The History and Evolution of Internal Maxillary Artery Bypass

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Key words
- Cephalic vein graft
- High-flow EC-IC bypass
- Internal maxillary artery bypass
- Radial artery graft
- Saphenous vein graft
- Superficial temporal artery graft

Abbreviations and Acronyms
CTA: Computed tomography angiography
CV: Cephalic vein
DTA: Deep temporal arteries
DUS: Doppler ultrasonography
EC-IC: Extracranial-to-intracranial
FR: Foramen rotundum
FS: Foramen spinosum
ICA: Internal carotid artery
IMA: Internal maxillary artery
ITF: Infratemporal fossa
LPM: Lateral pterygoid muscle
MCA: Middle cerebral artery
MMA: Middle meningeal artery
MRI: Magnetic resonance imaging
RA: Radial artery
RAG: Radial artery graft
SC-IC: Subcranial-intracranial
STA: Superficial temporal artery
SV: Saphenous vein
SVG: Saphenous vein graft

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Internal maxillary artery (IMA) bypass has gained momentum in the last 5 years for the treatment of complex cerebrovascular disorders and skull base tumors. However, some issues regarding this treatment modality have been proposed. As one of the most experienced neurosurgical teams to perform internal maxillary artery bypass in the world (>100 clinical cases), we reviewed the literature in aspects of basic anatomy of maxillary artery with its variations to the lateral pterygoid muscle, initial anastomosis modalities, and subsequent exposure techniques in cadaver studies, preoperative arterial evaluation methods, optimal interposed graft selections, and surgical outcome in the management of complex aneurysms, skull base tumors, and steno-occlusive disorders.

INTRODUCTION

The internal maxillary artery (IMA) is a vital structure located within the infratemporal and pterygopalatine fossae that has been widely explored in head, neck, oral, and maxillofacial surgery. However, its use in neurologic surgery remains sparse. During the past 5 years, the IMA has been proposed as an alternative donor vessel for connecting intracranial arteries via a short graft in both cadaveric studies and clinical practice of the treatment of intracranial complex aneurysms, skull base tumors, and steno-occlusive flow diseases.[1-12] This new technique has various potential advantages over the standard extracranial-to-intracranial (EC-IC) high-flow bypass technique.[1,5,6,13,14] First, this technique is highly attractive because of its ability to achieve anastomosis via a single cranial incision and avoid attendant complications from the cervical incision. Furthermore, the deep tunneling of the interposition graft decreases the likelihood of graft compression. In addition, the closer proximity between the IMA and the cranial base allows for a shorter graft length and, thus, decreases the risk of graft torsion. The disadvantages of the IMA bypass technique are that the anastomosis is deep and not as easily achieved as the anastomosis on the surface, and mobilization of the IMA requires a zygomatic osteotomy or extensive subtemporal bone removal. Therefore, before attempting such a bypass, the surgeon must practice on cadavers.

In this study, we retrospectively reviewed experiences with IMA bypass surgery reported in the available literature with a focus on the variations in IMA anatomy, an initial exploration of IMA bypass modalities, the current IMA exposure techniques used in both cadaveric studies and clinical microsurgical practice, and the surgical outcomes of the IMA bypass procedure in clinical practice. To the best of our knowledge, this is the first literature review regarding the IMA bypass from a neurosurgical perspective.

IMA ANATOMY

Knowledge regarding the anatomy of the human maxillary artery in the infratemporal fossa (ITF) is not only important to dentists, surgeons, or interventional radiologists but also to neurosurgeons. The IMA represents the larger of the 2 terminal branches of the external carotid artery, and anastomoses to branches arise from the main trunk of the internal carotid artery (ICA) and the ophthalmic artery.[15] The IMA runs from a posterior-lateral to an anterior-medial course in the ITF, enters the pterygopalatine fossa,[16] and distributes the blood flow to both hard and soft tissues and organs in the maxillofacial region, including the parotid gland, masseter muscles, rhino-oral structures, cranial nerves, and meninges.[15,17] The IMA originates at the mandibular level of the neck in the parenchyma of the parotid gland, turns anteriorly, and passes medially to the neck of the mandible condyle between the condylar process of the mandible and the sphenomandibular ligament and reaches the ITF.[18] Then, the IMA may run superficially or deeply to the lower head of the lateral pterygoid muscle (LPM) toward the pterygopalatine fossa.[18]

Figure 1. Anatomic segments of internal maxillary artery. Published with permission from Xiang'en Shi.

Anatomically, the IMA is divided into 3 portions based on its relationship with the LPM, and each section is named according to its trajectory (i.e., the mandibular, pterygoid, and pterygopalatine segments) (Figure 1).[2,14,15,18-24] The mandibular/first segment runs horizontally and posteriorly to the neck of the mandible and passes anteriorly along the lower head of the LPM between the ascending ramus of the mandibular condyle (superficially) and sphenomandibular ligament (deeply). The branches from the first segment divide into the anterior tympanic, middle meningeal, accessory meningeal, and inferior alveolar arteries.[18,24] The middle meningeal artery (MMA) is usually the first branch of the mandibular IMA, but the MMA can arise together with the inferior alveolar artery at a common trunk. The accessory meningeal artery arises directly from the IMA or the MMA, passes through the foramen ovale, and enters the skull.[24] The pterygoid/second segment of the IMA passes obliquely forward either laterally or medially to the lower head of the LPM in the ITF, reaches the pterygomaxillary fissure, and becomes embedded into the pterygoid venous plexus. The second segment gives off several branches that supply the temporal muscle via the anterior and posterior deep temporal arteries (DTAs) and mastication muscles that contain the pterygoid, masseteric, and buccal arteries. The anterior DTA (ADTA) arises near the end of the pterygoid segment,[18] and Yagmurlu et al.[24] further divided this second segment into the main trunk, which is the largest portion of the vessel in caliber, and a terminal portion that creates a loop and gives rise to small branches. The main trunk of the pterygoid IMA is located between the level of the neck of the mandibular condyle and the level of the buccal nerve, over which a branch of the mandibular nerve crosses. The terminal part of the pterygoid segment of the vessel is located between the level at which the buccal nerve crosses the vessel and the pterygomaxillary fissure. The first and second maxillary segments play an important role in the blood supply to the meninges, mastication muscles, and auditory organs of the inner ear.[2] The pterygopalatine/third segment runs between the 2 heads of the LPM and enters the pterygopalatine fossa through the pterygomaxillary fissure, which supplies the mucosal and denticulate areas of the nasal and oral cavities.[2] This segment gives rise to the posterior superior alveolar, infraorbital, recurrent meningeal, descending palatine (greater and lesser palatine), vidian, pharyngeal, and sphenopalatine arteries.

The optimal selection of an IMA anastomosis site has been controversial. Initially, investigators were prone to use the third segment of the IMA for bypass surgery.[1,13,22,25-29] Subsequently, several studies reported that the pterygopalatine IMA courses tortuously, forming a second S-shaped loop, which makes exposure difficult and time consuming.[22,30] In addition, Feng et al.[14] and Eller et al.[13] described that the multiple branches and depth of the IMA in the pterygopalatine fossa could lead to a kinking of the vessel. Vrionis et al.[22] reported that, on average, 8 blood vessels were required to be ligated and sacrificed in the pterygopalatine fossa. These features may increase the risk of damage to the IMA during exposure and complications related to a suboptimal bypass and potentially prevent adequate blood flow through the IMA, rendering the pedicle useless.[13,14] Thus, most