *Singapore Med J* 2001;42:508-12.
18. Wu AY, Kong NC, de Leon FA, Pan CY, Tai TY, Yeung VT, et al. An alarmingly high prevalence of diabetic nephropathy in Asian type 2 diabetic patients: the MicroAlbuminuria Prevalence (MAP) Study. *Diabetologia* 2005;48:17-26.
19. American Diabetes Association. Standards of medical care in diabetes – 2014. *Diabetes Care* 2014;37 Suppl 1:S14-80.
20. Leng GC, Fowkes FG, Lee AJ, Dunbar J, Housley E, Ruckley CV. Use of ankle brachial pressure index to predict cardiovascular events and death: a cohort study. *BMJ* 1996;313:1440-4.

21. Tavintharan S, Ning Cheung, Su Chi Lim, Tay W, Shankar A, Shyong Tai E, et al. Prevalence and risk factors for peripheral artery disease in an Asian population with diabetes mellitus. *Diab Vasc Dis Res* 2009;6:80-6.
22. Levey AS, Bosch JP, Lewis JB, Greene T, Rogers N, Roth D. A more accurate method to estimate glomerular filtration rate from serum creatinine: a new prediction equation. Modification of Diet in Renal Disease Study Group. *Ann Intern Med* 1999;130:461-70.
23. Karter AJ, Ferrara A, Liu JY, Moffet HH, Ackerson LM, Selby JV. Ethnic disparities in diabetic complications in an insured population. *JAMA* 2002;287:2519-27.
24. Stanton RC. Clinical challenges in diagnosis and management of diabetic kidney disease. *Am J Kidney Dis* 2014;63:S3-21.
25. Disthabanchong S. Lowering vascular calcification burden in chronic kidney disease: is it possible? *World J Nephrol* 2013;2:49-55.
26. McCullough PA, Jurkovitz CT, Pergola PE, McGill JB, Brown WW, Collins AJ, et al. Independent components of chronic kidney disease as a cardiovascular risk state: results from the Kidney Early Evaluation Program (KEEP). *Arch Intern Med* 2007;167:1122-9.
27. The Diabetes Control and Complications Trial Research Group. The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. *N Engl J Med* 1993;329:977-6.
28. Bakris GL, Weir MR, Shanifar S, Zhang Z, Douglas J, van Dijk DJ. Effects of blood pressure level on progression of diabetic nephropathy: results from the RENAAL study. *Arch Intern Med* 2003;163:1555-65.
29. Agency for Healthcare Research and Quality (AHRQ). 2012 National Healthcare Quality Report [Internet]. Rockville: AHRQ; 2013. Available at: <http://www.ahrq.gov/research/findings/nhqrdr/nhqr12/index.html>. Accessed 12 March 2014.
30. Health and Social Care Information Centre (HSCIC). National Diabetes Audit – 2011-2012 [Internet]. Leeds: HSCIC; 2013. Available at: <http://www.hscic.gov.uk/searchcatalogue?productid=13129&q=%22National+diabetes+audit%22&sort=Relevance&size=10&page=1#top>. Accessed 12 March 2014.

Prevalence of Chronic Kidney Disease in Singaporean Adults with Type 2 Diabetes Mellitus

Serena KM Low,¹ MBBS, MSc (Public Health), Chee Fang Sum,² FRCPI, FRCPE, FACE, Lee Ying Yeoh,³ MD, MRCP, Subramaniam Tavintharan,⁴ FAMS, FRCP, MCI, Xiao Wei Ng,⁴ PhD (Food Science), Simon BM Lee,⁵ MBBS, M Med (Family Med), MCFP, Wern Ee Tang,⁶ MBBS, M Med (Family Med), FCFP, Su Chi Lim,² MBBS, MRCP, PhD

Abstract

Introduction: Diabetes mellitus (DM) is a major cause of chronic kidney disease (CKD). The epidemiology of CKD secondary to type 2 DM (T2DM) (i.e. diabetic nephropathy (DN)) has not been well studied in Singapore, a multi-ethnic Asian population. We aimed to determine the prevalence of CKD in adult patients with T2DM. **Materials and Methods:** We conducted a cross-sectional study on patients (n = 1861) aged 21 to 89 years with T2DM who had attended the DM centre of a single acute care public hospital or a primary care polyclinic between August 2011 and November 2013. Demographic and clinical data were obtained from patients using a standard questionnaire. Spot urine and fasting blood samples were sent to an accredited hospital laboratory for urinary albumin, serum creatinine, HbA1c and lipid measurement. CKD was defined and classified using the 2012 Kidney Disease: Improving Global Outcomes (KDIGO) guidelines and classification. **Results:** The distribution by risk of adverse CKD outcomes was: low risk, 47%; moderate risk, 27.2%; high risk, 12.8%; and very high risk, 13%. The prevalence of CKD in patients with T2DM was 53%. Variables significantly associated with CKD include neuropathy, blood pressure $\geq 140/80$ mmHg, triglycerides ≥ 1.7 mmol, body mass index, duration of diabetes, HbA1c $\geq 8\%$, age, cardiovascular disease, and proliferative retinopathy. **Conclusion:** CKD was highly prevalent among patients with T2DM in Singapore. Several risk factors for CKD are well recognised and amenable to intervention. Routine rigorous screening for DN and enhanced programme for global risk factors reduction will be critical to stem the tide of DN.

Ann Acad Med Singapore 2015;44:xx-xx

Key words: Albuminuria, Renal impairment, Risk factors

Introduction

According to the National Health Survey, the percentage of Singapore residents with diabetes mellitus (DM) aged between 18 and 69 years has risen from 8.2% in 2004 to 11.3% in 2010.^{1,2} DM can lead to a myriad of long-term health complications such as coronary heart disease, kidney failure and stroke.³ Of note, DM is a major cause of kidney failure.⁴ There is a rising trend of end-stage renal disease (ESRD) due to DM. The proportion of diabetics among new ESRD patients increased from 48.2% in 1999 to 63.5% in 2011.⁵ The problem of kidney failure arising from DM will be of even more concern as DM prevalence increases.

There are guidelines⁶⁻⁸ to facilitate detection and

appropriate management of patients with chronic kidney disease (CKD). The Kidney Disease: Improving Global Outcomes (KDIGO) 2012 clinical practice guideline for the evaluation and management of CKD has recently updated the original 2002 version with enhanced classification of CKD. This includes adding the cause and categories of albuminuria besides glomerular filtration rate (GFR) in the assessment, and refining GFR category 3 into 3a and 3b. The risk categorisation of CKD is reflected in the yearly rate of decline in renal function, e.g. GFR drop of ≤ 1 mL/min/1.73m²/year in subjects with low risk of CKD progression and ≥ 4 mL/min/1.73m²/year in those with high risk of CKD progression.⁶ It will be useful to

¹Clinical Services, Khoo Teck Puat Hospital, Singapore

²Diabetes Centre, Khoo Teck Puat Hospital, Singapore

³Department of Medicine, Khoo Teck Puat Hospital, Singapore

⁴Clinical Research Unit, Khoo Teck Puat Hospital, Singapore

⁵Yishun Polyclinic, Singapore

⁶National Healthcare Group Polyclinics, Singapore

Address for Correspondence: Dr Serena Low, Research Laboratory, Basement 1, Khoo Teck Puat Hospital, 90 Yishun Central, Singapore 768828.

Email: low.serena.km@alexandrahealth.com.sg

understand the prevalence of the CKD based on the revised categories. Furthermore, information on the burden of CKD in DM patients in Singapore is limited although there has been extensive research on this group internationally.⁹⁻¹⁵ There were a few studies that examined the status of renal function among patients with diabetes in Singapore.¹⁶⁻¹⁸ For example, the Diabcare-Singapore 1998 study revealed abnormal levels of urinary protein (>500 mg/24 hours) in 16%, microalbuminuria in 36% and raised serum creatinine in 3% of the patients tested in 22 diabetes clinics from general hospitals and primary healthcare centres.¹⁵ While these studies have shed light on the renal status in terms of albuminuria and elevated creatinine, little is known about CKD prevalence among patients with DM using the KDIGO revised guidelines. We therefore undertook a study to determine the prevalence of CKD as well as its associated factors in patients with Type 2 DM (T2DM). We hope to establish a baseline profile for the risk of CKD outcome with the findings in order to develop future prevention and management strategies tailored to patients with T2DM.

Materials and Methods

Study Design

This is a cross-sectional study involving 1861 adult patients aged between 21 and 89 years with T2DM who attended the DM centre or a primary care polyclinic in the northern region of Singapore between August 2011 and November 2013. The polyclinics in Singapore provide medical care for acute and chronic conditions, medical examination, screening and other services. The DM centre is a one-stop centre located in Khoo Teck Puat Hospital (KTPH) for people with DM in the northern region of Singapore. It manages patients with DM with more complications that require a higher level of holistic care. The study was approved by the National Healthcare Group Domain Specific Review Board in Singapore and all patients signed written informed consent.

The exclusion criteria were as follows: T1DM, pregnancy, active inflammation, cancer, on non-steroid anti-inflammatory drugs (NSAIDs) on the day of the assessment, on oral steroids equivalent to >5 mg/day of prednisolone, fasting glucose <4.5 mmol or >15 mmol, HbA1c >12%, inability to give informed consent and insertion of pacemaker or any device that may be affected by electric current.

Measurement

Data on demographics, vascular risk factors, diabetic complications and medications were extracted from a standard questionnaire answered by all patients. Blood pressure was measured by trained nurses using a standard

electronic sphygmomanometer. The measurement was done on the arm of the subject with an appropriate cuff in the sitting position, and an average of 3 readings was taken. High blood pressure (BP) was deemed as systolic blood pressure ≥ 140 mmHg and/or diastolic blood pressure ≥ 80 mmHg, taking reference from the 2014 American Diabetes Association (ADA) recommendations.¹⁹ Ankle pressure was measured after a 5-minute rest in supine position with a standardised Doppler ultrasonic device. Ankle brachial index (ABI) was calculated as the ratio of the higher of the 2 systolic pressures at the ankle to the higher of the right and left brachial artery pressures. Peripheral artery disease (PAD) was defined as present if the lower ABI ≤ 0.9 .^{20,21} Neuropathy was assessed using a neurothesiometer for vibration and a 5.07 (10 g) monofilament on non-calloused plantar sites for light touch. For monofilament assessment in the foot, the test is considered abnormal if a patient fails to feel at least 3 out of 10 sites. For neurothesiometer readings, a mean of 3 values greater than 25 volts indicates that the patient is at risk, and the test is considered as abnormal. Neuropathy was defined as the presence of an abnormal finding in monofilament or neurothesiometer testing. Retinopathy was ascertained from patients' medical record. If this was absent, the patient was asked for the information through questionnaire.

Spot urine creatinine was obtained along with spot urine albumin and serum creatinine. An average reading for a maximum of 3 tests was obtained. Blood samples for HbA1c and lipids were also taken from the patients. The spot urine and blood samples were sent to the hospital laboratory accredited by the College of the American Pathologists (CAP) for measurement. The following assays or methods were used for measurement: Roche cobas® c501 immunoturbidimetric assay for urinary albumin; Roche cobas® c501 enzymatic colorimetric test for serum creatinine, total cholesterol (TC), low-density lipoprotein cholesterol (LDL-cholesterol), high-density lipoprotein cholesterol (HDL-cholesterol) and triglycerides (TG); and monoclonal antibody agglutination reaction using Siemens DCA Vantage® analyser for glycated haemoglobin (HbA1c). Lipid abnormalities were considered as follows: LDL-cholesterol ≥ 2.6 mmol/L (high LDL-cholesterol); HDL-cholesterol ≤ 1 mmol/L in men or ≤ 1.3 mmol/L in women (low HDL-cholesterol); TC ≥ 5.2 mmol/L (high TC); and TG ≥ 1.7 mmol/L (high TG), taking references from the 2014 ADA recommendations.¹⁹

The Modification of Diet in Renal Disease (MDRD) formula was used to calculate the estimated GFR (eGFR).²² We are aware of another equation—the Chronic Kidney Disease Epidemiology (CKD-EPI) collaboration equations—formulated for the general population (i.e. not limited to T2DM). We have decided to adopt the MDRD

formula given the wealth of publications based on this equation. The KDIGO 2012 CKD guidelines defined albuminuria categories as normal or mildly increased, moderately increased and severely increased for urinary albumin to creatinine ratio (ACR) values of <30 mg/g, 30 to 300 mg/g and >300 mg/g respectively. In the KDIGO 2012 CKD Guidelines, CKD was defined by the presence of decreased GFR <60 mL/min per 1.73 m² or kidney damage as indicated by ACR ≥30 mg/g or other markers for more than 3 months.⁶ As we were unable to ascertain if the above abnormalities persisted for more than 3 months, we defined CKD as GFR <60 mL/min per 1.73 m² or ACR ≥30 mg/g in our study.

Statistical Analysis

Categorical data were expressed as number (percentage) and continuous data as means ± standard deviation (SD) unless otherwise stated. Differences in patient characteristics, risk factors, medications and complications among categories of risk for CKD outcomes (low, moderate and high/very high risk) were studied using chi-square test for categorical variables, and one-way ANOVA or Kruskal Wallis for continuous variables where appropriate. Logistic regression was used to estimate the odds ratio (OR) for the association between patient characteristics and CKD. Variables were subsequently included in the age-adjusted multivariable logistic regression if $P < 0.1$ in the bivariate logistic regression. Statistical significance is taken at $P < 0.05$. Statistical analysis was performed using STATA version 13 (STATA Corporation, College Station, Texas).

Results

Table 1 shows the baseline characteristics of the 1861 patients with T2DM as follows: mean age, 57.5 ± 10.7 years; 50.1% males; duration of diabetes, 10 years (4 years to 16 years), mean body mass index (BMI), 27.7 ± 5.2 kg/m²; mean HbA1c, 7.5% (6.8% to 8.5%); 46.6% with BP ≥140/80 mmHg; 17.1% with high TC; 51.5% with high LDL-cholesterol; 37.9% with low HDL-cholesterol; and 35.9% with high TG.

The distribution by risk for outcome of CKD was as follows: low risk, 47%; moderate risk, 27.2%; high risk, 12.8%; and very high risk, 13%. Of the 1861 patients, 53% had CKD, 21.4% had GFR <60 mL/min per 1.73 m² and 48% had ACR ≥30 mg/g. Figure 1 shows the distribution by GFR and albuminuria categories.

The characteristics of patients by CKD risk categories are shown in Table 1. Patients with moderate or high/very high risk of CKD tended to be older, of Malay ethnicity, had longer duration of diabetes, with higher BMI, HbA1c ≥8%, BP ≥140/80 mmHg, low HDL cholesterol, and high

TG ($P < 0.001$ for all).

Compared to the low risk for CKD group, the moderate and high/very high risk groups had higher proportions of use of insulin, aspirin, angiotensin-converting enzyme (ACE) inhibitor or angiotensin II receptor blocker (ARB) and statins ($P < 0.001$ for all). In terms of complications, patients in the moderate and high/very high risk groups were more likely to have proliferative retinopathy, neuropathy and CVD (which includes heart attack, blockade of arteries, balloon angioplasty of blocked artery of the heart, bypass operation, stroke or PAD ($P < 0.001$ for all)).

Risk Factors for CKD

The significant risk factors in the multivariable model were neuropathy (OR 3.64, 95% CI, 1.99 to 6.65); BP ≥140/80 mmHg (OR 2.45, 95% CI, 1.86 to 3.23), TG ≥1.7 mmol/L (OR 1.77, 95% CI, 1.3 to 2.4), BMI (OR 1.07, 95% CI, 1.04 to 1.1); duration of DM (OR 1.05, 95% CI, 1.03 to 1.07), HbA1c ≥9% (OR 1.8, 95% CI, 1.16 to 2.78), age (OR 1.02, 95% CI, 1 to 1.03), HbA1c 8% to <9% (OR 1.57, 95% CI, 1.06 to 2.34); CVD (OR 1.45, 95% CI, 1.02 to 2.05) and proliferative retinopathy (OR 1.79, 95% CI, 1 to 3.2) (Table 2).

Discussion

The prevalence of CKD among T2DM, defined as ACR ≥30 mg/g or GFR <60 mL/min per 1.73 m², was reported to range from 27.9% to 77% in other countries.⁹⁻¹⁵ The wide variation in the burden of CKD in these studies could be due to differences in CKD definition or patient profiles such as ethnicity and healthcare setting, i.e. primary care catchment versus hospital care. In our study, 53% of T2DM patients had CKD as defined by KDIGO. The higher prevalence of CKD in our study population as compared to most of the earlier studies could be attributed to the more advanced cases managed in KTPH DM Centre (i.e. referral bias to a secondary hospital). It may also reflect the high (and rising) burden of diabetes in an urbanised society like Singapore—our latest national health survey suggested that approximately 11.3% of the adult population had diabetes.² Although it is likely that most of the CKD is secondary to DM, we do not know the proportion of individuals whose CKD can be attributable to other causes such as hypertension, IgA nephropathy and chronic glomerulonephritis. Other possible reasons for the relatively high prevalence of CKD in our study populations include: Asian's ethnic related susceptibility to diabetic nephropathy;²³ seniority of study population and age-dependent eGFR formula;²⁴ high burden of atherosclerosis and arterial calcification.²⁵ Nonetheless, the high prevalence of CKD in our study constitutes a significant public health concern as it not only

Table 1. Characteristics of Patients by CKD Risk Categories (Low, Moderate and High/Very High)

Characteristics	All* (n = 1861)	Low Risk* (n = 875)	Moderate Risk* (n = 506)	High/Very High Risk* (n = 480)	P Value
Age (years)	57.5 ± 10.7	55.8 ± 10.8	57.6 ± 10.4	60.5 ± 10.3	<0.001
Gender					
Male	932 (50.1)	428 (48.9)	240 (47.4)	264 (55)	0.038
Ethnic group					<0.001
Chinese	950 (51.1)	464 (53)	236 (46.6)	250 (52.1)	
Malay	427 (22.9)	152 (17.4)	135 (26.7)	140 (29.2)	
Indian	428 (23)	228 (26.1)	120 (23.7)	80 (16.7)	
Others	56 (3)	31 (3.5)	15 (3)	10 (2.1)	
Duration of diabetes (years)	10 (4 – 16)	7 (3 – 12)	10 (4 – 16.5)	15 (9 – 20)	0.0001
Control of Risk Factors					
Smoking history					0.012
Never	1570 (84.6)	755 (86.3)	422 (83.7)	393 (82.4)	
Ex-smoker	131 (7.1)	54 (6.2)	29 (5.8)	48 (10.1)	
Current smoker	155 (8.4)	66 (7.5)	53 (10.5)	36 (7.6)	
Body mass index (kg/m ²)	27.7 ± 5.2	27.1 ± 4.9	28.4 ± 5.5	28.2 ± 5.2	<0.001
Waist circumference (cm)	95.3 (88.1 – 104.5)	93.6 (87.1 – 103.1)	96.8 (89.1 – 106.7)	96.5 (88.4 – 104.2)	0.0006
HbA1c (%)	7.5 (6.8 – 8.5)	7.2 (6.7 – 8.2)	7.6 (6.9 – 8.7)	8 (7.1 – 9)	0.0001
HbA1c group					<0.001
<7%	575 (30.9)	334 (38.2)	140 (27.7)	101 (21)	
7% to <8%	588 (31.6)	292 (33.4)	157 (31)	139 (29)	
8% to <9%	365 (19.6)	135 (15.4)	111 (21.9)	119 (24.8)	
≥9%	333 (17.9)	114 (13)	98 (19.4)	121 (25.2)	
Systolic BP (mmHg)	139 (127 – 152)	133 (123 – 146)	141 (130 – 153)	149 (136 – 164)	0.0001
Diastolic BP (mmHg)	79.1 ± 9.6	77.9 ± 8.8	80.6 ± 9.6	79.7 ± 10.7	<0.001
BP ≥140/80 mmHg	568 (46.6)	198 (33.8)	179 (53.9)	191 (63.5)	<0.001
Total cholesterol (mmol/L)	4.3 (3.8 – 4.9)	4.3 (3.8 – 4.9)	4.3 (3.8 – 4.9)	4.4 (3.8 – 5)	0.189
Total cholesterol ≥5.2 mmol/L	318 (17.1)	131 (15)	91 (18)	96 (20)	0.05
HDL cholesterol in men (mmol/L)	1.2 (1 – 1.3)	1.2 (1 – 1.4)	1.2 (1 – 1.3)	1.1 (0.9 – 1.3)	0.0125
HDL cholesterol in women (mmol/L)	1.4 (1.2 – 1.6)	1.4 (1.2 – 1.6)	1.3 (1.1 – 1.6)	1.3 (1.1 – 1.5)	0.0001
HDL cholesterol ≤1 mmol/L in men or ≤1.3 mmol/L in women	704 (37.9)	288 (32.9)	209 (41.3)	207 (43.2)	<0.001
LDL cholesterol (mmol/L)	2.6 (2.2 – 3.2)	2.6 (2.2 – 3.2)	2.6 (2.2 – 3.2)	2.7 (2.2 – 3.3)	0.547
LDL cholesterol ≥2.6 mmol/L	957 (51.5)	444 (50.7)	256 (50.6)	257 (53.7)	0.534
Triglycerides (mmol/L)	1.4 (1 – 2)	1.3 (1 – 1.8)	1.4 (1.1 – 1.9)	1.7 (1.2 – 2.3)	0.0001
Triglycerides ≥1.7 mmol/L	668 (35.9)	239 (27.3)	187 (37)	242 (50.5)	<0.001

BP: Blood pressure; CKD: Chronic kidney disease; CVD: Cardiovascular disease; HDL: High-density lipoprotein; LDL: Low-density lipoprotein; PAD: Peripheral artery disease

*Categorical variables were expressed as numbers (%). Continuous variables were expressed as mean ± SD for normally distributed variables or median (25% and 75% quartile) for non-normally distributed variables.

Table 1. Characteristics of Patients by CKD Risk Categories (Low, Moderate and High/Very High) (Con't)

Characteristics	All* (n = 1861)	Low Risk* (n = 875)	Moderate Risk* (n = 506)	High/Very High Risk* (n = 480)	P Value
Medications					
Use of insulin	536 (29)	155 (17.8)	138 (27.4)	243 (51.1)	<0.001
Use of aspirin	427 (23.1)	130 (14.9)	114 (22.8)	183 (38.4)	<0.001
Use of ace-inhibitor or angiotensin receptor blocker	1105 (59.5)	355 (40.6)	359 (71.1)	391 (81.8)	<0.001
Use of statins	1507 (81.2)	672 (77)	415 (82.3)	420 (87.9)	<0.001
Complications					
Retinopathy					<0.001
Normal	1284 (71.7)	669 (79.6)	366 (75.8)	249 (53.1)	
Non-proliferative	327 (18.3)	138 (16.4)	77 (15.9)	112 (23.9)	
Proliferative	181 (10.1)	33 (3.9)	40 (8.3)	108 (23)	
PAD	250 (14.4)	80 (9.7)	69 (14.6)	101 (23.2)	<0.001
Neuropathy	171 (9.6)	30 (3.6)	35 (7.2)	106 (23.7)	<0.001
PAD and neuropathy	46 (2.6)	5 (0.6)	8 (1.6)	33 (7.3)	<0.001
Heart attack	32 (3.6)	5 (1.2)	9 (3.6)	18 (8.2)	<0.001
Blockade of arteries to the heart	84 (9.7)	25 (6.3)	27 (11)	32 (14.6)	0.003
Balloon angioplasty of blocked artery of the heart	49 (5.6)	16 (3.9)	15 (6)	18 (8.1)	0.084
Bypass operation	42 (4.8)	12 (2.9)	17 (6.8)	13 (5.9)	0.051
Stroke	29 (3.3)	8 (2)	9 (3.6)	12 (5.4)	0.062
CVD	356 (20)	117 (13.9)	106 (22.1)	133 (29.2)	<0.001

BP: Blood pressure; CKD: Chronic kidney disease; CVD: Cardiovascular disease; HDL: High-density lipoprotein; LDL: Low-density lipoprotein; PAD: Peripheral artery disease

*Categorical variables were expressed as numbers (%). Continuous variables were expressed as mean $\pm$ SD for normally distributed variables or median (25% and 75% quartile) for non-normally distributed variables.

				Persistent Albuminuria Categories			Total
				A1	A2	A3	
				Normal to Mildly Increased	Moderately Increased	Severely Increased	
				<30 mg/g n (%)	30 – 300 mg/g n (%)	>300 mg/g n (%)	
GFR Categories (ml/min per 1.73 m ²)	G1	Normal or high	≥90	469 (25)	256 (14)	55 (3)	780 (42)
	G2	Mildly decreased	60 – 89	406 (22)	188 (10)	88 (5)	682 (37)
	G3a	Mildly to moderately decreased	45 – 59	62 (3)	68 (4)	49 (3)	179 (10)
	G3b	Moderately to severely decreased	30 – 44	28 (2)	53 (3)	37 (2)	118 (6)
	G4	Severely decreased	15 – 29	3 (0)	19 (1)	48 (3)	70 (4)
	G5	Kidney failure	<15	0 (0)	1 (0)	31 (2)	32 (2)
	Total			968 (52)	585 (31)	308 (17)	1861 (100)

Low risk
 Moderate risk
 High risk
 Very high risk

Fig. 1. Distribution by GFR and albuminuria categories (n = 1861). Classification is based on KDIGO 2012 Clinical Practice Guidelines for the Evaluation and Management of Chronic Kidney Disease.⁶ GFR: Glomerular filtration rate

Table 2. Factors Associated with CKD Status

Characteristics	OR (95% CI) P Value	
	Bivariate	Multivariable*
Age (per year)	1.03 (1.02 – 1.04) <0.001	1.02 (1 – 1.03) 0.016
Male vs female	1.09 (0.91 – 1.31) 0.343	
Duration of diabetes (per year)	1.06 (1.05 – 1.07) <0.001	1.05 (1.03 – 1.07) <0.001
Chinese vs others	1.3 (0.76 – 2.23) 0.344	1.14 (0.48 – 2.73) 0.769
Malays vs others	2.24 (1.28 – 3.94) 0.005	1.5 (0.61 – 3.7) 0.374
Indians vs others	1.09 (0.62 – 1.9) 0.769	0.78 (0.32 – 1.92) 0.591
Ex-smoker vs non-smoker	1.32 (0.92 – 1.9) 0.131	
Current smoker vs non-smoker	1.25 (0.9 – 1.74) 0.191	
Body mass index (per kg/m ²)	1.05 (1.03 – 1.07) <0.001	1.07 (1.04 – 1.1) <0.001
HbA1c 7% to <8% vs HbA1c <7%	1.4 (1.11 – 1.77) 0.004	1.04 (0.73 – 1.47) 0.835
HbA1c 8% to <9% vs HbA1c <7%	2.36 (1.8 – 3.09) <0.001	1.57 (1.06 – 2.34) 0.025
HbA1c ≥9% vs HbA1c <7%	2.66 (2.01 – 3.52) <0.001	1.8 (1.16 – 2.78) 0.008
BP ≥140/80 mmHg	2.76 (2.18 – 3.48) <0.001	2.45 (1.86 – 3.23) <0.001
Total cholesterol ≥5.2 mmol/L	1.33 (1.04 – 1.7) 0.021	1.02 (0.7 – 1.5) 0.908
HDL cholesterol ≤1 mmol/L in men or ≤1.3 mmol/L in women	1.49 (1.23 – 1.8) <0.001	1.25 (0.92 – 1.68) 0.153
LDL cholesterol ≥2.6 mmol/L	1.05 (0.88 – 1.27) 0.564	
Triglycerides ≥1.7 mmol/L	2.05 (1.69 – 2.5) <0.001	1.77 (1.3 – 2.4) <0.001
Non-proliferative retinopathy vs normal	1.5 (1.17 – 1.9) 0.001	0.93 (0.64 – 1.35) 0.703
Proliferative retinopathy vs normal	4.88 (3.29 – 7.23) <0.001	1.79 (1 – 3.2) 0.049
Neuropathy	4.81 (3.21 – 7.22) <0.001	3.64 (1.99 – 6.65) <0.001
CVD	2.13 (1.67 – 2.72) <0.001	1.45 (1.02 – 2.05) 0.039

CKD: Chronic kidney disease; CVD: Cardiovascular disease; HDL: High-density lipoprotein; LDL: Low-density lipoprotein

*The multivariable model includes age, ethnic group, duration of diabetes, BMI, HbA1c group, BP ≥140/80 mmHg, total cholesterol ≥5.2 mmol/L, HDL cholesterol ≤1 mmol/L in men or ≤1.3 mmol/L in women, triglycerides ≥1.7 mmol/L, history of retinopathy, history of neuropathy, and history of CVD.

heralds the rise of ESRD, but also an in-tandem rise in other closely associated comorbidities such as cardiovascular diseases. This may contribute to the rising cost of health care for serious chronic conditions in Singapore. It also highlights the importance of routine rigorous screening for CKD and subsequently aggressive intervention to retard renal progression. In corollary, relevant health education targeting T2DM patients, their families and care providers will be vital.²⁴

Our study has demonstrated that serious comorbidities such as neuropathy, cardiovascular disease and proliferative retinopathy are highly prevalent among individuals with CKD (Table 2). Of note, a study in Japan showed that diabetic micro and macroangiopathies were more prevalent in the later stages of both GFR and albuminuria.¹⁵ Therefore, simultaneous screening for these comorbidities should be carefully considered and acted upon when clinically indicated. Our data reiterated that major traditional risk factors (e.g. smoking, hyperglycaemia, dyslipidaemia and hypertension) are associated with CKD. These risk factors

are likely to be causal because several landmark clinical trials have provided strong evidence to suggest that diligent control of these risk factors can retard renal progression as well as ameliorate the risk for cardiovascular disease.^{26–28} Therefore, our data reminded us of the need to strengthen our diabetes care programme to meet the rising challenge of CKD.

Our study shows that only 30.9% of patients had met the target of HbA1c <7% and 53.4% had BP <140/80 mmHg. The lipid targets were achieved in more than 60% of patients, with the exception of LDL-cholesterol where 48.5% met the target of <2.6 mmol/L. Our results on treatment targets are comparable with findings from other countries. The National Healthcare Quality Report from the US shows that the proportions of adults aged 40 and above with diagnosed DM who achieved HbA1c <7% and BP <140/80 mmHg were 52% and 65% respectively,²⁹ whereas the 2011 to 2012 National Diabetes Audit report from the UK showed that proportions of patients in England and Wales who achieved HbA1c <6.5% and <7.5%, BP

<140/80 mmHg and cholesterol <5 mmol/L were 24.7%, 62.7%, 48.1% and 77% respectively.³⁰ Therefore, it is important to continue to strive towards optimising risk factor management among our T2DM population. Having said so, we are cognisant of the possibility that not meeting the traditionally recommended glycaemic target of HbA1c <7% may reflect the evolving paradigm shift in clinical practice guidelines, which recommend less intensive glycaemic control in population with heavy comorbidities such as CKD or CVD because of the paradoxical increase in mortality that is probably related to treatment-associated severe hypoglycaemia.¹⁹

There are limitations in our study. Firstly, the cross-sectional design of our study precludes any causal inference between CKD and their risk factors. Secondly, it is possible for misclassification on retinopathy to occur when the information was obtained from questionnaire. Another limitation was that our study was confined to only patients with T2DM in the polyclinics and diabetes centre in a local hospital, and hence the findings cannot be generalised to the general diabetes patient population, including those with T1DM.

To the best of our knowledge, this is the first study on the prevalence of CKD and its risk outcomes in patients with T2DM using the recent KDOQI 2012 criteria in Singapore. The findings have established the baseline profile of CKD prevalence and CKD risks amongst patients with T2DM for future management and prevention strategies. They will help clinicians appreciate the magnitude of CKD among patients with T2DM and exercise vigilance in diabetes care, especially in those known risk factors. It is hoped that our study will provide impetus for further research on renal complications in DM patients so as to improve clinical outcomes.

Conclusion

CKD is highly prevalent among patients with T2DM in Singapore. Several risk factors for CKD are well elucidated and amenable to interventions. Our data suggest substantial unmet challenges of CKD risk factors among T2DM population. Therefore, routine screening for renal impairment and enhanced programme for global risk factors reduction is important to stem the tide of CKD in T2DM.

Acknowledgement

The authors would like to thank Dr Tan Hwee Huan for her comments on the manuscript. The study was funded by National Medical Research Council, Program Project Grant (NMRC/PPG/AH(KTPH)/2011).

REFERENCES

1. Ministry of Health, Singapore. National Health Survey 2004. Singapore, Ministry of Health, 2005.
2. Ministry of Health, Singapore. National Health Survey 2010. Singapore, Ministry of Health, 2011.
3. Health Promotion Board, Singapore. Information paper on diabetes in Singapore. Singapore, Health Promotion Board, 2011.
4. Vathsala A. Twenty-five facts about kidney disease in Singapore: in remembrance of World Kidney Day. *Ann Acad Med Singapore* 2007;36:157-60.
5. Health Promotion Board, Singapore. Trends of end stage renal disease in Singapore. Singapore, Health Promotion Board, 2013.
6. Kidney Disease: Improving Global Outcomes (KDIGO) CKD Work Group. KDIGO 2012 clinical practice guideline for the evaluation and management of chronic kidney disease. *Kidney Int Suppl* 2013;3:1-150.
7. The Renal Association. Detection, monitoring and care of patients with CKD [Internet]. Hampshire: the Renal Association; 2011. Available at: <http://www.renal.org/guidelines/clinical-practice-guidelines-committee#sthash.GN5rsYnj.dpbs>. Accessed 20 February 2014.
8. Levin A, Hemmelgarn B, Culeton B, Tobe S, McFarlane P, Ruzicka M, et al. Guidelines for the management of chronic kidney disease. *CMAJ* 2008;179:1154-62.
9. Rodriguez-Poncelas A, Garre-Olmo J, Franch-Nadal J, Diez-Espino J, Mundet-Tuduri X, Barrot-De la Puente J, et al. Prevalence of chronic kidney disease in patients with type 2 diabetes in Spain: PERCEDIME2 study. *BMC Nephrol* 2013;14:46.
10. Jia W, Gao X, Pang C, Hou X, Bao Y, Liu W, et al. Prevalence and risk factors of albuminuria and chronic kidney disease in Chinese population with type 2 diabetes and impaired glucose regulation: Shanghai diabetic complications study (SHDCS). *Nephrol Dial Transplant* 2009;24:3724-31.
11. Lou QL, Ouyang XJ, Gu LB, Mo YZ, Ma R, Nan J, et al. Chronic kidney disease and associated cardiovascular risk factors in Chinese with type 2 diabetes. *Diabetes Metab J* 2012;36:433-42.
12. Coll-de-Tuero G, Mata-Cases M, Rodriguez-Poncelas A, Pepió JM, Roura P, Benito B, et al. Chronic kidney disease in the type 2 diabetic patients: prevalence and associated variables in a random sample of 2642 patients of a Mediterranean area. *BMC Nephrol* 2012;13:87.
13. de Boer IH, Rue TC, Hall YN, Heagerty PJ, Weiss NS, Himmelfarb J. Temporal trends in the prevalence of diabetic kidney disease in the United States. *JAMA* 2011;305:2532-9.
14. Thomas MC, Weekes AJ, Broadley OJ, Cooper ME, Mathew TH. The burden of chronic kidney disease in Australian patients with type 2 diabetes (the NEFRON study). *Med J Aust* 2006;185:140-4.
15. Ito H, Oshikiri K, Mifune M, Abe M, Antoku S, Takeuchi Y, et al. The usefulness of the revised classification for chronic kidney disease by the KDIGO for determining the frequency of diabetic micro- and macroangiopathies in Japanese patients with type 2 diabetes mellitus. *J Diabetes Complications* 2012;26:286-90.
16. Lee WR, Lim HS, Thai AC, Chew WL, Emmanuel S, Goh LG, et al. A window on the current status of diabetes mellitus in Singapore – the Diabcare-Singapore 1998 study. *Singapore Med J* 2001;42:501-7.
17. Lee WR, Emmanuel S, Lim HS, Thai AC, Chew WL, Goh LG, et al. The status of diabetes mellitus in primary care institution and restructured hospitals in Singapore. *Singapore Med J* 2001;42:508-12.
18. Wu AY, Kong NC, de Leon FA, Pan CY, Tai TY, Yeung VT, et al. An alarmingly high prevalence of diabetic nephropathy in Asian type 2 diabetic patients: the MicroAlbuminuria Prevalence (MAP) Study. *Diabetologia* 2005;48:17-26.
19. American Diabetes Association. Standards of medical care in diabetes – 2014. *Diabetes Care* 2014;37 Suppl 1:S14-80.
20. Leng GC, Fowkes FG, Lee AJ, Dunbar J, Housley E, Ruckley CV. Use of ankle brachial pressure index to predict cardiovascular events and death: a cohort study. *BMJ* 1996;313:1440-4.

21. Tavintharan S, Ning Cheung, Su Chi Lim, Tay W, Shankar A, Shyong Tai E, et al. Prevalence and risk factors for peripheral artery disease in an Asian population with diabetes mellitus. *Diab Vasc Dis Res* 2009;6:80-6.
22. Levey AS, Bosch JP, Lewis JB, Greene T, Rogers N, Roth D. A more accurate method to estimate glomerular filtration rate from serum creatinine: a new prediction equation. Modification of Diet in Renal Disease Study Group. *Ann Intern Med* 1999;130:461-70.
23. Karter AJ, Ferrara A, Liu JY, Moffet HH, Ackerson LM, Selby JV. Ethnic disparities in diabetic complications in an insured population. *JAMA* 2002;287:2519-27.
24. Stanton RC. Clinical challenges in diagnosis and management of diabetic kidney disease. *Am J Kidney Dis* 2014;63:S3-21.
25. Disthabanchong S. Lowering vascular calcification burden in chronic kidney disease: is it possible? *World J Nephrol* 2013;2:49-55.
26. McCullough PA, Jurkovitz CT, Pergola PE, McGill JB, Brown WW, Collins AJ, et al. Independent components of chronic kidney disease as a cardiovascular risk state: results from the Kidney Early Evaluation Program (KEEP). *Arch Intern Med* 2007;167:1122-9.
27. The Diabetes Control and Complications Trial Research Group. The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. *N Engl J Med* 1993;329:977-6.
28. Bakris GL, Weir MR, Shanifar S, Zhang Z, Douglas J, van Dijk DJ. Effects of blood pressure level on progression of diabetic nephropathy: results from the RENAAL study. *Arch Intern Med* 2003;163:1555-65.
29. Agency for Healthcare Research and Quality (AHRQ). 2012 National Healthcare Quality Report [Internet]. Rockville: AHRQ; 2013. Available at: <http://www.ahrq.gov/research/findings/nhqrdr/nhqr12/index.html>. Accessed 12 March 2014.
30. Health and Social Care Information Centre (HSCIC). National Diabetes Audit – 2011-2012 [Internet]. Leeds: HSCIC; 2013. Available at: <http://www.hscic.gov.uk/searchcatalogue?productid=13129&q=%22National+diabetes+audit%22&sort=Relevance&size=10&page=1#top>. Accessed 12 March 2014.

Academic Medicine Education Institute (AM·EI): Transforming the Educational Culture of Health Professionals

Sok Hong Goh,¹_{MSC}, Kok Hian Tan,^{2,3}_{MBBS}, Robert K Kamei,^{2,4}_{MD}, Wen Hsin Koo,⁵_{MBBS}, Sandy Cook,^{1,2,4}_{PhD}

Abstract

Introduction: The Academic Medicine Education Institute (AM·EI), jointly established by Duke-NUS Graduate Medical School (Duke-NUS) and Singapore Healthcare Services (SingHealth), is a newly formed health professions education academy designed to cultivate best education practices and create a community of health professions educators. To achieve the aims of AM·EI, the needs of SingHealth educators have to be understood. Therefore, this study was carried out to assess educators' perceptions towards the current education climate and their academic needs. **Materials and Methods:** A 28-item questionnaire consisting of free-response, Likert-type and ranking questions was developed. The questionnaire was electronically distributed to 200 medical and nursing educators, and made available to attendees of the 2012 SingHealth Duke-NUS Scientific Congress through hardcopies. **Results:** A total of 150 completed questionnaires were received (94 from electronic survey and 56 from Congress). Five themes emerged from the analysis of responses to free-response questions: 1) faculty development, 2) development of a community of educators, 3) recognition for educational efforts, 4) institutional support, and 5) better communication about SingHealth educational activities. Respondents were in highest agreement with the statements (rating of 3.7 out of 5): "The SingHealth education programmes are of high quality", "New learning or teaching methods are welcomed in this institution/hospital", and "An academic appointment is important to me". The competencies that respondents felt to be the most important were facilitating discussions, presentation skills, and providing feedback (respective means = 5.1, 5, 5 of 7). **Conclusion:** This needs assessment provided us with important insights regarding SingHealth medical educators' perceptions of their education environment and established key priorities for the AM·EI's programming efforts.

Ann Acad Med Singapore 2015;44:xxx-xx

Key words:

Introduction

In 2010, Duke-NUS Graduate Medical School (Duke-NUS) and Singapore Healthcare Services (SingHealth) launched an initiative to improve the lives of patients by combining their individual strengths to become an integrated academic healthcare cluster. This new academic healthcare cluster has a mission to provide outstanding clinical service, discover and promote better ways to care for patients through research and education. At the same time, increasing numbers of medical students had been rotating through SingHealth clinics, making high-quality

education practices a priority. To meet educational goals, Duke-NUS together with SingHealth formed the Academic Medicine Education Institute (AM·EI) to function as a health professions education academy for the healthcare cluster.¹ Our task in AM·EI was to incorporate educational best practices to support and develop all aspects of education across a wide spectrum of healthcare educators, including physicians, nurses, allied healthcare professionals, and administrators.

Similar medical education academies have been very successful in other countries – they have been increasing

¹Medical Education, Research and Evaluation, Duke-NUS Graduate Medical School, Singapore

²Academic Medicine, Duke-NUS Graduate Medical School, Singapore

³Office of Academic Medicine, SingHealth, Singapore

⁴Office of Education, Duke-NUS Graduate Medical School, Singapore

⁵Group Education Office, SingHealth, Singapore

Address for Correspondence: Goh Sok Hong, Medical Education, Research and Evaluation Department, Duke-NUS Graduate Medical School Singapore, 8 College Road, Singapore 169857.

Email: sokhong.goh@duke-nus.edu.sg

grants and research output of their educators, improving interdepartmental collaboration, and facilitating faculty interest in continued professional education.²⁻⁴ In Singapore, an education unit known as the Centre for Medical Education was established by the Yong Loo Lin School of Medicine and National University Health System (NUHS) to provide faculty development programmes. For the SingHealth Duke-NUS academic healthcare cluster, there has been a perceived lack of quality education programmes within the cluster to engage SingHealth faculty effectively and for them to participate optimally. AM·EI places a special emphasis on building a scholarly community among healthcare educators and aims to combine the best of centralised educational activities and teaching academies in order to sustain teaching, learning, curriculum development, and scholarly educational research. As such, it aims to foster a community of healthcare educators, requiring wide-ranging and inclusive development programmes. In this respect, the AM·EI shares several similar concepts with the recommendations put forth by World Health Organization (WHO) in the WHO Education Guidelines 2013.⁵

As the AM·EI is the first all inclusive, interprofessional institute of its kind within this newly formed academic medical center, the educators' perceptions, needs and expectations in educational development and scholarship were not known. Thus, to better understand the SingHealth healthcare educators' views of their current climate and academic needs, we developed a survey to explore the current perceptions of the academic medical education environment, the health profession's competencies viewed as most important by the educators', and their programmatic needs. The purpose of this needs assessment was to guide the AM·EI as it develops relevant training programmes and initiatives to support educational activities. IRB exemption for this study was obtained from the SingHealth Centralised Institutional Review Board (CIRB).

Materials and Methods

Sites and Subjects

We surveyed a convenient sample of educators within the SingHealth and Duke-NUS systems. Educators in all health professions (i.e. medicine, nursing, allied health professions, etc.) were eligible to participate in the survey.

Questionnaire Development

A 28-item questionnaire was developed by the AM·EI executive committee, a panel of experts in medical education from both Duke-NUS and SingHealth. In order to understand the current needs and educators' expectations of the system, the panel developed the following 4 sections:

- Three free text questions:

- "What do you think the AM·EI could do to improve the quality of education at SingHealth?"
- "What would you personally like the AM·EI to do for you as an educator?"
- "How can we best engage all the educators to improve the quality of education at SingHealth?"
- Demographics: Seven items that asked participants about their specialties, their current involvement and years of experience in education, and the educational methods they had used in the past.
- Attitudes towards current educational environment: Twelve statements that participants rate on a 5-point Likert-type scale (1 = "strongly disagree," 5 = "strongly agree")
- Key education competencies: Seven competencies selected by a panel of 4 medical education experts from Duke-NUS. Participants rank these competencies in order of importance (1 = "least important," 7 = "most important").

Distribution

Approximately 200 SingHealth educators in 4 newly formed Academic Clinical Programs (ACPs), consisting of medicine, obstetrics and gynaecology, paediatrics, and surgery, as well as the department of nursing were given a link to the online questionnaire between 8 May 2012 and 18 May 2012. In addition, a hardcopy version of the questionnaire was made available at an AM·EI booth for attendees of the 2012 SingHealth Duke-NUS Scientific Congress (3 August 2012 to 4 August 2012).

Analysis

Data obtained from the survey were analysed using descriptive statistics and a nonparametric test of significance for ordinal data. The open-ended question responses were transcribed verbatim, and separated into individual comments which were then analysed for content and themes. Two research assistants independently examined the comments to identify recurring codes, subthemes, and themes. The research assistants then convened to decide upon a final list of themes and subthemes, and re-sorted individual comments into subthemes.

Results

We received a total of 150 responses. Ninety-four responses (63%) were received from the ACPs and nursing, and 56 responses (about 37%) were collected during the congress. The majority of respondents were medical clinical educators (40%) or nursing educators (38%). Further demographic details are included in Table 1.

Table 1. Demographics, Teaching Experiences and Educational Methods Used by Study Respondents

Demographics	% of Total Respondents
Demographics – Primary role (n = 150)	
Medical clinical educator (n = 60)	40
Nursing educator (n = 58)	38
Allied health educator(n = 13)	9
Others (n = 19)	13
Involvement in teaching (n = 150)	
Yes (n = 125)	83
No (n = 25)	17
Experience in education (n = 150)	
More than 20 years (n = 16)	11
10 to 19 years (n = 37)	25
5 to 9 years (n = 29)	19
Less than 5 years (n = 38)	25
Missing responses (n = 30)	20
Educational methods used (tick all that apply; n = 125)*	
Lecture-based (n = 95)	76
Case-based (n = 92)	74
Problem-based learning (n = 29)	23
Team-based learning (n = 26)	21
Stimulation (n = 25)	20
Role-play (n = 23)	18
E-learning (n = 20)	16
Others (n = 10)	8

*Percentages may not add up to 100% because each respondent can select more than 1 answer.

Educators' Perceived Scholarly Needs

A total of 328 individual comments collected from 104 respondents were received and analysed. Five main themes were identified from a qualitative content analysis of the responses to the open-ended questions: 1) faculty development, 2) development of a community of educators, 3) recognition for educational efforts, 4) institutional support, and 5) better communication about SingHealth educational activities. Several subthemes were also identified within each theme. The subthemes are identified in Table 2, along with a number of comments included and an illustrative comment for each. The authors' interpretation of each theme is highlighted below.

Faculty Development

Educators indicated that faculty development programmes should be tailored to the Duke-NUS/SingHealth community and made more easily accessible. Moreover, in order to accommodate the range of teaching competencies, educators

believed that professional development opportunities should be varied. On an individual basis, educators wanted feedback and standardisation for their teaching performance, and individual development of their teaching skills.

Development of a Community of Educators

Most educators believed that they would be assisted by the development of a community of educators. Their responses indicated that this community should support forums for within-profession and interprofessional collaboration, reflection, and communication. Furthermore, this community should not be limited to health professions educators in the Duke-NUS/SingHealth system. Educators also wanted to interact with international experts in medical education and supported increased student-teacher interactions. They suggested that AM·EI help embed the role of clinician-educator into clinical setting by increasing awareness about education being a discreet discipline, formalising the education role with appropriate rewards and recognition.

Recognition

Simply put, SingHealth and faculty educators felt that the current promotion criteria did not adequately consider efforts related to teaching and educational activities.

Institutional Administrative Support

The majority of educators requested institutional support in the form of protected time for teaching and training, administrative and information technology support, monetary resources, increased teaching facilities, and access to academic journals.

Better Communication about SingHealth Educational Activities

Educators believed AM·EI should improve communication between faculty and education administration by clearly articulating AM·EI's vision, defining faculty roles within that vision, and updating educators on the progress and outcome of teaching efforts, training efforts and programmes. This included receiving timely updates on management changes.

Perception of Academic Medical Education Environment

Table 3 presents the mean scores (range, 1 to 5) and standard deviation for each individual item asking about each participant's perceptions of the current academic education environment. The 3 items that respondents were in highest agreement with were: "The SingHealth education programmes are of high quality", "New learning or teaching

Table 2. Themes, Subthemes, and Illustrative Comments from Open-ended Question Responses

Theme	Subthemes (Total Number of Comments)	Illustrative Comments
Faculty development	Training and skill advancement (95)	“Provide the necessary training needs of an educator.”
	Standardisation and assessment (16)	“Check level of competency regularly.”
	Innovation in teaching (14)	“Be innovative and willing to adopt new technologies in the delivery of medical education.”
	Provide opportunities to teach (9)	“Give me more opportunity to teach.”
Development of a community of educators	Collaboration within and between institutions (26)	“Collaboration between medical, nursing and allied health in conducting courses and training.”
	Create a platform for sharing ideas (20)	“Seminars for educators to share their experiences.”
	Building relationships (11)	“The education institute could match clinician educator-track doctors with mentors.”
	Promoting a culture of education (9)	“Have a common vision and mindset.”
Recognition	Acknowledgement of efforts (17)	“Recognise existing talents on the ground.”
	Providing incentives (10)	“Reward teaching efforts financially.”
	Identify and recruit teaching talent (6)	“Selecting and developing the right candidates for teaching positions/assignments.”
Institutional administrative support	Provision of resources (26)	“The education institute should act as a resource center for clinician educators to consult for advice on things like curriculum planning/ education research.”
	Protected time (21)	“Allocate appropriate time which is protected for teaching.”
	Administrative and IT support (20)	“Assist with the setting up of nursing clinical development unit.”
	Provision of facilities (6)	“Provide facilities e.g. rooms, clinics.”
Better communication about SingHealth educational activities	Communication and outreach (10)	“Regular follow-up on latest management changes.”
	Accept feedback (6)	“Connect with educators for exchange of feedback and evaluation.”
	Ground-up approach (6)	“Allow the educators on the ground to initiate activities for themselves.”

methods are welcomed in this institution/hospital”, and “An academic appointment is important to me” (mean 3.7 out of 5), respectively. The 2 lowest rated items were: “Academic medicine is never compromised when more clinical work needs to be done” (3.0) and “Staff worries that efforts made in education will be rewarded less than service” (3.1).

Importance of Competencies

Table 4 presents the mean importance score (range, 1 to 7; 7 = most important) and standard deviation for each of the 7 competencies. “Facilitate discussion,” “presentation skills,” and “provide feedback” received the highest mean rankings, respectively.

Discussion

Our needs analysis helped us to identify our educators’ priorities, most valued competencies, and expectations for our institute.

The qualitative analysis highlighted a willingness to do more teaching as illustrated by respondents’ wish for protected time, more administrative support for educational activities, and greater recognition for education accomplishments from their institutions. These findings reflect recent assertions from Wong⁶ and Yap⁷ that medical educators in Singapore are committed to teaching and academia, but education activities are often sacrificed to provide greater time and resources to research and clinical practice. As a centralised medical education academy, the

Table 3. Mean and Standard Deviation for Perceptions of Academic Medical Education Learning Environment

Questions	Mean (SD)
I work at SingHealth because I have an opportunity to teach. (n = 135)	3.6 (0.9)
My colleagues are interested in teaching. (n = 136)	3.5 (0.8)
The SingHealth Education programs are high quality. (n = 135)	3.7 (0.8)
It has been easy for me to participate in SingHealth's programmes to improve teaching skills. (n = 133)	3.4 (0.9)
Management offers adequate resources necessary for academic medicine to thrive. (n = 134)	3.3 (1)
In the department, we discuss ways to improve handling of academic issues in our work. (n = 135)	3.4 (1.1)
New learning or teaching methods are welcomed in this institution/hospital. (n = 135)	3.7 (0.9)
Opportunities to participate in academic events and educational & research scholarly activities are available. (n = 134)	3.5 (1)
An academic appointment is important to me. (n = 133)	3.7 (1)
Staff worries that efforts made in education will be rewarded less than service. (n = 135)	3.1 (1.1)
Academic medicine issues have brought about some positive changes here. (n = 134)	3.6 (0.8)
Academic medicine is never compromised when more clinical work needs to be done. (n = 130)	3.0 (1)

Likert scale (1 = Strongly disagree to 5 = Strongly agree)

AM·EI should provide greater resources and recognition so that faculty's education activities can be viewed with greater value.

Even though not all educators' felt their perceived needs were being met at the time of assessment, educational activities such as academic appointments, protected time, and high-quality education programmes when available were greatly appreciated and valued. It was clear that under the current system educators felt clinical work took priority and academic and scholarly efforts were compromised.

As a result of this data, the AM·EI has implemented several initiatives to respond to the stated needs of Duke-NUS/SingHealth educators.

Faculty Development

At the time of submission, we have developed 20 workshops that have attracted 1954 participants from all disciplines. In addition, we have established monthly medical education grand rounds as a vehicle to bring in distinguished speakers and have our seasoned educators share their experiences. Further, in collaboration with the Graduate Medical Education Office, we have partnered with annual education conferences that offer workshops and topics of interest to our educators.

Table 4. Mean Ranking and Standard Deviation of Educators' Competencies

Educators' Competencies	Mean (SD)
Facilitate discussion (n = 139)	5.1 (1.6)
Presentation skills (n = 139)	5 (1.9)
Provide feedback (n = 138)	5 (1.8)
Coaching skills (n = 150)	4.6 (2.3)
Evaluation skills (n = 150)	4.1 (2.1)
Instructional pedagogies (n = 138)	3.9 (2.3)
Leadership skills (n = 150)	3.8 (2.3)

Likert scale (1 = Least important to 7 = Most important)

Community of Educators

We created an all-inclusive interprofessional community of educators. Membership is available to anyone from our respective institutions with a passion for healthcare education, including trainees, students, staff, and seasoned educators. One of our signature programs is an AM·EI fellowship designed to bring together those with a significant responsibility in education and facilitate their broad understanding of the Academy of Medical Education (AoME) Health Professions Competencies,⁸ and develop their skills in programme development and scholarship. We believe this fellowship will be important in the development of clinician-educators necessary to drive educational innovation.

Recognition

We established a Golden Apple Award process that recognises the scholarly educators and newsletters that highlight the work of our outstanding educators in regular communications. Regular reports from the AM·EI are being given to the ACP chairs about the contribution and professional development of their faculty in the area of education.

Resources

We provide institutional support through a monetary grant for innovative medical education scholarship, and provide greater administrative support with our partner, the SingHealth Academy. Further, we offer financial remuneration (and recognition) for faculty who teach AM·EI courses.

Communications

A concerted effort has been made to establish regular communications about the AM·EI activities, and ways to involve our educators. We hope that educators will continue

to share with us their needs and interests so as to improve the programming and recognition of our educators. Further, we have 3 active committees designed to communicate and address upcoming interests or needs of our educators. These committees are:

- Advocacy – enhance a supportive culture for and value of education in the health care system, and identifying and recognising educational efforts.
- Professional development – develop the interdisciplinary programmes and seminars that build the skills and competencies of the educators. This committee also established a standardised evaluation form for regular feedback to our faculty for their teaching efforts within the AM·EI.
- Scholarship – support innovation and scholarship in education through courses, grants and consultation.

Limitations

While this was only a convenience sample of educators which may limit the generalisability of the data, it represented those who are either actively involved in education or had an expressed interest in education, making it useful as a starting point for the AM·EI to better understand the issues and concerns of the educators within the newly formed academic medical cluster. Their opinions were therefore deemed sufficient for the purposes of this assessment, and for developing a baseline understanding of the opinions and needs of health professions educators in SingHealth's unique academic environment. As we involve more people in the AM·EI, their input and needs will be discussed and explored for implementation.

The collection of qualitative data through written responses instead of focus groups and interviews may limit the richness of our data. However, it allowed us to capture a broader set of responses and obtain a larger sample than we would have if focus groups or interviews were utilised.

We hope that continued support for medical education by the AM·EI will drive SingHealth towards a stellar culture of education innovation and scholarship which ultimately translates into better care for our patients.

Conclusion

AM·EI is designed to increase institutional support for academic medicine and educational scholarship by synergising faculty development efforts, resources, and support for medical education and medical education scholarship. Our initial needs assessment defined faculty development, community building, and administrative support and recognition as priorities for health professions

educators in the Duke-NUS and SingHealth system. This assessment allowed us to tailor faculty development programmes that aim to facilitate interdisciplinary learning, support faculty development, and recognise educational achievement. These continued efforts in medical education are leading the way in fulfilling the mission of the academic medical cluster established by our institutions.

REFERENCES

1. Krishnan RR, Ng I. Academic medicine: vision to reality. *Ann Acad Med Singapore* 2013;42:2-4.
2. Searle NS, Thompson BM, Friedland JA, Lomax JW, Drutz JE, Coburn M, et al. The prevalence and practice of academies of medical educators: a survey of U.S. medical schools. *Acad Med* 2010;85:48-56.
3. Al Shawwa LA. The establishment and roles of the Medical Education Department in the faculty of Medicine, King Abdul Aziz University, Jeddah Saudi Arabia. *Oman Med J* 2012;27:4-9.
4. Dewey CM, Friedland JA, Richards BF, Lamki N, Kirkland RT. The emergence of academies of educational excellence: A survey of U.S. medical schools. *Acad Med* 2005;80:358-65.
5. World Health Organization. Transforming and scaling up health professionals' education and training: WHO Education Guidelines 2013. Geneva, World Health Organization, 2013.
6. Wong JE. The future of medical education: the second 100 years. *Ann Acad Med Singapore* 2005;34:166C-71C.
7. Yap HK. Academic medicine in Singapore. *Ann Acad Med Singapore* 1998;27:757-8.
8. Academy of Medical Educators. Professional Standards [Internet]. Cardiff: Academy of Medical Educators; 2014. Available at: <http://www.medicaleducators.org/index.cfm/profession/professional-standards/> Accessed 6 August 2014.

Academic Medicine Education Institute (AM·EI): Transforming the Educational Culture of Health Professionals

Sok Hong Goh,¹*MSc*, Kok Hian Tan,^{2,3}*MBBS*, Robert K Kamei,^{2,4}*MD*, Wen Hsin Koo,⁵*MBBS*, Sandy Cook,^{1,2,4}*PhD*

Abstract

Introduction: The Academic Medicine Education Institute (AM·EI), jointly established by Duke-NUS Graduate Medical School (Duke-NUS) and Singapore Healthcare Services (SingHealth), is a newly formed health professions education academy designed to cultivate best education practices and create a community of health professions educators. To achieve the aims of AM·EI, the needs of SingHealth educators have to be understood. Therefore, this study was carried out to assess educators' perceptions towards the current education climate and their academic needs. **Materials and Methods:** A 28-item questionnaire consisting of free-response, Likert-type and ranking questions was developed. The questionnaire was electronically distributed to 200 medical and nursing educators, and made available to attendees of the 2012 SingHealth Duke-NUS Scientific Congress through hardcopies. **Results:** A total of 150 completed questionnaires were received (94 from electronic survey and 56 from Congress). Five themes emerged from the analysis of responses to free-response questions: 1) faculty development, 2) development of a community of educators, 3) recognition for educational efforts, 4) institutional support, and 5) better communication about SingHealth educational activities. Respondents were in highest agreement with the statements (rating of 3.7 out of 5): "The SingHealth education programmes are high quality", "New learning or teaching methods are welcomed in this institution/hospital", and "An academic appointment is important to me". The competencies that respondents felt to be the most important were facilitating discussions, presentation skills, and providing feedback (respective means = 5.1, 5, 5 of 7). **Conclusion:** This needs assessment provided us with important insights regarding SingHealth medical educators' perceptions of their education environment and established key priorities for the AM·EI's programming efforts.

Ann Acad Med Singapore 2015;44:xxx-xx

Key words: Academy, Duke-NUS, Singapore, SingHealth

Introduction

In 2010, Duke-NUS Graduate Medical School (Duke-NUS) and Singapore Healthcare Services (SingHealth) launched an initiative to improve the lives of patients by combining their individual strengths to become an integrated academic healthcare cluster. This new academic healthcare cluster has a mission to provide outstanding clinical service, discover and promote better ways to care for patients through research and education. At the same time, increasing numbers of medical students had been rotating through SingHealth clinics, making high-quality

education practices a priority. To meet educational goals, Duke-NUS together with SingHealth formed the Academic Medicine Education Institute (AM·EI) to function as a health professions education academy for the healthcare cluster.¹ Our task in AM·EI was to incorporate educational best practices to support and develop all aspects of education across a wide spectrum of healthcare educators, including physicians, nurses, allied healthcare professionals, and administrators.

Similar medical education academies have been very successful in other countries – they have been increasing

¹Medical Education, Research and Evaluation, Duke-NUS Graduate Medical School, Singapore

²Academic Medicine, Duke-NUS Graduate Medical School, Singapore

³Office of Academic Medicine, SingHealth, Singapore

⁴Office of Education, Duke-NUS Graduate Medical School, Singapore

⁵Group Education Office, SingHealth, Singapore

Address for Correspondence: Ms Goh Sok Hong, Medical Education, Research and Evaluation Department, Duke-NUS Graduate Medical School Singapore, 8 College Road, Singapore 169857.

Email: sokhong.goh@duke-nus.edu.sg

grants and research output of their educators, improving interdepartmental collaboration, and facilitating faculty interest in continued professional education.²⁻⁴ In Singapore, an education unit known as the Centre for Medical Education was established by the Yong Loo Lin School of Medicine and National University Health System (NUHS) to provide faculty development programmes. For the SingHealth Duke-NUS academic healthcare cluster, there has been a perceived lack of quality education programmes within the cluster to engage SingHealth faculty effectively and for them to participate optimally. AM·EI places a special emphasis on building a scholarly community among healthcare educators and aims to combine the best of centralised educational activities and teaching academies in order to sustain teaching, learning, curriculum development, and scholarly educational research. As such, it aims to foster a community of healthcare educators, requiring wide-ranging and inclusive development programmes. In this respect, the AM·EI shares several similar concepts with the recommendations put forth by World Health Organization (WHO) in the WHO Education Guidelines 2013.⁵

As the AM·EI is the first all inclusive, interprofessional institute of its kind within this newly formed academic medical center, the educators' perceptions, needs and expectations in educational development and scholarship were not known. Thus, to better understand the SingHealth healthcare educators' views of their current climate and academic needs, we developed a survey to explore the current perceptions of the academic medical education environment, the health profession's competencies viewed as most important by the educators', and their programmatic needs. The purpose of this needs assessment was to guide the AM·EI as it develops relevant training programmes and initiatives to support educational activities. IRB exemption for this study was obtained from the SingHealth Centralised Institutional Review Board (CIRB).

Materials and Methods

Sites and Subjects

We surveyed a convenient sample of educators within the SingHealth and Duke-NUS systems. Educators in all health professions (i.e. medicine, nursing, allied health professions, etc.) were eligible to participate in the survey.

Questionnaire Development

A 28-item questionnaire was developed by the AM·EI executive committee, a panel of experts in medical education from both Duke-NUS and SingHealth. In order to understand the current needs and educators' expectations of the system, the panel developed the following 4 sections:

- Three free text questions:

- "What do you think the AM·EI could do to improve the quality of education at SingHealth?"
- "What would you personally like the AM·EI to do for you as an educator?"
- "How can we best engage all the educators to improve the quality of education at SingHealth?"
- Demographics: Seven items that asked participants about their specialties, their current involvement and years of experience in education, and the educational methods they had used in the past.
- Attitudes towards current educational environment: Twelve statements that participants rate on a 5-point Likert-type scale (1 = "strongly disagree," 5 = "strongly agree")
- Key education competencies: Seven competencies selected by a panel of 4 medical education experts from Duke-NUS. Participants rank these competencies in order of importance (1 = "least important," 7 = "most important").

Distribution

Approximately 200 SingHealth educators in 4 newly formed Academic Clinical Programs (ACPs), consisting of medicine, obstetrics and gynaecology, paediatrics, and surgery, as well as the department of nursing were given a link to the online questionnaire between 8 May 2012 and 18 May 2012. In addition, a hardcopy version of the questionnaire was made available at an AM·EI booth for attendees of the 2012 SingHealth Duke-NUS Scientific Congress (3 August 2012 to 4 August 2012).

Analysis

Data obtained from the survey were analysed using descriptive statistics and a nonparametric test of significance for ordinal data. The open-ended question responses were transcribed verbatim, and separated into individual comments which were then analysed for content and themes. Two research assistants independently examined the comments to identify recurring codes, subthemes, and themes. The research assistants then convened to decide upon a final list of themes and subthemes, and re-sorted individual comments into subthemes.

Results

We received a total of 150 responses. Ninety-four responses (63%) were received from the ACPs and nursing, and 56 responses (about 37%) were collected during the congress. The majority of respondents were medical clinical educators (40%) or nursing educators (38%). Further demographic details are included in Table 1.

Table 1. Demographics, Teaching Experiences and Educational Methods Used by Study Respondents

Demographics	% of Total Respondents
Demographics – Primary role (n = 150)	
Medical clinical educator (n = 60)	40
Nursing educator (n = 58)	38
Allied health educator(n = 13)	9
Others (n = 19)	13
Involvement in teaching (n = 150)	
Yes (n = 125)	83
No (n = 25)	17
Experience in education (n = 150)	
More than 20 years (n = 16)	11
10 to 19 years (n = 37)	25
5 to 9 years (n = 29)	19
Less than 5 years (n = 38)	25
Missing responses (n = 30)	20
Educational methods used (tick all that apply; n = 125)*	
Lecture-based (n = 95)	76
Case-based (n = 92)	74
Problem-based learning (n = 29)	23
Team-based learning (n = 26)	21
Stimulation (n = 25)	20
Role-play (n = 23)	18
E-learning (n = 20)	16
Others (n = 10)	8

*Percentages may not add up to 100% because each respondent can select more than 1 answer.

Educators' Perceived Scholarly Needs

A total of 328 individual comments collected from 104 respondents were received and analysed. Five main themes were identified from a qualitative content analysis of the responses to the open-ended questions: 1) faculty development, 2) development of a community of educators, 3) recognition for educational efforts, 4) institutional support, and 5) better communication about SingHealth educational activities. Several subthemes were also identified within each theme. The subthemes are identified in Table 2, along with a number of comments included and an illustrative comment for each. The authors' interpretation of each theme is highlighted below.

Faculty Development

Educators indicated that faculty development programmes should be tailored to the Duke-NUS/SingHealth community and made more easily accessible. Moreover, in order to accommodate the range of teaching competencies, educators

believed that professional development opportunities should be varied. On an individual basis, educators wanted feedback and standardisation for their teaching performance, and individual development of their teaching skills.

Development of a Community of Educators

Most educators believed that they would be assisted by the development of a community of educators. Their responses indicated that this community should support forums for within-profession and interprofessional collaboration, reflection, and communication. Furthermore, this community should not be limited to health professions educators in the Duke-NUS/SingHealth system. Educators also wanted to interact with international experts in medical education and supported increased student-teacher interactions. They suggested that AM·EI help embed the role of clinician-educator into clinical setting by increasing awareness about education being a discreet discipline, formalising the education role with appropriate rewards and recognition.

Recognition

Simply put, SingHealth and faculty educators felt that the current promotion criteria did not adequately consider efforts related to teaching and educational activities.

Institutional Administrative Support

The majority of educators requested institutional support in the form of protected time for teaching and training, administrative and information technology support, monetary resources, increased teaching facilities, and access to academic journals.

Better Communication about SingHealth Educational Activities

Educators believed AM·EI should improve communication between faculty and education administration by clearly articulating AM·EI's vision, defining faculty roles within that vision, and updating educators on the progress and outcome of teaching efforts, training efforts and programmes. This included receiving timely updates on management changes.

Perception of Academic Medical Education Environment

Table 3 presents the mean scores (range, 1 to 5) and standard deviation for each individual item asking about each participant's perceptions of the current academic education environment. The 3 items that respondents were in highest agreement with were: "The SingHealth education programmes are of high quality", "New learning or teaching

Table 2. Themes, Subthemes, and Illustrative Comments from Open-ended Question Responses

Theme	Subthemes (Total Number of Comments)	Illustrative Comments
Faculty development	Training and skill advancement (95)	“Provide the necessary training needs of an educator.”
	Standardisation and assessment (16)	“Check level of competency regularly.”
	Innovation in teaching (14)	“Be innovative and willing to adopt new technologies in the delivery of medical education.”
	Provide opportunities to teach (9)	“Give me more opportunity to teach.”
Development of a community of educators	Collaboration within and between institutions (26)	“Collaboration between medical, nursing and allied health in conducting courses and training.”
	Create a platform for sharing ideas (20)	“Seminars for educators to share their experiences.”
	Building relationships (11)	“The education institute could match clinician educator-track doctors with mentors.”
	Promoting a culture of education (9)	“Have a common vision and mindset.”
Recognition	Acknowledgement of efforts (17)	“Recognise existing talents on the ground.”
	Providing incentives (10)	“Reward teaching efforts financially.”
	Identify and recruit teaching talent (6)	“Selecting and developing the right candidates for teaching positions/assignments.”
Institutional administrative support	Provision of resources (26)	“The education institute should act as a resource center for clinician educators to consult for advice on things like curriculum planning/ education research.”
	Protected time (21)	“Allocate appropriate time which is protected for teaching.”
	Administrative and IT support (20)	“Assist with the setting up of nursing clinical development unit.”
	Provision of facilities (6)	“Provide facilities e.g. rooms, clinics.”
Better communication about SingHealth educational activities	Communication and outreach (10)	“Regular follow-up on latest management changes.”
	Accept feedback (6)	“Connect with educators for exchange of feedback and evaluation.”
	Ground-up approach (6)	“Allow the educators on the ground to initiate activities for themselves.”

methods are welcomed in this institution/hospital”, and “An academic appointment is important to me” (mean 3.7 out of 5), respectively. The 2 lowest rated items were: “Academic medicine is never compromised when more clinical work needs to be done” (3.0) and “Staff worries that efforts made in education will be rewarded less than service” (3.1).

Importance of Competencies

Table 4 presents the mean importance score (range, 1 to 7; 7 = most important) and standard deviation for each of the 7 competencies. “Facilitate discussion,” “presentation skills,” and “provide feedback” received the highest mean rankings, respectively.

Discussion

Our needs analysis helped us to identify our educators’ priorities, most valued competencies, and expectations for our institute.

The qualitative analysis highlighted a willingness to do more teaching as illustrated by respondents’ wish for protected time, more administrative support for educational activities, and greater recognition for education accomplishments from their institutions. These findings reflect recent assertions from Wong⁶ and Yap⁷ that medical educators in Singapore are committed to teaching and academia, but education activities are often sacrificed to provide greater time and resources to research and clinical practice. As a centralised medical education academy, the

Table 3. Mean and Standard Deviation for Perceptions of Academic Medical Education Learning Environment

Questions	Mean (SD)
I work at SingHealth because I have an opportunity to teach. (n = 135)	3.6 (0.9)
My colleagues are interested in teaching. (n = 136)	3.5 (0.8)
The SingHealth Education programs are high quality. (n = 135)	3.7 (0.8)
It has been easy for me to participate in SingHealth's programmes to improve teaching skills. (n = 133)	3.4 (0.9)
Management offers adequate resources necessary for academic medicine to thrive. (n = 134)	3.3 (1)
In the department, we discuss ways to improve handling of academic issues in our work. (n = 135)	3.4 (1.1)
New learning or teaching methods are welcomed in this institution/hospital. (n = 135)	3.7 (0.9)
Opportunities to participate in academic events and educational & research scholarly activities are available. (n = 134)	3.5 (1)
An academic appointment is important to me. (n = 133)	3.7 (1)
Staff worries that efforts made in education will be rewarded less than service. (n = 135)	3.1 (1.1)
Academic medicine issues have brought about some positive changes here. (n = 134)	3.6 (0.8)
Academic medicine is never compromised when more clinical work needs to be done. (n = 130)	3.0 (1)

Likert scale (1 = Strongly disagree to 5 = Strongly agree)

AM·EI should provide greater resources and recognition so that faculty's education activities can be viewed with greater value.

Even though not all educators' felt their perceived needs were being met at the time of assessment, educational activities such as academic appointments, protected time, and high-quality education programmes when available were greatly appreciated and valued. It was clear that under the current system educators felt clinical work took priority and academic and scholarly efforts were compromised.

As a result of this data, the AM·EI has implemented several initiatives to respond to the stated needs of Duke-NUS/SingHealth educators.

Faculty Development

At the time of submission, we have developed 20 workshops that have attracted 1954 participants from all disciplines. In addition, we have established monthly medical education grand rounds as a vehicle to bring in distinguished speakers and have our seasoned educators share their experiences. Further, in collaboration with the Graduate Medical Education Office, we have partnered with annual education conferences that offer workshops and topics of interest to our educators.

Table 4. Mean Ranking and Standard Deviation of Educators' Competencies

Educators' Competencies	Mean (SD)
Facilitate discussion (n = 139)	5.1 (1.6)
Presentation skills (n = 139)	5 (1.9)
Provide feedback (n = 138)	5 (1.8)
Coaching skills (n = 150)	4.6 (2.3)
Evaluation skills (n = 150)	4.1 (2.1)
Instructional pedagogies (n = 138)	3.9 (2.3)
Leadership skills (n = 150)	3.8 (2.3)

Likert scale (1 = Least important to 7 = Most important)

Community of Educators

We created an all-inclusive interprofessional community of educators. Membership is available to anyone from our respective institutions with a passion for healthcare education, including trainees, students, staff, and seasoned educators. One of our signature programs is an AM·EI fellowship designed to bring together those with a significant responsibility in education and facilitate their broad understanding of the Academy of Medical Education (AoME) Health Professions Competencies,⁸ and develop their skills in programme development and scholarship. We believe this fellowship will be important in the development of clinician-educators necessary to drive educational innovation.

Recognition

We established a Golden Apple Award process that recognises the scholarly educators and newsletters that highlight the work of our outstanding educators in regular communications. Regular reports from the AM·EI are being given to the ACP chairs about the contribution and professional development of their faculty in the area of education.

Resources

We provide institutional support through a monetary grant for innovative medical education scholarship, and provide greater administrative support with our partner, the SingHealth Academy. Further, we offer financial remuneration (and recognition) for faculty who teach AM·EI courses.

Communications

A concerted effort has been made to establish regular communications about the AM·EI activities, and ways to involve our educators. We hope that educators will continue

to share with us their needs and interests so as to improve the programming and recognition of our educators. Further, we have 3 active committees designed to communicate and address upcoming interests or needs of our educators. These committees are:

- Advocacy – enhance a supportive culture for and value of education in the health care system, and identifying and recognising educational efforts.
- Professional development – develop the interdisciplinary programmes and seminars that build the skills and competencies of the educators. This committee also established a standardised evaluation form for regular feedback to our faculty for their teaching efforts within the AM·EI.
- Scholarship – support innovation and scholarship in education through courses, grants and consultation.

Limitations

While this was only a convenience sample of educators which may limit the generalisability of the data, it represented those who are either actively involved in education or had an expressed interest in education, making it useful as a starting point for the AM·EI to better understand the issues and concerns of the educators within the newly formed academic medical cluster. Their opinions were therefore deemed sufficient for the purposes of this assessment, and for developing a baseline understanding of the opinions and needs of health professions educators in SingHealth's unique academic environment. As we involve more people in the AM·EI, their input and needs will be discussed and explored for implementation.

The collection of qualitative data through written responses instead of focus groups and interviews may limit the richness of our data. However, it allowed us to capture a broader set of responses and obtain a larger sample than we would have if focus groups or interviews were utilised.

We hope that continued support for medical education by the AM·EI will drive SingHealth towards a stellar culture of education innovation and scholarship which ultimately translates into better care for our patients.

Conclusion

AM·EI is designed to increase institutional support for academic medicine and educational scholarship by synergising faculty development efforts, resources, and support for medical education and medical education scholarship. Our initial needs assessment defined faculty development, community building, and administrative support and recognition as priorities for health professions

educators in the Duke-NUS and SingHealth system. This assessment allowed us to tailor faculty development programmes that aim to facilitate interdisciplinary learning, support faculty development, and recognise educational achievement. These continued efforts in medical education are leading the way in fulfilling the mission of the academic medical cluster established by our institutions.

REFERENCES

1. Krishnan RR, Ng I. Academic medicine: vision to reality. *Ann Acad Med Singapore* 2013;42:2-4.
2. Searle NS, Thompson BM, Friedland JA, Lomax JW, Drutz JE, Coburn M, et al. The prevalence and practice of academies of medical educators: a survey of U.S. medical schools. *Acad Med* 2010;85:48-56.
3. Al Shawwa LA. The establishment and roles of the Medical Education Department in the faculty of Medicine, King Abdul Aziz University, Jeddah Saudi Arabia. *Oman Med J* 2012;27:4-9.
4. Dewey CM, Friedland JA, Richards BF, Lamki N, Kirkland RT. The emergence of academies of educational excellence: A survey of U.S. medical schools. *Acad Med* 2005;80:358-65.
5. World Health Organization. Transforming and scaling up health professionals' education and training: WHO Education Guidelines 2013. Geneva, World Health Organization, 2013.
6. Wong JE. The future of medical education: the second 100 years. *Ann Acad Med Singapore* 2005;34:166C-71C.
7. Yap HK. Academic medicine in Singapore. *Ann Acad Med Singapore* 1998;27:757-8.
8. Academy of Medical Educators. Professional Standards [Internet]. Cardiff: Academy of Medical Educators; 2014. Available at: <http://www.medicaleducators.org/index.cfm/profession/professional-standards/> Accessed 6 August 2014.

Is the Apprehension Test Sufficient for the Diagnosis of Anterior Shoulder Instability in Young Patients without Magnetic Resonance Imaging (MRI)?

Krishna Kumar, ¹MD, Milindu Makandura, ¹MBBS, Nicholas Leong, ¹MBBS, Louise Gartner, ²FRCR, Chin Hwee Lee, ²MD, Dennis ZW Ng, ¹MBBS, Chyn Hong Tan, ¹FRCS, Prem V Kumar, ^{1,3}FRCS

Abstract

Introduction: The purpose of this study is to compare the sensitivities and positive predictive values (PPV) of the anterior apprehension test and magnetic resonance imaging (MRI) in the diagnosis of anterior labral tears in young patients with shoulder instability and to determine if surgery could be carried without this investigation in selected patients. **Materials and Methods:** We undertook a retrospective study of 168 patients aged between 15 and 30 years with a history of shoulder dislocation and compared the sensitivities and the PPV of the apprehension test with both MRI and magnetic resonance arthrograms (MRA) in the diagnosis of a Bankart lesion. The radiological investigations were interpreted by general practice radiologists and specialised musculoskeletal radiologists. All patients had their diagnosis confirmed by shoulder arthroscopy. **Results:** Our results showed that the apprehension test was highly reliable when it was positive with a PPV of 96%. It was more sensitive than MRI in the diagnosis of a Bankart lesion. The clinical test was significantly better when a musculoskeletal radiologist interpreted the MRI. The MRA interpreted by a musculoskeletal radiologist had the highest rates of sensitivity in detecting Bankart lesions. The figure was similar to that for the apprehension test. There was no difference in the PPVs among the clinical test, the MRI and the MRA read by the 2 categories of radiologists. **Conclusion:** We conclude that a routine MRI may be unnecessary in evaluating a young patient with clinically evident anterior shoulder instability if the apprehension test is positive. A MRA that can be interpreted by a musculoskeletal radiologist will be the next best investigation if the clinical test is negative or equivocal.

Ann Acad Med Singapore 2015;44:xx-xx

Key words: Dislocation, Imaging, Shoulder

Introduction

A good history and a detailed physical examination is often sufficient to make a diagnosis of a recurrent anterior dislocation of the shoulder, even in the absence of a radiologically documented dislocation of the joint.¹ The anterior apprehension test has recently been supplemented with the relocation, crank, and load and shift tests to increase its accuracy. The advent of computer tomography (CT) arthrogram, magnetic resonance imaging (MRI) and magnetic resonance arthrogram (MRA) have enabled surgeons to predict preoperatively the intra-articular pathology with greater accuracy so as to counsel patients and to obtain informed consent. A small study in 1996¹ has

shown that a physical examination using several tests had a higher sensitivity but a similar specificity in predicting a glenoid labral tear than MRI, although this study has been refuted in a 1997 study by Seeger et al.² A more recent study³ has suggested that the need for routine MRAs may not be as crucial as currently accepted in the management of a clinically unstable shoulder especially in the young patient. However, the MRA showed a sensitivity of 95% and a specificity of 100% for detecting anterior labral tears in a study by Parmar et al.⁴ This study suggests that the MRA rather than MRI should be the investigative modality of choice. There is therefore confusion regarding the role of MRI or MRA in shoulder instability. These investigations

¹University Orthopaedics, Hand and Reconstructive Microsurgery Cluster, National University Hospital, National University Health System, Singapore

²Department of Diagnostic Imaging, National University Hospital, National University Health System, Singapore

³Department of Orthopaedic Surgery, Yong Loo Lin School of Medicine, National University of Singapore, National University Health System, Singapore
Address for Correspondence: Prof V Prem Kumar, Department of Orthopaedic Surgery, University Orthopaedics, Hand and Reconstructive Microsurgery Cluster, National University Health System, NUHS Tower Block, Level 11, 1E Kent Ridge Road, Singapore 119228.

Email: prem_kumar@nuhs.edu.sg

however, have come with additional costs to the patient, both in terms of expense and time delay in obtaining them. In addition, their accuracy has also been challenged.¹ The routine use of these modalities now, needs critical re-evaluation in the face of rising healthcare expenditure.^{1,3} Do these investigations provide information that may not be obtained in a routine arthroscopic evaluation of the joint and do any additional findings affect the management plan of the surgeon at the time of arthroscopy?

The hypothesis of this present study is that a well conducted apprehension test is sufficient to make a diagnosis of a recurrent anterior instability of the shoulder and an associated labral tear in the young patient without the need for additional investigations such as the MRI or MRA.

Materials and Methods

We accessed the Shoulder and Elbow Registry of our institution between the years 2007 and 2013 and identified 230 patients with a history of recurrent anterior dislocation of the shoulder who were eligible for the study.

Inclusion and Exclusion Criteria

The inclusion criteria were all patients between 15 to 30 years of age with a history of recurrent anterior dislocation of the shoulder and who had undergone arthroscopic surgery at our institution. Only patients with documentation of the anterior apprehension test in the case notes were included. Both positive and negative findings must be indicated in the files before they were included. First time dislocators were excluded as we never operated on this group. Also patients with previous shoulder surgery, multidirectional instability (MDI) or posterior instability were excluded as were patients who had experienced pain on the apprehension test, or excessive pain that prevented the performance of the test or guarding that prevented the apprehension test manoeuvre.

Patient Recruitment

Sixty-two patients were removed from the study as they failed to meet the inclusion criteria, leaving 168 patients for the study. Three patients were excluded from the analysis of the MRI/MRA data as the images could not be retrieved, leaving 62 patients with MRI records and 103 with MRA findings.

Ethical approval was obtained from the national Disease Specific Review Board (DSRB).

All clinical assessment was performed by 2 senior fellowship-trained consultant surgeons. A retrospective review of the MRI/MRA films was conducted by 2 fellowship-trained senior musculoskeletal radiologists who

were blinded from the clinical findings and the surgical notes. For the purpose of the study, a musculoskeletal radiologist was defined as someone who was fellowship-trained in musculoskeletal radiology and who had a minimum of 5 years' experience in the subject. The existing reports in the system had been initially interpreted by a general radiologist. For the purpose of this study, a general radiologist was defined as one whose practice was more of a general nature, with no fellowship training in musculoskeletal radiology. A review of the surgical operative notes was conducted and all findings were recorded. All surgeries were performed by 1 of the 2 senior authors (VPK, TCH).

Anterior Apprehension Test

The test was performed with the patient in a standing position. The examiner stood behind the patient and abducted the arm to 110° with 15° of extension and 15° of external rotation. The examiner observed the patient for apprehension with the aid of a mirror placed in front of the patient (Fig. 1). If no apprehension is elicited, then an anteriorly directed force is applied to the humeral head from behind. The fingers of the examiner are however kept anterior, in order to prevent the humeral head from dislocating.

The presence or absence of apprehension was noted in the file. The test was carried out as described by 2 experienced surgeons who have been performing this test since they started practice. The test was performed by the 2 surgeons on their respective patients.

Radiological Investigations

All MRI and MRA images were interpreted from the picture archiving and communication system (PACS) system. Imaging was performed using either the Siemens 1.5 Tesla or the GE 1.5 Tesla unit. Arthrography was performed by the radiologist. A radio-opaque marker was

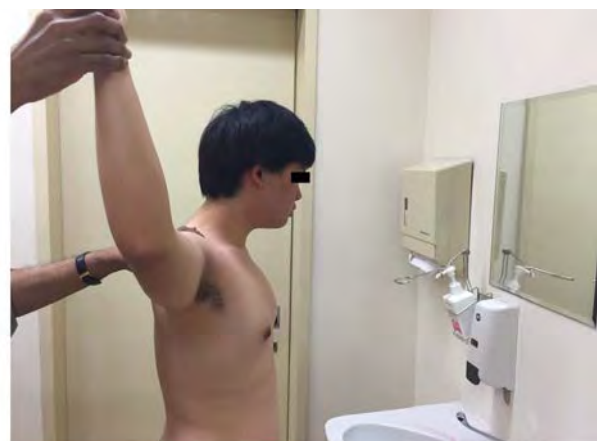


Fig 1. The anterior apprehension test.

used to locate a site over the inferomedial quadrant of the humeral head. After skin preparation, the shoulder was draped and the injection site and soft tissue infiltrated with local anaesthetic (lignocaine 1%).

A 22G spinal needle was inserted into the glenohumeral joint under fluoroscopic guidance and the position confirmed by injection of a small amount of Omnipaque 300 iodinated contrast media. Capsular distension was achieved using 10 mL to 15 mL of diluted gadolinium (0.1 mL gadolinium in 20 mL normal saline). The patient was then sent for the MRA study.

In our study, 2 independent senior fellowship-trained musculoskeletal radiologists retrospectively reviewed all MRI and MRA images, which were previously reported by general radiologists.

When comparing the apprehension test with imaging, paired data was used to ensure a more accurate comparison and to enable calculations of statistical significance. When MRI and MRA were compared, unpaired data was used.

Arthroscopy

All the surgeries were performed under general anaesthesia. A 30° Karl Storz arthroscope was used via the standard posterior portal for the assessment of the joint. One senior author used a beach chair position, while the other performed the procedure with the patient in the lateral decubitus position. The extent and location of the Bankart lesion and all other findings were recorded in the surgical notes. All patients had the Bankart lesion repaired. Two patients with an engaging Hill-Sach's lesion had a remplissage procedure. All other lesions were too insignificant to be addressed surgically.

Statistical Study

Comparison of sensitivities and positive predictive values (PPVs) of the clinical tests and the imaging modalities were analysed using McNemar test for paired data and Pearson chi-square test for unpaired data. A value of $P < 0.05$ was considered to be statistically significant.

Results

Apprehension Test

A total of 168 patients had the apprehension test documented in the files (Table 1). The average age was 23 years (range, 17 to 29 years); 150 patients were males. Of the 168 patients, 145 (86%) had a positive test; 139 of this group had a Bankart lesion on arthroscopy, giving a PPV of 96%. Of the total 168 patients, 161 had a Bankart lesion on arthroscopy. The sensitivity of the apprehension test was calculated at 86%. However the specificity was only 14%.

Imaging

Sixty-two MRIs and 103 MRAs were reviewed by both groups of radiologists (Table 1). Images for 3 other patients could not be retrieved.

The general radiologists identified 28 Bankart lesions on MRI out of 58 identified at arthroscopy, and all 28 were found to have the lesions at surgery, giving a PPV of 100% and a sensitivity of 48%.

Musculoskeletal radiologists identified 43 Bankart lesions on MRI out of 58 found on arthroscopy, and all 43 were identified on arthroscopy, giving them a sensitivity of 74% and a PPV of 100%. The difference in sensitivity between the 2 groups of radiologists was significant with a P value of 0.001.

Eighty-three out of 103 MRAs were reported positive for Bankart lesions by the general radiologists. Of these, 81 were positive on arthroscopy, giving a PPV of 98%. The sensitivity for MRA by the general radiologist was calculated at 83%.

Musculoskeletal radiologists interpreting MRAs identified 91 out of the 98 Bankart lesions found on arthroscopy, giving them a sensitivity of 93%. The difference in the sensitivities between the 2 groups of radiologists was also found to be statistically significant with a P value of 0.021. However there was no difference in the PPVs between the 2 categories of radiologists (98% versus 97%).

Apprehension Test vs Imaging

There were 46 patients with a Bankart lesion on arthroscopy who had both apprehension tests as well as MRIs read by both general practice and musculoskeletal radiologists (Fig. 2). Out of the 46, 21 were correctly identified on MRI by general radiologists giving a sensitivity of 46% but 42 had a positive apprehension test, giving it a sensitivity of 91%. The difference was statistically significant ($P < 0.001$).

The musculoskeletal radiologists identified 32 on MRI out of 46 Bankart lesions, giving them a sensitivity of 70%. The sensitivity of the apprehension test in this group was 91%. The difference was statistically significant with a P value of 0.021.

Seventy-eight patients with Bankart lesions at surgery had both an apprehension test and MRAs read by both groups of radiologists. Both MRAs read by general practice radiologists and the apprehension tests were positive in 65 out of 78 of the patients giving them equal sensitivities of 83%. The musculoskeletal radiologists, correctly identified Bankart lesions in 71 out of 78 patients giving a sensitivity of 91%. However, there was no statistical difference between this and the figure for the apprehension test (83%), the P value being 0.18.

Table 1. Details of Arthroscopic Findings and Findings of Clinical Examination and Imaging Studies

		Arthroscopic Findings		
		Bankart Positive	Bankart Negative	Total
Anterior apprehension test	Positive	139	6	145
	Negative	22	1	23
	Total	161	7	168
	Sensitivity		86%	
	Specificity		14%	
	Predictive value		96%	
	Negative predictive value		4%	
MRI general	Positive	28	0	28
	Negative	30	4	34
	Total	58	4	62
	Sensitivity		48%	
	Specificity		100%	
	Positive predictive value		100%	
	Negative predictive value		12%	
MRI by MSK radiologist	Positive	43	0	43
	Negative	15	4	19
	Total	58	4	62
	Sensitivity		74%	
	Specificity		100%	
	Positive predictive value		100%	
	Negative predictive value		21%	
MRA general	Positive	81	2	83
	Negative	17	3	20
	Total	98	5	103
	Sensitivity		83%	
	Specificity		60%	
	Positive predictive value		98%	
	Negative predictive value		15%	
MRA by MSK radiologist	Positive	91	3	94
	Negative	7	2	9
	Total	98	5	103
	Sensitivity		93%	
	Specificity		40%	
	Positive predictive value		97%	
	Negative predictive value		22%	

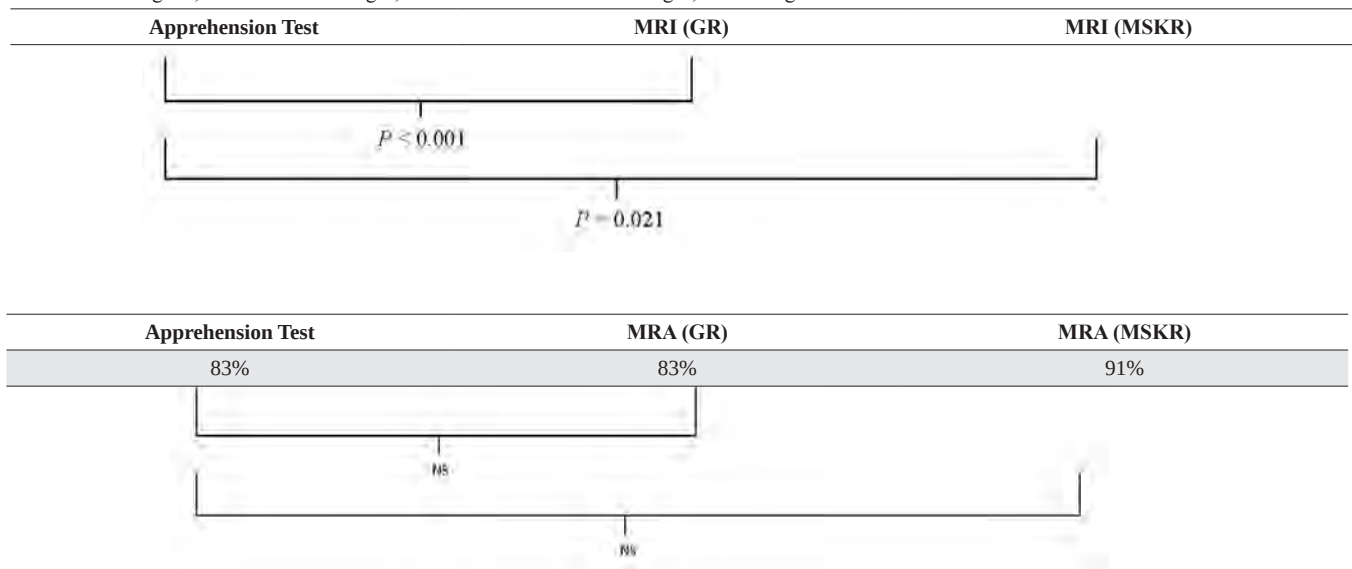
MRA: Magnetic resonance arthrogram; MRI: Magnetic resonance imaging; MSK: Musculoskeletal

MRI vs MRAs

When comparing MRIs and MRAs, we had 58 patients with a Bankart lesion on arthroscopy that had an MRI done and 98 patients with Bankart lesions that had an MRA done. Both the radiological investigations were reported by both groups of radiologists. MRI interpreted

by the general radiologists had a sensitivity of 48% and MRA a sensitivity of 83% with a P value of <0.001 . With musculoskeletal radiologists interpreting the images, the sensitivity of MRI was 74% and sensitivity of MRA was 93% and this difference was also statistically significant ($P = 0.001$).

Fig. 2. Image depicting the comparison of the sensitivities of the apprehension test, the MRI and MRA. MRI: Magnetic resonance imaging; MRA: Magnetic resonance arthrogram; GR: General radiologist; MSKR: Musculoskeletal radiologist; NS: Not significant



Other Lesions

Besides labral tears, 75 Hill-Sachs lesions, 12 superior labrum, anterior to posterior (SLAP) tears, 1 bony Bankart and 3 partial thickness rotator cuff tears were identified at arthroscopy (Table 2). The majority of the lesions were identified on MRA. There were no HAGL lesions in this series.

Discussion

This study was initiated to critically compare the apprehension test with an MRI/MRA in confirming an anterior labral tear in the young patient with recurrent anterior instability of the shoulder. For the clinical examination, we chose the anterior apprehension test as it was the earliest test described, easy to perform, reproducible and more predictable in our hands than the load and shift test, the relocation test or the surprise/release test. Hegedus et al⁵ in his systemic review of various shoulder physical examination tests showed that the apprehension test had a

positive likelihood ratio of 17.21 and a negative likelihood ratio of 0.39 for the diagnosis of anterior instability. It was the most sensitive (65%) and specific (95.4%) test compared to all other tests including the relocation test and the load and shift manoeuvre. Only the 2 experienced fellowship-trained shoulder surgeons carried out the anterior apprehension test on their respective patients in our study and this ensured the consistency of the test through the study period. Although in clinical practice, surgeons may use more than 1 test to establish the diagnosis and indeed this was observed in this study in some patients, we decided to look at only the apprehension test for the purpose of this investigation.

Our study showed that the apprehension test was very reliable with a PPV of 96%. We are not aware of a similar study analysing the reliability of any other described tests for shoulder instability. Liu et al¹ used several tests including the load and shift and crank tests and was able to show a better sensitivity than an MRI in diagnosing labral tears. However, they were unable to establish the superiority of any 1 clinical test. Jonas et al³ identified 83 labral tears in

Table 2. Additional Findings

	MRI Other Findings by General Radiologist	MRI Other Findings by MSK Radiologist	MRA Other Findings by General Radiologist	MRA Other Findings by MSK Radiologist	Arthroscopy Other Findings
Hill Sachs	34	38	72	83	75
SLAP tear	4	4	10	5	12
Bony Bankart	-	-	-	-	1
Cuff tear	1	1	7	2	3
Total	39	43	89	90	91

MRA: Magnetic resonance arthrogram; MRI: Magnetic resonance imaging; MSK: Musculoskeletal; SLAP: Superior labrum, anterior to posterior

90 patients with a positive anterior apprehension test giving a PPV of 92%. Only 54 were correctly identified on MRAs (sensitivity 65%). Our, and previous other studies^{1,3} just point to the importance of a clinical examination rather than investigations when making a diagnosis. Investigations may perhaps be indicated when clinical examinations are negative or equivocal.

In our institute, as is possibly the practice worldwide, an MRI or MRA is routinely ordered after the standard X-rays to confirm the intra-articular pathology. Of the 2, MRIs have gained favour as they are faster to perform, non-invasive, less expensive and is preferred by patients. Also, the complications with arthrography are avoided.⁶ However, concerns regarding its reliability in detecting labral lesions¹ have led to the use of the MRA as a preferred investigation of choice, by radiologists, for patients with shoulder instability. In our study, MRI or MRA was decided by the treating surgeon in consultation with the patient.

The present study expands on the previous works by Liu et al¹ and Jonas et al³ to compare an established clinical examination (apprehension test) with the MRI and the MRA for the diagnosis in shoulder instability and to establish the preferred investigation for patients with equivocal clinical findings. The study also compares the interpretation of the radiological investigations by the general radiologist with those by the specialised musculoskeletal radiologist. We felt this study was an important one, as a study by Theodoropoulos et al⁷ found that hospital-based subspecialised radiologists performed better than community-based general radiologists in the diagnosis of labral lesions, rotator cuff tears, Hill-Sachs lesions and biceps tendon pathologies.

Our initial study premise was to show that clinical testing in the form of the apprehension test was sufficient for the diagnosis and there was perhaps no indication for routine MRIs in young patients with shoulder instability. The sensitivity of the MRI by both the general and the musculoskeletal radiologist was inferior to the apprehension test (Fig. 2). Liu et al¹ reported a sensitivity of 59% with MRIs in detecting labral tears. They did not specify the experience of the radiologist reading the MRIs. Physical examination on the other hand using several different techniques including the apprehension test had a sensitivity of 90%, similar to our finding (Fig. 2). Others⁸ demonstrated a sensitivity of 95% with the MRI for diagnosing arthroscopically proven anterior labral tears. That study focused on demonstrating the inaccuracy of MRIs in demonstrating posterior labral tears but again failed to mention the experience of the radiologists interpreting the MRIs. As the study was from a radiology department from a naval hospital, we may assume that the readings were by specialised radiologists dealing with young patients with shoulder instability. It is

apparent that even with experienced radiologists, accuracy in diagnosing labral tears with MRIs varied from centre to centre. On the balance our study and those of others¹ have shown the limited value of routine MRIs in young patients with anterior shoulder instability.

The sensitivity of the apprehension test was similar to those of MRAs read by both groups of radiologists (Fig. 2). These findings show that the MRA is probably a much more powerful investigative tool when compared to MRI whether in the hands of general or musculoskeletal radiologists for identifying Bankart lesions even if it came with the disadvantages of increased cost, increased time to perform and being an invasive procedure besides the risks of well documented complications.⁶ Fotiadou et al⁹ also showed that MR arthrography had a sensitivity of 96% and a specificity of 80% for the overall detection of antero-inferior labral abnormalities. Ricchetti et al¹⁰ reported a sensitivity of 83.3% with MRA in identifying glenoid labral tears. However, Jonas et al³ revealed a sensitivity of only 65% with MRAs. Smith et al¹¹ in a meta-analysis reported a sensitivity of 88% with MRAs. The latter 4 studies suffered from the fact that the MRA interpretation was performed by a number of different radiologists of varying experience. In a study of 43 adolescent patients, Eisner et al¹² reported that although the MRA had a sensitivity of 100%, it failed to identify the extent of labral pathology noted at the time of arthroscopy. Our study also showed a significantly higher sensitivity in detecting labral tears with MRAs than MRIs regardless of the experience of the radiologists. In conclusion, an MRA would be the investigation of choice if indeed the surgeon desired any additional investigations for a patient with shoulder instability and equivocal clinical findings.

The MRI or MRA may be requested by surgeons to identify other lesions that may need to be addressed at the time of arthroscopy. In this study, except for 2 Hill-Sachs lesions which required attention, all other lesions were too insignificant to require surgical management. A bony Bankart is another lesion that may need to be addressed and was found in only 1 patient in this study. We conclude that it is uncommon in patients with recurrent instability to have a clinically significant bony defect. The benefits of MRI therefore appear to be minimal.

We caution that our study is confined to the young patient with shoulder instability where the primary lesion would be a Bankart lesion. By limiting the review population to the 15 to 30 year age group, we hope to exclude a good many degenerative conditions, thus making our study conclusions more robust.

Limitations

The study has some limitations. It was retrospective. Although this may be seen as a crucial drawback of the

study, we felt that the findings were still valid as all the investigators, senior surgeons performing the test, and original radiologists were to all intents and purposes “blinded”. All radiological investigations were performed after the clinical examination. The subsequent interpretation by the musculoskeletal radiologists was also blinded. This study truly reflects how these individuals would perform in a busy everyday clinical practice. A prospective study with well informed investigators may introduce a bias that may not truly reflect everyday practice.

The apprehension test showed a very poor specificity in our series (14%) when compared to other studies.¹ This was probably due to the fact that all our patients were identified from the Shoulder and Elbow Registry and were essentially patients who have had surgery. Hence, the chance of identifying true negatives would be less likely. However as we were primarily interested in the sensitivities, we chose not to perform a statistical analysis on the specificities, as the numbers of true negatives were low.

Ten different radiologists with varying degrees of experience performed the initial reporting. This may have influenced the findings by this category of radiologists. There were no controls. Since all cases listed for arthroscopy were those who were clinically symptomatic and likely to have labral lesions, the chances of finding the lesion was theoretically higher. The final limitation is that different numbers of patients had different tests. This will be an inherent shortfall in such a study.

The strengths of the study are several. To our knowledge, this is the first study to compare the apprehension test alone directly to MRI and MRA and to cross verify the findings with arthroscopy. Previous studies tended to compare either of the 2 variables and used various physical examination tests rather than just the apprehension test.¹ Our study also has the largest reported number of patients studied (168 cases).

It is our hope that this study will be able to decrease the surgeon’s dependence on MRI scans for evaluating shoulder instability in the young patient. The data would suggest that it would be acceptable to rely on the apprehension test alone unless the history and physical examination are inconclusive. If at all the surgeon feels compelled to have imaging, MR arthrogram interpreted by a musculoskeletal radiologist should be the modality of choice.

Conclusion

The anterior apprehension test, if positive, may be sufficient to confirm the presence of an anterior labral tear in young patients with recurrent dislocations of the shoulder. If the test is negative or equivocal, an MRA read by a musculoskeletal radiologist will be the investigation of choice.

REFERENCES

1. Liu SH, Henry MH, Nuccion S, Shapiro MS, Dorey F. Diagnosis of glenoid labral tears. A comparison between magnetic resonance imaging and clinical examinations. *Am J Sports Med* 1996;24:149-54.
2. Seeger LL, Yao L, Gold RH. Diagnosis of glenoid labral tears: a comparison between magnetic resonance imaging and clinical examination. *Am J Sports Med* 1997;25:141-4.
3. Jonas SC, Walton MJ, Sarangi PP. Is MRA an unnecessary expense in the management of a clinically unstable shoulder? A comparison of MRA and arthroscopic findings in 90 patients. *Acta Orthop* 2012;83:267-70.
4. Parmar H, Jhankaria B, Maheshwari M, Singrakhia M, Shanbag S, Chawla A, et al. Magnetic resonance arthrography in recurrent anterior shoulder instability as compared to arthroscopy; a prospective comparative study. *J Postgrad Med* 2002;48:270-3.
5. Hegedus EJ, Goode AP, Cook CE, Michener L, Myer CA, Myer DM, et al. Which physical examination tests provide clinicians with the most value when examining the shoulder? Update of a systemic review with meta-analysis of individual tests. *Br J Sports Med* 2012;46:964-78.
6. Newberg AH, Munn CS, Robbins AH. Complications of arthrography. *Radiology* 1985;155:605-6.
7. Theodoropoulos JS, Andreisek G, Harvey EJ, Wolin P. Magnetic resonance imaging and magnetic resonance arthrography of the shoulder: dependence on the level of training of the performing radiologist for diagnostic accuracy. *Skeletal Radiol* 2010;39:661-7.
8. Legan JM, Burkhard TK, Goff WB 2nd, Balsara ZN, Martinez AJ, Burks DD, et al. Tears of the glenoid labrum: MR imaging of 88 arthroscopically confirmed cases. *Radiology* 1991;179:241-6.
9. Fotiadou A, Drevelegas A, Nasuto M, Guglielmi G. Diagnostic performance of magnetic resonance arthrography of the shoulder in the evaluation of antero-inferior labrum abnormalities: a prospective study. *Insights Imaging* 2013;4:157-62.
10. Ricchetti ET, Ciccolti MC, Ciccotti MG, Williams GR Jr, Lazarus MD. Sensitivity of preoperative magnetic resonance imaging and magnetic resonance arthrography in detection of panlabral tears of the glenohumeral joint. *Arthroscopy* 2013;29:274-9.
11. Smith TO, Drew BT, Toms AP. A meta-analysis of the diagnostic test accuracy of MRA and MRI for the detection of glenoid labral injury. *Arch Orthop Trauma Surg* 2012;132:905-19.
12. Eisner EA, Roocroft JH, Edmonds EW. Underestimation of labral pathology in adolescents with anterior shoulder stability. *J Pediatr Orthop* 2012;32:42-7.

Is the Apprehension Test Sufficient for the Diagnosis of Anterior Shoulder Instability in Young Patients without Magnetic Resonance Imaging (MRI)?

Krishna Kumar, ¹MD, Milindu Makandura, ¹MBBS, Nicholas JJ Leong, ¹MBBS, Louise Gartner, ²FRCS, Chin Hwee Lee, ²MD, Dennis ZW Ng, ¹MBBS, Chyn Hong Tan, ¹FRCS, V Prem Kumar, ^{1,3}FRCS

Abstract

Introduction: The purpose of this study is to compare the sensitivities and positive predictive values (PPV) of the anterior apprehension test and magnetic resonance imaging (MRI) in the diagnosis of anterior labral tears in young patients with shoulder instability and to determine if surgery could be carried without this investigation in selected patients. **Materials and Methods:** We undertook a retrospective study of 168 patients aged between 15 and 30 years with a history of shoulder dislocation and compared the sensitivities and the PPV of the apprehension test with both MRI and magnetic resonance arthrograms (MRA) in the diagnosis of a Bankart lesion. The radiological investigations were interpreted by general practice radiologists and specialised musculoskeletal radiologists. All patients had their diagnosis confirmed by shoulder arthroscopy. **Results:** Our results showed that the apprehension test was highly reliable when it was positive with a PPV of 96%. It was more sensitive than MRI in the diagnosis of a Bankart lesion. The clinical test was significantly better when a musculoskeletal radiologist interpreted the MRI. The MRA interpreted by a musculoskeletal radiologist had the highest rates of sensitivity in detecting Bankart lesions. The figure was similar to that for the apprehension test. There was no difference in the PPVs among the clinical test, the MRI and the MRA read by the 2 categories of radiologists. **Conclusion:** We conclude that a routine MRI may be unnecessary in evaluating a young patient with clinically evident anterior shoulder instability if the apprehension test is positive. A MRA that can be interpreted by a musculoskeletal radiologist will be the next best investigation if the clinical test is negative or equivocal.

Ann Acad Med Singapore 2015;44:xx-xx

Key words: Dislocation, Radiological investigations, Glenohumeral joint

Introduction

A good history and a detailed physical examination is often sufficient to make a diagnosis of a recurrent anterior dislocation of the shoulder, even in the absence of a radiologically documented dislocation of the joint.¹ The anterior apprehension test has recently been supplemented with the relocation, crank, and load and shift tests to increase its accuracy. The advent of computer tomography (CT) arthrogram, magnetic resonance imaging (MRI) and magnetic resonance arthrogram (MRA) have enabled surgeons to predict preoperatively the intra-articular pathology with greater accuracy so as to counsel patients and to obtain informed consent. A small study in 1996¹ has

shown that a physical examination using several tests had a higher sensitivity but a similar specificity in predicting a glenoid labral tear than MRI, although this study has been refuted in a 1997 study by Seeger et al.² A more recent study³ has suggested that the need for routine MRAs may not be as crucial as currently accepted in the management of a clinically unstable shoulder especially in the young patient. However, the MRA showed a sensitivity of 95% and a specificity of 100% for detecting anterior labral tears in a study by Parmar et al.⁴ This study suggests that the MRA rather than MRI should be the investigative modality of choice. There is therefore confusion regarding the role of MRI or MRA in shoulder instability. These investigations

¹University Orthopaedics, Hand and Reconstructive Microsurgery Cluster, National University Hospital, National University Health System, Singapore

²Department of Diagnostic Imaging, National University Hospital, National University Health System, Singapore

³Department of Orthopaedic Surgery, Yong Loo Lin School of Medicine, National University of Singapore, National University Health System, Singapore
Address for Correspondence: Prof V Prem Kumar, Department of Orthopaedic Surgery, University Orthopaedics, Hand and Reconstructive Microsurgery Cluster, National University Health System, NUHS Tower Block, Level 11, 1E Kent Ridge Road, Singapore 119228.

Email: prem_kumar@nuhs.edu.sg

however, have come with additional costs to the patient, both in terms of expense and time delay in obtaining them. In addition, their accuracy has also been challenged.¹ The routine use of these modalities now, needs critical re-evaluation in the face of rising healthcare expenditure.^{1,3} Do these investigations provide information that may not be obtained in a routine arthroscopic evaluation of the joint and do any additional findings affect the management plan of the surgeon at the time of arthroscopy?

The hypothesis of this present study is that a well conducted apprehension test is sufficient to make a diagnosis of a recurrent anterior instability of the shoulder and an associated labral tear in the young patient without the need for additional investigations such as the MRI or MRA.

Materials and Methods

We accessed the Shoulder and Elbow Registry of our institution between the years 2007 and 2013 and identified 230 patients with a history of recurrent anterior dislocation of the shoulder who were eligible for the study.

Inclusion and Exclusion Criteria

The inclusion criteria were all patients between 15 to 30 years of age with a history of recurrent anterior dislocation of the shoulder and who had undergone arthroscopic surgery at our institution. Only patients with documentation of the anterior apprehension test in the case notes were included. Both positive and negative findings must be indicated in the files before they were included. First time dislocators were excluded as we never operated on this group. Also patients with previous shoulder surgery, multidirectional instability (MDI) or posterior instability were excluded as were patients who had experienced pain on the apprehension test, or excessive pain that prevented the performance of the test or guarding that prevented the apprehension test manoeuvre.

Patient Recruitment

Sixty-two patients were removed from the study as they failed to meet the inclusion criteria, leaving 168 patients for the study. Three patients were excluded from the analysis of the MRI/MRA data as the images could not be retrieved, leaving 62 patients with MRI records and 103 with MRA findings.

Ethical approval was obtained from the national Disease Specific Review Board (DSRB).

All clinical assessment was performed by 2 senior fellowship-trained consultant surgeons. A retrospective review of the MRI/MRA films was conducted by 2 fellowship-trained senior musculoskeletal radiologists who

were blinded from the clinical findings and the surgical notes. For the purpose of the study, a musculoskeletal radiologist was defined as someone who was fellowship-trained in musculoskeletal radiology and who had a minimum of 5 years' experience in the subject. The existing reports in the system had been initially interpreted by a general radiologist. For the purpose of this study, a general radiologist was defined as one whose practice was more of a general nature, with no fellowship training in musculoskeletal radiology. A review of the surgical operative notes was conducted and all findings were recorded. All surgeries were performed by 1 of the 2 senior authors (VPK, TCH).

Anterior Apprehension Test

The test was performed with the patient in a standing position. The examiner stood behind the patient and abducted the arm to 110° with 15° of extension and 15° of external rotation. The examiner observed the patient for apprehension with the aid of a mirror placed in front of the patient (Fig. 1). If no apprehension is elicited, then an anteriorly directed force is applied to the humeral head from behind. The fingers of the examiner are however kept anterior, in order to prevent the humeral head from dislocating.

The presence or absence of apprehension was noted in the file. The test was carried out as described by 2 experienced surgeons who have been performing this test since they started practice. The test was performed by the 2 surgeons on their respective patients.

Radiological Investigations

All MRI and MRA images were interpreted from the picture archiving and communication system (PACS) system. Imaging was performed using either the Siemens 1.5 Tesla or the GE 1.5 Tesla unit. Arthrography was performed by the radiologist. A radio-opaque marker was

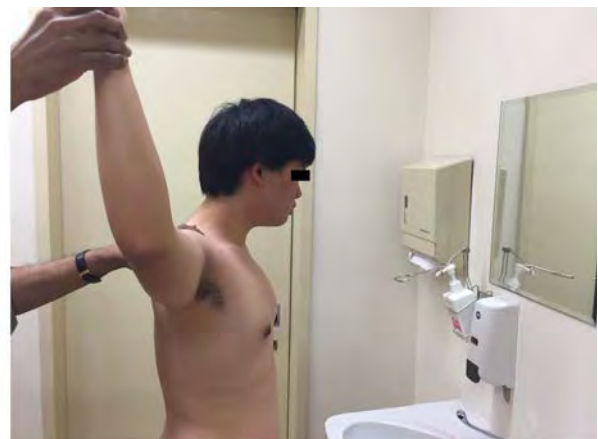


Fig 1. The anterior apprehension test.

used to locate a site over the inferomedial quadrant of the humeral head. After skin preparation, the shoulder was draped and the injection site and soft tissue infiltrated with local anaesthetic (lignocaine 1%).

A 22G spinal needle was inserted into the glenohumeral joint under fluoroscopic guidance and the position confirmed by injection of a small amount of Omnipaque 300 iodinated contrast media. Capsular distension was achieved using 10 mL to 15 mL of diluted gadolinium (0.1 mL gadolinium in 20 mL normal saline). The patient was then sent for the MRA study.

In our study, 2 independent senior fellowship-trained musculoskeletal radiologists retrospectively reviewed all MRI and MRA images, which were previously reported by general radiologists.

When comparing the apprehension test with imaging, paired data was used to ensure a more accurate comparison and to enable calculations of statistical significance. When MRI and MRA were compared, unpaired data was used.

Arthroscopy

All the surgeries were performed under general anaesthesia. A 30° Karl Storz arthroscope was used via the standard posterior portal for the assessment of the joint. One senior author used a beach chair position, while the other performed the procedure with the patient in the lateral decubitus position. The extent and location of the Bankart lesion and all other findings were recorded in the surgical notes. All patients had the Bankart lesion repaired. Two patients with an engaging Hill-Sach's lesion had a remplissage procedure. All other lesions were too insignificant to be addressed surgically.

Statistical Study

Comparison of sensitivities and positive predictive values (PPVs) of the clinical tests and the imaging modalities were analysed using McNemar test for paired data and Pearson chi-square test for unpaired data. A value of $P < 0.05$ was considered to be statistically significant.

Results

Apprehension Test

A total of 168 patients had the apprehension test documented in the files (Table 1). The average age was 23 years (range, 17 to 29 years); 150 patients were males. Of the 168 patients, 145 (86%) had a positive test; 139 of this group had a Bankart lesion on arthroscopy, giving a PPV of 96%. Of the total 168 patients, 161 had a Bankart lesion on arthroscopy. The sensitivity of the apprehension test was calculated at 86%. However the specificity was only 14%.

Imaging

Sixty-two MRIs and 103 MRAs were reviewed by both groups of radiologists (Table 1). Images for 3 other patients could not be retrieved.

The general radiologists identified 28 Bankart lesions on MRI out of 58 identified at arthroscopy, and all 28 were found to have the lesions at surgery, giving a PPV of 100% and a sensitivity of 48%.

Musculoskeletal radiologists identified 43 Bankart lesions on MRI out of 58 found on arthroscopy, and all 43 were identified on arthroscopy, giving them a sensitivity of 74% and a PPV of 100%. The difference in sensitivity between the 2 groups of radiologists was significant with a P value of 0.001.

Eighty-three out of 103 MRAs were reported positive for Bankart lesions by the general radiologists. Of these, 81 were positive on arthroscopy, giving a PPV of 98%. The sensitivity for MRA by the general radiologist was calculated at 83%.

Musculoskeletal radiologists interpreting MRAs identified 91 out of the 98 Bankart lesions found on arthroscopy, giving them a sensitivity of 93%. The difference in the sensitivities between the 2 groups of radiologists was also found to be statistically significant with a P value of 0.021. However there was no difference in the PPVs between the 2 categories of radiologists (98% versus 97%).

Apprehension Test vs Imaging

There were 46 patients with a Bankart lesion on arthroscopy who had both apprehension tests as well as MRIs read by both general practice and musculoskeletal radiologists (Fig. 2). Out of the 46, 21 were correctly identified on MRI by general radiologists giving a sensitivity of 46% but 42 had a positive apprehension test, giving it a sensitivity of 91%. The difference was statistically significant ($P < 0.001$).

The musculoskeletal radiologists identified 32 on MRI out of 46 Bankart lesions, giving them a sensitivity of 70%. The sensitivity of the apprehension test in this group was 91%. The difference was statistically significant with a P value of 0.021.

Seventy-eight patients with Bankart lesions at surgery had both an apprehension test and MRAs read by both groups of radiologists. Both MRAs read by general practice radiologists and the apprehension tests were positive in 65 out of 78 of the patients giving them equal sensitivities of 83%. The musculoskeletal radiologists, correctly identified Bankart lesions in 71 out of 78 patients giving a sensitivity of 91%. However, there was no statistical difference between this and the figure for the apprehension test (83%), the P value being 0.18.

Table 1. Details of Arthroscopic Findings and Findings of Clinical Examination and Imaging Studies

		Arthroscopic Findings		
		Bankart Positive	Bankart Negative	Total
Anterior apprehension test	Positive	139	6	145
	Negative	22	1	23
	Total	161	7	168
	Sensitivity		86%	
	Specificity		14%	
	Predictive value		96%	
	Negative predictive value		4%	
MRI general	Positive	28	0	28
	Negative	30	4	34
	Total	58	4	62
	Sensitivity		48%	
	Specificity		100%	
	Positive predictive value		100%	
	Negative predictive value		12%	
MRI by MSK radiologist	Positive	43	0	43
	Negative	15	4	19
	Total	58	4	62
	Sensitivity		74%	
	Specificity		100%	
	Positive predictive value		100%	
	Negative predictive value		21%	
MRA general	Positive	81	2	83
	Negative	17	3	20
	Total	98	5	103
	Sensitivity		83%	
	Specificity		60%	
	Positive predictive value		98%	
	Negative predictive value		15%	
MRA by MSK radiologist	Positive	91	3	94
	Negative	7	2	9
	Total	98	5	103
	Sensitivity		93%	
	Specificity		40%	
	Positive predictive value		97%	
	Negative predictive value		22%	

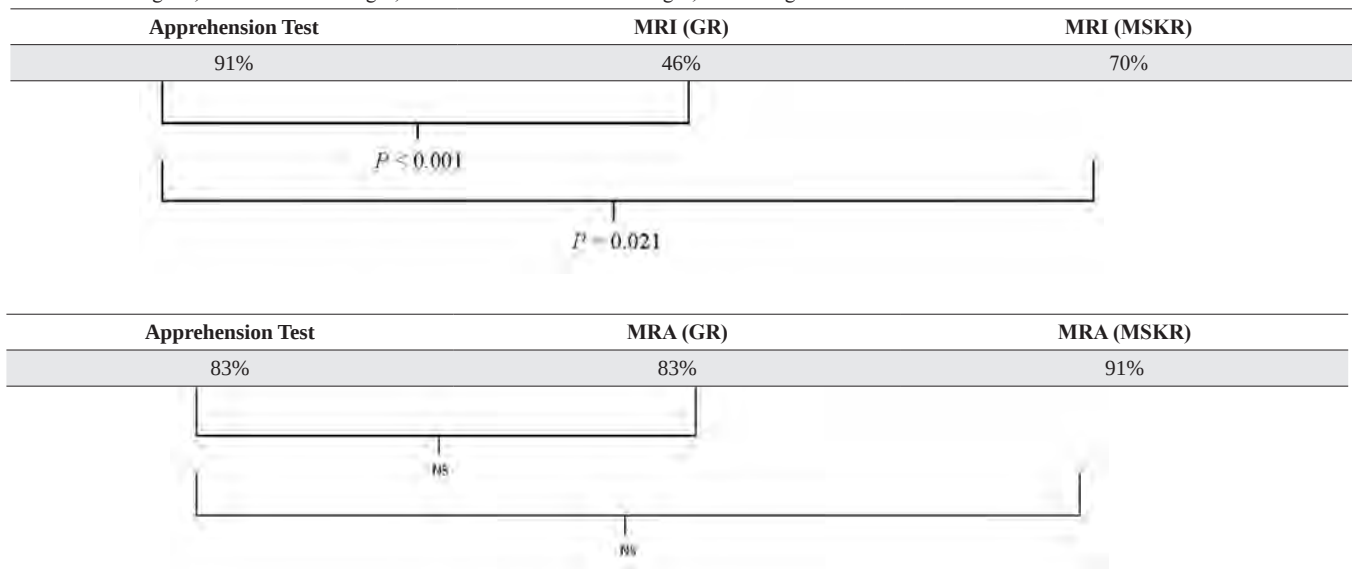
MRA: Magnetic resonance arthrogram; MRI: Magnetic resonance imaging; MSK: Musculoskeletal

MRI vs MRAs

When comparing MRIs and MRAs, we had 58 patients with a Bankart lesion on arthroscopy that had an MRI done and 98 patients with Bankart lesions that had an MRA done. Both the radiological investigations were reported by both groups of radiologists. MRI interpreted

by the general radiologists had a sensitivity of 48% and MRA a sensitivity of 83% with a P value of <0.001 . With musculoskeletal radiologists interpreting the images, the sensitivity of MRI was 74% and sensitivity of MRA was 93% and this difference was also statistically significant ($P = 0.001$).

Fig. 2. Image depicting the comparison of the sensitivities of the apprehension test, the MRI and MRA. MRI: Magnetic resonance imaging; MRA: Magnetic resonance arthrogram; GR: General radiologist; MSKR: Musculoskeletal radiologist; NS: Not significant



Other Lesions

Besides labral tears, 75 Hill-Sachs lesions, 12 superior labrum, anterior to posterior (SLAP) tears, 1 bony Bankart and 3 partial thickness rotator cuff tears were identified at arthroscopy (Table 2). The majority of the lesions were identified on MRA. There were no HAGL lesions in this series.

Discussion

This study was initiated to critically compare the apprehension test with an MRI/MRA in confirming an anterior labral tear in the young patient with recurrent anterior instability of the shoulder. For the clinical examination, we chose the anterior apprehension test as it was the earliest test described, easy to perform, reproducible and more predictable in our hands than the load and shift test, the relocation test or the surprise/release test. Hegedus et al⁵ in his systemic review of various shoulder physical examination tests showed that the apprehension test had a

positive likelihood ratio of 17.21 and a negative likelihood ratio of 0.39 for the diagnosis of anterior instability. It was the most sensitive (65%) and specific (95.4%) test compared to all other tests including the relocation test and the load and shift manoeuvre. Only the 2 experienced fellowship-trained shoulder surgeons carried out the anterior apprehension test on their respective patients in our study and this ensured the consistency of the test through the study period. Although in clinical practice, surgeons may use more than 1 test to establish the diagnosis and indeed this was observed in this study in some patients, we decided to look at only the apprehension test for the purpose of this investigation.

Our study showed that the apprehension test was very reliable with a PPV of 96%. We are not aware of a similar study analysing the reliability of any other described tests for shoulder instability. Liu et al¹ used several tests including the load and shift and crank tests and was able to show a better sensitivity than an MRI in diagnosing labral tears. However, they were unable to establish the superiority of any 1 clinical test. Jonas et al³ identified 83 labral tears in

Table 2. Additional Findings

	MRI Other Findings by General Radiologist	MRI Other Findings by MSK Radiologist	MRA Other Findings by General Radiologist	MRA Other Findings by MSK Radiologist	Arthroscopy Other Findings
Hill Sachs	34	38	72	83	75
SLAP tear	4	4	10	5	12
Bony Bankart	-	-	-	-	1
Cuff tear	1	1	7	2	3
Total	39	43	89	90	91

MRA: Magnetic resonance arthrogram; MRI: Magnetic resonance imaging; MSK: Musculoskeletal; SLAP: Superior labrum, anterior to posterior

90 patients with a positive anterior apprehension test giving a PPV of 92%. Only 54 were correctly identified on MRAs (sensitivity 65%). Our, and previous other studies^{1,3} just point to the importance of a clinical examination rather than investigations when making a diagnosis. Investigations may perhaps be indicated when clinical examinations are negative or equivocal.

In our institute, as is possibly the practice worldwide, an MRI or MRA is routinely ordered after the standard X-rays to confirm the intra-articular pathology. Of the 2, MRIs have gained favour as they are faster to perform, non-invasive, less expensive and is preferred by patients. Also, the complications with arthrography are avoided.⁶ However, concerns regarding its reliability in detecting labral lesions¹ have led to the use of the MRA as a preferred investigation of choice, by radiologists, for patients with shoulder instability. In our study, MRI or MRA was decided by the treating surgeon in consultation with the patient.

The present study expands on the previous works by Liu et al¹ and Jonas et al³ to compare an established clinical examination (apprehension test) with the MRI and the MRA for the diagnosis in shoulder instability and to establish the preferred investigation for patients with equivocal clinical findings. The study also compares the interpretation of the radiological investigations by the general radiologist with those by the specialised musculoskeletal radiologist. We felt this study was an important one, as a study by Theodoropoulos et al⁷ found that hospital-based subspecialised radiologists performed better than community-based general radiologists in the diagnosis of labral lesions, rotator cuff tears, Hill-Sachs lesions and biceps tendon pathologies.

Our initial study premise was to show that clinical testing in the form of the apprehension test was sufficient for the diagnosis and there was perhaps no indication for routine MRIs in young patients with shoulder instability. The sensitivity of the MRI by both the general and the musculoskeletal radiologist was inferior to the apprehension test (Fig. 2). Liu et al¹ reported a sensitivity of 59% with MRIs in detecting labral tears. They did not specify the experience of the radiologist reading the MRIs. Physical examination on the other hand using several different techniques including the apprehension test had a sensitivity of 90%, similar to our finding (Fig. 2). Others⁸ demonstrated a sensitivity of 95% with the MRI for diagnosing arthroscopically proven anterior labral tears. That study focused on demonstrating the inaccuracy of MRIs in demonstrating posterior labral tears but again failed to mention the experience of the radiologists interpreting the MRIs. As the study was from a radiology department from a naval hospital, we may assume that the readings were by specialised radiologists dealing with young patients with shoulder instability. It is

apparent that even with experienced radiologists, accuracy in diagnosing labral tears with MRIs varied from centre to centre. On the balance our study and those of others¹ have shown the limited value of routine MRIs in young patients with anterior shoulder instability.

The sensitivity of the apprehension test was similar to those of MRAs read by both groups of radiologists (Fig. 2). These findings show that the MRA is probably a much more powerful investigative tool when compared to MRI whether in the hands of general or musculoskeletal radiologists for identifying Bankart lesions even if it came with the disadvantages of increased cost, increased time to perform and being an invasive procedure besides the risks of well documented complications.⁶ Fotiadou et al⁹ also showed that MR arthrography had a sensitivity of 96% and a specificity of 80% for the overall detection of anteroinferior labral abnormalities. Ricchetti et al¹⁰ reported a sensitivity of 83.3% with MRA in identifying glenoid labral tears. However, Jonas et al³ revealed a sensitivity of only 65% with MRAs. Smith et al¹¹ in a meta-analysis reported a sensitivity of 88% with MRAs. The latter 4 studies suffered from the fact that the MRA interpretation was performed by a number of different radiologists of varying experience. In a study of 43 adolescent patients, Eisner et al¹² reported that although the MRA had a sensitivity of 100%, it failed to identify the extent of labral pathology noted at the time of arthroscopy. Our study also showed a significantly higher sensitivity in detecting labral tears with MRAs than MRIs regardless of the experience of the radiologists. In conclusion, an MRA would be the investigation of choice if indeed the surgeon desired any additional investigations for a patient with shoulder instability and equivocal clinical findings.

The MRI or MRA may be requested by surgeons to identify other lesions that may need to be addressed at the time of arthroscopy. In this study, except for 2 Hill-Sachs lesions which required attention, all other lesions were too insignificant to require surgical management. A bony Bankart is another lesion that may need to be addressed and was found in only 1 patient in this study. We conclude that it is uncommon in patients with recurrent instability to have a clinically significant bony defect. The benefits of MRI therefore appear to be minimal.

We caution that our study is confined to the young patient with shoulder instability where the primary lesion would be a Bankart lesion. By limiting the review population to the 15 to 30 year age group, we hope to exclude a good many degenerative conditions, thus making our study conclusions more robust.

Limitations

The study has some limitations. It was retrospective. Although this may be seen as a crucial drawback of the

study, we felt that the findings were still valid as all the investigators, senior surgeons performing the test, and original radiologists were to all intents and purposes “blinded”. All radiological investigations were performed after the clinical examination. The subsequent interpretation by the musculoskeletal radiologists was also blinded. This study truly reflects how these individuals would perform in a busy everyday clinical practice. A prospective study with well informed investigators may introduce a bias that may not truly reflect everyday practice.

The apprehension test showed a very poor specificity in our series (14%) when compared to other studies.¹ This was probably due to the fact that all our patients were identified from the Shoulder and Elbow Registry and were essentially patients who have had surgery. Hence, the chance of identifying true negatives would be less likely. However as we were primarily interested in the sensitivities, we chose not to perform a statistical analysis on the specificities, as the numbers of true negatives were low.

Ten different radiologists with varying degrees of experience performed the initial reporting. This may have influenced the findings by this category of radiologists. There were no controls. Since all cases listed for arthroscopy were those who were clinically symptomatic and likely to have labral lesions, the chances of finding the lesion was theoretically higher. The final limitation is that different numbers of patients had different tests. This will be an inherent shortfall in such a study.

The strengths of the study are several. To our knowledge, this is the first study to compare the apprehension test alone directly to MRI and MRA and to cross verify the findings with arthroscopy. Previous studies tended to compare either of the 2 variables and used various physical examination tests rather than just the apprehension test.¹ Our study also has the largest reported number of patients studied (168 cases).

It is our hope that this study will be able to decrease the surgeon’s dependence on MRI scans for evaluating shoulder instability in the young patient. The data would suggest that it would be acceptable to rely on the apprehension test alone unless the history and physical examination are inconclusive. If at all the surgeon feels compelled to have imaging, MR arthrogram interpreted by a musculoskeletal radiologist should be the modality of choice.

Conclusion

The anterior apprehension test, if positive, may be sufficient to confirm the presence of an anterior labral tear in young patients with recurrent dislocations of the shoulder. If the test is negative or equivocal, an MRA read by a musculoskeletal radiologist will be the investigation of choice.

REFERENCES

1. Liu SH, Henry MH, Nuccion S, Shapiro MS, Dorey F. Diagnosis of glenoid labral tears. A comparison between magnetic resonance imaging and clinical examinations. *Am J Sports Med* 1996;24:149-54.
2. Seeger LL, Yao L, Gold RH. Diagnosis of glenoid labral tears: a comparison between magnetic resonance imaging and clinical examination. *Am J Sports Med* 1997;25:141-4.
3. Jonas SC, Walton MJ, Sarangi PP. Is MRA an unnecessary expense in the management of a clinically unstable shoulder? A comparison of MRA and arthroscopic findings in 90 patients. *Acta Orthop* 2012;83:267-70.
4. Parmar H, Jhankaria B, Maheshwari M, Singrakhia M, Shanbag S, Chawla A, et al. Magnetic resonance arthrography in recurrent anterior shoulder instability as compared to arthroscopy; a prospective comparative study. *J Postgrad Med* 2002;48:270-3.
5. Hegedus EJ, Goode AP, Cook CE, Michener L, Myer CA, Myer DM, et al. Which physical examination tests provide clinicians with the most value when examining the shoulder? Update of a systemic review with meta-analysis of individual tests. *Br J Sports Med* 2012;46:964-78.
6. Newberg AH, Munn CS, Robbins AH. Complications of arthrography. *Radiology* 1985;155:605-6.
7. Theodoropoulos JS, Andreisek G, Harvey EJ, Wolin P. Magnetic resonance imaging and magnetic resonance arthrography of the shoulder: dependence on the level of training of the performing radiologist for diagnostic accuracy. *Skeletal Radiol* 2010;39:661-7.
8. Legan JM, Burkhard TK, Goff WB 2nd, Balsara ZN, Martinez AJ, Burks DD, et al. Tears of the glenoid labrum: MR imaging of 88 arthroscopically confirmed cases. *Radiology* 1991;179:241-6.
9. Fotiadou A, Drevelegas A, Nasuto M, Guglielmi G. Diagnostic performance of magnetic resonance arthrography of the shoulder in the evaluation of antero-inferior labrum abnormalities: a prospective study. *Insights Imaging* 2013;4:157-62.
10. Ricchetti ET, Ciccolti MC, Ciccotti MG, Williams GR Jr, Lazarus MD. Sensitivity of preoperative magnetic resonance imaging and magnetic resonance arthrography in detection of panlabral tears of the glenohumeral joint. *Arthroscopy* 2013;29:274-9.
11. Smith TO, Drew BT, Toms AP. A meta-analysis of the diagnostic test accuracy of MRA and MRI for the detection of glenoid labral injury. *Arch Orthop Trauma Surg* 2012;132:905-19.
12. Eisner EA, Roocroft JH, Edmonds EW. Underestimation of labral pathology in adolescents with anterior shoulder stability. *J Pediatr Orthop* 2012;32:42-7.

Is the Apprehension Test Sufficient for the Diagnosis of Anterior Shoulder Instability in Young Patients without Magnetic Resonance Imaging (MRI)?

Krishna Kumar, ¹MD, Milindu Makandura, ¹MBBS, Nicholas JJ Leong, ¹MBBS, Louise Gartner, ²FRCS, Chin Hwee Lee, ²MD, Dennis ZW Ng, ¹MBBS, Chyn Hong Tan, ¹FRCS, V Prem Kumar, ^{1,3}FRCS

Abstract

Introduction: The purpose of this study is to compare the sensitivities and positive predictive values (PPV) of the anterior apprehension test and magnetic resonance imaging (MRI) in the diagnosis of anterior labral tears in young patients with shoulder instability and to determine if surgery could be carried without this investigation in selected patients. **Materials and Methods:** We undertook a retrospective study of 168 patients aged between 15 and 30 years with a history of shoulder dislocation and compared the sensitivities and the PPV of the apprehension test with both MRI and magnetic resonance arthrograms (MRA) in the diagnosis of a Bankart lesion. The radiological investigations were interpreted by general practice radiologists and specialised musculoskeletal radiologists. All patients had their diagnosis confirmed by shoulder arthroscopy. **Results:** Our results showed that the apprehension test was highly reliable when it was positive with a PPV of 96%. It was more sensitive than MRI in the diagnosis of a Bankart lesion. The clinical test was significantly better when a musculoskeletal radiologist interpreted the MRI. The MRA interpreted by a musculoskeletal radiologist had the highest rates of sensitivity in detecting Bankart lesions. The figure was similar to that for the apprehension test. There was no difference in the PPVs among the clinical test, the MRI and the MRA read by the 2 categories of radiologists. **Conclusion:** We conclude that a routine MRI may be unnecessary in evaluating a young patient with clinically evident anterior shoulder instability if the apprehension test is positive. A MRA that can be interpreted by a musculoskeletal radiologist will be the next best investigation if the clinical test is negative or equivocal.

Ann Acad Med Singapore 2015;44:xx-xx

Key words: Dislocation, Glenohumeral joint, Radiological investigations

Introduction

A good history and a detailed physical examination is often sufficient to make a diagnosis of a recurrent anterior dislocation of the shoulder, even in the absence of a radiologically documented dislocation of the joint.¹ The anterior apprehension test has recently been supplemented with the relocation, crank, and load and shift tests to increase its accuracy. The advent of computer tomography (CT) arthrogram, magnetic resonance imaging (MRI) and magnetic resonance arthrogram (MRA) have enabled surgeons to predict preoperatively the intra-articular pathology with greater accuracy so as to counsel patients and to obtain informed consent. A small study in 1996¹ has

shown that a physical examination using several tests had a higher sensitivity but a similar specificity in predicting a glenoid labral tear than MRI, although this study has been refuted in a 1997 study by Seeger et al.² A more recent study³ has suggested that the need for routine MRAs may not be as crucial as currently accepted in the management of a clinically unstable shoulder especially in the young patient. However, the MRA showed a sensitivity of 95% and a specificity of 100% for detecting anterior labral tears in a study by Parmar et al.⁴ This study suggests that the MRA rather than MRI should be the investigative modality of choice. There is therefore confusion regarding the role of MRI or MRA in shoulder instability. These investigations

¹University Orthopaedics, Hand and Reconstructive Microsurgery Cluster, National University Hospital, National University Health System, Singapore

²Department of Diagnostic Imaging, National University Hospital, National University Health System, Singapore

³Department of Orthopaedic Surgery, Yong Loo Lin School of Medicine, National University of Singapore, National University Health System, Singapore

Address for Correspondence: Prof V Prem Kumar, Department of Orthopaedic Surgery, University Orthopaedics, Hand and Reconstructive Microsurgery Cluster, National University Health System, NUHS Tower Block, Level 11, 1E Kent Ridge Road, Singapore 119228.

Email: prem_kumar@nuhs.edu.sg

however, have come with additional costs to the patient, both in terms of expense and time delay in obtaining them. In addition, their accuracy has also been challenged.¹ The routine use of these modalities now, needs critical re-evaluation in the face of rising healthcare expenditure.^{1,3} Do these investigations provide information that may not be obtained in a routine arthroscopic evaluation of the joint and do any additional findings affect the management plan of the surgeon at the time of arthroscopy?

The hypothesis of this present study is that a well conducted apprehension test is sufficient to make a diagnosis of a recurrent anterior instability of the shoulder and an associated labral tear in the young patient without the need for additional investigations such as the MRI or MRA.

Materials and Methods

We accessed the Shoulder and Elbow Registry of our institution between the years 2007 and 2013 and identified 230 patients with a history of recurrent anterior dislocation of the shoulder who were eligible for the study.

Inclusion and Exclusion Criteria

The inclusion criteria were all patients between 15 to 30 years of age with a history of recurrent anterior dislocation of the shoulder and who had undergone arthroscopic surgery at our institution. Only patients with documentation of the anterior apprehension test in the case notes were included. Both positive and negative findings must be indicated in the files before they were included. First time dislocators were excluded as we never operated on this group. Also patients with previous shoulder surgery, multidirectional instability (MDI) or posterior instability were excluded as were patients who had experienced pain on the apprehension test, or excessive pain that prevented the performance of the test or guarding that prevented the apprehension test manoeuvre.

Patient Recruitment

Sixty-two patients were removed from the study as they failed to meet the inclusion criteria, leaving 168 patients for the study. Three patients were excluded from the analysis of the MRI/MRA data as the images could not be retrieved, leaving 62 patients with MRI records and 103 with MRA findings.

Ethical approval was obtained from the national Disease Specific Review Board (DSRB).

All clinical assessment was performed by 2 senior fellowship-trained consultant surgeons. A retrospective review of the MRI/MRA films was conducted by 2 fellowship-trained senior musculoskeletal radiologists who

were blinded from the clinical findings and the surgical notes. For the purpose of the study, a musculoskeletal radiologist was defined as someone who was fellowship-trained in musculoskeletal radiology and who had a minimum of 5 years' experience in the subject. The existing reports in the system had been initially interpreted by a general radiologist. For the purpose of this study, a general radiologist was defined as one whose practice was more of a general nature, with no fellowship training in musculoskeletal radiology. A review of the surgical operative notes was conducted and all findings were recorded. All surgeries were performed by 1 of the 2 senior authors (VPK, TCH).

Anterior Apprehension Test

The test was performed with the patient in a standing position. The examiner stood behind the patient and abducted the arm to 110° with 15° of extension and 15° of external rotation. The examiner observed the patient for apprehension with the aid of a mirror placed in front of the patient (Fig. 1). If no apprehension is elicited, then an anteriorly directed force is applied to the humeral head from behind. The fingers of the examiner are however kept anterior, in order to prevent the humeral head from dislocating.

The presence or absence of apprehension was noted in the file. The test was carried out as described by 2 experienced surgeons who have been performing this test since they started practice. The test was performed by the 2 surgeons on their respective patients.

Radiological Investigations

All MRI and MRA images were interpreted from the picture archiving and communication system (PACS) system. Imaging was performed using either the Siemens 1.5 Tesla or the GE 1.5 Tesla unit. Arthrography was performed by the radiologist. A radio-opaque marker was



Fig 1. The anterior apprehension test.

used to locate a site over the inferomedial quadrant of the humeral head. After skin preparation, the shoulder was draped and the injection site and soft tissue infiltrated with local anaesthetic (lignocaine 1%).

A 22G spinal needle was inserted into the glenohumeral joint under fluoroscopic guidance and the position confirmed by injection of a small amount of Omnipaque 300 iodinated contrast media. Capsular distension was achieved using 10 mL to 15 mL of diluted gadolinium (0.1 mL gadolinium in 20 mL normal saline). The patient was then sent for the MRA study.

In our study, 2 independent senior fellowship-trained musculoskeletal radiologists retrospectively reviewed all MRI and MRA images, which were previously reported by general radiologists.

When comparing the apprehension test with imaging, paired data was used to ensure a more accurate comparison and to enable calculations of statistical significance. When MRI and MRA were compared, unpaired data was used.

Arthroscopy

All the surgeries were performed under general anaesthesia. A 30° Karl Storz arthroscope was used via the standard posterior portal for the assessment of the joint. One senior author used a beach chair position, while the other performed the procedure with the patient in the lateral decubitus position. The extent and location of the Bankart lesion and all other findings were recorded in the surgical notes. All patients had the Bankart lesion repaired. Two patients with an engaging Hill-Sach's lesion had a remplissage procedure. All other lesions were too insignificant to be addressed surgically.

Statistical Study

Comparison of sensitivities and positive predictive values (PPVs) of the clinical tests and the imaging modalities were analysed using McNemar test for paired data and Pearson chi-square test for unpaired data. A value of $P < 0.05$ was considered to be statistically significant.

Results

Apprehension Test

A total of 168 patients had the apprehension test documented in the files (Table 1). The average age was 23 years (range, 17 to 29 years); 150 patients were males. Of the 168 patients, 145 (86%) had a positive test; 139 of this group had a Bankart lesion on arthroscopy, giving a PPV of 96%. Of the total 168 patients, 161 had a Bankart lesion on arthroscopy. The sensitivity of the apprehension test was calculated at 86%. However the specificity was only 14%.

Imaging

Sixty-two MRIs and 103 MRAs were reviewed by both groups of radiologists (Table 1). Images for 3 other patients could not be retrieved.

The general radiologists identified 28 Bankart lesions on MRI out of 58 identified at arthroscopy, and all 28 were found to have the lesions at surgery, giving a PPV of 100% and a sensitivity of 48%.

Musculoskeletal radiologists identified 43 Bankart lesions on MRI out of 58 found on arthroscopy, and all 43 were identified on arthroscopy, giving them a sensitivity of 74% and a PPV of 100%. The difference in sensitivity between the 2 groups of radiologists was significant with a P value of 0.001.

Eighty-three out of 103 MRAs were reported positive for Bankart lesions by the general radiologists. Of these, 81 were positive on arthroscopy, giving a PPV of 98%. The sensitivity for MRA by the general radiologist was calculated at 83%.

Musculoskeletal radiologists interpreting MRAs identified 91 out of the 98 Bankart lesions found on arthroscopy, giving them a sensitivity of 93%. The difference in the sensitivities between the 2 groups of radiologists was also found to be statistically significant with a P value of 0.021. However there was no difference in the PPVs between the 2 categories of radiologists (98% versus 97%).

Apprehension Test vs Imaging

There were 46 patients with a Bankart lesion on arthroscopy who had both apprehension tests as well as MRIs read by both general practice and musculoskeletal radiologists (Fig. 2). Out of the 46, 21 were correctly identified on MRI by general radiologists giving a sensitivity of 46% but 42 had a positive apprehension test, giving it a sensitivity of 91%. The difference was statistically significant ($P < 0.001$).

The musculoskeletal radiologists identified 32 on MRI out of 46 Bankart lesions, giving them a sensitivity of 70%. The sensitivity of the apprehension test in this group was 91%. The difference was statistically significant with a P value of 0.021.

Seventy-eight patients with Bankart lesions at surgery had both an apprehension test and MRAs read by both groups of radiologists. Both MRAs read by general practice radiologists and the apprehension tests were positive in 65 out of 78 of the patients giving them equal sensitivities of 83%. The musculoskeletal radiologists, correctly identified Bankart lesions in 71 out of 78 patients giving a sensitivity of 91%. However, there was no statistical difference between this and the figure for the apprehension test (83%), the P value being 0.18.

Table 1. Details of Arthroscopic Findings and Findings of Clinical Examination and Imaging Studies

		Arthroscopic Findings		
		Bankart Positive	Bankart Negative	Total
Anterior apprehension test	Positive	139	6	145
	Negative	22	1	23
	Total	161	7	168
	Sensitivity		86%	
	Specificity		14%	
	Predictive value		96%	
	Negative predictive value		4%	
MRI general	Positive	28	0	28
	Negative	30	4	34
	Total	58	4	62
	Sensitivity		48%	
	Specificity		100%	
	Positive predictive value		100%	
	Negative predictive value		12%	
MRI by MSK radiologist	Positive	43	0	43
	Negative	15	4	19
	Total	58	4	62
	Sensitivity		74%	
	Specificity		100%	
	Positive predictive value		100%	
	Negative predictive value		21%	
MRA general	Positive	81	2	83
	Negative	17	3	20
	Total	98	5	103
	Sensitivity		83%	
	Specificity		60%	
	Positive predictive value		98%	
	Negative predictive value		15%	
MRA by MSK radiologist	Positive	91	3	94
	Negative	7	2	9
	Total	98	5	103
	Sensitivity		93%	
	Specificity		40%	
	Positive predictive value		97%	
	Negative predictive value		22%	

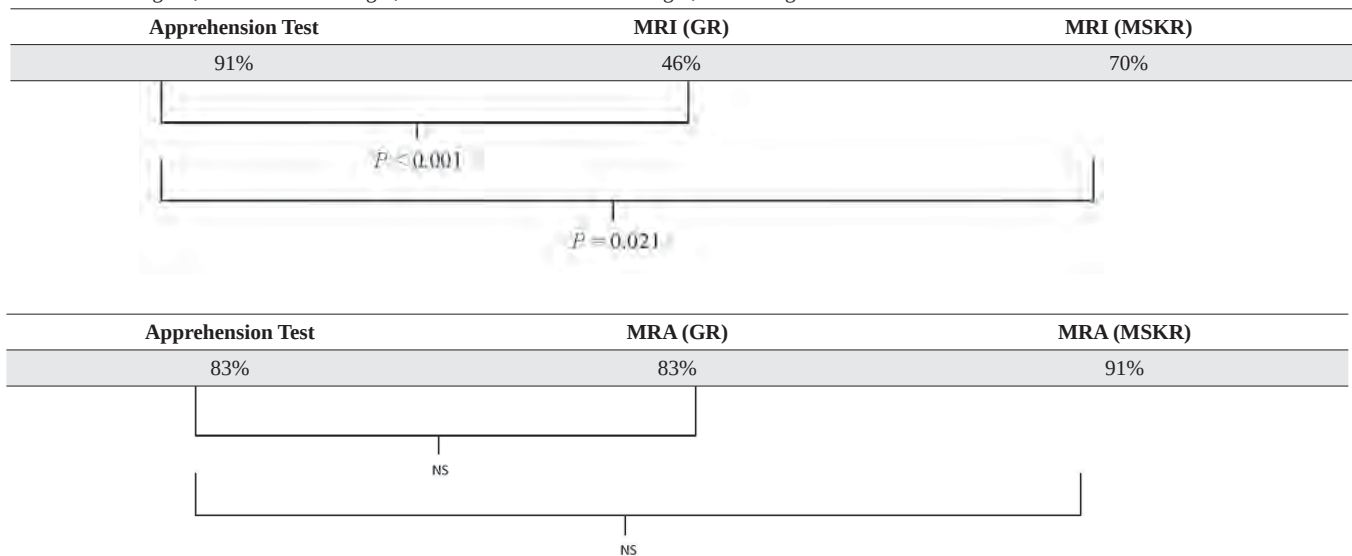
MRA: Magnetic resonance arthrogram; MRI: Magnetic resonance imaging; MSK: Musculoskeletal

MRI vs MRAs

When comparing MRIs and MRAs, we had 58 patients with a Bankart lesion on arthroscopy that had an MRI done and 98 patients with Bankart lesions that had an MRA done. Both the radiological investigations were reported by both groups of radiologists. MRI interpreted

by the general radiologists had a sensitivity of 48% and MRA a sensitivity of 83% with a P value of <0.001 . With musculoskeletal radiologists interpreting the images, the sensitivity of MRI was 74% and sensitivity of MRA was 93% and this difference was also statistically significant ($P = 0.001$).

Fig. 2. Image depicting the comparison of the sensitivities of the apprehension test, the MRI and MRA. MRI: Magnetic resonance imaging; MRA: Magnetic resonance arthrogram; GR: General radiologist; MSKR: Musculoskeletal radiologist; NS: Not significant



Other Lesions

Besides labral tears, 75 Hill-Sachs's lesions, 12 superior labrum, anterior to posterior (SLAP) tears, 1 bony Bankart and 3 partial thickness rotator cuff tears were identified at arthroscopy (Table 2). The majority of the lesions were identified on MRA. There were no HAGL lesions in this series.

Discussion

This study was initiated to critically compare the apprehension test with an MRI/MRA in confirming an anterior labral tear in the young patient with recurrent anterior instability of the shoulder. For the clinical examination, we chose the anterior apprehension test as it was the earliest test described, easy to perform, reproducible and more predictable in our hands than the load and shift test, the relocation test or the surprise/release test. Hegedus et al⁵ in his systemic review of various shoulder physical examination tests showed that the apprehension test had a

positive likelihood ratio of 17.21 and a negative likelihood ratio of 0.39 for the diagnosis of anterior instability. It was the most sensitive (65%) and specific (95.4%) test compared to all other tests including the relocation test and the load and shift manoeuvre. Only the 2 experienced fellowship-trained shoulder surgeons carried out the anterior apprehension test on their respective patients in our study and this ensured the consistency of the test through the study period. Although in clinical practice, surgeons may use more than 1 test to establish the diagnosis and indeed this was observed in this study in some patients, we decided to look at only the apprehension test for the purpose of this investigation.

Our study showed that the apprehension test was very reliable with a PPV of 96%. We are not aware of a similar study analysing the reliability of any other described tests for shoulder instability. Liu et al¹ used several tests including the load and shift and crank tests and was able to show a better sensitivity than an MRI in diagnosing labral tears. However, they were unable to establish the superiority of any 1 clinical test. Jonas et al³ identified 83 labral tears in

Table 2. Additional Findings

	MRI Other Findings by General Radiologist	MRI Other Findings by MSK Radiologist	MRA Other Findings by General Radiologist	MRA Other Findings by MSK Radiologist	Arthroscopy Other Findings
Hill Sachs	34	38	72	83	75
SLAP tear	4	4	10	5	12
Bony Bankart	-	-	-	-	1
Cuff tear	1	1	7	2	3
Total	39	43	89	90	91

MRA: Magnetic resonance arthrogram; MRI: Magnetic resonance imaging; MSK: Musculoskeletal; SLAP: Superior labrum, anterior to posterior

90 patients with a positive anterior apprehension test giving a PPV of 92%. Only 54 were correctly identified on MRAs (sensitivity 65%). Our, and previous other studies^{1,3} just point to the importance of a clinical examination rather than investigations when making a diagnosis. Investigations may perhaps be indicated when clinical examinations are negative or equivocal.

In our institute, as is possibly the practice worldwide, an MRI or MRA is routinely ordered after the standard X-rays to confirm the intra-articular pathology. Of the 2, MRIs have gained favour as they are faster to perform, non-invasive, less expensive and is preferred by patients. Also, the complications with arthrography are avoided.⁶ However, concerns regarding its reliability in detecting labral lesions¹ have led to the use of the MRA as a preferred investigation of choice, by radiologists, for patients with shoulder instability. In our study, MRI or MRA was decided by the treating surgeon in consultation with the patient.

The present study expands on the previous works by Liu et al¹ and Jonas et al³ to compare an established clinical examination (apprehension test) with the MRI and the MRA for the diagnosis in shoulder instability and to establish the preferred investigation for patients with equivocal clinical findings. The study also compares the interpretation of the radiological investigations by the general radiologist with those by the specialised musculoskeletal radiologist. We felt this study was an important one, as a study by Theodoropoulos et al⁷ found that hospital-based subspecialised radiologists performed better than community-based general radiologists in the diagnosis of labral lesions, rotator cuff tears, Hill-Sachs lesions and biceps tendon pathologies.

Our initial study premise was to show that clinical testing in the form of the apprehension test was sufficient for the diagnosis and there was perhaps no indication for routine MRIs in young patients with shoulder instability. The sensitivity of the MRI by both the general and the musculoskeletal radiologist was inferior to the apprehension test (Fig. 2). Liu et al¹ reported a sensitivity of 59% with MRIs in detecting labral tears. They did not specify the experience of the radiologist reading the MRIs. Physical examination on the other hand using several different techniques including the apprehension test had a sensitivity of 90%, similar to our finding (Fig. 2). Others⁸ demonstrated a sensitivity of 95% with the MRI for diagnosing arthroscopically proven anterior labral tears. That study focused on demonstrating the inaccuracy of MRIs in demonstrating posterior labral tears but again failed to mention the experience of the radiologists interpreting the MRIs. As the study was from a radiology department from a naval hospital, we may assume that the readings were by specialised radiologists dealing with young patients with shoulder instability. It is

apparent that even with experienced radiologists, accuracy in diagnosing labral tears with MRIs varied from centre to centre. On the balance our study and those of others¹ have shown the limited value of routine MRIs in young patients with anterior shoulder instability.

The sensitivity of the apprehension test was similar to those of MRAs read by both groups of radiologists (Fig. 2). These findings show that the MRA is probably a much more powerful investigative tool when compared to MRI whether in the hands of general or musculoskeletal radiologists for identifying Bankart lesions even if it came with the disadvantages of increased cost, increased time to perform and being an invasive procedure besides the risks of well documented complications.⁶ Fotiadou et al⁹ also showed that MR arthrography had a sensitivity of 96% and a specificity of 80% for the overall detection of antero-inferior labral abnormalities. Ricchetti et al¹⁰ reported a sensitivity of 83.3% with MRA in identifying glenoid labral tears. However, Jonas et al³ revealed a sensitivity of only 65% with MRAs. Smith et al¹¹ in a meta-analysis reported a sensitivity of 88% with MRAs. The latter 4 studies suffered from the fact that the MRA interpretation was performed by a number of different radiologists of varying experience. In a study of 43 adolescent patients, Eisner et al¹² reported that although the MRA had a sensitivity of 100%, it failed to identify the extent of labral pathology noted at the time of arthroscopy. Our study also showed a significantly higher sensitivity in detecting labral tears with MRAs than MRIs regardless of the experience of the radiologists. In conclusion, an MRA would be the investigation of choice if indeed the surgeon desired any additional investigations for a patient with shoulder instability and equivocal clinical findings.

The MRI or MRA may be requested by surgeons to identify other lesions that may need to be addressed at the time of arthroscopy. In this study, except for 2 Hill-Sachs lesions which required attention, all other lesions were too insignificant to require surgical management. A bony Bankart is another lesion that may need to be addressed and was found in only 1 patient in this study. We conclude that it is uncommon in patients with recurrent instability to have a clinically significant bony defect. The benefits of MRI therefore appear to be minimal.

We caution that our study is confined to the young patient with shoulder instability where the primary lesion would be a Bankart lesion. By limiting the review population to the 15 to 30 year age group, we hope to exclude a good many degenerative conditions, thus making our study conclusions more robust.

Limitations

The study has some limitations. It was retrospective.

Although this may be seen as a crucial drawback of the study, we felt that the findings were still valid as all the investigators, senior surgeons performing the test, and original radiologists were to all intents and purposes “blinded”. All radiological investigations were performed after the clinical examination. The subsequent interpretation by the musculoskeletal radiologists was also blinded. This study truly reflects how these individuals would perform in a busy everyday clinical practice. A prospective study with well informed investigators may introduce a bias that may not truly reflect everyday practice.

The apprehension test showed a very poor specificity in our series (14%) when compared to other studies.¹ This was probably due to the fact that all our patients were identified from the Shoulder and Elbow Registry and were essentially patients who have had surgery. Hence, the chance of identifying true negatives would be less likely. However as we were primarily interested in the sensitivities, we chose not to perform a statistical analysis on the specificities, as the numbers of true negatives were low.

Ten different radiologists with varying degrees of experience performed the initial reporting. This may have influenced the findings by this category of radiologists. There were no controls. Since all cases listed for arthroscopy were those who were clinically symptomatic and likely to have labral lesions, the chances of finding the lesion was theoretically higher. The final limitation is that different numbers of patients had different tests. This will be an inherent shortfall in such a study.

The strengths of the study are several. To our knowledge, this is the first study to compare the apprehension test alone directly to MRI and MRA and to cross verify the findings with arthroscopy. Previous studies tended to compare either of the 2 variables and used various physical examination tests rather than just the apprehension test.¹ Our study also has the largest reported number of patients studied (168 cases).

It is our hope that this study will be able to decrease the surgeon’s dependence on MRI scans for evaluating shoulder instability in the young patient. The data would suggest that it would be acceptable to rely on the apprehension test alone unless the history and physical examination are inconclusive. If at all the surgeon feels compelled to have imaging, MR arthrogram interpreted by a musculoskeletal radiologist should be the modality of choice.

Conclusion

The anterior apprehension test, if positive, may be sufficient to confirm the presence of an anterior labral tear in young patients with recurrent dislocations of the shoulder. If the test is negative or equivocal, an MRA read by a musculoskeletal radiologist will be the investigation of choice.

REFERENCES

1. Liu SH, Henry MH, Nuccion S, Shapiro MS, Dorey F. Diagnosis of glenoid labral tears. A comparison between magnetic resonance imaging and clinical examinations. *Am J Sports Med* 1996;24:149-54.
2. Seeger LL, Yao L, Gold RH. Diagnosis of glenoid labral tears: a comparison between magnetic resonance imaging and clinical examination. *Am J Sports Med* 1997;25:141-4.
3. Jonas SC, Walton MJ, Sarangi PP. Is MRA an unnecessary expense in the management of a clinically unstable shoulder? A comparison of MRA and arthroscopic findings in 90 patients. *Acta Orthop* 2012;83:267-70.
4. Parmar H, Jhankaria B, Maheshwari M, Singrakhia M, Shanbag S, Chawla A, et al. Magnetic resonance arthrography in recurrent anterior shoulder instability as compared to arthroscopy; a prospective comparative study. *J Postgrad Med* 2002;48:270-3.
5. Hegedus EJ, Goode AP, Cook CE, Michener L, Myer CA, Myer DM, et al. Which physical examination tests provide clinicians with the most value when examining the shoulder? Update of a systemic review with meta-analysis of individual tests. *Br J Sports Med* 2012;46:964-78.
6. Newberg AH, Munn CS, Robbins AH. Complications of arthrography. *Radiology* 1985;155:605-6.
7. Theodoropoulos JS, Andreisek G, Harvey EJ, Wolin P. Magnetic resonance imaging and magnetic resonance arthrography of the shoulder: dependence on the level of training of the performing radiologist for diagnostic accuracy. *Skeletal Radiol* 2010;39:661-7.
8. Legan JM, Burkhard TK, Goff WB 2nd, Balsara ZN, Martinez AJ, Burks DD, et al. Tears of the glenoid labrum: MR imaging of 88 arthroscopically confirmed cases. *Radiology* 1991;179:241-6.
9. Fotiadou A, Drevelegas A, Nasuto M, Guglielmi G. Diagnostic performance of magnetic resonance arthrography of the shoulder in the evaluation of antero-inferior labrum abnormalities: a prospective study. *Insights Imaging* 2013;4:157-62.
10. Ricchetti ET, Ciccolti MC, Ciccotti MG, Williams GR Jr, Lazarus MD. Sensitivity of preoperative magnetic resonance imaging and magnetic resonance arthrography in detection of panlabral tears of the glenohumeral joint. *Arthroscopy* 2013;29:274-9.
11. Smith TO, Drew BT, Toms AP. A meta-analysis of the diagnostic test accuracy of MRA and MRI for the detection of glenoid labral injury. *Arch Orthop Trauma Surg* 2012;132:905-19.
12. Eisner EA, Roocroft JH, Edmonds EW. Underestimation of labral pathology in adolescents with anterior shoulder stability. *J Pediatr Orthop* 2012;32:42-7.