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The maxillary vein: an anatomical narrative review with clinical implications for oral and maxillofacial surgeons

Kazzara Raeburn[1], Yohei Takeshita[2], Hiroaki Takakura[3], Shogo Kikuta[4], Yuki Kunisada[3], Soichiro Ibaragi[3], Rarinthorn Samrid[5,6], Marios Loukas[1], R. Shane Tubbs[1,6,7,8,9,10,11], Joe Iwanaga[4,6,7,8,9,12]

[1]Department of Anatomical Sciences, St. George's University, St. George's, Grenada, [2]Department of Oral and Maxillofacial Radiology, Faculty of Medicine, Dentistry and Pharmaceutical Sciences, Okayama University, Okayama, [3]Department of Oral and Maxillofacial Surgery, Faculty of Medicine, Dentistry and Pharmaceutical Sciences, Okayama University, Okayama, [4]Dental and Oral Medical Center, Kurume University School of Medicine, Kurume, Japan, [5]Department of Anatomy, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand, [6]Department of Neurosurgery, Clinical Neuroscience Research Center, Tulane University School of Medicine, New Orleans, LA, [7]Department of Neurology, Clinical Neuroscience Research Center, Tulane University School of Medicine, New Orleans, LA, [8]Department of Structural & Cellular Biology, Tulane University School of Medicine, New Orleans, LA, [9]Department of Neurosurgery and Ochsner Neuroscience Institute, Ochsner Health System, New Orleans, LA, [10]Department of Surgery, Tulane University School of Medicine, New Orleans, LA, USA, [11]University of Queensland, Brisbane, Australia, [12]Division of Gross and Clinical Anatomy, Department of Anatomy, Kurume University School of Medicine, Kurume, Japan

Abstract: The maxillary vein, despite its clinical significance, remains underexplored in anatomical literature. It plays a crucial role in venous drainage of the maxillofacial region and is closely associated with surgical procedures such as sagittal split ramus osteotomy, mandibuloplasty, and condylar or parotid surgeries. Due to its variable anatomy and proximity to critical structures, the maxillary vein poses a risk of significant hemorrhage if injured. Its small size and deep location make preoperative identification challenging, especially without contrast-enhanced imaging. Embryologically, the maxillary vein originates from the primitive maxillary vein and develops through complex anastomoses with other craniofacial veins. Anatomical studies have revealed several variations, including the presence of accessory mandibular foramina and unusual venous connections, which may increase surgical risk. Understanding the detailed anatomy and potential variations of the maxillary vein is essential for minimizing complications and improving surgical outcomes. Despite its importance, more anatomical and clinical research is needed to better define its course, variations, and implications in oral and maxillofacial surgery.

Key words: Embryology, Anatomy, Radiology, Cadaver, Mandible

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Introduction

Venous drainage in the head and neck plays a critical role in various pathological conditions. This system often varies in terms of vein distribution, size, and location [1, 2]. For example, the facial vein drains into the cavernous sinus via the angular vein, potentially leading to cavernous sinus thrombosis. Considering its importance, the presence of morphological variations is essential knowledge for healthcare professionals, including anatomists, anesthetists, clinicians, radiologists oral and maxillofacial surgeons [3]. The development of advanced therapeutic techniques and surgical tools has established orthognathic surgery as a widely adopted standard in oral surgery [4]. However, serious complications, such as unexpected major hemorrhage, can arise and

Corresponding author:
Joe Iwanaga
Department of Neurosurgery, Clinical Neuroscience Research Center, Tulane University School of Medicine, New Orleans, LA 70112, USA
E-mail: iwanagajoeca@gmail.com

pose a life-threatening risk [3-5]. A thorough preoperative evaluation of the major vessels' anatomy is essential in planning a careful surgical approach and being well-prepared to manage potential intraoperative hemorrhage. Although the anatomy of the maxillary artery and the retromandibular and facial veins have been well described, there is very little published information on the anatomy of the maxillary vein. Venous injury during surgery can also lead to significant hemorrhage as well as the arterial injury, increasing operative time and risk of infection and flap failure. Patil et al. [6] documented a variation of the maxillary vein in which, in the absence of the retromandibular vein, the maxillary vein bifurcates into anterior and posterior branches, directly connecting to an atypical external jugular vein and the facial vein, respectively. Odaka and Matsunaga [7] outlined the path of the maxillary vein and its spatial relationship to the mandibular ramus and noted that hemorrhage during mandibuloplasty was often linked to the anatomical course of the maxillary vein. In this article, we review the anatomy of the maxillary vein to discuss clinical correlation such as bilateral sagittal split ramus osteotomy and mandibuloplasty. The authors state that every effort was made to follow all local and international ethical guidelines and laws that pertain to the use of human cadaveric donors in anatomical research [8].

Review

Anatomy

The pterygoid venous plexus (PVP) is an extensive venous layer parallel to the second and third parts of the maxillary artery [9] and a venous network located medial to the mandibular ramus and in and around medial and lateral pterygoid muscles. It is generally considered the veins of the face have no valves. However, small valves may be present but are usually nonfunctional, and the movement of the pterygoid muscles forces blood to drain from the PVP into the retromandibular vein via the maxillary veins [10]. The maxillary veins run the posteromedial aspect of the mandibular ramus and are formed by the merging of veins from the PVP (Fig. 1) [3, 7, 11, 12].

The maxillary vein descends along the medial surface of the temporalis muscle before running horizontally near the bony surface of the mandibular ramus, beginning at the base of the coronoid process [3, 7]. It travels backward between the sphenomandibular ligament and the neck of the condyle before entering the parotid gland (Fig. 2) [11]. Within the parotid gland, the maxillary vein joins with the superficial temporal vein to become a retromandibular vein [3, 7, 11, 12]. The maxillary vein plays a critical role in draining blood from the maxillofacial to the cervical region, as the retromandibular vein eventually empties into the internal jugular vein [7]. Since the maxillary vein courses along the medial surface of the mandibular ramus, making precise anatomical knowledge of its path is crucial for performing mandibular ramus-related surgery efficiently and safely [7].

Embryology

The development of the venous system in the head and neck during embryogenesis is intricate, involving substantial

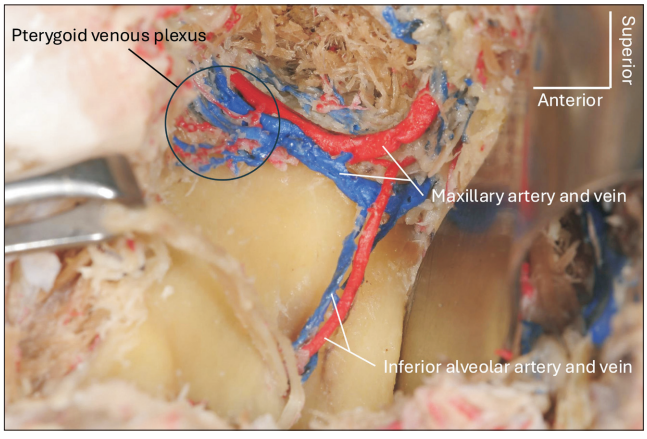

Fig. 1. Cadaveric image of the right maxillary vein (medial view).

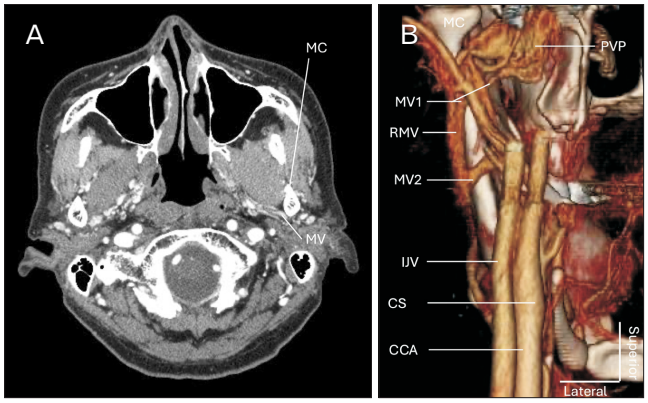

Fig. 2. Contrast-enhanced computed tomographic images of the MV. (A) Axial image shows the relationship of the MC and MV. Posterior view of the three-dimensional reconstructed (B) computed tomographic images presenting the venous flow from the PVP to the RMV through the MV1. An additional MV2 drains into the RMV. MC, mandibular condyle; PVP, pterygoid venous plexus; MV, maxillary vein; RMV, retromandibular vein; IJV, internal jugular vein; CS, carotid sinus; CCA, common carotid artery.

changes and refinements to establish effective blood drainage pathways for these regions. Among these, the formation of the maxillary vein is especially significant, as it facilitates drainage from the face and upper jaw. This vein's development is a key component of the vascular system, ensuring proper integration and function within the broader circulatory framework of the head and neck [13]. The veins of the head and neck begin developing around days 22–30 with the formation of the primary head vein, also known as the anterior cardinal vein. The ventral pharyngeal vein (VPV) drains the area of the developing mandibular and hyoid arches connecting to the common cardinal vein. By day 39, as the embryo grows and the neck elongates, the VPV shifts its drainage point from the common cardinal vein to the cranial part of the precardinal vein, which will later become the internal jugular vein. The primitive maxillary vein (PMV) develops cranially and laterally towards the ventral pharyngeal vein. It starts to drain the orbital area, and as it extends, it eventually drains regions supplied by the trigeminal nerve. By around day 49 of development, the PMV extends and forms anastomoses with the linguofacial vein (Fig. 3A). Between days 53 to 58, the PMV undergoes significant changes (Fig. 3B). It transforms into the common facial vein, which receives blood from the retromandibular vein and other tributaries (Fig. 3C). A plexiform anastomosis develops between the lateral tributaries of the linguofacial and maxillary veins around the outer labial margin. The anterior connection between the facial vein and external jugular vein disappears, and the facial vein becomes draining directly to the common facial vein (Fig. 3D). Additionally, the adult pterygoid plexus forms from the numerous plexiform and more medial tributaries of the maxillary vein [13-15]. The anterior or posterior communicating vein remnants/variations might result in the variant maxillary vein [2].

Surgical applications

Numerous studies have highlighted the risks associated with the maxillary vein and other vascular structures in split sagittal ramus osteotomy (SSRO). Sahoo et al. [16] reported instances of significant bleeding involving the inferior alveolar and maxillary arteries and veins. Similarly, Sugahara et al. [5] found that vascular injuries along the medial and posterior borders of the mandibular ramus were key contributors to bleeding during SSRO. The maxillary vein, located posteromedial to the ramus, is closely associated with the temporal muscle and encased in the periosteum, making it challenging to visualize during surgery. This proximity to the medial and posterior borders of the mandible increases its vulnerability to injury during SSRO.

Odaka and Matsunaga [7] highlighted additional risks posed by surgical tools such as ramus retractors, periosteal elevators, and raspatories during medial periosteum dissec-

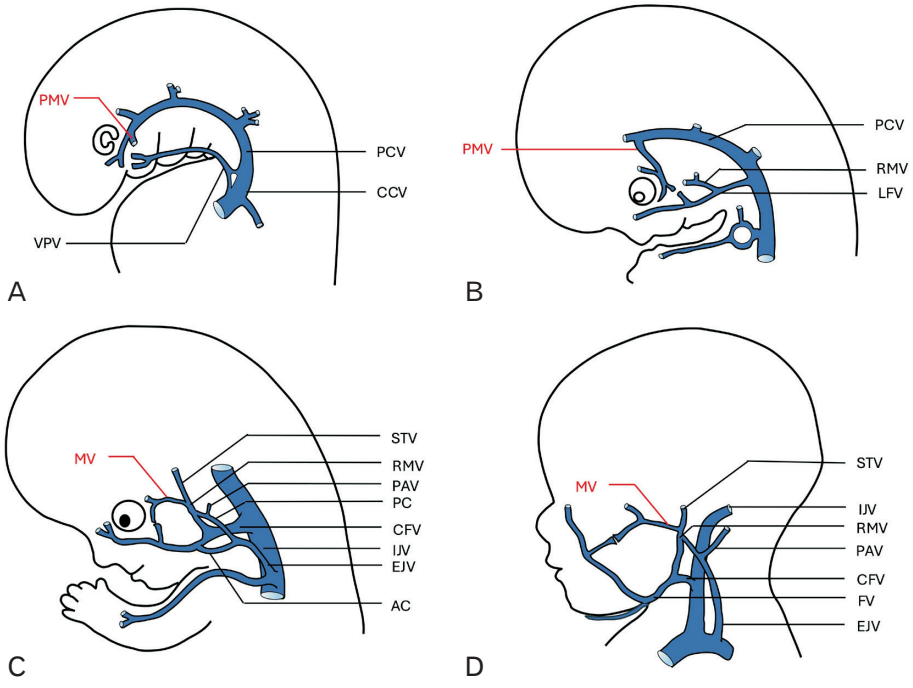

Fig. 3. Development of the primitive maxillary vein, maxillary vein, and associated veins with crown-rump length measurements. (A) 10 mm embryo (Day 50). (B) 18 mm embryo (Day 59). (C) 40 mm embryo (Day 76). (D) Newborn. PMV, primitive maxillary vein; PCV, precardinal vein; CCV, common cardinal vein; VPV, ventral pharyngeal vein; RMV, retromandibular vein; LFV, linguofacial vein; MV, maxillary vein; STV, superficial temporal vein; PAV, posterior auricular vein; PC, posterior communication; CFV, common facial vein; IJV, internal jugular vein; EJV, external jugular vein; AC, anterior communication; FV, facial vein. Modified from Padget. Am J Anat 1956;98:307-55 [13].

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tion, particularly in areas where the maxillary vein lies near the temporalis muscle. The positional relationship of the maxillary vein to the mandible elevates the risk of hemorrhage during SSRO procedures. They further identified that hemorrhage during mandibuloplasty was often linked to the anatomical course of the maxillary vein [7]. Their findings showed that the vein traverses from the center of the mandibular notch to the posteromedial surface of the ramus, remaining in close contact with the periosteum and separated from the bone by only a thin layer of connective tissue. If severed, the maxillary vein, which conducts blood to the retromandibular vein and eventually drains into the internal jugular vein, could lead to significant blood loss. Therefore, understanding the orientation and vascular branches of the maxillary vein is crucial for surgeons performing mandibuloplasty to mitigate the risk of hemorrhage [7].

It has been reported that bleeding from the PVP and the maxillary artery can be seen during Le Fort I osteotomy [16]. Given the vascular circulation and anatomical proximity, injury to the maxillary vein—though rare—can occur. However, it is not possible to definitively determine whether the source of bleeding is the maxillary vein or the PVP.

Massive hemorrhage is associated with unfortunate postoperative outcomes, especially with hemodynamic instability [17, 18]. The most important step by the surgical team in hemorrhage is identifying and rapidly controlling the source of bleeding [19]. The maxillary vein, as well as the PVP and the maxillary artery, should be noted not only in SSRO but also in parotid and mandibular condyle surgery. The surgeon must have a clear understanding of the vascular anatomy surrounding the surgical field. Additionally, meticulous dissection is essential to preserve the periosteum, as injury to these veins can typically be avoided if the periosteum remains intact.

Anatomical variations

The maxillary vein can be short and multiple and typically drains from the inferior alveolar vein [9]. The inferior alveolar vein draining into the maxillary vein can also be multiple. According to Iwanaga et al. [20], the accessory mandibular foramina (AMFs) are pathways of either tributary of the inferior alveolar vein, maxillary vein, or a branch of the inferior alveolar artery. The mean diameter of the AMFs is <0.5 mm, relatively small, but it can still cause bleeding, especially when the foramen is large. The authors suggested to call those AMFs "foramina for ramus osteotomy". Another report on the interesting variation of the maxillary vein is a venous connection between the maxillary vein and facial vein through the AMF of the mandible. Although the venous drainage of the fetal mandible is not well understood, the facial vein might be one of the primary drainages of the mandible and the inferior alveolar vein. The remnant of the fetal venous system in and around the mandible might have presented as a variation [3]. The anatomy of the maxillary vein can vary between individuals. Variations of the maxillary vein and other associated variations, such as AMFs, are crucial for comprehensive understanding of surgery of the mandibular ramus [20]. Nishi et al. [2] reported the "venous condylar ring" formed by variant maxillary veins. This variation can lead to massive hemorrhage if injured. The challenge lies in the difficulty of identifying such venous variations preoperatively on computed tomography, unless contrast-enhanced imaging is used. Even a small incision near the condyle must be performed with caution to avoid complications.

Conclusion

We found that there is limited information available on the maxillary vein, including its anatomy, anatomical variations, embryology, and surgical relevance. Despite this, it may pose a significant risk of intraoperative injury. Although its small size may make it difficult to assess in radiological images, anatomical studies are warranted.

ORCID

Kazzara Raeburn: https://orcid.org/0009-0000-2322-9148
Yohei Takeshita: https://orcid.org/0000-0002-9345-5797
Hiroaki Takakura: https://orcid.org/0000-0001-5112-8854
Shogo Kikuta: https://orcid.org/0000-0002-2236-2884
Yuki Kunisada: https://orcid.org/0000-0001-6356-0740
Soichiro Ibaragi: https://orcid.org/0000-0003-2897-1231
Rarinthorn Samrid:
https://orcid.org/0000-0001-8958-9162
Marios Loukas: https://orcid.org/0000-0003-2811-6657
R. Shane Tubbs: https://orcid.org/0000-0003-1317-1047
Joe Iwanaga: https://orcid.org/0000-0002-8502-7952

Author Contributions

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Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

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