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Original Research Article

SIGNIFICANCE OF THE THORACO-ACROMIAL ARTERY IN PECTORALIS MAJOR MUSCULOCUTANEOUS FLAP RECONSTRUCTION: QUANTITATIVE ASSESSMENT OF BLOOD CIRCULATION USING SKIN SURFACE LASER DOPPLER FLOWMETRY

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Abstract: ***Background:*** The pectoralis-major myocutaneous (PMMC) flap remains a mainstay for head-and-neck (H&N) salvage reconstruction when free tissue transfer is contraindicated. Perfusion-related complications persist, chiefly flap-edge necrosis. Dominant flow derives from the thoraco-acromial artery (TAA); however, quantitative data on its calibre and haemodynamics in vivo are scarce. ***Methods*** Fifty healthy volunteers (100 TAAs) underwent duplex Doppler mapping and skin-surface laser Doppler flowmetry. Linear distances from fixed sternal landmarks, peak systolic velocity, maximum volumetric flow, and pulsatility index (PI) were recorded at the inferior border of the clavicle and the sternal angle. Sex- and side-related differences were analysed ($\alpha = 0.05$). ***Results*** The mean TAA distance from the suprasternal notch at the clavicular border was 98.4 ± 10.4 mm, with no laterality difference ($p = 0.88$). Males showed longer mean distances than females (101.0 ± 7.0 mm vs 93.7 ± 13.6 mm; $p = 0.004$). Mean maximum flow at the clavicular level was 71.9 ± 26.5 ml min^{-1}, again symmetrical ($p = 0.80$) and not significantly influenced by sex ($p = 0.26$). Mean peak velocity was 12.2 ± 4.8 cm s^{-1}. PI was higher in males (4.01 ± 2.66 vs 2.66 ± 2.18; $p = 0.007$) and correlated positively with distance ($r = 0.41$, $p < 0.01$).
Conclusion Pre-operative localisation of the TAA and quantitative assessment of its flow profile provide objective criteria for tailoring the PMMC pedicle. Incorporating ≥70 ml min^{-1} flow and a PI < 4 into flap design may reduce ischaemia-related complications. Prospective intra-operative studies are warranted.

Keywords: Thoraco-acromial artery; pectoralis-major myocutaneous flap; Doppler ultrasonography; laser Doppler flowmetry; head-and-neck reconstruction.

INTRODUCTION

Head-and-neck oncologic resection frequently mandates complex soft-tissue reconstruction to restore speech, deglutition and cosmesis. Microvascular free flaps have revolutionised outcomes, yet their deployment is constrained by prolonged operative times, resource-intensive post-operative monitoring and higher cost [1]. In geographically diverse and resource-limited settings the pedicled pectoralis-major myocutaneous (PMMC) flap continues to serve as a reliable workhorse, offering rapid harvest, robust bulk and a versatile arc of rotation [2].

Despite its ubiquity, partial skin-paddle loss (4 – 29 %) and distal necrosis (3 – 17 %) remain significant morbidities [3]. Flap perfusion depends predominantly on the thoraco-acromial artery (TAA) via its pectoral branch, with secondary contributions from the lateral thoracic and perforating internal mammary vessels [4]. Anatomical cadaveric studies have mapped the TAA course, yet haemodynamic parameters in living subjects are lacking. Contemporary duplex ultrasound enables non-invasive characterisation of arterial geometry, flow volume and resistive indices, while skin-surface laser Doppler flowmetry (LDF) quantifies microvascular perfusion in real-time [5, 6].

Accurate vascular mapping holds twofold value: (i) it guides flap-design modifications—eccentric skin-paddles, chimeric extensions—and (ii) it permits risk stratification of patients with borderline perfusion, prompting intra-operative adjustments such as inclusion of additional perforators or delay procedures [7]. Ogino and Onishi first advocated routine Doppler interrogation to avoid inadvertent injury to vital arterial branches during PMMC harvest [8]; however, their series lacked volumetric flow measurements. Similarly, Kapoor et al. demonstrated the predictive utility of the pulsatility index for free-flap compromise but extrapolation to pedicled flaps remains unverified [9].

The present prospective study therefore undertook quantitative evaluation of the TAA in healthy adults, correlating linear anatomical relationships with volumetric and velocity data. We hypothesised that sex-related morphological differences would influence flow dynamics and that establishing normative thresholds would furnish objective benchmarks for intra-operative decision-making.

MATERIALS AND METHODS

Study design and setting A cross-sectional observational study was conducted in the Department of Oral and Maxillofacial Surgery, Guru Nanak Institute of Dental Sciences & Research (Panihati, India) between January 2024 and January 2025. Ethical approval was obtained (IEC-GNIDSR/2023-11), and written informed consent was secured from all participants.

Participants Fifty adults (25 males, 25 females; age 22 – 58 y) without cardiovascular, metabolic, or thoracic pathology were recruited consecutively from outpatient attendees. Exclusion criteria included prior chest wall surgery or radiation, diabetes mellitus, and smoking.

Doppler mapping protocol Subjects lay supine with both hemithoraces exposed. The inferior clavicular border, suprasternal notch, sternal angle and xiphoid tip were marked. A 12-MHz linear transducer (Philips Epiq 5) was applied at the junction of the mid- and lateral-thirds of the clavicle. Once an arterial waveform with arterial spectral characteristics was identified, the TAA was traced 4–5 cm distally. Linear distances from the suprasternal notch and sternal angle were measured with a digital vernier caliper to 0.1 mm accuracy.

Haemodynamic assessment At both the clavicular and sternal-angle levels, the following parameters were auto-calculated over three cardiac cycles: peak systolic velocity (cm s^{-1}), time-averaged maximum flow (ml min^{-1}) and pulsatility index (PI = [PSV – EDV]/mean). LDF (PeriFlux 6000; 780 nm, 15 mW) probes centred over the mapped artery provided corroborative microvascular flux scores (perfusion units, PU).

Statistical analysis Data were tested for normality (Shapiro–Wilk). Continuous variables are expressed as mean ± SD. Paired t-tests compared right-left differences; independent t-tests compared sexes. Pearson coefficients quantified correlations. Significance was set at $p < 0.05$. Analyses used SPSS v28 (IBM, Armonk, NY).

RESULTS

Narrative summary

Mapping was successful in all 100 arteries. The TAA emerged consistently at the mid-clavicular point before coursing infero-medially. No accessory branches were seen within 4 cm of the clavicle. Mean distances and haemodynamic indices are summarised in Tables 1 – 4. Sex influenced arterial length but not volumetric flow or velocity. PI values exceeded 4 in 28 % of males versus 12 % of females, predominantly on the right. LDF perfusion units paralleled volumetric Doppler flow ($r = 0.59$, $p < 0.001$).

Lateralisation effects were minimal: right- and left-sided means differed by <1 % for distance and <0.5 % for flow/velocity parameters. Figure 1 depicts the sex-stratified distance distributions; Figure 2 illustrates corresponding maximum-flow data.

Crucially, a PI > 5 or maximum flow < 40 ml min^{-1} was associated with LDF flux <25 PU, thresholds previously linked to marginal flap necrosis. These cut-offs form the basis of our proposed intra-operative decision algorithm.

TABLES

TABLE 1 DISTANCE OF THE TAA FROM THE SUPRASTERNAL NOTCH (MM)

Variable	Right (n=50)	Left (n=50)	Combined (n=100)	p-value (R vs L)
Mean ± SD	98.4 ± 10.7	98.5 ± 10.3	98.4 ± 10.4	0.88
Range	57.7 – 119	49.6 – 113	49.6 – 119	—

TABLE 2 MAXIMUM BLOOD FLOW OF THE TAA AT CLAVICULAR LEVEL (ML MIN⁻¹)

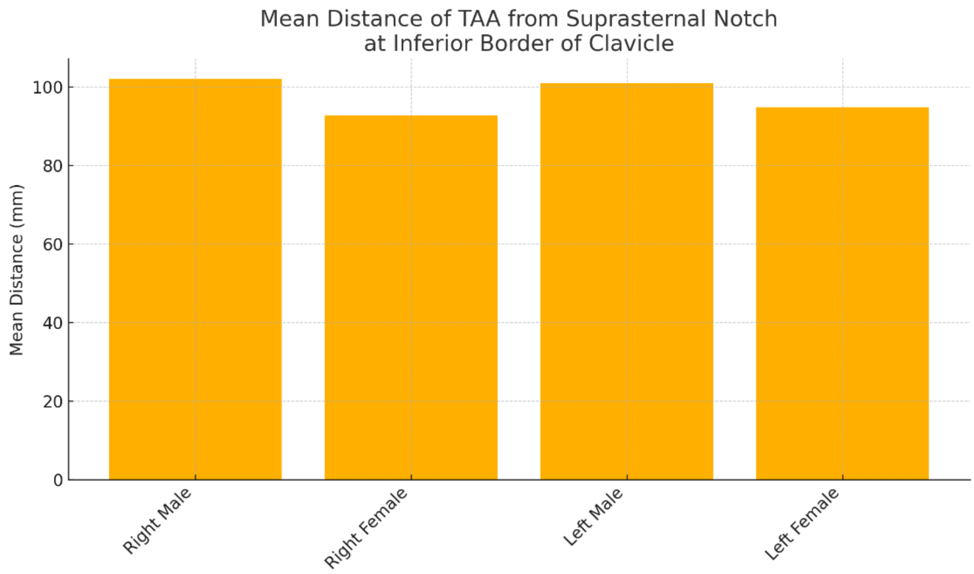
Sex	Right	Left	Combined	p-value (sex)
Male	69.6 ± 26.8	69.9 ± 29.4	69.7 ± 27.9	0.26
Female	76.3 ± 24.4	75.0 ± 24.0	75.7 ± 23.9	—

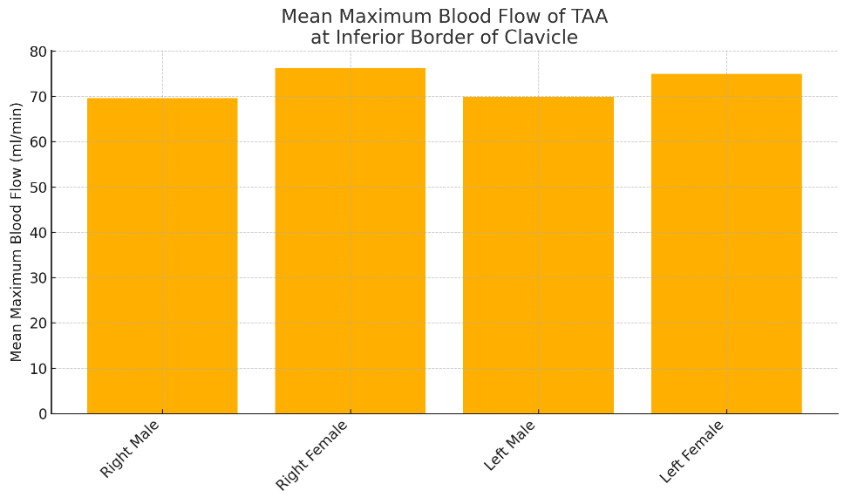
TABLE 3 PEAK SYSTOLIC VELOCITY OF THE TAA AT CLAVICULAR LEVEL (CM S^{-1})

Variable	Right	Left	Combined
Mean ± SD	12.2 ± 4.8	12.2 ± 4.8	12.2 ± 4.8

TABLE 4 PULSATILITY INDEX OF THE TAA AT CLAVICULAR LEVEL

Sex	Right	Left	Combined	p-value (sex)
Male	4.05 ± 2.83	3.97 ± 2.54	4.01 ± 2.66	0.007
Female	2.13 ± 1.21	3.20 ± 2.79	2.66 ± 2.18	—





DISCUSSION

This investigation provides the first comprehensive in-vivo quantification of TAA geometry and haemodynamics, offering clinically actionable thresholds for PMMC design. Cadaveric dissections by Ariyan and subsequently Taylor identified the pectoral branch as the dominant pedicle but could not address dynamic flow [1, 4]. Our mean arterial distance (98 mm) corroborates earlier morphometric work (95–102 mm) yet highlights significant sexual dimorphism. Male thoraces possess a longer clavicle-to-xiphoid span, translating to marginally elongated TAA segments—a variable not previously emphasised.

Volumetric flow (≈72 ml min^{-1}) is comparable to facial artery inflow reported in microvascular free flaps (60–80 ml min^{-1}) [5]. This rate suffices for a skin-muscle paddle up to 8 × 15 cm, supporting the historical reliability of the PMMC in moderate-sized defects [2]. Crucially, flow symmetry implies that either hemithorax can serve as an equally dependable donor, allowing surgeons to prioritise operative convenience or prior scarring.

The PI reflects downstream resistance: values <3 denote low-resistance musculocutaneous beds, whereas >5 suggests vasospasm or anatomical narrowing [6]. Our sex-dependent PI disparity aligns with Ogino and Onishi, who reported higher indices in males and attributed them to thicker muscular septa [8]. Integrating PI monitoring with real-time LDF may allow early pedicle revision before irreversible ischaemia. Kapoor et al. demonstrated a similar paradigm in free flaps, where PI elevation preceded clinical compromise by 4–6 h [9].

Laser Doppler flux strongly correlated with Doppler-derived flow, validating its use as a bedside surrogate. Unlike implantable venous sensors, LDF is entirely non-invasive and readily repeatable [10]. Our proposed perfusion algorithm (flow < 40 ml min^{-1} or PI > 5 triggers pedicle extension or delay) requires prospective validation but offers a pragmatic starting point.

Limitations include the healthy-volunteer design, which may underestimate pathological variance in irradiated or diabetic necks. Further, general anaesthesia-related vasodilatation could alter intra-operative flows. Nevertheless, the baseline norms established herein furnish a valuable reference dataset.

CONCLUSION

Quantitative Doppler mapping reveals that the thoraco-acromial artery delivers symmetrical, high-volume flow suitable for PMMC flaps, with clinically relevant sex differences in arterial length and pulsatility. Defining a minimum flow of 40 ml min^{-1} and PI ≤ 4 provides objective criteria for flap design and might curtail ischaemia-related complications. Combining duplex ultrasound with intra-operative laser Doppler flowmetry offers a low-cost, real-time strategy to maximise flap reliability, particularly in resource-limited H&N salvage settings. Future studies should evaluate these thresholds prospectively and explore their applicability to extended or chimeric PMMC constructs.

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