The anatomical basis for improving the reliability of the supraclavicular flap

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Summary Introduction: The supraclavicular flap has re-emerged as a feasible option for head and neck reconstruction where a thin, pliable donor tissue is required or where free flap techniques may impose too great a surgical risk in frail patients. Whilst our understanding of the vasculature of this flap has improved immensely, the microvasculature and in particular the venous drainage of the distal half of the supraclavicular flap remain relatively unclear. The present study aims to detail the arterial supply and venous drainage of the supraclavicular flap, particularly relating to the interperforator anastomoses.

Methods: The arterial and venous systems of the supraclavicular flap were injected with a radiopaque medium in eighteen fresh cadavers (twenty three and twelve flaps, respectively). Dissected supraclavicular flaps were subjected to plain X-ray imaging plus CT angiography to visualise the arterial and venous systems and relations to surrounding muscle and fascia. Further, the nature of any true or choke anastomoses was described.

Results: The arterial supply of the supraclavicular flap is a combination of axial pattern proximally and random pattern distally, demarcated by the origin of deltoid muscle. The venous system must undergo significant shunting into high pressure vessels once the preferred natural venous pathways are ligated whilst the flap is raised. A vast number of anastomoses, both arterial and venous exist over the body of deltoid and are critical to distal flap tissue survival.

Conclusion: The vascularity of the supraclavicular flap is complex and relies upon relatively small, superficial vessels. This technique is a prototypical example of the angiosome concept at work and thus relies heavily on our understanding of the location and nature of the

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anastomoses along its course. We conclude that the supraclavicular flap remains a reliable method for reconstructing head and neck defects so long as the constraints of a complicated suprafascial vascular system are respected.

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Introduction

Optimal reconstruction of head and neck defects requires a delicate balance between form and function. While numerous techniques exist, the overarching premise to ‘replace like with like’ favours the use of locoregional tissues, such as the anterior thorax, neck, shoulders or upper back to achieve improved colour and texture match. However, using locoregional tissues may present a compromise, as donor sites may be more visible in these highly aesthetically sensitive areas.

The supraclavicular flap has been explored sporadically as an option for reconstructing soft tissue defects of the head and neck since the 1800’s. This flap provides the benefits of a thin fasciocutaneous tissue, amenable to folding or contouring to the recesses of the oral cavity, lateral face and cervicomandibular region. Further, it is possible to achieve direct closure of the donor defect, the linear scar of which is easily concealed beneath clothing.

Following the first published description of the ‘supraclavicular random patterned flap’ by Mutter in 1842, several reports emerged of success in resurfacing cervicofacial burn contractures. However, widespread utilisation of the supraclavicular flap has been restricted, due to concerns of reliability, first detailed by Blevins and Luce. Much of this conjecture can be explained by the fact that until relatively recently, the vascular anatomy and flow mechanics of this region was incompletely understood. Further, confusion over vessel nomenclature and differences in technique only compounded the scepticism.

The present study aimed to describe the arterial supply of the supraclavicular flap in relation to the interperforator anastomoses with direct implications for the reliability of the distal tip. In addition, we aimed to describe the venous drainage in a truly dynamic, anterograde system. Both of these primary end points have a direct impact on both flap safety and potential application for microvascular free tissue transfer.

Materials and methods

Anatomical basis for reliability of supraclavicular flap

Anatomical dissection studies procured a total of eighteen fresh donor cadavers (eleven female, seven male, aged 36–94 years) from the Donor Body Program at the University of Melbourne and were conducted following institutional ethics board approval. All specimens were free from trauma and scars over the upper limbs and neck.

Arterial studies

The arterial supply to the supraclavicular flap was studied in twenty-three flaps in seventeen fresh cadavers. The supraclavicular artery was located similar to previous descriptions. An incision was made over the surface marking of the omohyoid muscle as it emerges laterally to sternocleidomastoid, before exploring the plane deep to the deep investing fascia. Here, the transverse cervical vein was first identified, followed by the underlying transverse cervical artery (TCA). The supraclavicular artery emerged from the TCA in all cases, and was cannulated using a 24-gauge cannula (BD Insyte, Becton Dickinson, Madrid, Spain). The TCA was ligated distally, as was the thyrocervical trunk and axillary artery proximal to the circumflex humeral arteries. This method isolated the supraclavicular artery from its main connections whilst maintaining the vascular relationship between the flap and surrounding soft tissue. Specimens were perfused with warm normal saline (40 °C) until a clear effluent emerged from small skin incisions made outside the distal extent of the flap. Coloured ink was then injected until the skin became discoloured and leaks were identified and ligated with silk suture or cautious use of electrocautery. Lead oxide was injected as per the method of Rees and Taylor and the flap dissected under 4× magnification surgical loupes following overnight incubation at 4 °C.

To fully investigate the relationship between the fasciocutaneous tissue of the supraclavicular flap and the musculocutaneous perforators from the underlying deltoid muscle, the flap was raised with inclusion of the entire deltoid belly in seventeen flaps. The remaining six specimens were purely fasciocutaneous flaps. Importantly, to fully evaluate the distal extent of supraclavicular arterial territory, all dissections continued to a distance of 5 cm distal to the insertion of deltoid muscle and 2 cm anterior and posterior to the widest point of the muscle (Figure 1).

After flap dissection, specimens were assessed radiographically by both plain film and static computer tomographic angiography (CT) as previously described.

Venous studies

Twelve flaps from six fresh cadavers were dissected after anterograde perfusion of the venous system. A five centimetre incision was made at the distal most extent of the flap in the mid coronal line, extending only to the subdermal plexus and one to three subdermal veins cannulated and perfused with normal saline then ink as above. Initial studies maintained a patent cephalic vein whilst later studies ligated the cephalic vein at the elbow and deltopectoral groove. The venae commitantes of the brachial artery were ligated proximally using 3-0 silk ligatures. A more dilute solution of lead oxide was injected similar to the method of Crock and Taylor, until dermal capillaries were filled beyond the most proximal extent of the flap. The flap was then incubated and dissected as above.
Radiographic imaging of injected flaps was conducted using both CT angiographic protocols and plain film angiography. CT angiography was conducted using a 128-slice scanner (Siemens Biograph mCT, Germany) and post-processing utilised a custom-designed colour look-up table (CLUT) for three-dimensional volume rendering (VR) plus a modified three-dimensional multiplanar reconstruction (MPR). All reconstructions were undertaken using Osirix 4.0 64-bit (Pixmeo, Switzerland). All specimens were subjected to plain film radiography (85 kV, 110 mAs, 32 ms; Fuji, Japan) in both sagittal and transverse planes.

Results

Arterial studies

Initially, dye and contrast infiltration of the supraclavicular artery often resulted in flow down the route of least resistance, namely deep anastomoses with the branches of the TCA and musculocutaneous perforators of both circumflex humeral arteries. This resulted in less-than-expected cutaneous dye staining, which dramatically increased following ligation of anastomosing large vessels (as per Materials and methods).

The supraclavicular artery was identified as a branch from the TCA in all specimens. In all but one case, the TCA emerged from the thyrocervical trunk at the first part of the subclavian artery. The single exceptional case demonstrated that the thyrocervical trunk emerged from the second part of the subclavian artery but that the TCA and supraclavicular branches were otherwise normal. The mean diameter of the supraclavicular artery was 1.1 mm at the origin.

In each case, the supraclavicular artery coursed laterally and superficially from the origin, penetrating the overlying fascia an average of 30 mm distally. It then continued in the suprafascial plane, crossing the junction of the mid- and lateral thirds of the clavicle. At this point, the artery often divided into multiple smaller branches, forming direct anastomoses with collateral arteries originating from the deltid and acromial branches of the thoracoacromial artery and the superficial branch of the TCA. Once superficial to the bulk of deltid muscle, flow was reinforced through direct linking musculocutaneous perforators from the posterior and anterior circumflex humeral arteries (Figure 2). The number of direct linking vessels from deltid that reinforce the distal supraclavicular branches diminished considerably at the insertion of deltid, and indirect linking ‘choke’ anastomoses remained (Figure 3). As such, a choke zone was formed at the insertion of deltid muscle.

The anterior and posterior extent of supraclavicular territory was in contrast with the clear demarcation of the distal dimensions. Posteriorly, there existed multiple direct anastomoses between the supraclavicular branches and the superficial branch of the TCA and suprascapular artery. Anteriorly, the acromial and deltid branches from the thoracoacromial artery formed multiple indirect ‘choke’ anastomoses. Further, the anterior territory was often greater where a large calibre anterior branch of the supraclavicular artery was found. This vessel formed anastomoses with the perforating branches of the pectoral branch of the thoracoacromial artery (Figure 4).

Venous studies

Infiltration of the venous drainage of the supraclavicular flap demonstrated two distinct patterns of drainage; one proximal and the other distal, demarcated by the origin of deltid (Figure 5). Distally, subdermal veins superficial to deltid drained to either the cephalic vein or the venae committantes of the brachial artery, and flow was seen...
communicating between the primary and secondary venous systems via venae communicans. Reminiscent of the arterial system, secondary venous drainage occurred via the perforating veins through deltoid muscle to both circumflex humeral veins. Subdermal veins draining into the cephalic vein did so by either deep perforating veins through the deltoid, or via longer length adipofascial perforating veins that coursed anteriorly.

At the level of the deltoid origin, a distinct pattern of venous drainage was seen. Here, venous return occurred by both the venae committantes of the supraclavicular artery and also the superficial cervical vein. The former drained to the transverse cervical vein and subclavian vein while the later drained to the external jugular vein. In studies in which the valves were rendered incompetent by means of hydrogen peroxide injection, there were no divisions between proximal and distal drainage systems and venous communication occurred unencumbered from the distal tip of the flap to the external jugular vein and vena committantes of the supraclavicular artery. Therefore, a watershed area of venous drainage exists at the level of the origin of deltoid resulting from directionality of valves.

Discussion

The results of this study enhance our understanding of the perfusion patterns of the supraclavicular artery and the venous drainage of this territory with relevance to the supraclavicular flap. The arterial supply to this region has been documented using dissection and CT angiography in earlier cadaveric studies, however, these may have been limited to pre-dissected flaps. Further, the application of CT angiography to preoperative planning has been verified by Adams et al. Our study, demonstrated the territory of the supraclavicular artery in intact cadavers and also in the same tissue following flap dissection, using both dissection techniques and radiologic studies. We demonstrate the entire territory of the supraclavicular flap and most importantly, the areas in which perfusion is dubious or absent. It is these territories that are under threat if included in the flap design and may be responsible for some of the previous reports of flap necrosis using the supraclavicular flap. In particular, Blevins and Luce’s clinical series using the ‘cervicohumeral flap’ specifically questioned the safe distal extent of this technique and recommended extending the flap dimensions no further than the deltoid insertion. While their conclusions were based on clinical observation, our study provides the specific anatomical detail required to influence surgical decisions.

Previously, the territory of the supraclavicular artery was shown to rely partially on perfusion through direct and indirect anastomoses. Proximally, these include perforators arising from the TCA (as demonstrated by Cordova et al.). Once the proximal edge of the flap is raised, these perforators receive retrograde flow through anastomoses with the supraclavicular artery. An anterior branch arising near the origin of the supraclavicular artery may also course
directly over the clavicle, variably across the middle half of the bone. In our study, this branch supplied an anterior skin territory superficial to pectoralis major, reinforced by perforating branches of the pectoral branch of the thoracoacromial artery. This territory has proven valuable as an extension for the supraclavicular flap and allows a bilobed design (Figure 6).14 More distally small perforators were seen to emerge from the supraclavicular artery, to supply skin over the acromioclavicular joint, and also provide retrograde flow into terminal branches of the acromial and deltid branches of the thoracoacromial artery. These anastomoses appeared robust and were partially responsible for the more anterior arrangement of the flap with respect to deltoid.7

The division of the supraclavicular artery as it crosses the region of the acromioclavicular joint resulted in flow changing from axial to a random pattern relying on subfascial and subdermal plexuses, as is more commonly utilised in the fasciocutaneous flap, the anterolateral thigh flap.11 Critically, as musculocutaneous perforators emerge from deltoid, they provide a reinforcing network of direct perforator-to-perforator anastomoses plus suprafascial anastomoses to serve as deep inter-perforator communications.

The numerous musculocutaneous perforators that emerge from the deltoid muscle are of critical importance to the distal perfusion of the supraclavicular flap. These vessels emanate proximally and distally from the vascular hilum of the deltoid, and contribute to the cutaneous supply of the overlying skin, as demonstrated by the lateral arm flap. However, these vessels diminish considerably at the insertion of deltoid, with negligible continuation distal to this point. Consequently, this results in a relative paucity of direct perforator-to-perforator anastomoses plus suprafascial anastomoses to serve as deep inter-perforator communications.

The venous studies described here provide a demonstration of true antegrade venous drainage. To our knowledge, no previous study of the supraclavicular flap has examined antegrade flow. However, the relatively weak valves of the subdermal veins allow retrograde perfusion studies where cannulation of the transverse cervical vein or venae commitantes of the supraclavicular artery have been used successfully.7,15

These studies clearly demonstrate that the distal and proximal halves of the flap represent two distinct territories of venous drainage. However, the standard technique of flap elevation includes the division of communicating veins to

Figure 5  CT angiography of a cadaveric supraclavicular flap demonstrating a cross-sectional view of the venous drainage from distal (right of image) to proximal (left of image). The blue arrows indicate how the venous system must traverse from beneath the deep fascia (indicated by white dots) at the distal extent, becoming suprafascial over deltoid muscle (D) before piercing the fascia again in the supraclavicular drainage.

Figure 6  Cadaveric injection study. Red ink injection into the supraclavicular artery distal to the branching point of the anterior branch (seen in Figure 4) in contrast to the blue ink injected into the isolated anterior branch.
the cephalic vein and deep communications to the venae commitantes of the circumflex humeral arteries. Consequently, we hypothesise that as venous pressure increases within the distal part of the flap, overcoming any valves within the subdermal plexus and taking advantage of any oscillating veins would result in shunting of venous drainage from the distal to proximal halves of the flap (Figure 7).

We demonstrated that the superficial cervical vein (a tributary of the external jugular vein) and venae commitantes of the supraclavicular artery provide the venous drainage of the proximal portion of the flap and echo those of earlier studies, who described the venous drainage through a retrograde infiltration protocol.7,15

Implications for use in free tissue transfer

There have been very few reports of a free supraclavicular flap, despite the many potential benefits already outlined in terms of the donor site. Although the arterial supply has become clearer, the venous drainage has not been described in sufficient detail. Considering the diameter of the supraclavicular artery (average 1.1 mm at the origin), we advise that the pedicle be divided as proximally as possible to ensure the greatest vessel diameter, although care must be taken to avoid injuring the nearby brachial plexus. Venous drainage should include either the external jugular vein or its tributary the superficial cervical vein, in addition to the venae commitantes of the either the supraclavicular artery or the cephalic vein. This technique theoretically offers pathways of venous drainage for the entire flap territory without relying on valvular incompetence and provides large vessel diameter.

Conflict of interest

Nil.

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References


