

OSSIFICATION OF LIGAMENTS NEAR THE FORAMEN OVALE: AN ANATOMIC STUDY WITH POTENTIAL CLINICAL SIGNIFICANCE REGARDING TRANSCUTANEOUS APPROACHES TO THE SKULL BASE

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OBJECTIVE: There is paucity of information regarding the specific anatomy and clinical significance of ossified ligaments near the foramen ovale (e.g., pterygospinous and pterygoalar ligaments). The present study was undertaken to define this anatomy in more detail and to review the literature regarding these anatomic variations.

METHODS: One hundred fifty-four adult human dry skulls were analyzed for the presence of ossified ligaments of pterygospinous (ligament of Civinini) and pterygoalar (ligament of Hyrtl). Measurements were made of these bony structures and observations made of their relationships to the inferior aspect of the foramen ovale and neighboring structures.

RESULTS: Two ossifications each (2.6%) of the ligaments of Civinini and Hyrtl were found. One of each of these (1.3%) was completely ossified, thereby resulting in 2 complete foramina (i.e., 1 foramen of Civinini and 1 foramen of Hyrtl). A significant correlation was found between the left and right sides, with either complete or incomplete ossification of these ligaments being found on left sides (75%) (incomplete Civinini on right side and all others on left side). The complete foramen of Civinini was found to have an area of 16.7 mm², and the complete foramen of Hyrtl was found to have an area of 9.42 mm².

CONCLUSION: Such anomalous bony obstructions could interfere with transcutaneous needle placement into the foramen ovale or distort anatomic relationships during approaches to the cranial base.

KEY WORDS: Anatomy, Cranial base, Gasserian ganglion, Neurosurgery, Skull base

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Ossification of the ligaments (e.g., supracapular ligament) can lead to symptomatic compression of regional structures, especially nerves, and should be considered in patients in whom other etiologies for a compressive syndrome cannot be identified. Although the cause of ossification of ligaments of the cranium is not fully understood, some have opined a chemical or genetic predisposition (12, 17, 25, 29). This can manifest as nerve palsy, neuralgia, numbness, headache, and syncope (20). Ossification of ligaments of the cranial base can also obstruct surgical corridors and interfere with operative access in this area (10).

In 1835, Civinini, an Italian anatomist, described the lateral pterygoid process as approaching the spine of the sphenoid and some-

times fusing (6). In 1837, he also described the pterygospinous ligament (Civinini's ligament) (7). Civinini found that this ligament ossified in 2% to 3% of his specimens (7). Interestingly, even though this ligament and the ossified foramen that may result is named after Civinini (Fig. 1), Ingrassias (1510–1580), an Italian anatomist and physician, probably described it first (28). Some authors have reported this ossification incidence as ranging from 2% to 4% (8, 11, 26). Nayak et al. (18) found that this ligament was fully ossified in 5.76% of their specimens and incompletely ossified in 3.84%. Shaw (23) thought that some form of ossification of this ligament was present in 1 in 10 of the adult population. When completely ossified, nerve and arterial branches destined for the medial pterygoid can traverse such a foramen (2), which is usually incomplete in man and anthropoids (18).

ABBREVIATIONS: CT, computed tomographic

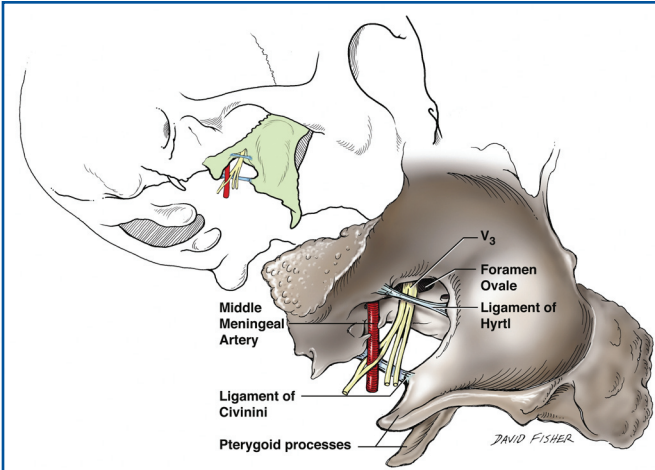


FIGURE 1. Schematic view of the skull base demonstrating the ligaments of Civinini and Hyrtl and their relationships to the foramen ovale. For reference, note the middle meningeal artery traveling from the infratemporal fossa, through a loop of the auriculotemporal nerve, and into the foramen spinosum.

In 1862, the German anatomist Hyrtl described the pterygoalar ligament (Hyrtl's ligament) that, when ossified, forms the pterygoalar foramen, the so-called foramen masticatorium, crotaphiticobuccinatorium, or Hyrtl's foramen (Fig. 1) (13). This ligament travels from the inferior surface of the sphenoid greater wing, near the anterolateral edge of the foramen spinosum, to the root of the lateral pterygoid process. This structure, therefore, and as the ligament of Civinini, is also lateral to the foramen ovale. Shaw (23) thought that this ossification was found in approximately 1 in 100 of the adult population. When fully ossified, branches of the mandibular nerve, such as the nerve to the masseter and deep temporal nerves, can travel through the foramen that is created.

In the present study, we sought to elucidate the detailed anatomy of such complete and incomplete foramina (27) and demonstrate their relationships to the foramen ovale. Such data may be useful to neurosurgeons who operate in this region or perform transcutaneous procedures aimed at the foramen ovale.

MATERIALS AND METHODS

One hundred fifty-two adult dry skulls underwent evaluation for the presence of the foramina of Civinini and/or Hyrtl. If present, the dimensions of these foramina were measured and documented in reference to their relationship to the inferior surface of the foramen ovale and surrounding structures. Additionally, the area of each foramen was calculated. All measurements were made with calipers. Statistical analysis was performed with Statistica for Windows (StatSoft, Inc., Tulsa, OK) with significance set at a *P* value of less than 0.05.

RESULTS

Two ossifications each (2.6%) of the ligaments of Civinini and Hyrtl were found (Figs. 2–7). One of each of these (1.3%) was

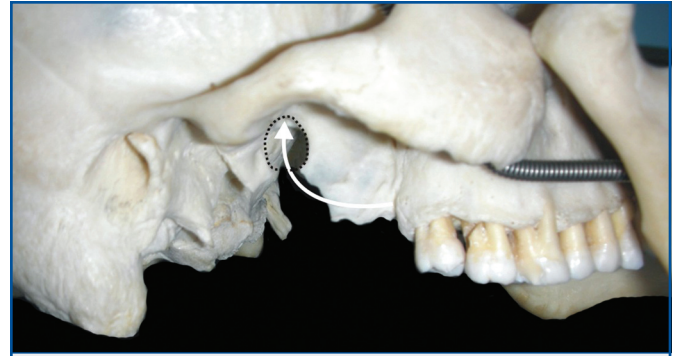


FIGURE 2. Specimen illustrating a right incomplete ossification of the ligament of Civinini (outlined). The arrow points up to the foramen ovale.

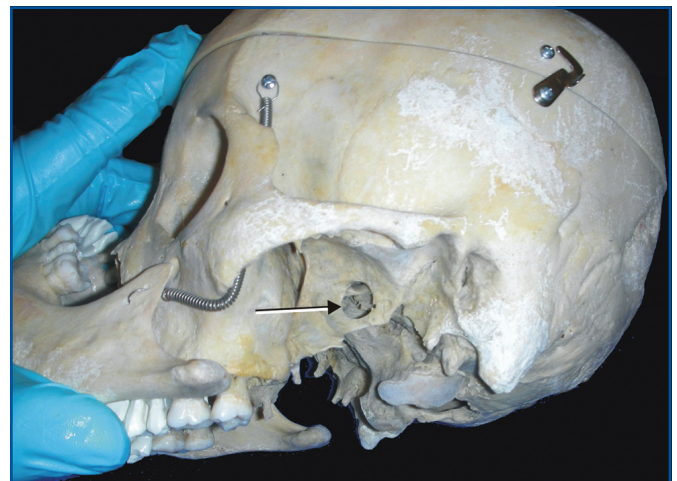


FIGURE 3. Specimen illustrating a left complete ossification of the ligament of Civinini. The foramen ovale is just medial and superior to this large opening.

completely ossified, thereby resulting in 2 complete foramina (i.e., 1 foramen of Civinini and 1 foramen of Hyrtl). A correlation was found between left and right sides with either complete or incomplete ossification of these ligaments being found on the left side. Regarding left and right sides, 75% of these bony bars/foramina were identified on left sides. The complete foramen of Civinini was found to have an area of 16.7 mm², and the complete foramen of Hyrtl was found to have an area of 9.42 mm². Statistical significance was found when comparing the presence or absence of these structures for left versus right sides.

None of the specimens had a known history of any medical disease that would predispose them to hypertrophic calcification/ossification, as most of these were derived from dealers of osteological materials without medical histories.

DISCUSSION

We found a relatively small incidence of the foramina of Civinini and Hyrtl. Complete and incomplete foramina were

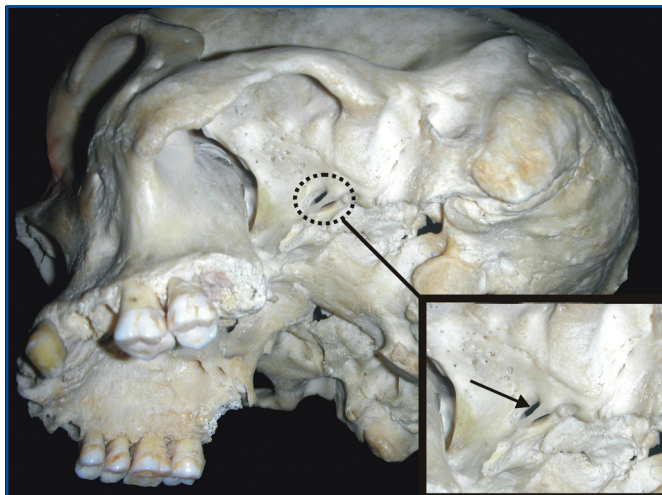
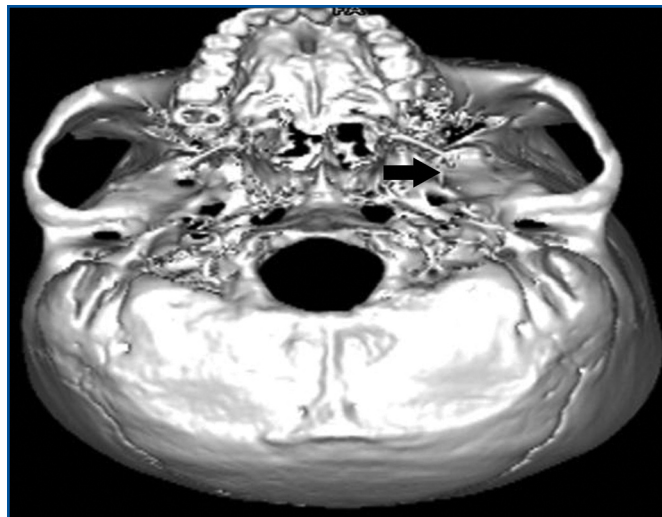
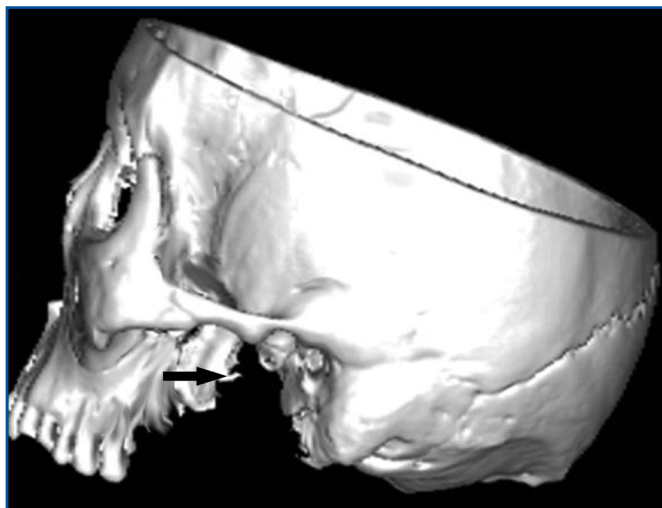


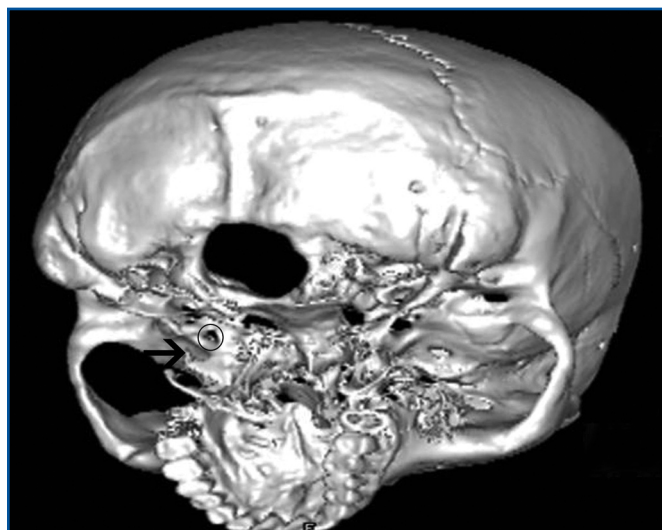
FIGURE 4. Specimen demonstrating the complete ossification of the ligament of Hyrtl. In effect, this forms a bony bar just inferolateral to the foramen ovale. The arrow (inset) points to the entrance into the formed foramen.



FIGURES 6. Reconstructed CT image of the specimen seen in Figure 3. Parts of the bony ring are seen at the arrow tip. Note the foramen ovale (just inferior to the arrow) and its proximity to this bony variation.



FIGURES 5. Reconstructed computed tomographic (CT) image of the specimen seen in Figure 3. Parts of the bony ring are seen at the arrow tip.



FIGURES 7. Reconstructed CT image of the specimen seen in Figure 3. Parts of the bony ring are seen at the arrow tip. Note the foramen ovale (circled) and its proximity to this bony variation.

found in 2.6% of our specimens. This number could, in fact, be greater because some of these fine structures could have been damaged during processing of the osteological material. Moreover, a larger sample size might have revealed additional variations, thereby increasing this percentage. Regarding the ligament of Civinini, some have opined that such fibers are derived from modified parts of the lateral pterygoid muscle (i.e., a third head of this muscle) (16, 18, 21, 28). Antonopoulou et al. (1) hypothesized that this ligament was derived from the pterygoid fascia. Interestingly, in lemurs, the ligament of Civinini travels medial to the foramen ovale (18). Nayak et al. (18) extolled that ossification of this ligament is likely a phylo-

genetic remnant. For our study, one must also consider that certain comorbidities of the individuals from whom the samples were derived could have had a role in the formation of such osteological variations.

An ossified ligament of Civinini can cause entrapment of the lingual branch of V3 (20) by which this nerve travels between this ligament and the medial pterygoid muscle. Other branches of the mandibular nerve can also be involved (8). Such entrapment can result in numbness of the tongue and associated pain with movement of the mandible (18, 20). Peuker et al. (20) believed

such compression of the auriculotemporal nerve, which carries postganglionic fibers to the parotid gland, might interfere with salivation. A study performed by Shaw (23) revealed that the ligament of Civinini could occlude blood vessels supplying the trigeminal ganglion. Others have also indicted such ossification in cases of trigeminal neuralgia (3–5, 9, 22). Some have thought that such additional bone might be analogous to foramen ovale overgrowth, as is seen in some cases of Paget's disease (23). Radiographically, ossification of the ligament of Civinini can appear as a bifurcated or duplicated foramen ovale (15, 20).

Nayak et al. (18) observed that the vertical height of the foramen of Civinini was approximately 4 mm for left and right sides. The diameter of the foramen of Hyrtl ranged from 7 to 11 mm in the study by Skrzat et al. (24). These dimensions were approximately comparable to our findings. Although Peker et al. (19) found no significance with regard to age and the frequency of ossification of skull ligaments, we did identify significance in regard to side of such ossifications of the ligaments of Civinini and Hyrtl.

Implications of Ossified Ligaments of Civinini or Hyrtl for Treatment of Trigeminal Neuralgia

Approaches to the trigeminal ganglion can be difficult when a bony bar results from ossification of the ligaments of Civinini or Hyrtl because these obstruct the foramen ovale (20). Gerber (10) concentrated on problems with anesthesia of the trigeminal nerve and percutaneous approaches to the trigeminal ganglion, especially with lateral subzygomatic routes. Peuker et al. (20) and Kapur et al. (14) also concluded that such osseous bars might block the passage of needles aimed at the foramen ovale. During percutaneous procedures involving the foramen ovale, calcification of the above ligaments should be considered if the surgeon has difficulty penetrating the foramen with the needle despite multiple attempts involving slightly different needle angles. Unfortunately, ossification of the ligaments of Civinini or Hyrtl might not appear on regular pre- or intraoperative fluoroscopy imaging used to guide the needle through the foramen. Therefore, the surgeon will not be alarmed during surgery regarding the presence of these obstructive ossified ligaments.

If the surgeon cannot easily penetrate the foramen with the needle intraoperatively despite several attempts, the procedure may be aborted and a postoperative computed tomographic (CT) scan of the cranial base may be obtained to better delineate the anatomy of obstructive lesions around the foramen, including the ossified ligaments described above. However, we would not suggest a preoperative CT scan of the cranial base for all patients undergoing transcutaneous approaches to the foramen ovale. Parenthetically, one of the more pronounced specimens we were unable to identify on typical axial images was submitted to a CT scan. However, 3-dimensional reconstruction did allow for visualization of the bony variation (Figs. 5–7). If ossified ligaments exist, detail study of the anatomy around the foramen and the use of intraoperative CT-guided neuronavigation could potentially guide the needle around the ossified ligaments (Figs. 5–7). If the foramen remains inaccessible because

of the anatomy of the ossified ligaments, other procedures including microvascular decompression or radiosurgery rhizotomy may be considered for the treatment of medically refractory trigeminal neuralgia.

CONCLUSIONS

Although anatomically interesting, ossification of the pterygospinous and pterygoalar ligaments should be considered by the neurosurgeon during such procedures as transfacial needle approaches to the foramen ovale. Such information may also be of particular use to anesthesiologists, dentists, and oral maxillofacial surgeons who perform invasive procedures in or near the infratemporal fossa.

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENTS

Tubbs et al. have conducted a cadaver study of skull base anatomy, with special attention to 2 small ligaments found in the vicinity of the foramen ovale. Because the study was conducted on dry skulls, the findings described are restricted to ossification of these 2 ligaments (pterygospinous and pterygoalar). The authors carefully document the anatomy of these ossified ligaments, both in schematic form and by high-resolution photography. The incidence of ossification of these ligaments in this series appears to be just over 2%. The computed tomographic reconstructions of these ligaments clearly document their presence and should serve as an aid to neurosurgeons who are contemplating percutaneous procedures for trigeminal neuralgia. Such ossifications may create difficulties to successful cannulation of the foramen ovale and should be looked for if the needle cannot successfully enter

the foramen. As the incidence of this type of ossified ligament does appear to be low, I would not recommend routine scanning of patients prior to percutaneous procedures. However, in the setting of a failed cannulation, the possibility of ossification of these ligaments should be entertained. It is interesting to note that even in their best specimen, the authors had difficulty identifying the ligament on source computed tomographic images. The complexity of this region would therefore appear to require a 3-dimensional reconstruction and careful examination, as was done in this study.

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On rare occasions, the surgeon attempting to treat trigeminal neuralgia via a percutaneous approach may encounter insurmountable resistance to entry into the foramen ovale. This study provides a potential explanation for such cases. The authors have nicely demonstrated ossification of the ligaments in the region of the foramen ovale in a small but significant number of anatomical specimens. All physicians performing percutaneous procedures targeted at the Gasserian ganglion should be aware of these variants and the possibility that they may impede the delivery of therapeutic interventions.

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This is a study about a rare condition, ossification of ligaments related with the foramen ovale, that is justified both for the enrichment of fine cranial anatomic knowledge and for its possible clinical implication once this condition can be potentially related with trigeminal nerve symptoms and can eventually interfere with percutaneous approaches to the trigeminal ganglion. This study conducted by Tubbs et al. is very well done, and the issues related with the topic are particularly well discussed. As also mentioned by the authors, I would like only to stress that, although having studied a large number of specimens (154 skulls), considering the rarity of this condition (they found only 2 ossifications of each one of the 2 studied ligaments), this number of skulls might be still insufficient to fully describe its possible anatomical findings and variations. In this direction, their findings can motivate and can orient future in vivo radiological studies both of patients with and without trigeminal symptoms.

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