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Research Article

Surgical Neuroanatomy of the Frontal Region Applied to Decompressive Craniectomy

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Abstract

The study of Neuroanatomy had a spectacular advance with the advent of Neurosurgical techniques and approaches and Microsurgery. One of the great references of Surgical Neuroanatomy is Dr. Albert Rhoton who stood out for his work in cadaveric dissections, later published in his books on "Cranial Anatomy and Surgical Approcahes". For the neurosurgeon in training, it is very important to know in detail the topography of the skull regions for a correct surgical performance. The objective of this work is to describe the cranio-cerebral topographic anatomy of the frontal region through cadaveric dissection and apply it to neurosurgery through Bifrontotemporal Decompressive Craniectomy. A frontal region dissection was performed through a bicoronal incision exposing the skull by reclining the frontal myocutaneous flap. After craniectomy, the frontal dura and the relief of the superior longitudinal sinus can be seen. When reclining the dura, the brain tissue with its frontal drainage veins appears. To perform the bifrontotemporal decompressive craniectomy, the frontal flap is reclined first and then the craniectomy is performed with a bone bridge over the midline to protect the venous sinus. The dural opening in a "U"-shape with medial base allows good decompression of the cranial content and preserves the integrity of venous vessels by respecting the midline. Dural reconstruction is a late step that, depending on each case, may or may not be performed. The acquisition of practical skills through cadaveric dissection is a very important tool for the neurosurgeon and allows the assimilation of key neuroanatomical knowledge to carry out good surgical practice.

Keywords: *Surgical neuroanatomy, frontal lobe, bifrontotemporal decompressive craniectomy, cadaveric dissection.*

Introduction

A little less than 500 years ago, almost in the middle of the 16th century, Andreas Vesalius published "The human corporis fabrica", based on anatomy from dissections in human cadavers. His illustrations made in collaboration with "Tiziano's workshop" illustrators, his public dissections highlighted the importance of the study of human anatomy from dissection. Although technological development in the medical-surgical area has advanced exponentially in the last century, detailed anatomical knowledge continues to be one of the most important bases for neurosurgeons who want to obtain the best results in their surgical interventions. The acquisition of skills and practical knowledge are very important for the neurosurgeon in training who is often faced with the resolution of very complex cases. The dissection of cadaveric specimens, as Vesalius has shown, allows one to acquire that detailed and exquisite knowledge of the complex cranio-cerebral anatomy.

Objective

The objective of this work is to describe the cranio-cerebral topographic anatomy of the frontal region through cadaveric dissection and apply it to neurosurgery by means of bifrontotemporal decompressive craniectomy.

Materials and Methods

For fixation and cadaveric preservation, formalin solution was used. Cadaveric dissection was performed using standard dissection materials: left hand forceps with and without teeth, Metzenbaum/Iris/Mayo scissors, N° 11 and N°24 scalpel blades, N°3 and N°4 scalpel handles, drill, self-locking bit, Gigli saw.

Photos were obtained with a high definition camera, they were edited with the PowerPoint program and saved in JPEG format. In each step, the dissection was carried out following the anatomical landmarks and the planes were exposed to compare them with the surgical neuroanatomy.

Results

Cranial Neuroanatomy

From an anterior view, the main bony landmarks of the frontal bone are observed (figure 1-A). It has two parts: an upper part (scale) and a lower part (orbital). It articulates posteriorly with the parietal bone, laterally with the great wings of the sphenoid and zygomatic bone, inferiorly with the nasal, maxillary, ethmoid and sphenoid bones. The coronal suture (formed by the union of the frontal bone with the parietal bone) joins in the midline with the sagittal suture (interparietal) forming the Bregma. The frontal scale has frontal tuberosities or prominences on both sides of the midline. Inferiorly are the supraorbital edges (which are part of the roof of the orbital fossa or cavities), which in turn present the supraorbital notch (the place where the supraorbital vessels and nerves pass). Medially to the orbital fossa, the frontal bone articulates with the nasal bones forming the frontonasal suture. The crossing of this suture with the internasal suture forms the Nasion. Superior to this last point is a bony elevation between the supraorbital ridges called Glabella. At the lateral ends, the coronal suture is directed inferiorly towards the temporal fossa crossing the superior temporal line (Stephanion point) to end in the area of the Pterion (point formed by the sutures that join the bones: frontal, greater wing of the sphenoid, temporal scale and parietal). Knowledge and management towards the depth of this last region is of great importance for the surgical management of the temporal pole, the middle cranial fossa and the anterior portion of the sylvian fissure.

Cadaveric Dissection

1. Surface planes

To start the dissection of the frontal region (figure 1-B), a bicoronal incision is made, similar to that used in the neurosurgical practice, starting 1 cm in front of the tragus, crossing the midline and following the direction of the coronal plane towards the contralateral side. The incision covers the full thickness of the cutaneous and subcutaneous planes up to the bone of cranial calvaria. To make this incision, it is very important to know the regional anatomy, taking into account the arteries that participate in the irrigation of the frontal flap (supratrochlear, supraorbital and superficial temporal arteries). In figure 1-B, the approximate location of the supraorbital vasculonervious pedicle is marked on the skin. The location of the midline helps us to predict the location of the superior longitudinal sinus and the anatomical repairs necessary to find it (e.g. the sagittal suture). On the sides, the superior temporal line can be located on the skin, which gives us the reference of the superior insertion of the temporal muscle. It is also an important repair for the approximate location of intracranial structures such as the inferior frontal sulcus. Between the midline and the superior temporal line, the location of the following brain structures (from medial to lateral) can be projected in depth: superior frontal gyrus, superior frontal sulcus, middle frontal gyrus and inferior frontal sulcus. The inferior frontal gyrus is located immediately inferior to the superior temporal line.

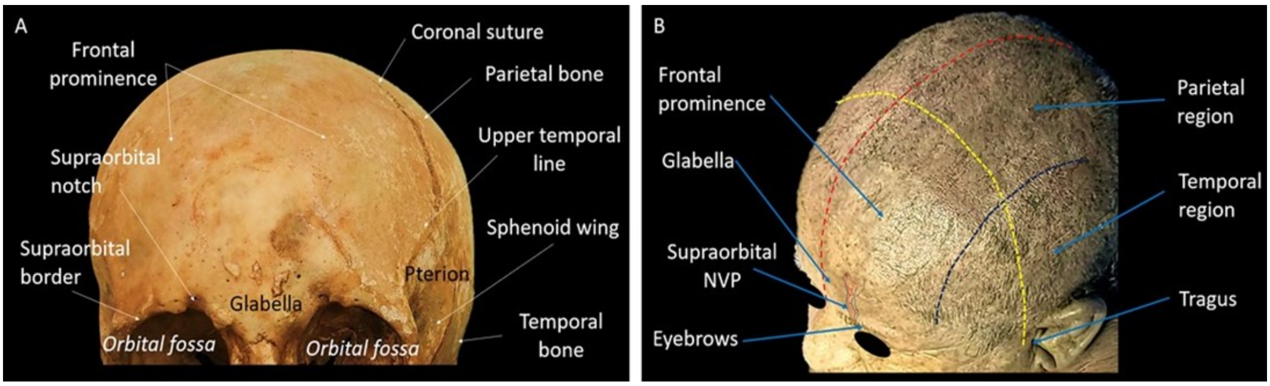

*Figure 1. **(A)** Anterior view of the cranial vault showing the scale and the orbital portion of the frontal bone and its most important bone reliefs and relationships. **(B)** Superior, lateral and left view of the frontal region of a cadaveric specimen showing the superficial tissues not yet dissected. The projection of the midline that coincides with the trajectory of the sagittal suture and the superior longitudinal sinus is shown in red dashed line. The blue dashed line shows the projection of the superior temporal line indicating the insertion of the temporal muscle. The yellow dashed line shows the path to be followed by the bicoronal incision. NVP: Neurovascular pedicle.*

By reclining the frontal myocutaneous planes (figure 2-C), the entire coronal suture and the anterior portion of the sagittal suture are exposed. The frontal bone scale is observed that protrudes anteriorly, forming the frontal eminences. Inferiorly, at the level of the eyebrow, the supraorbital borders are the anatomical landmark to stop the umlaut of the myocutaneous planes downwards. In the medial third of the same border, we find a neurovascular pedicle originating from the orbital cavity and it is necessary to preserve. It is the supraorbital vasculonervious pedicle. The injury to this pedicle could condition the irrigation of the frontal flap, compromising its vitality. Sensitivity of the frontal region would also be affected by injury to the supraorbital nerve, which corresponds to a part of the sensitive territory of the trigeminal nerve. The aponeurotic galea (figure 2-C) located on the internal side of the myocutaneous flap is a thin sheet of connective tissue that must be preserved during the opening of planes, since it can be used later as a graft or flap for the dural reconstruction (or duroplasty) of the region, thus avoiding the formation of cerebrospinal fluid fistulas.

2. Bone plane. Craniectomy

In the next step, the bone platelet is removed (figure 2-D) by performing a frontal craniectomy using burr holes and Gigli saw. The coronal suture was preserved in its entirety to have a better approximation of the frontal cranio-cerebral anatomical relationships. By removing the frontal bone, the dura that covers the anterior portion of the frontal lobe can be seen. Knowing the anatomical structures in this step is essential for vascular control during surgical practice. On the midline, on a path from the glabella to the bregma, is the anterior third of the superior longitudinal sinus, often accompained by small granulations on the convexity called arachnoid granulations of Pacchioni (place where the cerebrospinal fluid passes from the subarachnoid space into the venous blood of the sinus). The dura that forms this venous sinus projects through the midline forming a septum called the falx cerebri (which separates the right cerebral hemisphere from the left), and which inserts anteriorly into the foramen caecum and the crista galli. Injury to the superior longitudinal sinus and arachnoid granulations in surgical procedures gives rise to profuse and challenging to control bleeding that cannot be controlled with eletrocautery due to the retractable nature of the dural tissue. In turn, the anterior third is the only portion of the superior longitudinal sinus that allows surgical ligation to stop bleeding in uncontrollable cases. When opening the upper wall of the superior longitudinal sinus (figure 2-D), the morphology and extension over the frontal lobe and the arrangement of the arachnoid granulations within it were observed.

The anterior branches of the middle meningeal artery run through the thickness of the dura, from posterior to anterior and from inferior to superior, following the convexity. It is important to remember the origin of this artery in the maxillary artery, its intracranial course crossing the spinous foramen and running through the middle cranial fossa and the inner face of the cranial calvaria. This artery is usually the source of bleeding in the extradural compartment (between the inner face of the skull and periosteal dura).

On the midline and at the level of the plane of the glabella is the frontal sinus (figure 2-D). It is a pneumatic cavity lined with mucous epithelium that has direct communication with the middle meatus of the nasal cavities through the nasofrontal duct. The opening of this pneumatic cavity during craniectomy puts the dura that covers the frontal lobe in direct communication with the microenvironment of the nasal cavity, being a potential and dangerous cause of postoperative infections due to poor management of this region.

With regard to the management of the frontal sinus and the superior longitudinal sinus, it should be known that in surgical practice the best way to respect these structures is to preserve a “bony bridge” in the midline, which is 3 or 4 cm wide from the glabella to bregma. In cadaveric dissection, the extraction of the entire bone platelet allows us to appreciate and have a better understanding of the arrangement of these structures by exposing them to the dissector’s view.

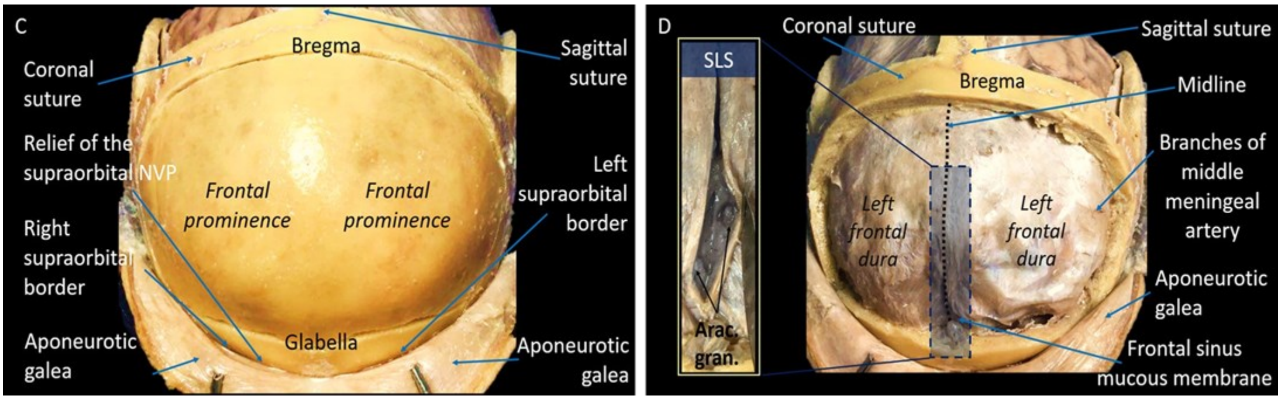

*Figure 2. **(C)** The frontal bone scale is observed from an anterior view, which is evident once the frontal myocutaneous flap has been dissected. The lower limit to stop subgaleal dissection is the supraorbital border, which marks the roof of the orbital cavities. An attempt should be made to preserve the supraorbital NVP so as not to compromise the vitality of the flap in the surgical act. **(D)** The frontal dura is visualized after frontal craniectomy. In the midline the roof of the superior longitudinal sinus that was opened is visualized superiorly, and inferiorly the mucosa of the frontal sinus. SLS: Superior Longitudinal Sinus; Arac. Gran: arachnoid granulation.*

3. Deep plane. Dura and Frontal Lobe

Finally, the opening of the dura that covers the frontal lobe is performed (figure 3-E). The correct way to perform it is through an incision on the posterior, lateral and anterior margins respecting the medial border on the midline and which is in direct relation to the superior longitudinal sinus ("U"-shaped incision with a medial base). This form of dural opening must be performed with great care because immediately in the depth is the brain tissue covered by the pia mater and arachnoid. The dura is reclined toward the midline and the drainage veins of the superior aspect of the anterior frontal lobe are observed. These veins, of considerable size, are the anterior frontal vein, the middle frontal vein and the posterior frontal vein, which collect the venous blood in the frontal lobe and flow into the lateral wall of the superior longitudinal sinus. The correct management of these vascular structures allows to control intraoperative bleeding and avoid brain injuries due to venous infarcts during neurosurgery. In figure 3-E and figure 3-F the arrangement of said veins and the lateral wall of the superior longitudinal sinus can be seen. By reclining the dura, the superior and lateral surface of the frontal lobe is exposed. Forming part of this lobe and adjacent to the midline is the superior frontal gyrus, which is delimited from the middle frontal gyrus by the superior frontal sulcus. This groove extends anteroposteriorly, parallel to and 2 to 3 cm away from midline. On the lower and more lateral margin is the inferior frontal gyrus, which is delimited superiorly from the middle frontal gyrus by the inferior frontal sulcus (figure 3-E). The most anterior end of the frontal lobe is known as the frontal pole and it is the site of the lobe that presents the greatest predisposition to the development of contusions due to traumatic brain injury (TBI).

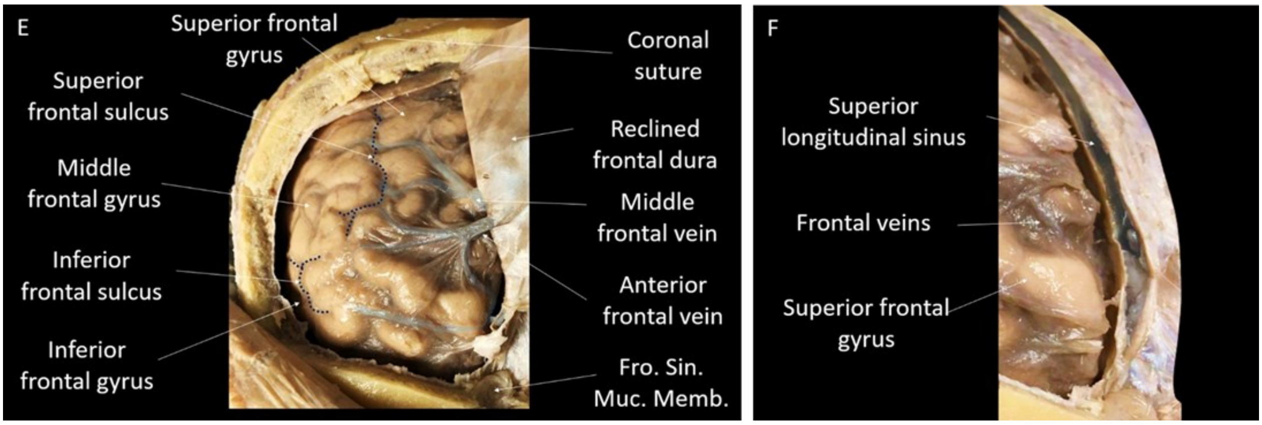

Figure 3. ***(E)*** *Anterior view of the frontal lobe. The dura was open in a "U" shape with a base towards the midline where the superior longitudinal sinus is located. The tributary frontal veins of the venous sinus are visualized.* ***(F)*** *Right lateral view of the anterior third of the superior longitudinal sinus in which the lateral wall of the sinus has been extracted, visualizing its interior space and some arachnoid granulations. Fro. Sin. Muc. Memb: Frontal sinus mucous membrane.*

Discussion

Decompressive craniectomy is an emergency neurosurgical procedure performed with the aim of reducing pressure within the cranial cavity when it increases. Cerebral edema, occupying masses and intracranial hemorrhages are the main causes of increased intracranial pressure that justify this surgical practice, since they present high morbidity and mortality if they are not resolved quickly and in a timely manner. Cerebral decompression requires a wide opening of the skull and dura for the maximum decrease in intracranial pressure. Within this surgical practice, one of the options, when there is diffuse cerebral edema or any lesion that implies a global brain involvement with increased intracranial pressure, is the bifrontotemporal decompressive craniectomy. The anatomical knowledge of the frontotemporal craniocerebral region is of great importance to optimize the intraoperative and immediate postoperative results and long-term results.

Bifrontotemporal Descompressive Craniectomy

1. Bicoronal incision. Frontal flap

A bicoronal incision is made and the frontal myocutaneous flap is reclined, preserving the integrity of the aponeurotic galea for later dural reconstruction. The coronal suture, frontal bone, and pterion region are exposed (figure 4-G). The frontal flap is dissected until the supraorbital edges are found, which indicate the location of the roof of the orbits. The location of the supraorbital pedicle must be kept in mind to preserve its structures and the vitality of the flap. The following are recognized at this stage: the midline, coronal suture, superior temporal line, supraorbital border, supraorbital pedicle, glabella, bregma, pterion.

2. Craniectomy. Bridge bone

Burr holes are made (figure 4-G) with a high-speed motor marking the edges of the craniectomy. The "bony bridge" is left on the midline (figure 4-H) which serves as protection for the superior longitudinal sinus. At the same, it allows the anchorage of the dura to the bone plane, thus achieving additional protection against venous sinus hemorrhages. The same bone bridge prevents the opening of the frontal sinus, protecting the cranial cavity against infections associated with germs in the nasal cavities and paranasal sinuses. Another important structure related to the dura is the middle meningeal artery (figure 4-H) and its frontal branches. Electrocautery of these vascular branches allows control of arterial bleeding and prevents the formation of extradural haematomas.

3. Durotomy

The incision of the dura that covers the frontal lobe is made to achieve the greatest decompression of the cranial cavity (figure 5-I). One method of making the incision is to cut the anterior, lateral and posterior edges respecting the integrity of the medial border that is related to the superior longitudinal sinus and frontal afferent veins ("U" shaped incision with medial base). In this stage, the brain parenchyma is exposed, which in this example is bruised and hemorrhagic (figure 5-I) due to the magnitude of the brain trauma. The brain expansion achieved by decompression can also be seen here, this being the key objective of the procedure.

4. Duroplasty

Once the cerebral decompression is completed, dural reconstruction (duroplasty) is performed with autologous tissue obtained from the frontal aponeurotic galea, in the form of an isolated graft or pedicled flap (figure 5-J). A hermetic duroplasty has the advantage of reducing the formation of cerebrospinal fluid fistulas. Duroplasty must also allow the brain to expand without difficulty in order to reduce intracranial pressure. If this last objective cannot be achieved, it is better not to perform the duroplasty. The closure of the muscular and cutaneous planes will follow at this stage to finish the surgery.

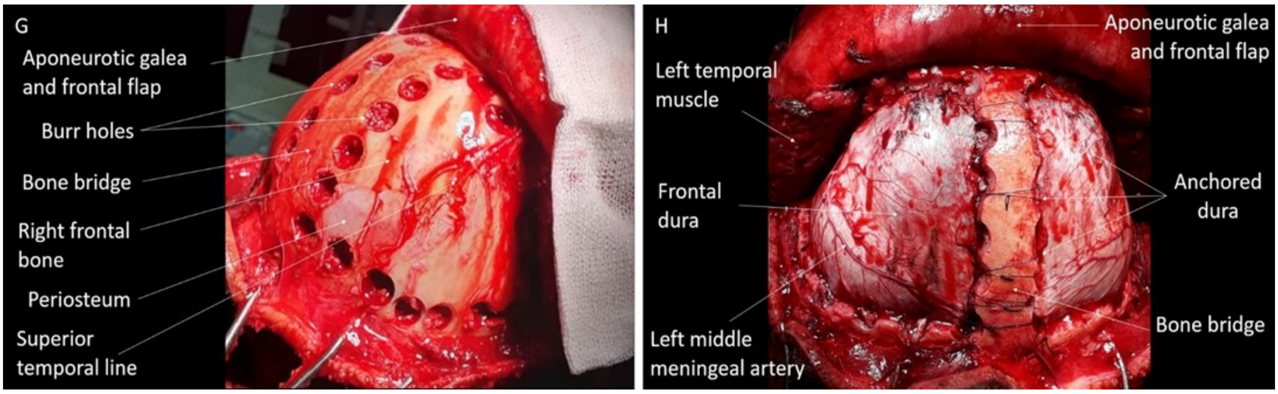

*Figure 4. **(G)** Right anterior surgical view of the frontal region. The myocutaneus flap was reclined anteriorly, visualizing the aponeurotic galea on its deep face. The burr holes were made in order to preserve the bone tissue that covers the superior longitudinal sinus in the midline. **(H)** Superior view. The frontal bone platelet was extracted bilaterally, leaving the bone bridge on the midline. The dura that covers the frontal lobes is anchored to the bony bridge by suture threads ? The left middle meningeal artery is seen on its way over the convexity.*

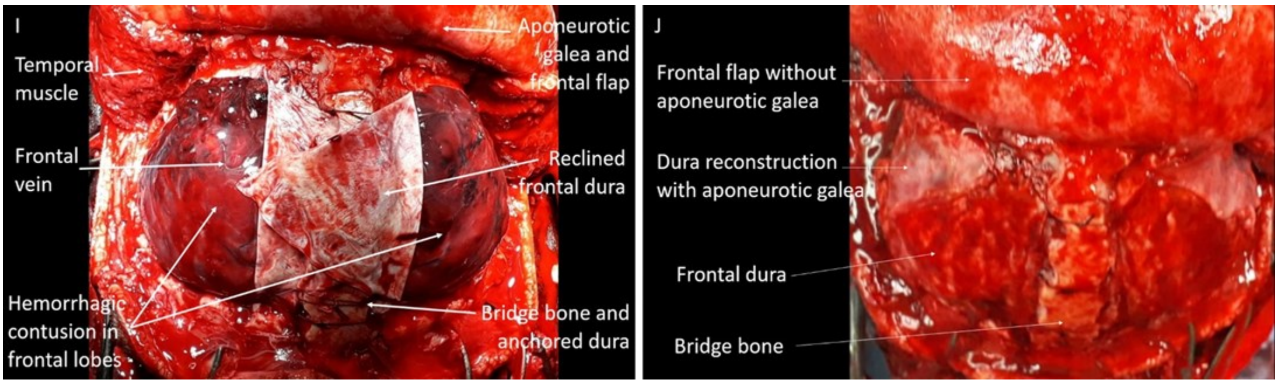

*Figure 5. **(I)** Anterosuperior view. The brain base is upwards. The dura opened in a "U" shape with a base towards the superior longitudinal sinus bilaterally. Due to the magnitude of the trauma, the brain is bruised and hemorrhagic. **(J)** After the surgical decompression, autologous tissue can be taken from the aponeurotic galea and the duroplasty performed.*

Conclusion

Knowledge of surgical neuroanatomy is a key aspect in the training of the neurosurgeon to successfully address each of the brain regions. The dissection of the frontal region in cadaveric models allows to obtain an exquisite theoretical and practical understanding and to develop a broader visual and spatial capacity of the regional topography.

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Conflict of Interest

The author declares no conflicts of interest.

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