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Editorial

The intertwining of neuroanatomy, neuroimaging, and neurosurgery

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The intimate relationship between neurosurgery and neuroanatomy—including the complex anatomy of the skull—is absolute. There is no neurosurgical procedure that can be performed without knowledge of neuroanatomy, and there is no meaningful way to divide these domains into separate compartments. To open the cranial vault without a solid command of the structures it contains would be not only dangerous but conceptually impossible. Neurosurgery, at its core, is the applied art and science of neuroanatomy.

The inseparability of anatomy and surgery

Every neurosurgical step — from skin incision to dural opening and from cortical exposure to deep microsurgical dissection — demands a mastery of anatomy. But anatomy is not static; it is dynamic, context-dependent, and often variable between individuals. Surgeons are challenged daily not only to recall canonical descriptions but also to interpret variations, anomalies, and pathologies that shift the terrain of familiar landmarks. This is why neuroanatomy remains a lifelong study for the neurosurgeon: each patient presents a unique anatomical landscape, and surgery must adapt accordingly.

The role of neuroimaging

Alongside anatomy, neuroimaging has become an inseparable partner in neurosurgery. It is no longer conceivable to enter the cranial cavity without preoperative imaging. MRI, in particular, provides an unparalleled window into brain parenchyma, vascular structures, and spatial relationships. Preoperative imaging not only guides decision-making but also enhances safety, allowing surgeons to plan approaches that minimize unnecessary damage.

Intraoperative imaging, when available, extends this principle into the surgical theater itself, offering real-time confirmation of anatomy and surgical progress.

Neuronavigation systems, coupled with imaging datasets, enable unprecedented accuracy and precision. Yet, these technologies remain inaccessible to many institutions worldwide. Even in advanced centers, emergencies or technical failures can deprive the surgeon of neuronavigation. In such circumstances, reliance on anatomical knowledge and external cranial landmarks remains indispensable.

Craniometric landmarks in neurosurgery

Cranial landmarks — palpable or visible points on the skull — have guided neurosurgeons for centuries. Their constancy allows reliable estimation of the location of underlying structures, even in the absence of sophisticated tools. The coronal suture, bregma, inion, pterion, and other reference points have guided trepanations and craniotomies from antiquity to the modern era.

It is in this context that the parietal foramen (PF) deserves renewed attention (1–9). Traditionally regarded as a minor anatomical curiosity, the PF is, in fact, an anatomical structure with significant surgical implications. Present in the majority of skulls—identified in nearly 70% of individuals (7,10)—the PF establishes a direct conduit between extracranial and intracranial compartments, transmitting emissary veins, arterial twigs, and neural branches (9).

Functional significance of the parietal foramen

The emissary vein traversing the PF is valveless, enabling bidirectional blood flow between the scalp and intracranial venous systems. Physiologically, this arrangement allows regulation of intracranial pressure and temperature. During postural changes or Valsalva maneuvers, these veins adapt to shifting hemodynamic conditions. From a thermal perspective, blood passing from the cooler scalp circulation to the intracranial cavity may contribute to brain cooling — a hypothesis supported by evolutionary studies linking emissary veins and cranial foramina with adaptation to bipedality and encephalization.

The PF thus embodies more than a structural opening: it represents an interface of physiology, evolution, and clinical relevance.

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Risks and opportunities

Clinically, the PF presents both risks and opportunities. On the one hand, emissary veins constitute potential pathways for intracranial infection, a concern recognized since the early descriptions of pyogenic disease spreading via venous channels. They may also be a source of intraoperative bleeding or, in rare but catastrophic instances, air embolism.

On the other hand, emissary veins can be harnessed therapeutically. In parasagittal meningiomas, they may participate in tumor drainage, influencing surgical planning. Interventional neuroradiologists may use the PF as an access route for embolization of dural vessels. Far from a vestigial structure, the PF is increasingly recognized as a potential ally in diagnosis and treatment.

The PF as a surgical landmark

Perhaps the most compelling aspect of the PF is its value as a surgical landmark. Our recent investigations demonstrate that the PF has a relatively constant relationship with the superior sagittal sinus (SSS). Unlike the sagittal suture or midline, which show variability in their relationship to the SSS, the PF provides a more stable reference point. On the left side in particular, the PF is consistently located lateral to the SSS, often within a narrow margin of variability.

For neurosurgeons, this has profound implications. During parietal craniotomies—especially in emergencies without neuronavigation—the PF can guide the safe placement of bone flaps, helping avoid inadvertent injury to the SSS. Given that venous sinus injury can be fatal, the PF's consistency provides reassurance where uncertainty otherwise prevails.

We propose that incisions made at least 1 cm lateral to the PF reduce the risk of vascular damage. Even in the subset of cases where the PF lies directly above the SSS, the sinus margins remain several millimeters distant, offering a margin of safety.

Expanding the neurosurgical atlas

In this sense, the PF exemplifies the broader mission of *Neurological Surgery and Anatomy*: to integrate anatomical discovery with surgical innovation. Structures that were once overlooked may gain new relevance when studied using modern methods. Contrast-enhanced MRI now permits differentiation between true foramina and minor bony defects, allowing accurate in vivo correlations. Morphometric analyses deepen our understanding of variability, informing safer surgical practice.

In this issue, Brainer-Lima and collaborators (11) illuminate an often-overlooked anatomical structure, enriching the neurosurgeon's atlas with an elegant demonstration of the parietal foramen (PF) as a dependable craniometric landmark of direct relevance to neurosurgical practice.

Future directions

Much remains to be studied. Larger, multicentric investigations are needed to assess PF variability across populations, ages, and races. Pediatric anatomy, in particular, may differ significantly from adult patterns, with implications for surgical procedures in children. Physiological studies may further clarify the role of emissary veins in thermoregulation and intracranial pressure dynamics. Clinically, interventional techniques exploiting the PF as an access route deserve exploration.

Conclusion

The parietal foramen should no longer be relegated to the margins of anatomical teaching. Its prevalence, constancy, and clinical implications demand recognition. For neurosurgeons, awareness of the PF is not only an exercise in academic interest but a practical necessity. It offers guidance in times of uncertainty, serves as a safeguard against iatrogenic injury, and even provides a potential avenue for therapeutic innovation.

In this way, the PF reminds us of the essential unity of neuroanatomy, neuroimaging, and neurosurgery. To see, to understand, and to act — these are inseparable steps. And it is only through their amalgamation that neurosurgery advances, one anatomical insight at a time.

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