5th Yahya Cohen Lecture: Angiosomes and Extension of Skin Flaps—Anatomic Study and Clinical Implications†

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Master of the Academy of Medicine, Singapore; Mr Chairman; Chairman, Chapter of Surgeons; Ladies and Gentlemen:

I would like to express my gratitude to the Chapter of Surgeons and the Academy of Medicine, Singapore for the honour of presenting this 5th Yahya Cohen Lecture.

This lecture was inaugurated in November 1996 to honour one of our founder members of the Academy Medicine, Singapore: Dr Yahya Cohen.

He was born 80 years ago in Singapore, of Jewish parentage, and graduated from King Edward VII College of Medicine in 1938 with distinctions in medical jurisprudence, surgery and obstetrics and gynaecology. He continued his postgraduate medical studies on a Queens' scholarship in England and received further training in General Surgery and Plastic Surgery in Edinburgh and Oxford. He also received his Fellowship of the Royal College of England.

During his long and illustrious career, Dr Cohen is one of the founding members of the Academy of Medicine, Singapore and was its first scribe in 1957. He was founder chairperson of the Chapter of Surgeons in 1966. When he retired in 1972, he was a Clinical Professor and Head of the Government Surgical Unit.

Although I have not had the privilege to work for him, he was remembered by his colleagues and trainees as a firm disciplinarian particularly to maintain high standards in surgical practice. Surgeons considered to have been fortunate to train under him include Dr V K Pillay and Professor S S Ratnam. His conscientious care of patients and meticulous skills were renowned during his time. Dr J E Choo and Dr Rajmohan Nambiar who succeeded him to head the Government Surgical Unit perpetuated his traditions.

His students often repeated his teaching skills and quotes.

"Surgery is not about operating. It is being able to look at a patient and make a correct diagnosis. In fact, a good surgeons will not go rushing in with a knife – he would see how much can be done to help him without cutting him up".

"The patient is the drawing board of the surgeon, students you should not just look at the pictures in the books, you should look at the patient. It is not the textbook you rely on, the patient is the reality. It is your patient that is depending on you who else is there that is important".

Dr Cohen, whose surgical career spans 40 years, is one of the founding members of the surgical fraternity. His love of medicine and teaching of students and young doctors has become legendary. The gold medal for the best clinical student in the Master of Medicine (Surgery) has been named in his honour.

In 1993, the Singapore Association of Plastic Surgeons accorded him an honorary membership reserved for renowned international plastic surgeons. This was to recognise his training and interests of this surgical practice, which included cleft deformities and treatment of cutaneous diseases.

The Academy of Medicine, Singapore and the surgical fraternity of Singapore are proud to honour one of our own with this named lecture.

Introduction

There has been a resurgence of interest in applied anatomy particularly by plastic surgeons since the 1920s. This has largely been spurred on by the description of axial pattern flap, fasciocutaneous flap and muscle flap by leading plastic surgeons, e.g. I A McGregor, I T Jackson, S Mathes, F Nahai, Lamberty, etc., from all over the world.

The understanding and description of how flaps work and behave have been described in anatomical and physiological studies. Anatomical studies are more easily documented. These involved meticulous and time consuming hours spent in dissection. I would like to acknowledge my co-author Tan Bien Keem who undertook the major portions of these anatomical dissections.

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We embarked on an injection study in an attempt to explain why certain flaps are more reliable and why certain design and orientation of flaps will affect the blood supply to the flaps.

Axial pattern flaps[1] and angiosomes[2-4] (vascular territories) of the body have provided us with a better understanding of blood supply to underlying tissues and its overlying skin flaps. These studies have made flap transfers safer. A more predictable behaviour of these skin flaps is now understood. However, when flaps are pedicled, the reach and size of the flap limits its usage.

Extended flaps of these established flaps, e.g. pectoralis major, deltopectoral (Bakamjian), often need delay. This process of delay phenomenon enables the skin flaps to be transferred more reliably,[5] predictably with a bigger area of skin paddle. We would like to investigate the possibility of extending these myocutaneous flaps, e.g. trapezius[6,7] and pectoralis major,[8-10] through injection studies without process of delay in head and neck reconstruction. The use of trapezius[6,7] and pectoralis major[8-10] myocutaneous flaps had been the regional flaps of choice in head and neck reconstruction.

The limitations of these pedicled myocutaneous flaps for reconstruction have been mobility, size and extend of its reach when based on conventional or known vascular territories.[1,2-4] Extensions or random pattern skin paddles have often been included in their design for reconstruction. The reliability and predictability of these skin flaps are reduced. There is increase morbidity for these patients particularly at the distal edge of these flaps, where coverage is most at risk in wound breakdown due to tension in suturing or absence of blood supply.

The skin is supplied by two systems of vessels: 1) direct cutaneous arteries, and 2) musculocutaneous arteries.

Extended myocutaneous flaps may therefore be planned on direct cutaneous arteries or perforators. This is provided the underlying muscle acting as carrier for the main segmental vessels are included. These perforators fascial and subdermal plexus are derived from these segmental vessels which the myocutaneous is primary based upon.

We based our studies on fresh cadaveric dissections in the lower trapezius myocutaneous supplied by the dorsal scapula artery (DSA).

The aims of this study were to:

1) evaluate contributions of DSA to lower trapezius muscle flap,
2) map out distribution of cutaneous perforators away from the trapezius muscle,
3) course of DSA and anatomic relationship to the extension of the trapezius myocutaneous flap territory, and
4) define distal limits and maximum dimensions of these extended lower trapezius myocutaneous flaps.

The blood supply of 23 fresh cadaveric trapezius muscle specimens of Asian origin were examined after injection with coloured latex, radiopaque contrast and methylene blue. Access to the transverse cervical artery and DSA can be accomplished via a supraclavicular incision at the root of the neck.

The transverse cervical artery was identified by its distinct transverse course across the floor of the posterior triangle. This artery was detached near its origin and cannulated for injection. The DSA was identified as distinct branch of the second or third part of the subclavian artery, passing posteriorly through the brachial plexus and turning inferiorly to supply the rhomboid muscles. Likewise, the vessel was divided and cannulated for injection.

Methylene Blue

Selective injections of the transverse cervical artery and DSA were performed using methylene blue in 4 specimens to study the individual cutaneous vascular territories. The areas of cutaneous staining by methylene blue were measured in length and breadth, and defined areas documented by photography.

Latex Injection

For some specimens, the course and distribution of the transverse cervical artery and DSA were outlined with coloured latex. Each arterial system was suffused with 10% buffered formalin before injection with coloured latex. Formalin-induced coagulation of latex, which solidified, was used to preserve the vascular tree. The specimens were stored at 4°C and allowed to cure overnight.

Dissection of the trapezius muscle and its latex-preserved arterial tree was accomplished with the cadaver prone. A midline incision beginning at the nape of the neck was made, and continued in a caudal direction over the vertebral spines down to the level of the second lumbar vertebra. Skin and subcutaneous tissue overlying the muscle were elevated off the muscle as a single sheet. Musculocutaneous perforators encountered were marked to document. Once uncovered, the entire muscle was freed from its spinal and scapular attachments and separated from the underlying rhomboid and levator scapulae muscles. Care was excised not to disrupt blood vessels which supplied the muscle, and every attempt was made to trace these from origin to termination. Each of the retrieved specimens was examined by dissection under 2.0 x loupe magnification to demonstrate the pattern of blood supply.

Barium-Gelatin Injectors

In 3 specimens, the respective blood vessels were injected with a suspension consisting of barium sulfate and gelatin.

Storage at 4°C overnight allowed the gelatin to set. X-ray studies of the specimens were accomplished using the Mammomat II (Siemens) soft X-ray imaging system, with exposure factors set at 25 kVp, 5.6 mAs.

What We Found

The DSA, with a mean proximal diameter of 2.66 mm (1.6 to 3.8 mm), was observed to arise directly from the second or third part of the subclavian artery in 12 out of 19 specimens.

When DSA originated directly from the subclavian artery, it was observed to pass between the trunks of the brachial plexus, taking a posterior course towards the scapula. Arching over the free margin of the serratus anterior muscle, it angled downward, travelling immediately deep to the medial border of the scapula. Throughout its descent, the DSA gave off branches which supplied the overlying levator scapulae, rhomboid minor and rhomboid major muscles. It also issued branches in segmental fashion to the medial border of the scapula. These consisted of osseus branches to the medial border of the scapula below the scapula below the scapula spine, as well as muscular branches to the inferior scapular angle.

The DSA's contributions to the scapular anastomoses were seen at two levels. Superior to the scapula spine, 1 or 2 branches given off anastomosed with branches of the suprascapular artery. Inferior to the scapula spine, around the inferior angle of the scapula, it divided into branches which anastomosed with branches of the circumflex scapular artery.

The diameter of DSA averaged 1.0 to 2.1 mm at this point. Along the deep surface of the trapezius muscle, fine ramifications of the DSA supplied the entire substance of the inferior trapezius. It also contributed branches that ascended to meet the transverse cervical artery at the junction between the middle and inferior third of the muscle. Along the lateral border of the muscles, branches emerged to anastomose with branches of the 5th to 9th intercostal arteries.

A number of musculocutaneous perforators supplying skin overlying the lower trapezius were noted. These belonged to the distribution of the DSA. Perforators emerging from the lower trapezius were mainly confined to the upper half of the lower trapezius. Few perforators issued from the distal tip of the lower trapezius. Surfacing from the substance of the muscle, these perforators were observed to take an oblique course in a direction parallel to the ribs. These supplied skin overlying the lower trapezius and latissimus dorsi (Figs. 1 to 4).

Methylene blue injections of the DSA produced a 20 x 16 cm cutaneous flare corresponding to the middle and lower trapezius. This staining extended 16 cm beyond the lateral border of the muscle to include skin overlapping the infero-medial aspect of the latissimus dorsi muscle level of T10 vertebrae laterally.

Clinical Implications

We attempted to study the blood supply of the DSA supplying the extended trapezius myocutaneous flap. Other workers had studied the deltopectoral flap[11,12] (Taylor Reid Daniel), and pectoralis major myocutaneous flap[8-10] and lateral arm flap.[13]

Fig. 1. Musculocutaneous perforator of DSA exposed along the lateral border of the trapezius muscle after methylene blue dye injection.

Fig. 2.Barium-gelatin injection X-ray studies. Descending branches of DSA. Notic the oblique lateral course parallel to the ribs of the perforators of DSA at the lower end of the trapezius muscle.

Fig. 3. Fifty-year-old patient with osteosarcoma of left temporal bone showing primary closure of donor site.

Fig. 4.Use of extended lower myocutaneous flap to cover left ear mastoid and base of skull.

Through these anatomical studies we can determine:

1) axis of skin flap,
2) dimensions of skin flaps based on and identified vessel to muscle,
3) extensions of skin flaps beyond the myocutaneous (angiosome) territories via a) perforators, b) fascial inclusions, and
4) possibility of using skin of adjacent skin angiosomes based on dynamic pressure equilibrium existing in blood vessels of each territory along boundary line.

We have used over 20 extended lower trapezius myocutaneous flaps without delay. This elliptical skin paddle is based mainly on fasciocutaneous extension beyond the trapezius muscle. This flap is at right angle beyond the lateroinferior margin of the trapezius muscle at the level of T10 at posterior axillary line. This includes the vessels' perforators and fascia over the latissimus dorsi muscle—largest dimension has been 13 x 6 cm beyond the margins of the trapezius muscle (Figs. 3 & 4).

Similarly, the extended lateral arm flaps[13,14] based on posterior radial collateral artery (PRCA) vessels have been successfully utilised, even when the skin paddle is 10 cm below the lateral epicondyle of the elbow. This flap has been used as a free tissue transfer, or pedicled for contralateral and reconstruction.

The extended pectoralis major myocutaneous flap is most often used in head and neck reconstruction. The axis is drawn 1 cm medial to the shoulder joint to the epigastrium. Extension of the skin paddle includes the fascia[14-17] over the rectus muscle continuous with the inferior pectoralis major muscle fibres. Extension of 4 x 5 cm has been obtained safely.

Conclusion

The concept of each cutaneous artery having a definite vascular territory of skin has been espoused by Manchot (1889), axial pattern flaps (1973), myocutaneous flaps (1980) and angiosomes (1987). This skin vascular territory, although reliable and valid, is not precise.

How far can one extend beyond these myocutaneous, fascial and skin flaps, can these extensions still be regarded as axial pattern flaps? Should all extension beyond the musculative of the myocutaneous flaps be regarded as random pattern flaps?[17]

If one can extend these flaps, is there an orientation on axis where the extension is most reliable? This can be ascertained by cadaveric injection studies—as shown by our study. These flaps extension based on perforators may suffer from absence of venous component as is commonly encountered in pedicled transverse abnormal myocutaneous flap used in breast reconstruction.

We know and have used flaps extensions of the lower trapezius (based on DSA), myocutaneous flap (based on medial pectoral vessels) with extensions on rectus fascia and extension of the lateral arm skin flap to 13 cm below the elbow.[15] Only the latter flap has been proven to be totally reliable under the free tissue setting.

Extensions of this lower trapezius myocutaneous flaps have been shown above to have:

1) direct skin vessel perforators from the major myocutaneous artery,
2) fascial extensions inclusion with elevations of the neighbouring muscles will enhance the blood supply to the skin paddle,
3) definite axes of orientation,
4) reliability of use in clinical setting, and
5) increasing size and reach of these flaps.

We conclude that it is possible to extend skin flaps beyond the conventional angiosomes/territories. This phenomenon needs further investigation to be included in the armamentarium of skin flap transfers for reconstruction. Where free tissues transfers are involved, the presence of both arterial and venous blood supply will ensure the reliability of these skin flaps.[18,19] Thus, blood circulation of free flaps will need to be more robust.

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