Anatomical Variability of the Maxillary Artery

Findings From 100 Asian Cadaveric Dissections

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Objective: To describe the anatomical variability of the maxillary artery.

Design: Anatomical study.

Setting: Academic institution.

Subjects: One hundred midsagittal sections of randomly selected adult cadaver heads with intact maxillary sinuses, pterygopalatine fossa, and surrounding structures.

Main Outcome Measures: The location of the proximal portion of the maxillary artery in relation to the lateral pterygoid muscle, the branches of the mandibular division of the trigeminal nerve, and the branching patterns of the third section of the maxillary artery.

Results: The first and second sections of the maxillary artery most commonly traveled through the lateral aspect of the lateral pterygoid muscle, with the inferior alveolar nerve, lingual nerve, and buccal nerve on the medial side of the maxillary artery (61.0%). The course and branching type of the third section of the maxillary artery were classified into 3 patterns: loop (61.0%), bifurcated (19.0%), and straight (18.0%). In most cases (62.0%), the division point of the maxillary artery was located on the superior and medial thirds of the posterior wall of the maxilla.

Conclusion: This study provides detailed information concerning the anatomical variability of the maxillary artery, which we hope will help prevent the arterial bleeding that may occur during mandibular or maxillary osteotomy or maxillectomy for ligation of the sphenopalatine artery.


The maxillary artery is the largest terminal branch of the external carotid artery. It is divided into 3 sections based on its relationship to the lateral pterygoid muscle: (1) the mandibular section, which is posterior to the lower border of the lateral pterygoid muscle; (2) the pterygoid section, which may take a course deep or superficial to the lateral pterygoid muscle; and (3) the pterygopalatine section, which is in the pterygopalatine fossa. This artery is widely distributed to the mandible, maxilla, teeth, muscles of mastication, palate, nose, and cranial dura mater.1,2

The first and second sections of the maxillary artery are related to the mandibular condyle and pterygoid muscle region.1 Therefore, internal fixation of the condyle or subcondylar fracture of the mandible and surgical procedures such as mandibular osteotomy and temporomandibular joint arthroplasty may induce intractable bleeding, which is difficult to control and may recur.1 In case of bleeding that is difficult to control, ligation of the external carotid artery may be necessary. In addition, during total or radical maxillectomy, ligation of the proximal section of the maxillary artery is necessary to reduce intraoperative bleeding.3,4

The third section of the maxillary artery, in the pterygopalatine fossa, is related to the maxilla and nasal cavity.2 During maxillary (Le Fort I, II, or III) or midfacial osteotomy, profuse bleeding is possible and complications such as postoperative hemorrhage, false aneurysm, and arteriovenous fistula have been reported.2,5 It also has been reported that the main vessel most commonly damaged after maxillectomy is the maxillary artery and its branches. In cases of intractable posterior or epistaxis, if posterior nasal packing fails, ligation of the sphenopalatine artery (SPA) or maxillary artery is necessary.8,9

Despite the clinical importance of the maxillary artery, reports describing it in its entirety are few because of its anatomical complexity and vulnerability, especially in the first 2 sections. With increasing use of endoscopic approaches to the pterygopalatine fossa, the recent literature has defined the anatomy of the fossa in relation to endoscopic landmarks. Unfortunately, consistent landmarks to locate the various structures in the pterygopalatine fossa have not been described.10

To perform mandibular osteotomy safely and to reduce intraoperative bleeding during...
radical maxillectomy, the anatomical orientation of the proximal section of the maxillary artery is important. To prevent complications after maxillary osteotomy due to bleeding, an accurate understanding is necessary of the courses of the maxillary artery and its branches in the pterygopalatine fossa. For ligation of the SPA in intractable cases of posterior epistaxis, surgical landmarks in relation to the SPA in the pterygopalatine fossa are essential to otorhinolaryngologists. Therefore, in this study we investigated the surgical anatomy of the maxillary artery. First, the courses of the first and second sections of the maxillary artery and their relationship to the lateral pterygoid muscle and mandibular nerve were studied via the lateral approach. Second, the course of the third section of the maxillary artery and its branching patterns were determined from the viewpoint of the posterior wall of the maxilla. Finally, the branching types of the maxillary artery, which are divided into the SPA and the descending palatine artery (DPA) in the pterygopalatine fossa, were analyzed and the locations of the division points were recorded.

METHODS

One hundred midsagittal sections from adult cadaver head specimens with intact maxillary sinuses and surrounding structures were injected with red latex through the external carotid artery. To identify the first and the second sections of the maxillary artery, the mandibular ramus and condyle were removed to expose the pterygomaxillary fissure through the lateral infratemporal fossa. The lateral pterygoid muscle was resected, and the maxillary artery was dissected up to the terminal branches in the pterygopalatine fossa. The course of the maxillary artery in relation to the lateral pterygoid muscle, inferior alveolar nerve, buccal nerve, and lingual nerve were recorded. To investigate the third section of the maxillary artery, the posterior wall of the maxillary sinus and the adipose tissue in the pterygopalatine fossa were removed to expose the maxillary artery under an operating microscope (original magnification, ×6). After identifying the location where the maxillary artery exited the pterygopalatine fossa, microscissors, fine forceps, and a pick were used to investigate the fine branches and to dissect up to the sphenopalatine foramen.

FIRST AND SECOND PARTS OF THE MAXILLARY ARTERY

The maxillary artery is divided into 3 main sections. We investigated the courses of the first and second sections and categorized their types in relation to the lateral pterygoid muscle and the mandibular nerve.

BRANCHING PATTERNS OF THE THIRD SECTION OF THE MAXILLARY ARTERY

We also investigated the course of the third section of the maxillary artery from the viewpoint of the posterior wall of the maxilla and classified its patterns in relation to the branches. The terminal branches of the third section of the maxillary artery were divided into the SPA and DPA in the pterygopalatine fossa and were classified as 1 of 3 types according to the classification by Morton and Khan.2 We measured the distance from the highest point to the lowest point of the posterior wall of the maxilla and the distance from the most medial point to the most lateral point. We divided the height and width into 3 equal lengths, thereby compartmentalizing the posterior wall of the maxilla into 9 sections. The terminal division point, where the maxillary artery divided into the SPA and DPA, was recorded for the imaginary 9 sections.

RESULTS

COURSES OF THE FIRST AND SECOND SECTIONS OF THE MAXILLARY ARTERY

We found large anatomical variations in the courses of the first and second sections of the maxillary artery. A total of 6 pattern types were noted around the mandible and the pterygoid muscle (Figure 1). Twenty-one

![Figure 1. The 6 types of relationships of the first and second sections of the maxillary artery to the lateral pterygoid muscle and mandibular nerve. A, Type A (21.0%). B, Type B (61.0%). C, Type C (7.0%). D, Type D (4.0%). E, Type E (6.0%). F, Type F (1.0%). 1 indicates lingual nerve; 2, inferior alveolar nerve; 3, external carotid artery; 4, maxillary artery; 5, medial pterygoid muscle; 6, buccinator muscle; 7, buccal nerve; and 8, lateral pterygoid muscle. See the “Courses of the First and Second Sections of the Maxillary Artery” subsection of the “Results” section for a description of each type.](http://archotol.jamanetwork.com/pdfaccess.ashx?url=/data/journals/otol/5690/ on 04/02/2017)
cases were type A, meaning the maxillary artery traveled through the lateral aspect of the lateral pterygoid muscle, the inferior alveolar nerve and lingual nerve were on the medial side of the maxillary artery, and the buccal nerve was located outside the maxillary artery (Figure 1A). Sixty-one cases were type B, meaning the maxillary artery traveled through the lateral side of the lateral pterygoid muscle, and the inferior alveolar nerve, lingual nerve, and buccal nerve were on the medial side of the maxillary artery (Figure 1B). Seven cases were type C, in which the maxillary artery traveled through the inside of the lateral pterygoid muscle, the inferior alveolar nerve and lingual nerve were on the medial aspect of the maxillary artery, and the buccal nerve was on the lateral surface of the maxillary artery and inferior head of the lateral pterygoid muscle (Figure 1C). Four cases were type D, meaning the maxillary artery traveled through the inside of the lateral pterygoid muscle, the inferior alveolar nerve and lingual nerve were on the medial side of the maxillary artery, and the buccal nerve was located on the lateral surface of the inferior head of the lateral pterygoid muscle (Figure 1D). Six cases were type E, in which the maxillary artery passed between the inferior alveolar nerve and lingual nerve on the medial side of the lateral pterygoid muscle and the buccal nerve was on the lateral surface outside the inferior head of the lateral pterygoid muscle (Figure 1E). One case was classified as type F, in which the maxillary artery passed through the inferior alveolar nerve on the medial side of the lateral pterygoid muscle, the lingual nerve was on the medial side of the maxillary artery, and the buccal nerve was situated on the lateral surface of the inferior head of the lateral pterygoid muscle (Figure 1F).

Figure 2. Patterns of the third section of the maxillary artery. A, Type 1: loop. B, Type 2: bifurcated. C, Type 3: straight. DPA indicates descending palatine artery; IOA, infraorbital artery; MA, maxillary artery; PSAA, posterior superior alveolar artery; and SPA, sphenopalatine artery. See the “Patterns of the Third Section of the Maxillary Artery” subsection of the “Results” section for a description of each type.

Figure 3. Bifurcated pattern of the third section of the maxillary artery (19.0%, or 19 of 100). DPA indicates descending palatine artery; IOA, infraorbital artery; ION, infraorbital nerve; MA, maxillary artery; PSAA, posterior superior alveolar artery; and SPA, sphenopalatine artery.

PATTERNS OF THE THIRD SECTION OF THE MAXILLARY ARTERY

The maxillary artery entered the pterygopalatine fossa through the pterygomaxillary fissure. There were 3 patterns of the maxillary artery from the viewpoint of the posterior wall of the maxilla. The maxillary artery emerged from the medial aspect, ran laterally, turned upward, and then traveled medially in 61 cases (Figure 2A [loop]); traveled from an inferior to a superior dissection to divide medially and laterally, each branch then ramifying into 2 more branches in 19 cases (Figure 2B [bifurcated] and Figure 3); and ran medially from the lateral aspect in 18 cases (Figure 2C [straight] and Figure 4). The final 2 cases were not included in 3 types, and these cases were classified as “others.” Of the loop types, 25 cases were loop 1, in which the short branches originat-
ing from the maxillary artery were divided into the infraorbital artery (IOA) and the posterior superior alveolar artery (PSAA) (Figure 5A). Twenty cases were of the loop 2 type, in which the IOA and the PSAA divided directly from the maxillary artery (Figure 5B). In the 16 cases that exhibited the loop 3 type, 3 or more branches divided directly from 1 point of the maxillary artery or had 2 arterial loops (Figure 5C).

BRANCHING TYPES OF THE MAXILLARY ARTERY AND THE LOCATION OF THE DIVISION POINT IN THE PTERYGOPALATINE FOSSA

The maxillary artery was located immediately posterior to the periosteum of the posterior maxillary sinus wall and anterior to the neural elements of the pterygopalatine fossa in all cases. We performed morphologic classification of the maxillary artery from the viewpoint of the posterior maxilla. Seventeen cases exhibited type Y (180° pattern) (Figure 6A), 36 exhibited the intermediate type (90° pattern) (Figure 6B), 17 exhibited type M (0° pattern) (Figure 6C), and 28 exhibited type T (>90° pattern) (Figure 6D). Two cases were classified as “other.” The posterior wall of the maxilla was divided into 9 sections. As a result of classifying the division point of the maxillary artery where it divided into the SPA and the DPA, the division point was placed on the superior and medial thirds of the posterior wall of the maxilla in most cases (62.0%). However, 30.0% of cases had the maxillary artery division point located on the middle and medial thirds (Figure 7).

COMMENT

The maxillary artery is widely distributed to the mandible, maxilla, teeth, muscles of mastication, palate, nose, and cranial dura mater. Therefore, many different specialists have an interest in understanding it, and there have been a variety of specialty reports on certain aspects of the maxillary artery. However, a comprehensive knowledge of the entire course of the maxillary artery is needed to avoid intraoperative hemorrhage and complications due to bleeding because it is the most vulnerable anatomical structure during craniofacial procedures.

The first 2 sections of the maxillary artery are in close proximity to the subcondyle region of the mandible and the pterygoid muscle. It is important to know the relationships between the maxillary artery and the structures around the mandible. Lasker et al11 reported that the relationship between the maxillary artery and the lateral pterygoid muscle differs according to race; they found that the maxillary artery traveled through the medial aspect of the lateral pterygoid muscle in 46% of white individuals, whereas the same was true in only 31% of African Americans. Sashi et al12 reported that the maxillary artery traveled on the lateral side of the lateral pterygoid muscle in 93% of dissected cases. In our study of 100 cadaveric dissections, the first and second sections of the maxillary artery traveled through the lateral aspect of the lateral pterygoid muscle in 82.0% (82 of 100) of cases and through the inside in only 18.0% (18 of 100) of cases. In Asians, the proximal section of the maxillary artery more frequently traveled through the lateral side of the lateral pterygoid muscle than in whites. Accord-
ing to our classifications, in types A and B, the maxillary artery runs on the lateral side of the lateral pterygoid muscle. To reduce intraoperative bleeding during total or radical maxillectomy, the maxillary artery must be tied in advance.3,4 Although the anatomical relationship between the maxillary artery and the lateral pterygoid muscle is not consistent, the pterygoid segment of the maxillary artery could be easily seen after blunt dissection of the buccal fat pad because most of the maxillary artery lies lateral to the lateral pterygoid muscle. Ligation of the maxillary artery could reduce intraoperative bleeding, and the operation field could be clearly inspected to perform oncologically sound resec-
tions. In addition, surgeons dealing with the subcondylar region should know the location of the maxillary artery because it is the principal source of bleeding during surgical procedures.1,13 A common complication of surgical treatment of subcondylar fractures is accidental puncture of the maxillary artery. Temporomandibular joint ankylosis is treated with condylectomy and gap arthroplasty. The maxillary artery could be distorted by fibrotic changes in this region. In addition, the maxillary artery is at risk of injury during intraoral vertical or oblique ramus osteotomy due to its close proximity to the operation regions.13

In our study, the branching order of the third section of the maxillary artery was generally similar to that described in various articles in the literature.5,14 In the pterygopalatine fossa region, the maxillary artery branches into 4 arteries. The PSAA and the IOA branch off first, and the DPA and SPA originate in the pterygopalatine fossa region. Previous reports on its course in the pterygopalatine fossa mentioned only that the maxillary artery entered through the pterygomaxillary fissure, traveling generally in an anterior, a medial, and a superior direction.2 In our investigation, the course was more complicated. There were 3 types of patterns, which were classified by the course of the maxillary artery through the pterygopalatine fossa. The PSAA and IOA came from a short branch of the maxillary artery (loop 1). This pattern was found in 25 of 100 dissections (25.0%). The second most common pattern indicated that the PSAA and IOA branched separately from the maxillary artery (loop 2).

Figure 6. The branching types of the maxillary artery in the pterygopalatine fossa. A, Type Y (180° pattern; 17.0%, or 17 of 100). B, The intermediate type (90° pattern; 36.0%, or 36 of 100). C, Type M (0° pattern; 17.0%, or 17 of 100). D, Type D (=90° pattern; 28.0%, or 28 of 100). DPA indicates descending palatine artery; ION, infraorbital nerve; and SPA, sphenopalatine artery.

Figure 7. The schema of the locations of the division point of the maxillary artery, where it divides into the descending palatine artery and the sphenopalatine artery in the pterygopalatine fossa.
This pattern was shown in 20 of 100 cases (20.0%). Choi and colleagues reported 2 types of patterns in which the PSAA and IOA arose. Twelve of 21 cases (57.1%) had these 2 arteries originate from a short branch of the maxillary artery; in 9 of 21 (42.9%), these 2 arteries came directly from the maxillary artery. Recently, Abuzayed et al\(^\text{13}\) obtained similar results to those of Choi and colleagues.

According to the morphologic classification of the third section of the maxillary artery by Morton and Khan,\(^\text{2}\) type T was observed in 28.0% (28 of 100) of our dissections, whereas the intermediate type was found in most dissections (36.0%, or 36 of 100). In addition, type Y was found in 17 of 100 cases (17.0%) in our study, which is lower than that found by Morton and Khan. In another study, the intermediate type was observed in 8 of 12 specimens, whereas types M and T were present in 4 cases each.\(^\text{14}\) Abuzayed et al\(^\text{13}\) reported that the intermediate and M types were the most common. In 21 specimens of Korean cadavers, type Y was observed in 19.0% of cases, the intermediate type in 33.3%, type T in 23.8%, and type M in 14.3% of cases; 9.0% of cases were classified as “other.”\(^\text{15}\) Our results are in close agreement with those of previous studies.

Other reports have described the branching types of the maxillary artery in the pterygopalatine fossa.\(^\text{3,10}\) Morton and Khan found that the arterial branching was contained in the middle third of the vertical height of the posterolateral wall of the antrum, with occasional extension into the upper third.\(^\text{3}\) In contrast to their study, we found the most arterial branching (62.0%) in the superior and medial thirds of the posterior wall of the maxilla. In 30.0% of the dissections, arterial branching was found in the middle and medial thirds. Isaacs and Goyal\(^\text{10}\) measured the distance between important neurovascular structures within the pterygopalatine fossa, but they did not describe the consistent landmarks of the maxillary artery in the pterygopalatine fossa because its course is tortuous and variable. Other authors have reported similar findings.\(^\text{3,10}\) In our study, we measured the height and width of the posterior wall of the maxilla and located the division site of the maxillary artery in this area. The medial and superior thirds of the posterior wall of the maxilla could be defined as landmarks for the location of the maxillary artery’s division point in the pterygopalatine fossa. The artery could be easily dissected from its landmark position in the fossa.

On the basis of our results, these data indicate that maxillary osteotomy can be performed safely without damaging the maxillary artery. Directing the osteotome superiorly should be avoided, and the osteotome should be kept in the medial and inferior directions to avoid damage to the artery and important structures in the pterygopalatine area. These results also provide guidelines for ligation of the SPA or maxillary artery in cases of intractable posterior epistaxis. When entering the pterygopalatine fossa through the maxilla, one should follow a medial and superior direction because the SPA is located in the medial and superior thirds of the posterior maxillary wall. This can be very helpful in avoiding damage to other branches of the maxillary artery and the maxillary nerve.

In conclusion, this study provides detailed information concerning the anatomical variability of the maxillary artery. We expect this to help prevent arterial bleeding during mandibular or maxillary surgery and when performing arterial ligation during intractable epistaxis.

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