

Transforming radiology to support population health

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This commentary highlights key areas in which diagnostic radiological services in Singapore will need to evolve in order to address the needs of Healthier SG and population health. Policymakers should focus on “doing the right thing” by improving access to radiological expertise and services to support community and primary care and “doing the thing right” by establishing robust frameworks to support value-based care.

The recent launch of Healthier SG—a national initiative by Singapore’s Ministry of Health (MOH) focusing on preventive health—will have far-reaching effects on the delivery of health services in Singapore.¹ Part of it involves a shift away from tertiary hospital-based to community-based care, to improve diagnostic imaging services in the home and community care settings. The proposed move from disease-related group to capitated funding means that care providers will have to adopt sound principles of cost-effectiveness. Radiological key opinion leaders, policymakers and health economists should review strengths, weaknesses, opportunities and threats.

Diagnostic radiology is deeply embedded within the healthcare value chain. The current delivery model is that of a facility-centric tertiary service, with a focus on high-end cross-sectional imaging at late disease stage.² Imaging performed at the primary care setting consists of mainly plain radiography and non-complex ultrasonography. The bulk of radiological expertise is concentrated in tertiary care settings, and patients are usually referred for a specialist decision if further imaging is indicated.

Together with the rest of the healthcare system, radiology needs to shift towards improving general population health, and early diagnosis and intervention instead. A focus on appropriate use of imaging³ and value-based radiology is vital to avoid spiralling healthcare costs, over-investigation, poor outcomes for patients and wastage of limited healthcare resources.

Doing the right thing: improving access to radiological expertise and services

In this section, we discuss the adoption and implementation of current and emerging technological advances in medical imaging that are aligned with the broader system imperatives (i.e. doing the right thing). In the context of Healthier SG, this would mean up-levelling the diagnostic imaging capabilities of healthcare providers in the community to reduce referrals and hospital admissions.

Pivot away from facility-centric services

(1) Point-of-care ultrasound (POCUS)

POCUS has been steadily gaining traction among care providers over the years. In the acute care setting, there is now a high level of exposure and interest from emergency physicians and intensivists, among other specialities. POCUS allows for real-time evaluation and administration of treatment, without reliance on facility-based scanning, i.e. radiology departments.

POCUS is likewise useful for assessment of a wide range of indications in the community setting, especially for the cardiovascular system and lungs.⁴ Community POCUS has been piloted by Community Health Teams at Tan Tock Seng Hospital (TTSH), with positive feedback. With trained care providers at the primary health level, POCUS can allow for a greater confidence in definitive diagnosis and management, potentially reducing unnecessary onward referrals.

The utility of POCUS is, however, limited by the expertise of the operator, and exacerbated by the less-than-ideal conditions for diagnostic-quality ultrasound in the home and inpatient settings. This highlights the need for coordinated training and accreditation frameworks that are lacking in our system today.⁵ Such frameworks will need to encompass under- and post-graduate training of a wide range of health professionals, both doctors and allied health professionals. Radiologists should engage other care providers to establish the gaps in our practice today and harmonise efforts to address them across various care settings in Singapore, “Beyond Hospital to Community.”

(2) Emerging novel technology

Radiologists have an opportunity to develop or adapt and assess (in partnership with health services researchers and health economists) new technology that can further

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shift the services into the community. For example, the potential of wearable ultrasound devices as real-time, non-invasive monitors of cardiorespiratory health⁶ that do not disrupt daily routines; more novel applications will arise as technologies mature.

Practical artificial intelligence (AI) applications

Radiologists should be proactive in evaluating and adopting AI algorithms that support and augment workflows, especially initiatives that improve the current and projected future manpower limitations—not only for radiologists but also radiographers and all allied health professionals—that conversely has the damaging potential to limit service availability. AI should improve efficiency and productivity, augment healthcare workers and prevent burnout.

(1) Optimising image acquisition and processing

AI solutions can help with pre- and post-processing for CT image optimisation at all stages of acquisition and reconstruction, with the aim of decreasing radiation and contrast media dose, thus improving image quality and augmenting radiographer productivity.⁷ With magnetic resonance imaging (MRI), there can be artifact correction from motion/eddy currents and scan time reduction.⁸ If implemented well, with adequate quality assurance, AI should add value unobtrusively in the background.

(2) Computer vision

Computer-aided detection systems can serve as an automated second observer to augment the radiologist in feature detection, extraction and classification.⁹ Individual algorithms for computed tomography (CT) lung nodule detection, mammographic breast lesion detection, and CT colonography polyp detection have been developed, but mostly in isolation, awaiting integration into general workflow. AI algorithms may also automate and accelerate quantitative analysis for lung nodule volumes, limb lengths and bone age.¹⁰ AI-powered radiomics holds potential for quantitative analysis of subtle textural details not perceptible to the human eye and has been explored mainly in the field of oncologic imaging.¹¹ After initial hype, controversy and hope in the community, the consensus opinion is that AI can augment, not replace radiologists; yet few workable solutions have been deployed successfully in health systems due to the challenges of integration.¹²

Workflow optimisation

Looking beyond the radiographic image and into the wider health system, other AI predictive analytics

can automate patient scheduling, with Changi General Hospital showing a 17.2% improvement in no-show rate by telephone reminders triggered by AI identification of patients at high risk of no-show.¹³ Similarly, during the COVID-19 pandemic, a collaboration between TTSH and the Agency for Science, Technology and Research's Institute of High-Performance Computing and Institute for Infocomm Research developed RadiLogic, which can analyse chest radiographs quickly and prioritise abnormal radiographs to a radiologist for early review.¹⁴ KK Women's and Children's Hospital was able to develop a deep-learning model to automatically triage paediatric MRI brain orders.¹⁵ Such triage tools can help sicker patients access care faster.

(3) Natural language processing (NLP) and analytics

Deep learning for NLP may be able to automatically extract and compile information from prior narrative radiological reports, such as disease characteristics, classification, or follow-up recommendations, or automatically link specific images.¹⁶ Such information can be useful to the referring physicians or radiologists reading follow-up studies.

NLP analytics may also help with quality assurance by identifying textual mentions of quality concerns within radiological reports.¹⁷

Doing the thing right: implementing value-based imaging

In this section, we discuss strategies that emphasise the implementation of evidence-based, cost effective imaging procedures. Singapore's move towards capitated funding shifts emphasis on value-based rather than on volume-based care; maximising the value of imaging would therefore be aligned to policy intent.

Screening using imaging

Screening is a keystone of the Healthier SG framework,¹ "Beyond Healthcare to Health", the intent being to detect and manage diseases at an early stage to reduce resource utilisation. We see opportunities for more widespread deployment of imaging as a cost-effective primary tool for the prevention of major disease burdens of the future.

(1) Deliberate screening

Among the mature national cancer screening programmes in Singapore, colorectal and breast cancer programmes already utilise radiological imaging.¹⁸ Greater uptake of these screening tools is needed to reap their benefits at the population level. Lung cancer screening using low-dose CT in the appropriate at-risk population has been shown in the US to save lives.¹⁹ In 2019, the College of

Radiologists, Singapore published a position paper proposing a modified workflow for practice in Singapore, highlighting the disparity in lung cancer patterns compared with Western countries.²⁰

(2) Opportunistic screening

In addition to screening programmes, opportunistic detection of abnormal findings unrelated to the primary reason for imaging studies is an added value that can and should be unlocked from the large amounts of patient data that radiological services generate daily.²¹ For example, some of the AI algorithms mentioned earlier should be able to automatically detect and quantify features of important chronic diseases (Table 1). Similar opportunistic screening has been described utilising MRI and dual-energy CT.²²

The advent of machine deep learning algorithms that can accurately segment body tissues on cross-sectional imaging is a game-changer because these measurements are laborious, time-consuming and subject to inter-operator variability. In the context of screening where the yield may be low and the volumes are high, automated software that is embedded within radiology reporting workstations can provide analysis results for clinicians to detect at-risk patients. While bone density and coronary calcium scores are already part of standard care, population-level disease prediction thresholds for newer variables, such as fat and muscle quantities, will need to be validated before mainstream deployment.

Table 1. Opportunistic CT screening.

Imaging feature screened	Application	Clinical value
Decreased bone attenuation ^a	Osteoporosis: The current gold standard for osteoporosis assessment, DXA, suffers from low screening rates and inaccuracy due to its two-dimensional nature; common confounders include vascular calcifications, degenerative changes and compression fractures. Opportunistic CT screening by direct Hounsfield unit measurement of bone attenuation may be used to infer bone quality.	Opportunistic CT screening has the potential to be useful in the relatively common scenario where DXA screening has not been performed but a CT scan is available for analysis. Early identification of at-risk individuals could be used to institute the appropriate treatment to reduce the risk of future debilitating fragility fracture.
Aortic ^b or coronary ^c calcium quantification	Cardiovascular risk stratification: For patients with a chest CT available for analysis, an AI algorithm may be able to automatically generate the CT coronary calcium score. Alternatively, where an abdominal but not a chest CT is available, the abdominal aortic calcifications may be quantified instead.	The patients at risk for cardiovascular disease can be opportunistically identified and started on preventive treatment regimens earlier.
Visceral and subcutaneous fat volumetric quantification ^d	Metabolic syndrome and cardiovascular risk stratification: Visceral fat and the visceral-to-subcutaneous fat ratio are strongly associated with future cardiovascular event and cancer risk, and automated CT volumetric quantification can be opportunistically applied for commonly performed imaging.	Clinicians may engage at-risk patients earlier for lifestyle modification; this may also trigger definitive screening for cancer and control of modifiable cardiovascular risk factors.
Cross-sectional area of truncal muscle ^e	Sarcopaenia: Cross-sectional areas of truncal muscle may be automatically calculated and utilised to diagnose sarcopaenia.	Sarcopaenia has been shown to be associated with decreased quality of life and increased mortality, especially in the context of illness/surgery. Early detection and intervention can retard progression.
Liver attenuation ^f	Hepatic steatosis: Automatic CT segmentation and attenuation measurement can be used to estimate CT fat fraction of the liver, to prevent diabetes, obesity, hyperlipidaemia, and metabolic syndrome.	Hepatic steatosis is a major risk factor for non-alcoholic steatohepatitis, with attendant risks of cirrhosis and hepatocellular carcinoma.

AI: artificial intelligence, CT: computed tomography, DXA: dual x-ray absorptiometry

^a Gausden EB, Nwachukwu BU, Schreiber JJ, et al. Opportunistic Use of CT Imaging for Osteoporosis Screening and Bone Density Assessment: A Qualitative Systematic Review. *J Bone Joint Surg Am* 2017;99:1580-90.

^b O'Connor SD, Graffy PM, Zea R, et al. Does Nonenhanced CT-based Quantification of Abdominal Aortic Calcification Outperform the Framingham Risk Score in Predicting Cardiovascular Events in Asymptomatic Adults? *Radiology* 2019;290:108-115.

^c Eng D, Chute C, Khandwala N, et al. Automated coronary calcium scoring using deep learning with multicenter external validation. *NPJ Digit Med* 2021;4:88.

^d Lee SJ, Liu J, Yao J, et al. Fully automated segmentation and quantification of visceral and subcutaneous fat at abdominal CT: application to a longitudinal adult screening cohort. *Br J Radiol* 2018;91:20170968.

^e Burns JE, Yao J, Chalhoub D, et al. A Machine Learning Algorithm to Estimate Sarcopenia on Abdominal CT. *Acad Radiol* 2020;27:311-20.

^f Graffy PM, Sandfort V, Summers RM, et al. Automated Liver Fat Quantification at Nonenhanced Abdominal CT for Population-based Steatosis Assessment. *Radiology* 2019;293:334-42.

Appropriate use of diagnostic imaging tests

Increasing access and demand in diagnostic imaging results in dramatic increase in volume and complexity of imaging studies; although these bring benefits to patients, they also put a strain on healthcare workers and the financial resources of the national health system. Wellness issues, such as repetitive stress injury, fatigue and burnout, need to be addressed before they reach a tipping point. The first target should be inappropriate use of diagnostic imaging services that are not supported by evidence. Decisions to undergo imaging tests require a sound understanding of the utility, limitations and potential harm of the procedures, and are best advised by medical professionals, made jointly with patients whenever possible.

The Appropriateness Criteria for Use of Imaging Technology initiative was started in 2018 by the Agency for Care Effectiveness (ACE), MOH Singapore. Supported by chapters and colleges within the Academy of Medicine, Singapore, 3 ACE Clinical Guidances (ACGs) have been published: when to order CT/MRI for headache (2022), when not to order a chest radiograph (2021), and when to order MRI for low back pain (2020).²³

These multidisciplinary guidelines, based on international consensus guidelines and cost-effectiveness analysis literature, address high-volume and high-cost tests, and will be periodically reviewed and integrated as clinical decision support tools into electronic medical records and order systems to assist implementation, like the American College of Radiology (ACR) Select tool.²⁴ In Singapore, MOH has collaborated with SingHealth to hardwire the “MRI for low back pain” ACG as a radiology order form into the electronic medical record system, as a behavioural nudge for ordering physicians. It is important that the international guidelines are contextualised to local practice; the ACR has to date more than 200 clinical scenarios, and we continue to prioritise our efforts towards implementing ACGs for high-value and high-volume imaging procedures to contribute towards the thrust of “Beyond Quality to Value.”

Structured reporting templates

As disease management trends towards algorithmic evidence-based pathways, it is helpful for referring physicians to be able to efficiently access and use actionable radiological reports.²⁵ Structured reporting templates are not only easier for the reader to understand, they guide the radiologist in including pertinent information without omission, while presenting the information in a systematic and uniform manner.

Structured radiology reports will undoubtedly elevate the value of imaging and radiologists in the overall patient care continuum. Work is now underway at the regional level by the Asian Oceanian Society of Radiology to conduct a survey of the knowledge, attitudes and practice of radiologists and referring clinicians as an initial step towards promoting widespread adoption. Structured reports also open up the possibility of large-scale data mining for developing predictive and AI algorithms, something that would be much harder to achieve through unstructured free text reports.

CONCLUSION

There are seismic shifts for the healthcare sector in Singapore on the horizon, and non-trivial obstacles to overcome: behavioural change is difficult, and manpower constraints in our small island are real. The policy, implementation and educational challenges require a thoughtful, coherent strategy to defeat the devil in the details. Yet at this post-COVID juncture, there appears to be willingness to consider innovative strategies and address wicked problems. The stars may align to improve radiological services in Singapore to democratise expertise and access, creating favourable conditions to maximise value. With visionary leadership and united effort, we can chart the continued success of Singapore's health services. Our staff, patients and population deserve the best diagnostic radiology care we can provide. For this call to action, the time is now.

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