Distribution of Palatal and Other Arteries in Cleft and Non-cleft Human Palates.

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Cleft lip and cleft palate are two possible effects of fusion failure of embryonic facial processes. Aberrant facial morphogenesis suggests aberrant arterial distribution. Prompted by surgical need, studies detailing major branches of the third or pterygopalatine portion of the maxillary artery acquire practical significance. Therefore postmortem arteriographic studies were undertaken to ascertain location of these major arteries and their branches in twelve near-term human fetuses. Comparison was made between arterial distributions in three cleft and nine non-cleft fetal palates. The question of bilateral symmetry was examined.

It is known that these major branches are commonly present on both sides, but the study revealed numerous variations in each facial half in both cleft and non-cleft palates. Variation implies morphologic contradiction with stereotype presentations.

So numerous are the variations that occasionally they may account for sudden and unexpected hemorrhage during surgery and retarded healing or sphacelus of flaps following surgery.

Introduction

Cleft palate is a serious disfigurement resulting from cranio-facial malformation. While many aspects of normal and abnormal craniofacial morphogenesis have been clarified, little or no attention has been given major branches of the pterygopalatine division of the maxillary artery even though they are nutrient to structures in the vicinity of the cleft.

Spriestersbach, et al., (1973) theorized that vessel and nerve pathways are variable in cleft and non-cleft human palates. They postulated that aberrant craniofacial morphogenesis implies commensurate aberrant vascular supply. Dickson, et al., (1975) stated that current concepts of normal and abnormal palatal vascular anatomy are based upon studies of subhuman subjects and concluded that there is need for human palatal research. Guns (1970) reported that surgical treatment failures
may be caused by infection or sphacelus of flaps and implied need for investigation of palatal vascular details in man. It is generally believed that successful palatoplasties are very dependent upon morphologic knowledge and that special need exists for study of nerve and vessel pathways in human subjects. Therefore, arteriographic studies were undertaken to ascertain the pathways and ramifications of the greater palatine, posterior superior alveolar, infraorbital, and facial arteries in near-term human fetuses.

It is known that the third or pterygopalatine portion of the maxillary artery provides major branches to the maxilla, teeth, palate, and linings of the nose and sinuses. There is complete agreement among anatomists (Gardner, Gray and O'Rahilly, 1963; Romanes, 1964; Warwick and Williams, 1973; and Woodburne, 1973) as to the general distribution of these major vessels in the deep and superficial portions of the normal human face. However, arterial distribution in instances of cleft palate and the question of bilateral symmetry in human cleft and non-cleft palates remain to be established. It is hoped that this study will provide at least some vascular details to satisfy the expressed surgical need.

Materials and methods

Arteries in the head and neck of near-term human fetuses were perfused with either India ink or calcium carbonate in water (Maher and Swindle, 1962). The facial mid-third was excised en bloc from each of twelve samples - three samples of cleft palate and nine samples of non-cleft palate. Each necropsy was bounded above by the orbital floor, anterolaterally by the lips and cheeks, and below by the palatal mucosa. All necropsies were cleared (Spalteholz) to reveal the perfused arteries. Using first gross dissection to expose major branches, their identification and that of their ramifications were confirmed stereomicroscopically.

Over 2000 postmortem examinations of near-term human fetuses were made in search of cleft palate samples. Only three were found that were judged acceptable for arterial perfusion. The cleft in each case extended forward at the midline to the level of the the incisive canal (Figure 1). Because of the cleft extent in each sample, they are all of the same class, namely uranostaphyloschisis.

Results

1. The Greater Palatine Artery. Both right and left greater palatine arteries and their medial and lateral branches in each of the twelve samples were identified. Major vessel location was found similar in all samples. The major arteries passed forward on the bony surface of the palate from their respective greater palatine foramen and entered the incisive canal (Figure 4). Continuing through the canal, the arteries divided and anastomosed with one another and with other major arteries terminating in that vicinity. The greater palatine arteries were found
to anastomose with:
1. the superior alveolar artery (Figure 5).
2. nasal branches of the sphenopalatine artery and
3. Superior labial branches of the facial artery via palatine branches that extended through the intermaxillary fissure from the incisive canal area.

These anastomoses were observed in both facial halves of cleft and non-cleft palate subjects. The arterial connections appeared to be normal in form rather than to present any form of angioplasty.
FIGURE 2. Human fetus, near term, uranostaphyloschisis. Nasal view of the left palatogingival mucoperiosteum. Bone and teeth have been removed to visualize contributions of lateral branches (LB) of the left greater palatine artery to dental sacs and other dental structures. Depicted are: the left greater palatine artery (GPA), its medial branches (MB), and its lateral branches (LB). Sites of the central incisor (CI), lateral incisor (LI), cuspid (C), 1st deciduous molar (1st) and second deciduous molar (2nd) are indicated. Incisions lateral to the greater palatine artery will sever all supply from the palatal network to dentoperiodontal structures (see text). Small arrows indicate the reflected palatonasal soft tissue coverings at the cleft margin.
In the posterior palate of all twelve samples, the greater palatine arteries lay upon the bony surface. Their separated relationship to the bony palatal surface suggested cause for inscriptions representing arterial pathways seen on the surface of the palate of dried skeletal preparations. However, as the arteries passed forward, they gradually separated from the bony surface and became more peripheral anteriorly. In route they emitted medial and lateral branches that divided, joined, and subsequently formed a relatively large network (macronet).

The macronet emitted three sets of branches: 1) peripheral, 2) deep, and 3) recurrent perforating osseous branches. Peripherally directed branches diminished in diameter as they extended to the surface and formed a fine network (micronet) in the reticular portion of the lamina propria. From the micronet post-reticular end arteries arose that terminated as capillaries in the papillary portion of the lamina propria. Deeply directed branches formed a micronet in the periosteum. The periosteal network continued into the bony palate and was joined by the periosteal network from the nasal floor and vicinity. As a consequence,
FIGURE 4. Human fetus near term. Oral view of non-cleft palate. Greater palatine arteries and their principal medial and lateral branches injected with calcium carbonate in water. Bilateral arterial variation is illustrated. The terminal portion of the right greater palatine artery (RGPA) is recurrent and forms a strong anastomosis with the superior alveolar artery (SAA). (See Figure 5.) The left greater palatine artery (LGPA) divides in the anterior palate and forms a large medial branch (MB) and an antero-lateral branch (LB). The lateral branch is recurrent and forms a strong anastomosis with the ipsilateral superior alveolar artery. The medial branch divides into two branches equal in caliber. One branch passes between the central incisors and continues through the intermaxillary suture and into the lip where it forms a strong anastomosis with the superior labial artery. The second branch is recurrent, passes into the nasal floor via the incisive canal and forms a strong anastomosis with the left lateral nasal septal artery (NA) from the sphenopalatine artery.
FIGURE 5. Nasal view of the right palato-alveolar area of the same specimen illustrated in Figure 4. Depicted are: the right greater palatine artery (RGPA), superior alveolar artery (SAA), and a substantial portion of the infraorbital artery (IOA). Note the greater palatine-superior alveolar arterial anastomosis indicated by the small arrow.
three distinct palatal vascular strata were identified i.e., mucosal, submucosal, and periosteal. Occasionally the macronet emitted relatively large branches (recurrent perforating osseous branches) that entered minor palatal foramina distributed at random throughout the bony palate (Figure 6). These minor foramina are readily visible in dried skeletal preparations. While size, number, and location of medial and lateral branches and their perforating osseous branches varied in each sample examined, their distribution was similar in all palates.

In normal palates, the arterial network extended across the median raphe (Figure 7). Arrangement varied thereat possibly because of differences in the arrangement of fibrous connective tissue at the midline.

In the cleft palate samples, the palatal mucoperiosteum and its vascular contents were reflected around the bony stumps of the underdeveloped palatine processes and became continuous with corresponding structures of the nasal floor (Figures 2 and 3). Numerous arterial connections between nasal and palatal soft tissue linings were observed in addition to those provided by major connections via the incisive canal in both the cleft and non-cleft palate samples. In the cleft palate samples, however, arterial connections were made at bony defect margins and by perforating osseous arteries. In the normal palate samples, connections were made by way of the incisive canal and by perforating osseous arteries. In both types of palates, lateral branches of the greater palatine artery not only supplied the gingiva but extended into, through, and above the alveolar ridge and made substantial contributions to dental sacs and dental pulps of all the maxillary teeth (Figures 2, 3 and 6).

2. The Posterior Superior Alveolar Artery. The artery was found to arise (1) directly from the maxillary artery and (2) from the maxillary artery via a short trunk in common with the infraorbital artery. The artery passed forward in the maxilla above all developing maxillary teeth and emitted branches to their surrounding bony walls, to their dental sacs, and to their pulps. It extended forward as far as the central incisors in all samples examined (Figure 5). This observation is in sharp contrast with the traditional view that it supplies posterior dental structures only and that the anterior dental structures are supplied by branches from the infraorbital artery. Furthermore, terminal branches were found to form strong anastomoses with one or more major arteries terminating in the vicinity, namely:

1) the greater palatine artery;
2) nasal septal branches of the sphenopalatine artery;
3) superior labial branches of the facial artery via the intermaxillary fissure; and
4) its corresponding vessel on the contralateral side.

3. The Infraorbital and Facial Arteries. The infraorbital artery lies below the floor of the orbit and emerges into the face via the infraorbital foramen (Figure 5). In all samples examined, no branches (traditionally described as anterior-superior alveolar arteries from the infraorbital artery) were observed passing through small canals in the
maxilla to supply the incisors. Occasionally a short trunk was observed above and near the apex of the cuspid tooth that connected the posterior alveolar artery with that of the infraorbital artery. In the face, the infraorbital artery divided one or more times, and these branches anas-
FIGURE 7. Human fetus near term, non-cleft palate. Periosteal surface of the palatomucoperiosteum at the midline and vicinity. A portion of the submucosal arterial macro-net and a portion of the mucosal micronet are depicted. The small arrows indicate the approximate boundaries of the palatal raphe. All the arteries are filled with carbon ink whereas in Figure 6 only the greater palatine arteries and their principal medial and lateral branches are filled with carbon ink. Note the similarity as to arrangement of the submucosal macro-net in the mid-term and near term fetuses.

tomosed with branches of the facial artery to form the great facial network. Branches from this network extended to the buccal and labial gingiva, continued through and over the alveolar process, and made substantial contributions to the surrounding bone, dental sacs, and pulps of all the maxillary teeth.
Discussion

Observations herewith reported provide opportunities for several clinical conjectures. Variations in palatal arterial distribution cannot be determined before surgery. This unavoidable lack of foreknowledge signals need for surgical caution with regard to: 1) flap design, 2) stretching of palatal flaps to obtain better tissue approximation, 3) flap repositioning without stretching and 4) suturing repositioned flaps. Stretching a palatal mucoperiosteal pedicle flap also stretches vessels contained within it causing narrowing of their lumina and possible vascular occlusion. Repositioning a pedicle flap without stretching changes branch angles and may alter piezometric flow within the flap to such extents as to diminish supply to the repositioned pedicle. Sutures too tightly secured and perhaps inadvertently placed around primary nutritional sources to a flap may cause strangulation necrosis. Therefore, excessive manipulations of a pedicle flap may alter its blood supply causing chronic ischemia and subsequent sphaecelus of the flap. Necrotic flaps may become infected secondarily.

Lateral branches of the greater palatine arteries provide substantial contributions to all maxillary deciduous and permanent dental structures (Figure 2). Incisions made parallel to the alveolar ridge and lateral to the greater palatine artery are designed for purposes of moving the pedicle flap medially to close the cleft. These incisions completely sever nutritional supply from the palatine network to all the maxillary teeth. However, the developing dental structures are also supplied by dental branches from the superior alveolar artery (Figure 5) and gingival-osseous branches from the great facial network. Whether these major contributions are able to provide adequate nutritional sources for normal dental development or whether temporary nutritional loss from the palatine network as the results of sectioning might be responsible for morphologic defects in hard dental structures remains to be clarified.

The palatal mucoperiosteum is detached from its bony base in the preparation of a palatal pedicle flap, and as a result the recurrent osseous branches are severed. These branches vary in size, number, location, and distribution frequency. Bleeding from their cut stumps at the bony surface may be judged as being somewhat insignificant at the time of surgery. However, after the flap is repositioned, should bleeding continue from these severed osseous vascular arterial stumps, blood may pool beneath the repositioned flap. Prolonged postsurgical subperiosteal hemorrhage may forcibly detach the flap at the repositioned flap-osseous interface.

Terminal branches of the greater palatine artery were found to anastomose variously with: 1) the lateral nasal septal artery, 2) the superior alveolar artery, 3) labial branches of the facial artery via branches of the palatal artery that pass through the maxillary fissure or via the external nares, and 4) with its companion on the contralateral side. One or more combinations of these variations may occur in both facial halves (Figures 4 and 5). Were one or both greater palatine arteries severed at the
incisive canal, it would be impossible to state which artery (ies) presents the cut, bleeding stump (s) exiting at the incisive canal. If these various anastomoses were to occur in the canal or in the nasal floor and only one or two major branches emerged through the foramen, it would be impossible to state which of several possible arteries it is that contributes to the greatest blood volume output. Furthermore, crossover anastomoses between terminal branches of major vessels can occur. For example, terminal branches of the left greater palatine artery may make strong connections with terminal branches of the right superior alveolar artery.

In conclusion, the theoretical considerations proposed by Spriestersbach and co-workers (1973) that there may be variability in arterial arrangement in cleft and non-cleft human subjects has now been demonstrated.

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