Recipient Vessel Selection in Head and Neck Reconstruction

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Objective: Recipient vessel caliber may be the single most important variable for flow to free tissue transfer. We performed cadaveric dissection of the external carotid artery and its branches to analyze average diameter in order to determine an algorithm for recipient vessel selection in head and neck reconstruction. Methods: The external carotid artery and branches were exposed on 3 lightly embalmed male human cadavers, aged 82 to 85 years. Each vessel was dissected, and luminal diameters were recorded with calipers. Results: The proximal ECA had the greatest average diameter (4 ± 0.6 mm) and potential flow; followed by distal ECA (2.85 ± 0.4 mm) facial (2.0 ± 0.6 mm), lingual (1.65 ± 0.6 mm), superior thyroid (1 ± 0.3 mm), and superficial temporal (0.85 ± 0.4 mm). There was a trend towards size variation between sides of the same cadaver. Conclusion: The external carotid artery has the greatest internal diameter and potential blood flow. It should be considered, when feasible, especially for defects of the upper third of the head. For defects of the lower third, the facial artery and the lingual artery should be utilized before the smaller diameter superior thyroid artery. Vessel selection is more challenging in the setting of radiation therapy, complex trauma, and prior neck surgery. In these settings, it is useful to have knowledge of the vascular anatomy and an objective algorithm for recipient vessel selection.

Approximately 390,000 new cases of head and neck cancer are diagnosed annually worldwide.1 The mainstay of treatment for early and locoregionally advanced disease is surgery and radiotherapy.2 For advanced disease requiring complex or composite reconstruction, microvascular free tissue transfer has become the standard of care.3 Indications for flap reconstruction are expanding due to increased surgical experience, advances in microvascular technique, and broadened flap selection. There is also reduced morbidity for those undergoing such procedures.4-8 Success rates of 98% to 99% have been reported...
by most large free flap series.\textsuperscript{9-12} The guiding principles are to restore anatomy, function, and favorable cosmesis.\textsuperscript{5} One underestimated factor to successful free tissue transfer is recipient vessel selection.\textsuperscript{8,13}

The most commonly used recipient arteries are branches of the external carotid system.\textsuperscript{13-15} Recipient vessel selection can be impacted by many factors, including defect location, quality of the available recipient vessels, pedicle length, and anastomotic method.\textsuperscript{14,16} Each one of these can have a substantial impact on the operation and outcome.\textsuperscript{14} Typically, the external carotid artery (ECA) gives off 6 branches before terminating as the maxillary and superficial temporal arteries. These include 3 anterior branches (superior thyroid, lingual, and facial), 1 medial branch (ascending pharyngeal), and 2 posterior branches (occipital and posterior auricular).\textsuperscript{17-19} The anterior branches are often preferred because of favorable orientation; however, there are multiple factors to consider when selecting a recipient vessels.\textsuperscript{15} Ideally, the recipient artery should be disease free, of suitable length, and have a similar diameter to the donor vessel.\textsuperscript{8}

Studies have shown that as recipient vessel diameter decreases, they may be less reliable.\textsuperscript{9,20} Vessel caliber effects flow exponentially, and higher flow is superior for patency and flap survival.\textsuperscript{21} Poiseuille’s law describes the relationship of flow through a conduit (Fig 1). In vivo, vessel length and blood viscosity do not change much under normal physiologic conditions and can be considered constants. Although blood is considered a non-Newtonian fluid, the relationships described in the equation still hold true.\textsuperscript{22,23} Poiseuille’s law shows that vessel radius is the most dominant variable affecting flow, as an increased radius yields an exponential increase in flow. Higher flow equates to increased flap circulation, improving flap survival.

\[ Q = \eta \pi Pr^4 / 8nl \]

\textbf{Figure 1.} Poiseuille’s law: \( Q = \) flow; \( \eta = \) viscosity, \( P = \) pressure gradient, \( r = \) radius, \( L = \) length.

The goal of this study was to analyze the external carotid system and formulate an algorithm for recipient vessel selection.

\textbf{METHODS}

Under 3.2\( \times \) and 4.5\( \times \) loupe magnification, external carotid arteries and branches were exposed on 3 lightly embalmed human cadavers (all male) ranging in age from 82 to 85 years (mean = 84 years) (Fig 2). None had prior neck operations. Each side branch was cut 1 cm distal to its origin, and the internal diameter measured with a surgical caliper (Fig 3). The external carotid was measured proximally and distally. Numbers were rounded up to the nearest 0.5 mm. Digital images were recorded.
RESULTS

The ECA and all branches were present in all 3 cadaveric specimens. No significant luminal atherosclerosis was found. The internal diameter of the proximal ECA, distal ECA, superior thyroid artery, lingual artery, facial artery, and superficial temporal artery (Fig 4) had average diameters of $4.0 \pm 0.6$, $2.9 \pm 0.4$, $1.0 \pm 0.3$, $1.7 \pm 0.6$, $2.0 \pm 0.6$, and
0.9 ± 0.4, respectively (Table 1). When comparing vessels of the same cadaver, there was an insignificant trend toward size variation between sides (Table 2).

**Table 1. Average internal diameter of the ECA and selected branches**

| Vessel                      | Diameter, mean ± SD |
|-----------------------------|---------------------|
| Proximal ECA                | 4.0 ± 0.6           |
| Distal ECA                  | 2.9 ± 0.4           |
| Superior thyroid artery     | 1.0 ± 0.3           |
| Lingual artery              | 1.7 ± 0.6           |
| Facial artery               | 2.0 ± 0.6           |
| Superficial temporal artery | 0.9 ± 0.4           |

*Distance in millimeters. ECA indicates external carotid artery.

**Figure 4.** The superficial temporal artery, commonly used for defects in the upper third of the head.

DISCUSSION

Microvascular free tissue transfer is a useful option in the armamentarium for reconstruction of head and neck defects. It is technically challenging, but success rates are high. This can be attributed to improved patient selection, flap choice, surgical technique, and postoperative management. Flap selection for appropriate characteristics, pedicle size, and length is important, but a detailed review of flap donor sites and pedicles is beyond the scope of this discussion. However, pedicle length and diameter influence recipient vessel selection and the need for vein grafting. Once the flap has been selected, one of the most
critical decisions a surgeon can make is the proper selection of recipient vessels. This requires a strong background in cervical vascular anatomy.

**Table 2. Comparison of diameter of the ECA and selected branches**

| Vessel                  | Cadaver 1 | Cadaver 2 | Cadaver 3 | Average |
|-------------------------|-----------|-----------|-----------|---------|
| Proximal ECA            | 4.0       | 3.5       | 4.5       | 4.0     |
| Right                   | 4.0       | 3.5       | 4.5       | 4.0     |
| Left                    | 3.0       | 4.5       | 4.5       | 4.0     |
| Distal ECA              | 3.0       | 3.0       | 3.0       | 3.0     |
| Right                   | 3.0       | 3.0       | 2.0       | 2.7     |
| Left                    | 3.0       | 2.0       | 3.0       | 2.7     |
| Superior thyroid artery  | 0.5       | 1.5       | 1.0       | 1.0     |
| Right                   | 0.5       | 1.5       | 1.0       | 1.0     |
| Left                    | 1.0       | 1.0       | 1.0       | 1.0     |
| Lingual artery          | 1.5       | 1.0       | 2.0       | 1.5     |
| Right                   | 1.5       | 1.0       | 2.0       | 1.8     |
| Left                    | 2.5       | 1.0       | 2.0       | 1.8     |
| Facial artery           | 2.5       | 1.5       | 3.0       | 2.3     |
| Right                   | 2.5       | 1.5       | 3.0       | 2.3     |
| Left                    | 1.5       | 1.5       | 2.0       | 1.7     |
| Superficial temporal artery | 0.5   | 1.5       | 1.0       | 1.0     |
| Right                   | 0.5       | 1.5       | 1.0       | 1.0     |
| Left                    | 0.5       | 0.5       | 1.0       | 0.7     |

*Distance in millimeters. ECA indicates external carotid artery.

The physiologic relationship between vessel size and blood flow is described by Poiseuille’s equation (Fig 1). The dominant influence of radius on flow is seen in this relationship and can aid in understanding of how physiologic and pathologic changes can affect perfusion pressure and flow. For example, if the radius decreases by one half, the flow will be reduced 16-fold. The smaller vessel has 6% of the flow of the larger. Accordingly, our algorithm is based on vessel size and location.

The ECA had the largest diameter and therefore has the greatest potential blood flow. It should be considered whenever practical, especially for defects in the upper third of the head. The superficial temporal artery can also be considered but should be the second choice due to its significantly smaller diameter. For defects in the lower third of the face, the facial artery is preferred, followed by lingual and superior thyroid arteries. There have been several algorithms for recipient vessel selection published in literature. Other algorithms suggest superficial temporal vessels for upper-third defects and facial or the superior thyroid arteries for defects of lower two-thirds. These algorithms are not based on vessel diameter but based on several other features, including ease of dissection, historical reliability, and proximity to the defect. These are important factors, but size may be more important than credited.

As primary radiation therapy for malignancies of the head and neck and metachronous tumors becomes more commonplace, the choice for most appropriate recipient vessel can become obscured. Patients who have had prior treatment with any combination of chemotherapy, radiation therapy, or surgery pose a greater challenge. In some situations, vein grafting is required to access vessels that were outside the zone of injury. However, this requires longer operating times, increased number of microanastomoses, and lower
Although not examined in this study, the transverse cervical artery may be a useful alternative in the vessel-depleted neck. It has a reported average diameter of 2.65 mm, and multiple studies have concluded that it is reliable and accessible. Its venae comitantes drain into the external jugular system and can provide suitable outflow.

The complex vascular anatomy of the head and neck provides many options for recipient vessels. It is important for reconstructive surgeons to be familiar with vascular anatomy of the head and neck, especially the relative size of potential recipient arteries. Selection of venous outflow is also of significance but is beyond the scope of this study.

Venae comitantes of the recipient artery, internal jugular, and external jugular are commonly used in an end-to-end or end-to-side fashion. Vein selection warrants further examination in future studies.

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