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Improving Recognition for Risk of Iatrogenic Skull Base Injury in Endoscopic Sinus Surgery Using the Gera and Thailand-Malaysia-Singapore (TMS) Classifications

A 31-year-old man diagnosed with type 2 chronic rhinosinusitis with nasal polyps, initially presenting with a 1-year history of nasal blockage and anosmia, was refractory to medical therapy and had been advised to undergo endoscopic sinus surgery (ESS). Bilateral frontal sinusotomy and complete ethmoidectomy were needed to ensure adequate delivery of post-operative topical steroids. During this portion of ESS, the anterior skull base would be vulnerable to iatrogenic injury. How could the surgeon prepare pre-operatively to avoid such a complication?

Despite advances in imaging technology, instrumentation and surgical techniques for ESS, complications may still happen. Iatrogenic injury to the anterior skull base causing a cerebrospinal fluid (CSF) leak is one of the dreaded complications of ESS. The anterior skull base is composed of the cribriform plate and the fovea ethmoidalis or ethmoid roof. These bony structures are

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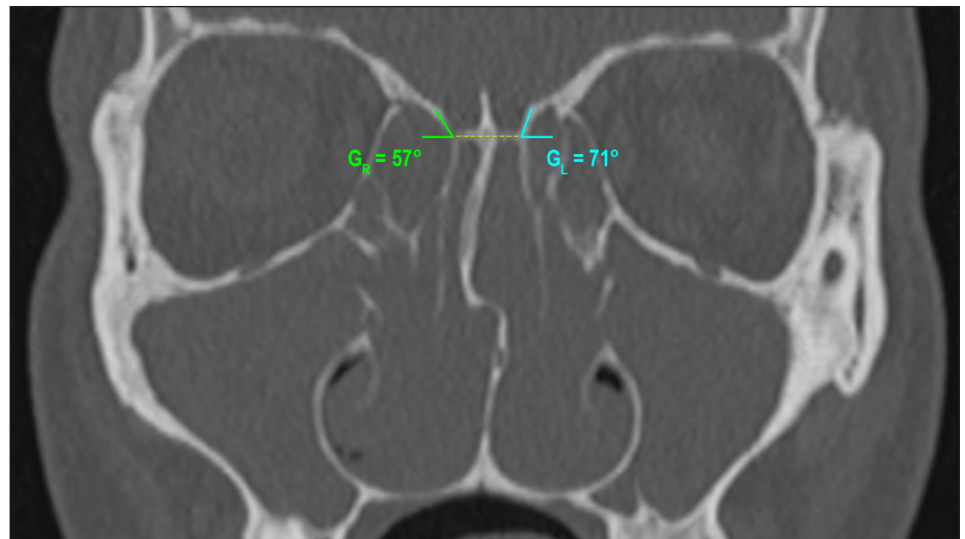


Figure 1. Paranasal sinus CT, coronal plane, bone window, at the level of the fronto-ethmoid angle, generated using the 3D MPR tool of Horos™ DICOM Viewer. The horizontal broken line corresponds to the level of the cribriform plate. This coronal slice shows the Gera classification. On the right side, the measured angle is 57° (GR) while on the left side, 71° (GL). Both angles are classified as Gera class II, or medium risk for iatrogenic injury. The Keros classification, as indicated by the depth of the olfactory fossa, is 2.4 mm on the right, or Keros type 1, and 4.4 mm on the left, or Keros type 2 (not shown in the image).

Keywords: paranasal sinuses; computed tomography; endoscopic surgery; cerebrospinal fluid leak

connected by the lateral lamella of the cribriform plate (LLCP) which delineates the lateral border of the olfactory fossa. The LLCP is known as the most vulnerable structure of the anterior skull base during ESS especially during ethmoidectomy and frontal sinusotomy.

Careful pre-operative evaluation of the paranasal sinus computed tomography (PNS CT) scan helps decrease the risk of this dreaded complication, but what exactly should be assessed? For the general otolaryngologist, the Keros classification has been the cornerstone of assessing the anterior skull base for risk of iatrogenic injury.¹ It distinguishes the depth of the olfactory fossa into 3 types: type 1 (1 to 3 mm); type 2 (4 to 7 mm); and type 3 (8 to 13 mm). Since its inception in 1962, the Keros classification has been long taught to aspiring otolaryngologists with the Keros type 3 posing the greatest risk of iatrogenic injury. However, it has been also pointed out that the classification has its limitations. It does not take into account the shape nor the slope of the anterior skull base in the coronal plane.²

In 2018, Gera *et al.* speculated that a percentage of patients classified as low risk using the Keros classification may have a high risk of injury because of a more pronounced slope of the anterior skull base in the coronal plane.² They proposed a novel classification system based on the angle formed by the LLCP and the continuation of the horizontal line passing through the cribriform plate.² The said angle was classified into three types: class I (>80 degrees, low risk); class II (45 to 80 degrees, medium risk); and class III (<45 degrees, high risk). Although only a prospective study can ultimately prove it, a retrospective study of 24 cases of CSF leak by Preti *et al.* concluded that the Gera classification might be more sensitive to anatomical variations associated with CSF leak than the Keros classification.³

Figure 1 shows a cut from the pre-operative PNS CT scan of the patient before undergoing ESS. It is important to note that the 3-dimensional multiplanar reconstruction (3D MPR) tool of the software being used (in this case, Horos™ DICOM viewer) should be utilized to ensure that the planes of the axial, coronal, and sagittal views are in line with the x-, y- and z-axes. On the right, the measured angle is 57° (Gera class II, medium risk), while the olfactory fossa depth is 2.4 mm (Keros type 1). On the left side, the measured angle is 71° (Gera class I, low risk), while the olfactory fossa depth of 4.4 mm (Keros type 2). Gera *et al.* found a significant positive correlation between the depth of the olfactory fossa, the length of the LLCP, and the cribriform plate.² In 2023, Leong *et al.*, developed a comprehensive pre-operative PNS CT check list prior to ESS which includes both the Keros and Gera classifications.⁴ By using a combination of both the Keros and Gera classification systems, the surgeon performing ESS can be better guided where to be more cautious in performing ethmoidectomy and frontal sinusotomy.

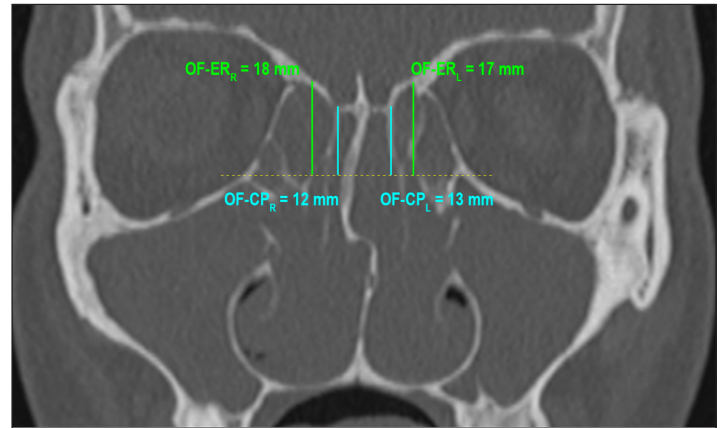


Figure 2. Paranasal sinus CT, coronal plane, bone window, at the level of the fronto-ethmoid angle, generated using the 3D MPR tool of Horos™ DICOM Viewer. The horizontal broken line corresponds to the level of the most medial aspects of the orbital floors bilaterally. This coronal slice shows the TMS classification. The horizontal broken line delineates the level of the most medial aspect of the orbital floor. TMS type 1 (low risk for injury) is seen bilaterally with the OF-ER and OF-CP values bilaterally measured to be more than 10 mm.

While performing right frontal sinusotomy in this patient, I was careful to stay anterolaterally to avoid the LLCP which is Gera Class II or medium risk. Bilateral ESS was completed without any complications. The importance of pre-operative evaluation of a patient's PNS CT prior to ESS cannot be overemphasized, especially for beginner surgeons. The Gera and TMS classifications can both be used to complement the Keros classification in assessing the risk for iatrogenic injury to the anterior skull base during ESS. It should be noted, however, that the recognition of risk for iatrogenic skull base injury through PNS CT scan review is only one of several factors that can influence complication rates. Other factors, examples of which include surgeon's expertise and disease severity, are beyond the scope of this article.

Note: All PNS CT scan images were viewed using Horos™ DICOM Viewer v3.3.6 (Purview, Annapolis, MD, USA), available at <https://horosproject.org/>.

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