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Anatomical considerations in endoscopic lacrimal surgery

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ABSTRACT

Purpose: To provide a review of the anatomy of the lacrimal drainage system and lateral wall of the nose pertaining to endoscopic dacryocystorhinostomy.
Methods: The authors performed a PubMed search of articles published pertaining to the anatomy of the lateral wall of the nose and the anatomy of endonasal and external dacryocystorhinostomy surgery.
Results: The article covers the regional surface and surgical anatomy for endoscopic dacryocystorhinostomy (DCR), including the maxillary line, middle turbinate, agger nasi air cell, lacrimal sac and fossa and the upper portion of the nasolacrimal drainage system. It also explores the dimensions and location of bony ostium formation to ensure full exposure and marsupialisation of the lacrimal sac. Finally, it covers the anatomy of potential complications of endoscopic DCR surgery including penetration of the skull base and orbit, inadvertent entry to the maxillary sinus and breach of the skin.
Conclusion: A good understanding of the anatomy of the lacrimal drainage system and the lateral wall of the nose will increase the likelihood of successful surgery and minimize the risk of complications and damage to neighbouring structures such as the orbit and skull base.

Contents

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1. Introduction

A good understanding of the anatomy of the lacrimal drainage system and the lateral wall of the nose is fundamental for lacrimal surgery. It will enable the creation of an adequately sized and appropriately positioned bony ostium to expose and marsupialize the lacrimal sac. This will increase the likelihood of successful surgery and minimize the risk of complications and damage to neighboring structures such as the orbit and skull base.

2. Methods

A Medline search was performed on PubMed using the terms 'anatomy', 'dacryocystorhinostomy', 'endoscopic', 'lateral nasal wall', 'maxillary line', 'middle turbinate', 'frontal process of maxilla', 'agger nasi' 'lacrimal bone', 'lacrimal fossa', 'ostium' 'lacrimal sac', 'nasolacrimal duct', 'punctum', 'canaliculus' and 'complication'. There was no restriction on the date of publication. Relevant papers were read and information and data pertinent to the surgical anatomy of endoscopic DCR included in this review.

3. Surface anatomy (Fig. 1)

The middle turbinate and the maxillary line are the two major endoscopic surface landmarks for localisation of the lacrimal sac when performing intranasal dacryocystorhinostomy (DCR). They provide a very good guide to the underlying structures although cannot be definitively relied upon (Ali et al., 2014).

3.1. Maxillary line

The maxillary line is the projection into the lateral wall of the nose of the medial most aspect of the frontal process of the maxilla.

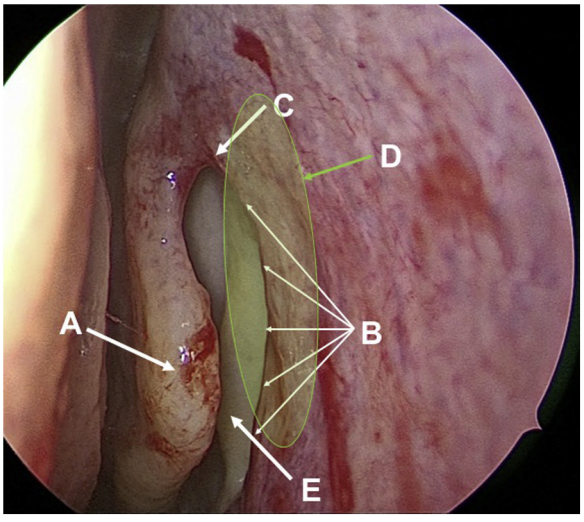

Fig. 1. Surface anatomy of the lateral wall of the nose in the region of the lacrimal sac.
A: middle turbinate.
B: maxillary line.
C: axilla of middle turbinate.
D: approximate location of underlying lacrimal sac.
E: vertical portion of the uncinate.

It is a curvilinear eminence that runs from the axilla of the middle turbinate to the root of the inferior turbinate. It is a relatively constant surgical landmark used to determine the location of the nasal mucosal flap.

3.2. The middle turbinate

The middle turbinate inserts onto the thick bone of the frontal process of the maxilla and the frontal bone. The anterior most line of this insertion is called the axilla. The axilla is a constant landmark used to orientate DCR surgery, as the lacrimal fossa predictably lies adjacent and extending superiorly, laterally and anteriorly to it. The middle turbinate and axilla are used to guide the supero-inferior dimension of nasal mucosal flap formation, with the lacrimal sac extending around 4–10 mm above the axilla (and around 5 mm above the internal ostium) and to a position in line with approximately half to two thirds of the way down the middle turbinate.(Wormald et al., 2000) This superior extension was not noted in earlier anatomical text but has since been reported in Caucasian, Asian and Turkish populations and removal of bone to expose this area has been suggested to be particularly important for improving long-term success rates (Fayet et al., 2005; Orhan et al., 2009; Woo et al., 2011).

3.3. Vertical portion of the uncinate and the bulla ethmoidalis

The middle turbinate can be retracted slightly medially to expose the middle meatus bounded laterally by the vertical portion of the uncinate process, posteriorly by the bulla ethmoidalis, superiorly by the agar nasi cell, formed by the insertion of the uncinate process in to the lateral nasal wall and inferiorly by the inferior turbinate. The frontal recess and maxillary sinus ostium both open into the middle meatus. The uncinate process is a thin sickle-shaped bone, comprised of a vertical portion that attaches to the lateral nasal wall. It superior insertion is variable, and although typically it attaches to the frontal process of the axilla, it may also insert directly into the skull base or into the superior portion of the middle turbinate. Inferiorly, its horizontal portion inserts into the inferior turbinate. The uncinate process is typically left untouched during routine DCR procedure, serving as the most posterior limit of the mucosal flap elevation. In Asian patients, where it may project more anteriorly to overly the posterior aspect of the lacrimal, some surgeons have advocated its removal to adequately expose the sac (Fayet et al., 2002; Soyka et al., 2010; Zhang et al., 2006). When performing routine DCR, the uncinate process may inadvertently be fractured or removed during mucosal elevation or lacrimal bone removal. Although this does not typically result in post-operative issues, lateral displacement of this structure, could theoretically narrow the maxillary ostium and result in an anatomical obstruction of the maxillary ostium. This may explain the approximately 1% risk of sinusitis developing after DCR surgery. At the posterior limit of the middle meatus is the bulla ethmoidalis, formed by the anterior ethmoid cell or cells. Like the uncinate process, its attachment is the lateral wall of the nose, but it typically projects more medially than the uncinate, making it sometime visible when performing a DCR. Instrumentation of the bulla ethmoidalis is not required in DCR surgery.

4. Step-by-step surgical anatomy

4.1. Local anaesthetic injection

The nasal mucosa is a respiratory ciliated epithelium containing goblet cells with a relatively vascular submucosal layer. Injecting local anaesthetic with adrenaline submucosally into the region of the lateral nasal wall adjacent to the axilla of the middle turbinate reduces bleeding and may improve the surgical field. As manipulation of the middle turbinate is quite stimulating, injection in this region may also assist in supressing intra-operative pain and its associated effect on haemaodynamic parameters.

4.2. Raising nasal mucosal flap

Although raising a nasal mucosal flap is not mandatory, preponderates of this technique, including the authors, believe that a flap can be used to abut against the posterior lacrimal sac flap to maintain a mucosal lined nasolacrimal drainage pathway and minimize bone exposure at the completion of the procedure. This in turn will improve post-operative healing, facilitating a predictably high success rate. For a posteriorly based flap, the superior incision is made 8–10 mm above the insertion of the middle turbinate, with an inferior incision approximately half way down the middle turbinate or just above the insertion of the inferior turbinate into the lateral nasal wall. The anterior extent of these incisions varies between surgeons, with some preferring a larger flap (brought forward approximately 10 mm) that can be comfortably reflected over the middle turbinate but leaves more exposed bone at the end of the procedure, and others preferring a smaller flap (brought forward 5 mm) that may be more prone to intruding on the surgical field, but leaves less exposed bone. The horizontal incisions are joined with a vertical incision. The flap is raised from the bone and over the maxillary line to expose the frontal process of the maxilla and the lacrimal bone (Fig. 3).

4.3. The lacrimal fossa, maxillary bone and lacrimal bone

The lacrimal sac sits in the lacrimal fossa. It is 7.2–10.4 mm wide, approximately 16 mm high and 2–4 mm deep in Caucasians (Chastain et al., 2005; Shams et al., 2012). The fossa is formed from the robust frontal process of the maxilla (FPM) anteriorly and the thin lacrimal bone (LB) posteriorly which meet at the lacrimomaxillary suture (LMS). It is bordered by the anterior lacrimal crest (projecting from the FPM) anteriorly and posterior lacrimal crest (projecting from the LB) posteriorly (Fig. 2). The location of the LMS is variable and has ethnic patterns. For example the fossa has been found to be maxillary bone dominant in 32% (15/47) of Caucasian cadaveric orbits but only in 12% and 8.3% of Turkish and Indian skulls respectively (Bisaria et al., 1989; Orhan et al., 2009; Shams et al., 2012). If the suture line is more posterior (FPM dominant fossa), greater force or use of the drill may be required to form the ostium than a more anteriorly placed LMS when the thin LB can be lifted with a fine tool such as a round knife. The lacrimal fossa shallows at its superior end and meets the frontal bone at the frontomaxillary and frontolacrimal sutures (Bisaria et al., 1989). Here, the FPM is thicker and constitutes a greater proportion of the fossa (sometimes with no lacrimal bone at all superiorly) further supporting the place of powered endoscopic DCR to create an ostium that fully exposes the superior aspect of the lacrimal sac (Woo et al., 2011; Wormald et al., 2000). The inferior end of the lacrimal fossa merges into the nasolacrimal canal which is enclosed by the FPM laterally and the lacrimal bone and inferior turbinate bone medially. The inferior extent of the lacrimal sac is variable, but generally an ostium that extends to the middle or lower third of the middle turbinate is adequate. The angulation of the FPM also impacts on bony ostium formation. Although not formally studied, anecdotally if the FPM is orientated in a more sagittal plane (sometimes describe as a shallow FPM) it is harder to grasp with rongeurs and may require more drilling than a FMP that is angled more towards the coronal plane. In the experience of the authors, this is often the case in patients of Asian descent, in whom greater use of the drill is required.

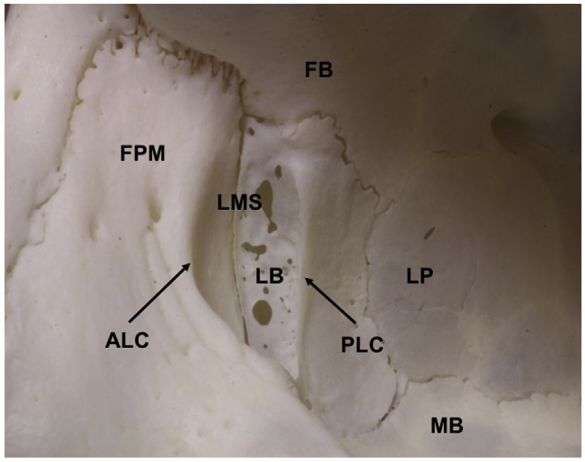

Fig. 2. The lacrimal fossa, viewed from externally (the external DCR view). Note the relatively anterior lacrimomaxillary suture line, making this a lacrimal bone dominant fossa.
FPM: frontal process of the maxilla.
FB: frontal bone.
LB: lacrimal bone.
LP: lamina papyracea.
MB: maxillary bone.
LMS: lacrimomaxillary suture.

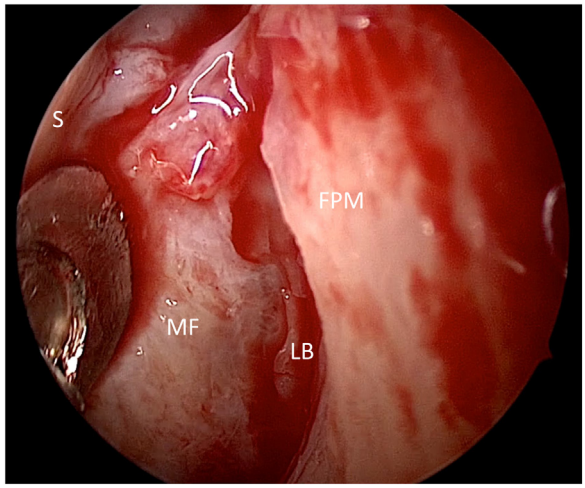

Fig. 3. The nasal mucosal flap and the frontal process of the maxilla in a left endoscopic DCR.
S: septum.
MF: mucosal flap reflected backwards over the middle turbinate.
FPM: frontal process of the maxilla.
LB: lacrimal bone.

4.4. The agger nasi air cell

The agger nasi – from the Latin meaning nasal mound – is the anterior most ethmoid air cell. It is present in 80–98.5% of individuals and was observed as early as 1911 to extend anterior to the lacrimo-maxillary suture in 86/100 skulls and was subsequently shown to extend anterior to the posterior lacrimal crest in 41–90%

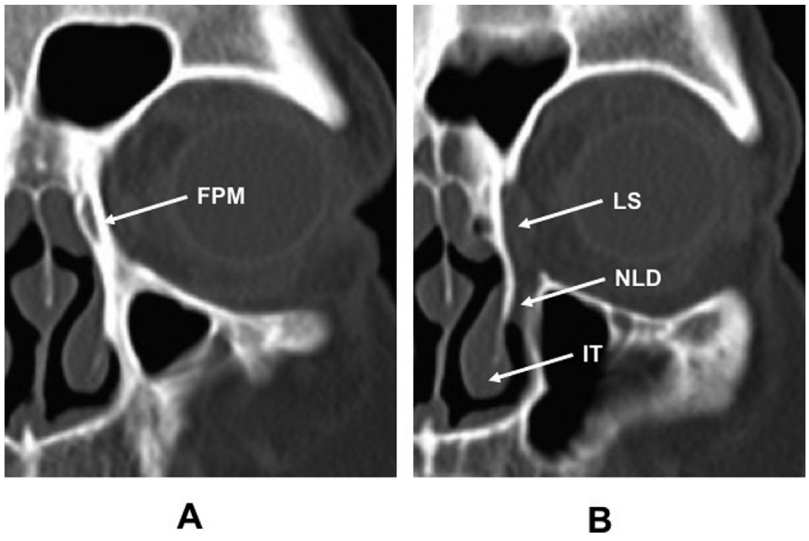

Fig. 4. Coronal CT scans of lacrimal sac region.
Scan A:
FPM: frontal process of maxilla.
Scan B (2 mm posterior to scan A)
LS: lacrimal sac.
NLD: nasolacrimal duct.
IT: inferior turbinate.

of individuals (Lee et al., 2004; Liang et al., 2014; Soyka et al., 2010; Whitnall, 1911; Woo et al., 2011; Zhang et al., 2006). It lies adjacent to the supero-posterior aspect of the lacrimal sac and therefore opening the agger nasi during DCR is important indication of adequate supero-posterior exposure of the lacrimal sac (Fig. 4).

4.5. Bony ostium

Ostial formation typically requires the use of the rongeur and drill (powered endo DCR) to maximize the exposure of the lacrimal sac and ensure that a well-placed bony ostium is formed. This will allow full marsupialisation of the lacrimal sac and provide at least 3–5 mm of bony clearance around the common canalicular exit (internal ostium), increasing the likelihood of a successful outcome (Chan and Selva, 2013; Lin et al., 2017; Paik et al., 2013; Welham and Wulc, 1987; Wormald et al., 2000).

4.6. Probing the lacrimal punctum, canaliculi and sac

The lacrimal sac is usually tented medially into the nose to provide counter traction during lacrimal sac incision, unless it already contains a tense mucocoele. The probing is done by passing probe (for example Bowman 00 size) from either the inferior or superior lacrimal punctum into the lacrimal sac. Familiarity with the anatomy of the upper drainage system and the technique of probing will minimise the risk of canalicular damage such as false passage formation or mucosal lining damage with subsequent stricture, which could prevent a DCR being successful. The inferior and superior punctum are located around 5 mm from the medial commissure with the inferior generally being slightly lateral to the superior. They are around 1 mm in diameter. The punctum opens into the vertical portion of the canaliculus which lies within the medial tarsal plate, and is 2.4–2.6 mm long in the lower lid and 2.8 mm in the upper lid and is directed slightly anteriorly and laterally (by 5°) (Hwang et al., 2005; Kakizaki et al., 2008; Takahashi et al., 2011). The probe must then be orientated 90 degrees medially to pass along the horizontal portion of the canaliculus which is angled posteriorly to pass beneath the medial canthal tendon and is 7–13 mm long and inclined slightly towards its fellow canaliculus (Sultanov, 1995). The inferior and superior canaliculi meet to form the common canaliculus which changes orientation to a slight anterior angulation and travels a further few millimetres to open into the lacrimal sac (Bedrossian, 2002; Tucker et al., 1996). In up to 10% of individuals the inferior and superior canaliculi have separate openings into the sac.

The lacrimal sac is stratified columnar epithelial lined cavity with the exit of the common canaliculus around three quarters of the way up its medial wall. It is usually tented up with a lacrimal probe to provide countertraction for lacrimal sac incision. The vertical incision runs from the superior most to inferior most extent of the middle of the lateral wall of the sac, ensuring that the blade is perpendicular to the sac so as not to shelve the incision in the mucosa, which can often be thickened from chronic inflammation. This forms an anterior and posterior leaf and horizontal incisions are made at the top and bottom of each of these to allow them to reflect anteriorly and posteriorly respectively.

5. Complications

DCR surgery requires a good understanding of the relationship between the lateral wall of the nose and the orbit, the skull base and the maxillary sinus, each of which can be breached intraoperatively and an awareness of the regional vascular anatomy to prevent or manage haemorrhage (Fayet et al., 2004).

5.1. Penetrating the skull base

In external DCR, the medial canthus or medial canthal tendon can be used as a landmark with ostium formation generally not extending more than around 3 mm above these structures. In endoscopic DCR if the mucosal flap and bony ostium are correctly located and the underlying lacrimal sac exposed, it is extremely unlikely that the skull base would be reached during ostium formation as it would require extensive removal of the thick frontal bone. However, the skull base can be breached by a spiral fracture extending through the frontal bone caused by excessive manipulation of the middle turbinate which inserts into the skull base or from aggressive twisting of rongeur during bone removal or by aggressive use

of the Killian speculum on the nasal septum to increase the volume of the nasal cavity (Fayet et al., 2007).

5.2. Penetrating the orbit

The root of the vertical portion of the uncinate may be partially detached during endoscopic DCR exposing the anterior part of the lamina papyracea which forms most of the medial wall of the orbit. This thin and fragile bone can be inadvertently removed with the lacrimal bone exposing periorbita, or orbital fat if the periorbita is breached. This does not usually have adverse consequences if the structures within the orbit are not traumatized.

5.3. Penetrating the maxillary sinus

The maxillary sinus is located beneath the orbit, with its ostium in the middle meatus guarded by the uncinate. It is typically postero-inferior to the DCR bony ostium, but it can be inadvertently exposed at the inferior end of either a large or a misplaced ostium. There is no evidence that this complication has adverse consequences, although theoretically, the formation of an additional ostium may impact on sinus mucus circulation and drainage.

5.4. Skin perforation

In contrast to external approach DCR surgery, while the anatomy of the internal aspect of the lateral wall of the nose is well visualised and understood, the proximity to the skin may not be as easily perceived. Orbicularis oculi muscle and skin lie on the lateral side of the lacrimal sac. These are usually not encountered in routine primary DCR, but in complex cases and particularly in redo surgery and/or with the use of excessive diathermy or laser, these can be breached creating a skin fistula (Yeniad et al., 2011).

5.5. Bleeding

There are no 'named' neurovascular bundles in the area of nasal mucosal elevation, bony ostium formation or lacrimal sac marsupialisation. However, challenging bleeds can arise from small vessels, with the agger nasi being a common source.

6. Conclusion

Endoscopic DCR is becoming increasingly widely adopted and is now the preferred DCR technique in many centres. Safe and successful surgery requires a good three-dimensional understanding of a challenging anatomical space.

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