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A study of the maxillary and sphenopalatine arteries in the pterygopalatine fossa and at the sphenopalatine foramen

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SUMMARY

Objectives: *Arterial ligation remains a key option in the treatment of persistent epistaxis and clarification of the arterial configuration of the distal maxillary/ sphenopalatine artery is important for understanding the rationale behind current surgical treatments. Greater understanding of the arterial anatomy will reduce the risk of technical failures and improve the reliability of surgical interventions for persistent epistaxis and will also be useful for surgeries involving the pterygopalatine fossa.*

Study Design: *Anatomical study in cadavers.*

Methods: *This is an anatomical study of 128 cadaveric tissue blocks containing the pterygopalatine fossa. In total, 118 tissue blocks were microdissected using a Watson-Barnet dissecting microscope. Ten injected tissue blocks were cleared by the Spalteholz technique. Photographic records were made.*

Results: *Analysis demonstrated three common configurations of the maxillary artery in the pterygopalatine fossa: a single looped form (18%) and two double-looped forms, 'E' (51%) and 'M' (31%). The maxillary artery bifurcates before the sphenopalatine foramen in 105 cases (89%). The sphenopalatine foramen lies at the posterior end of the middle turbinate; in 58% of cases it lies in both the superior and middle meati. Asymmetry in the size of the maxillary arteries was uncommon; only 3% could be described as 'dominant'.*

Conclusions: *The arterial configuration of the maxillary artery in the pterygopalatine fossa can be complex but may be classified into one of three forms. Some configurations may be more liable to lead to difficulties with branch identification during surgical treatment of epistaxis particularly in combination with an inadequate osteotomy. Clinicians should expect to find more than one vessel exiting the sphenopalatine foramen and actively search for these during surgery. Asymmetry in the maxillary/ sphenopalatine arteries is not common and contralateral ligations are not indicated.*

Key words: epistaxis, maxillary artery, arterial ligation, sphenopalatine artery, sphenopalatine foramen, pterygopalatine fossa

INTRODUCTION

Epistaxis is the most common ENT emergency [1] and in rare cases can be fatal. Difficulty in visualising the posterior nasal cavity hinders the precise identification and specific treatment of the bleeding site. Traditionally, packing has been the commonest modality of initial treatment [2] and those continuing to bleed or rebleed despite this non-specific treatment would be deemed 'persistent'. Further repacking under general anaesthesia (with or without septal surgery to improve access), embolization [3] or ligation of the maxillary artery [4,5] or ligation/cautery of the sphenopalatine artery [6] have all been advocated for further treatment, depending on the preference of individual centres.

Transantral ligation of the maxillary artery was once regarded as the most effective procedure for persistent posterior epistaxis [7] although it still had a significant reported failure and complication rates of around 10-17% on average [3]. Speculation on the reasons for unexplained failure of arterial ligation to control epistaxis was a recurring theme in the literature; some suggested inadequate technique, anastomotic anterograde filling, anastomotic retrograde filling [7] and aberrant vessels [8]. Uncertainty regarding the bleeding site and misconceptions of nasal vascular anatomy and physiology can lead to the proposal of additional and or alternative procedures for persistent bleeding. Revisiting the regional anatomy is appropriate with the

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establishment of endoscopic techniques of arterial ligation and or cautery as the first treatment option with lower rates of failure and complications.

MATERIALS AND METHODS

Sixty-four cadaveric heads (yielding 128 pterygopalatine fossae) belonging to the Laboratory of Human Anatomy of the University of Glasgow were used for this anatomical study.

Dissection and microdissection (n=118)

Tissue blocks containing the posterior antral wall and pterygopalatine fossa were taken from cadavers embalmed in the standard manner. The posterior portion of the lateral nasal wall was included to preserve the sphenopalatine foramen. The posterior antral wall was then completely osteotomised in a piecemeal fashion and the periosteum removed to reveal the vessels and nerves embedded in fibro-fatty tissue. Microdissection of the vessels of the pterygopalatine fossa was carried out with a Watson-Barnet dissecting microscope.

Photographic records were made at various stages of dissection to demonstrate the position and size of the vessels. Measurements of the diameter of the maxillary artery and its branches at various points and the dimensions of the sphenopalatine foramen were taken using vernier calipers accurate to 0.1 mm.

Spalteholz clearing of injected specimens (n=10)

5 other cadavers were injected with latex-Indian ink at the time of embalming. The 10 tissue blocks taken from these were then 'cleared' by the Spalteholz technique. This process involves fixation of decalcified blocks in a series of alcohol/ benzol solutions before immersion in a methylsalicylate/ benzyl benzoate mix which renders the tissue transparent and injected vessels are visible 'in situ'.

RESULTS

Pterygopalatine fossa

The pterygopalatine fossa approximates to the shape of a funnel flattened in the coronal plane. The fossa is bounded by the body of the sphenoid superiorly, and communicates with the ptergyomaxillary fissure laterally. The lateral wall of the nose forms the medial boundary whilst the sphenopalatine foramen connects the two in the form of a relatively long canal or fissure rather than a simple 'window'. The pterygopalatine fossa occupies the upper half/ two thirds of the posterior antral wall. It is wider superiorly, and then narrows down inferiorly with the apex pointing downwards into the canal for the greater palatine artery and nerve. The most superficial structure of the fossa is an inconstant thin-walled pterygopalatine vein (21% absent both sides and 59% absent on one side). The third part of the maxillary artery and its branches are tightly packed within the pterygopalatine fossa forming a layer superficial to the nerves (Figure 1).

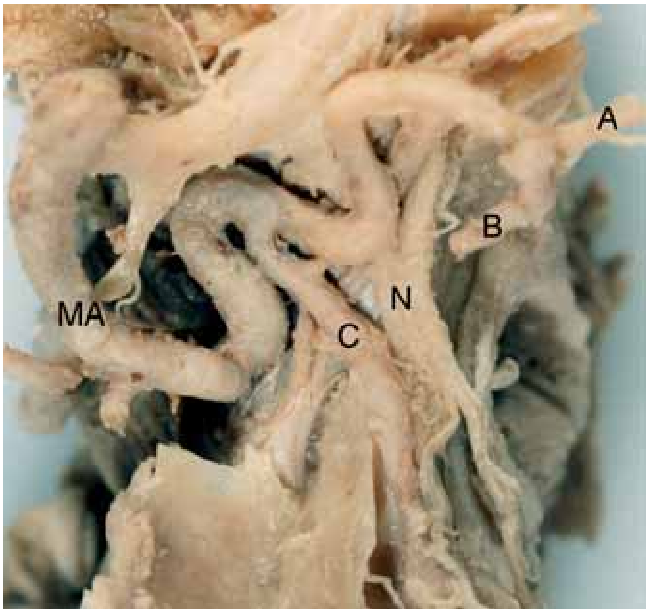

Figure 1. Photograph of the contents of the pterygopalatine fossa in situ demonstrating main maxillary artery (MA), sphenopalatine (A), posterior nasal artery (B), greater palatine artery (C) and nerve (N).

Arterial Configuration

The use of isolated tissue blocks allowed comprehensive dissections of the arteries in the pterygopalatine fossa and around the sphenopalatine foramen. Analysis of the patterns of arterial branching demonstrated two general configurations: **single looped** (looser form) (18%) and **double looped** (tighter form) (82%). In the latter form, the loops were orientated either on top of each other like an 'E' or 'epsilon' (51%), or side by side like a 'M' shape (31%) (Figure 2a-c).

Sphenopalatine Foramen

The opening of the sphenopalatine foramen is a vertically orientated oval at the end of a 4-7 mm canal located in the superomedial corner of the triangular pterygoplatine fossa. The mean vertical diameter is 6.2 mm (4.5-7.5 mm) and the mean horizontal diameter is 5.1 mm (3.5-6.0 mm).

The sphenopalatine foramen was consistently found in the lower part of the superior meatus at the posterior end of the attachment of the middle turbinate on the lateral nasal wall with some variation with respect to its exact relation to the middle turbinate. The inferior portion of sphenopalatine foramen lies below the posterior end of the line of attachment of the middle turbinate (ie partly in the middle meatus) and crista ethmoidalis in 68 (58%) of the cases. In 6 cases (5%) there is a broader bony bridge across separating the main foramen from the smaller accessory foramen that is usually placed inferior to the main foramen; only one of these accessory foramina transmitted a small vascular bundle.

The maxillary artery terminates as the sphenopalatine artery and the posterior nasal artery (Terminological Anatomica)

Figure 2. After the third part of the maxillary artery in the pterygopalatine fossa had been dissected out in situ, representative cases were removed for improved clarity during photography.
a). Single-looped configuration. Looser single-looped configuration 18%.

Figure 2(b). More tightly packed a'E' form double loop configuration 57%.

Figure 2(c). 'M' form double loop configuration 31%.

within the pterygopalatine fossa (that is before the sphenopalatine foramen) in 105 (89%). Of these, there were two, three and four branches in 81, 22 and 2 cases respectively (69%, 19% and 2% respectively). This means that in most cases, more than one vessel will traverse the sphenopalatine foramen and this must be borne in mind when dissecting the mucosa around the foramen/ foramina during endoscopic techniques. It was found that the maxillary artery is less likely to divide before the sphenopalatine foramen (38%) if it was in a single looped (loose) form in the pterygopalatine fossa.

Symmetry and size of the maxillary arteries

There was little difference in the size of the maxillary arteries between right and left sides. The mean for the left maxillary artery was 4.50 mm and the right 4.62 mm (Table 1). Although more than half (59%) of the maxillary arteries were 4.0 mm or less in size on one side or both, only a small number of these (3) showed a significant (more than 1.5 times) size difference between left and right sides that would fit into a definition of having 'dominant' maxillary arteries [9].

Spalteholz clearing

These preparations confirmed the findings of the pterygopalatine fossa from conventional microdissections provided novel demonstrations of the 'in-situ' configuration of the arteries in 3 dimensions.

Table 1. Average diameter of arteries (mm). The mean diameters of the arteries on the left and right sides are given in the first row. The number of 'asymmetric' arteries where one side is 10 mm or 20 mm larger than the other side is given in the second and third rows respectively.

N=118	**Left**	**Right**
Mean	4.50	4.62
>10mm greater than other side	8	11
>20mm greater than other side	1	2

DISCUSSION

This study includes the largest series of dissections of the distal maxillary artery and its branches in the pterygopalatine fossa and around the sphenopalatine foramen. Comprehensive microdissection was very time consuming but was preferred over 'xylene dissection' [10], which was found to be only partially effective and there were health and safety concerns. The arterial configurations were convoluted and complex with loops and multiple branches, making it potentially difficult to definitively identify individual branches at the time of surgery [8]. They have been described as being very variable with peaks and troughs of up to 15 mm with no discernible pattern [11]. However this study has shown that the configurations can be classified into one of three types: a single looped form, and 'E' and 'M' double looped forms. The 'M' form with two vertically stacked loops can be particularly misleading when combined with an inadequate osteotomy. Metson [7] advocates the removal of the entire posterior wall to improve visualisation of the vessels of the pterygopalatine fossa. Pearson [8] stated that there was increasing tortuosity with age in his study of 21 specimens, however a consistent trend could not be demonstrated in this study.

In the majority of cases there will be 2 or more vessels at the sphenopalatine foramen, these will need to be found at the time of operation during endoscopic ligation/ cautery and dealt appropriately. This figure is in agreement with most studies [12,13] although O'Flynn [14] found that there was usually only a single artery at sphenopalatine foramen. Comprehensive microdissections though time-consuming have an advantage over studies that rely on injections as the vessels may be unfilled in such cases [13]. The sphenopalatine foramen lies just above the level of the attachment of the middle turbinate but the vessels first run downwards in the mucosa of the lateral nasal wall meaning they are accessible by 'inferior' approaches to the sphenopalatine foramen. Studying cadavers rather than relying on osteologic features of skulls [19] that could be subject to artefactual damage, improves the reliability of the observations. The sphenopalatine foramen has a variable relationship to the posterior end of middle turbinate and has a variable number of vessels passing through it – these variations are important to bear in mind in practice.

Our study also demonstrates that the maxillary arteries are generally symmetrical in size if not configuration. One study [9] had found asymmetry in 6 of 12 specimens, with a dominant maxillary artery defined as one side being 1.5 times the diameter of the contralateral artery. It was proposed that if maxillary arteries smaller than 4 mm were found on one side, the contralateral side should be also be ligated on the basis that the contralateral vessel would be bigger in compensation and thus also more likely to refill the bleeding point. This highlights several misconceptions in nasal vascular anatomy/ physiology.

Firstly, if a particular vessel is abnormally small, it will be compensated by ipsilateral neighbouring vessels, rather than the corresponding contralateral vessel – this follows from their embryological development and has been elegantly shown in dissections of the arteries of the face and confirmed by angiography [15]. In this study, 59% of the maxillary arteries would be deemed 'small' yet only 3 cases would be consistent with a definition of 'dominant artery' demonstrating that contralateral compensation is not commonly seen in the nasal cavity.

Secondly, the aim of arterial ligation in epistaxis is simply to *reduce* pressure in the bleeding vessel sufficiently to allow the clotting (and then healing) processes to occur and not to totally abolish flow, otherwise ischaemic necrosis would be a common consequence (there is a single case report of inferior turbinate necrosis after endoscopic ligation of the sphenopalatine artery in this study [16]. Consequently, the technique is *expected* to fail in a proportion of cases when the reduction in pressure is insufficient. This point has been picked up by some authors in this study [17], but there still seems to be the need to invoke other factors to account for 'unexplained failures' such as 'aberrant pharyngeal arteries' or contralateral anastomoses.

For our analysis, we classify arteries in the nasal cavity as being either first or second order vessels with respect to the bleeding point. First order vessels would be vessels whose anatomic territories are adjacent to that of the bleeding vessel and whose dynamic territories would potentially overlap the bleeding point. Thus, in the commonest scenario where bleeding comes from sphenopalatine artery, the first order vessels would be the anterior and posterior ethmoidal arteries (internal carotid artery), greater palatine artery (external carotid artery) and septal branch of superior labial artery (external carotid artery). It is the flow in these vessels that would be most likely to contribute to continuing perfusion of the territory of the sphenopalatine artery territory and continued bleeding. This is borne out by angiographic studies [3,18]. Thus logically AEA ligation may be complementary to ligation of the maxillary/ sphenopalatine artery [19] but its effectiveness would be difficult to predict, particularly since the AEA is absent in 14.3% [20]. Second order vessels are those that (potentially) connect with first order arteries. However as, they are more distant from the bleeding point, and are separated by further set of choke vessels (physiological or anatomical), then simple laws of physics dictate that they would contribute considerably less to reperfusion of the bleeding point at least in the acute phase. These include vessels that have been implicated in previous studies such as the pharyngeal branch (small in calibre and travels through a narrow bony canal) and any contralateral anastomoses eg greater palatine to greater palatine artery or labial-to-labial artery, etc. That is, it is logical to treat vessels in the nose wherever possible, as close to the bleeding point as possible – ligation of the maxillary artery would mean that subsequent angiography or embolization would be less effective if needed.

Table 2. Results of articles reporting on results of transantral ligation. (12 papers, those not reporting a complication rate were excluded). For this analysis, the success rate is generally defined as no re-bleeding requiring surgical intervention in the same admission.

Author	Year	Number of patients	Success rate %	Complications %
Chandler [4]	1965	21	100	1
Lofgren [21]	1971	8	100	0
Rosnagle [5]	1973	50	90	16
Montgomery [22]	1980	60	85	3
McDonald [23]	1980	46	85	26
Wang [24]	1981	35	86	40
Schaitkin [25]	1981	17	76	47
Simpson [26]	1982	14	93	0
Nair [17]	1982	12	92	33
Small [1]	1984	16	100	38
Premachandra [9]	1992	23	100	26
Assimakopoulos [27]	1992	16	88	25
		Total = 279	Mean = 91.3%	Mean = 21.3%

Table 3. Results of articles reporting on endoscopic ligation (12 papers).

Author	Year	Number of patients	Success rate %	Complications %
Sulsenti [28]	1987	17	100	0
Budrovich [29]	1992	33	100	0
Winstead [30]	1996	10	90	0
White [31]	1996	2	100	0
El-Guindy [32]	1998	9	100	0
Pritkin [33]	1998	10	100	0
Snyderman [34]	1999	38	92	0
Ram [35]	2000	6	83	0
O'Flynn [14]	2000	12	100	0
Wormwald [36]	2000	13	92	0
Cascio [37]	2000	23	96	0
Voegels [38]	2001	11	100	0
Abdelkader [39]	2007	27	100	0
		Total=179	Mean=96.4%	Mean=0%

Table 4 Results of articles reporting on endoscopic cautery/diathermy (17 papers).

Author	Year	Number of patients	Success rate %	Complications %
Anderson [40]	1984	10	100	0
Borgstein [41]	1987	12	100	0
Wurman [42]	1988	18	67	6
Bingham [43]	1991	2	100	0
McGarry [44]	1991	12	92	0
O'Leary-Stickney [45]	1992	6	83	0
Elwany [46]	1996	38	68	3
Kaluskar [47]	1996	18	100	0
Pollice [48]	1997	30	100	3
Rudert [49]	1997	31	97	0
Frikart [50]	1998	139	92	0
Srinivasan [51]	2000	10	90	0
Tsai [52]	2002	9	89	0
Prepageran [53]	2003	4	100	0
Wiorowski [54]	2004	10	90	0
Durr [55]	2004	17	94	0
Abdelkader [39]	2007	8	100	0
		Total=364	Mean=91.9%	Mean=0.7%

All objective evidence from angiography and anatomical dissections, show substantial anastomosis between ipsilateral vessels only and there is no objective evidence of refilling of the nasal vessels from contralateral vessels. Many 'potential' routes do exist but refill very slowly. Angiographic work [18] demonstrates that 'transmedian anastomoses are common but are insufficient for ensuring supply of the contralateral maxillary artery system but sufficient to demonstrate adjacent parts of the contralateral branches'. Late refilling several months to years after is a different matter and can be due to reperfusion from many sources (angiography) eg from the internal carotid artery, occipital arteries etc.

Thus ligation of a unilaterally small maxillary artery may be associated with a higher chance of failure because first order vessels will be larger and will reperfuse the bleeding point much more effectively and ligation of contralateral vessels in such cases would not be beneficial.

From an extensive literature review, endoscopic techniques seem to have a lower failure and complication rate compared to transantral ligation (table 2, 3 and 4). Transantral ligation has an average success rate of 91.3% compared to 96.4% and 91.9% in endoscopic ligation and cautery respectively. Major complications with endoscopic techniques are near zero compared to an average of 20% in transantral ligation. However, it is inappropriate to draw too many conclusions from the simple analysis: some papers have very small numbers, some do not specifically mention complication rates whilst others also mention minor as well as major complications [34] It could be argued that distal clipping occludes the flow at a level that is distal to most retrograde anastomotic connections making it theoretically more effective and logical [14]. The major difference between transantral and endoscopic may simply be improved identification of vessels or at least there is not an actual need to correctly identify specific vessels, to ensure that the correct vessels are treated correctly. Pearson suggested that there were '3 essential clips' [8]. Endoscopic ligation/ cautery is replacing transantral techniques in most centres [31,32] in the treatment of persistent posterior epistaxis though more widespread usage particularly in the acute setting, is limited by the necessity of extra resources specialized equipment, appropriate staffing and experience.

The tightly packed arteries with a fragile thin-walled vein are vulnerable to damage during surgery involving the pterygopalatine fossa. Improved understanding of the arterial configuration within the fossa would allow safer surgical approaches when surgery is necessary for infections or neoplastic processes in this space or for access to the infratemporal fossa.

CONCLUSION

Care should be taken approaching dissection and identification of the vascular layer (thin vein and tightly packed arteries) of the pterygopalatine fossa. Although the configuration of the distal maxillary artery can be complex, it can be categorized for simplification into one of three subtypes, allowing the arterial anatomy of the pterygopalatine fossa to be more easily understood leading to safer surgery. Some configurations are more likely to lead to confusion particularly when combined with small posterior wall osteotomies.

More than one artery should be expected to exit from the pterygopalatine fossa into the nasal cavity via the sphenopalatine foramen, additional branches should be sought out specifically with careful dissection to reduce the chances of clipping/ cautery failing due to inadequate treatment.

Asymmetry of the maxillary / sphenopalatine arteries is not common. Contralateral ligation / cautery is not indicated; generally, treating epistaxis by ligating / cauterizing vessels in the nose close to the bleeding point will be most effective.

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ANNOUNCEMENT