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Technical Notes

HeaDax: A simple pre-surgical procedure for localizing superficial brain lesions in resource-limited environments

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ABSTRACT

Background: Intracranial convexity lesions are poorly defined by recognizable anatomical landmarks. Even in expert hands, exact localization of small subcortical lesion and its projection to the skull is sometimes unreliable and can cause potential surgical complications. In this report, a simple and handy technique for localizing superficial intracranial lesions on the scalp under computed tomography (CT)-scan guidance is described.

Methods: This technique, HeaDax, is based on using extracranial landmarks. We constructed an isosceles square triangle with three pieces of copper electrical wire and placed it on the skin scalp. Then, we took a CT-scan but without the need of the classic head reference planes (e.g., orbitomeatal or along the orbital roof).

Results: For the measurements, we need to have the intracranial lesion located on the CT slice with respect to the two landmarks which are the height and hypotenuse of the triangle. The promising preliminary results of HeaDax applied to a phantom skull model encourage us to use it successfully for our first patient presenting a right subcortial supramarginal retrorolandic cavernoma.

Conclusion: HeaDax procedure is a good alternative for localizing superficial intracranial lesions on the skin scalp under CT-scan or magnetic resonance imaging guidance. It can be used as a substitute when stereotactic and neuronavigation systems are not easily available, especially in developing countries and in resource-limited environments. HeaDax has a true potential for further developments and applications in cranial surgery.

Keywords: Computer-assisted surgery, Frameless stereotaxy, Global neurosurgery, Intracranial lesions, Localizer, Surgical planning

INTRODUCTION

Intracranial convexity lesions are poorly defined by recognizable anatomical landmarks.[1,4] Even in expert hands, the exact localization of small subcortical lesion and its projection to the skull is sometimes unreliable. When the craniotomy flap is not correctly placed or centered above the specified lesion, the neurosurgeon needs to use excessive brain retraction or perform new bony resection.[4,14] These can cause further tissue damage and potential perioperative complications.

Since the birth of modern neurosurgery, many methods have already been published and used to correlate an intracranial convexity lesion seen on neuroimaging with its scalp projection.[2,5,7-13,15-17] Some of these techniques are very accurate, but have bulky details. They are not always available or need expensive equipment such as conventional and frameless stereotaxy, neuronavigation systems, or intraoperative neuroimaging (e.g., ultrasound, computed tomography [CT]-scan, or magnetic resonance imaging [MRI]).[2,7,10,13,17] Unfortunately, not all neurosurgical departments worldwide can have such sophisticated and expensive stereotactic systems.

In this report, a simple and handy technique for localizing superficial intracranial lesions on the scalp under CT-scan guidance is described.

METHOD OF LOCALIZATION

Using a real adult human skull as a phantom head model, we tried to recreate practical pre-operative conditions and restrictions to apply our procedure. This technique required the following low-cost and commonly found materials: a permanent marker pen, a flexible ruler and square, a double-sided transparent tape, copper electrical wires, scissors, and a basic CT-scan machine.

The modus operandi is described in seven steps:

Step 1: After shaving the cranial area of interest, a right-angled isosceles lower-base triangle is drawn by a permanent marker pen on the skin scalp using a flexible ruler and square [Figure 1]. The height of the triangle must contain the possible lesion, but the latter does not have to be necessarily located in the center of the triangle.

Step 2: Stick a double-sided transparent tape on the three sides of the triangle. Place three pieces of copper electrical wire (as radio-opaque markers) corresponding to the sides of the triangle [Figure 2a].

Step 3: Head CT-scan is performed for the patient. Axial images are directly acquired with the traditional volume acquisition protocol where the reference plane (baseline) corresponds to the base of the triangle that is identified on the lateral scout view of the skull provided with the CT-scan images [Figure 2b]. Then, the axial slices are oriented parallel to this baseline. The number of sections and cut thickness will be at the discretion of the surgeon. Make sure that on all the axial sections where the lesion appears, the two radio-opaque markers are visible on the axial plane from the anterior to the posterior direction [Figure 3].

Step 4: For any axial section/slice of interest, it will be necessary to identify the height (H) of the section plane relative to the base of the triangle (baseline) using the mathematic formula [H = A–a], where (A) is the length of one side of the isosceles triangle and (a) the distance between the two markers on the corresponding axial cut [Figures 4 and 5].

Step 5: Then, for each axial section/slice of interest, specify the anterior and posterior limits of the lesion by calculating the distance of these limits compared to one of the two radio-opaque marks [Figure 6]. In lesion located near to the

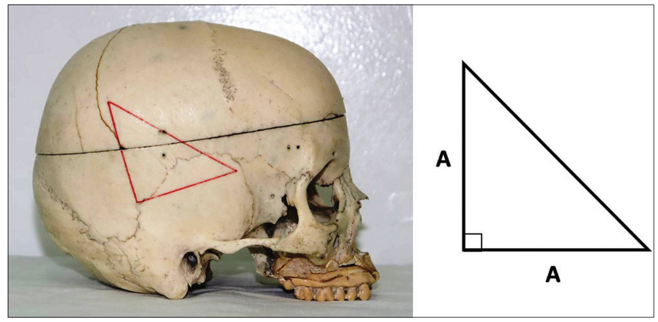

Figure 1: A right-angled isosceles lower-base triangle is drawn on the skull. For the present example, the lesion measures 20 × 20 × 22 mm in diameter and the height of the triangle is 50 mm.

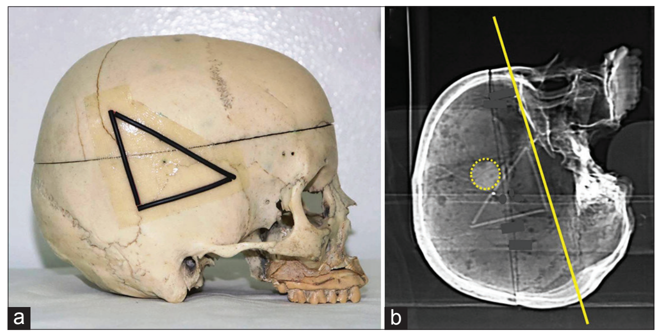

Figure 2: A double-sided transparent tape is stuck on the three sides of the triangle. We place three pieces of copper electrical wire (as radio-opaque markers) corresponding to the sides of the triangle (a). Axial images are directly acquired on head computed tomography-scan where the reference plane (baseline on yellow) corresponds to the base of the triangle that is identified on the lateral scout view of the skull (b).

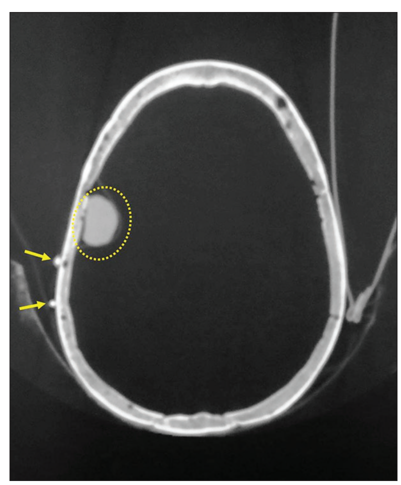

Figure 3: Make sure that on all the axial sections where the lesion (dotted circle) appears, the two radio-opaque markers (arrows) are visible on the axial plane from the anterior to the posterior direction.

vertex, supplementary distance from the midline must be measured on coronal plane which must be perpendicular to the triangle baseline.

Step 6: Finally, freehand connect the points limiting the lesion on the skin scalp, as shown in [Figure 7].

Step 7: The surgical approach will be at the discretion of the neurosurgeon taking into consideration his/her experience, the patient's condition, the surgical position, as well as the volume, shape, topography, and the potential nature of the lesion.

RESULTS

The promising preliminary results of HeaDax applied to a phantom skull model encourage us to use it for our first patient presenting a right parietal cavernoma.

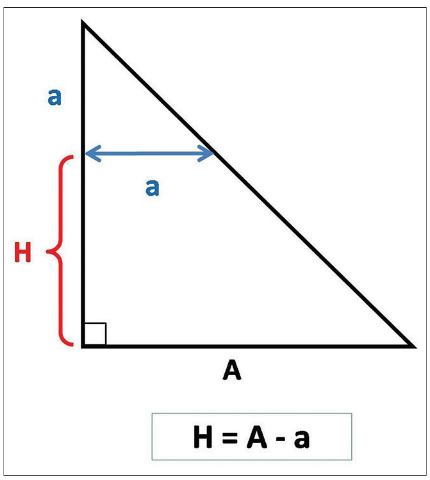

Figure 4: We identify the height "H" of the chosen section plane compared to the base of the triangle (baseline) using the mathematic formula [H = A–a], where "A" is the length of one side of the isosceles triangle and "a" the distance between the two markers on the corresponding axial cut.

This 29-year-old male diagnosed 2 months early with symptomatic epilepsy and slurred speech without other neurologic findings. CT-scan and MRI showed a right 10 mm subcortial supramarginal retrorolandic cavernoma [Figure 8]. He had no familial history of cerebral cavernous malformations. The subcortical lesion was localized using HeaDax procedure on CT-scan [Figure 9]. The cavernoma was entirely removed without complications [Figure 10]. Pathological analysis revealed cavernous malformation.

DISCUSSION

We had sought to get a simple, inexpensive, and useful method for preoperative extracranial localization of intracranial convexity lesion without the assistance of current stereotaxic or neuronavigation systems. HeaDax is a new procedure based on using classic extracranial landmarks as reported by many authors.[8,9,11,15,17] This method is based on projecting the three dimensional coordinates of the superficial intracranial lesion into a bi-dimensional extracranial surface on the skin scalp. However, unlike other used techniques, HeaDax has its own originality and simplicity. A CT-scan of the patient is taken with the three external landmarks in place. For the measurements, we need to have the intracranial lesion located on the CT slice with respect to the two landmarks which are the height and hypotenuse of the triangle. We have deliberately chosen an isosceles square triangle to simplify the calculations and to have a larger cranial region of interest.

Unlike other previous techniques, the variations of the head shape do not hinder the HeaDax procedure. Furthermore, the classic head reference planes (orbito-meatal or along the orbital roof) are not required.[3,4,6,8] We choose our own reference plane which corresponds to the base of our triangle (baseline) whatever the skull's inclination. Therefore, the axial images obtained are parallel to our chosen baseline.

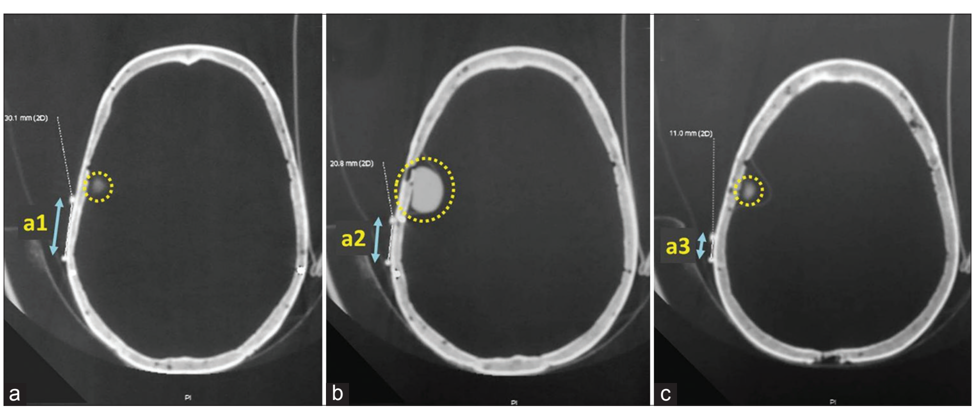

Figure 5: Axial computed tomography-scan. In the present example, the inferior limit of the lesion corresponds to "a1" of 30 mm; then, H1 is 20 mm (50 mm–30 mm) (a). "a2" corresponds to the center of the lesion (b) and "a3" corresponds to the superior limit of the lesion (c).

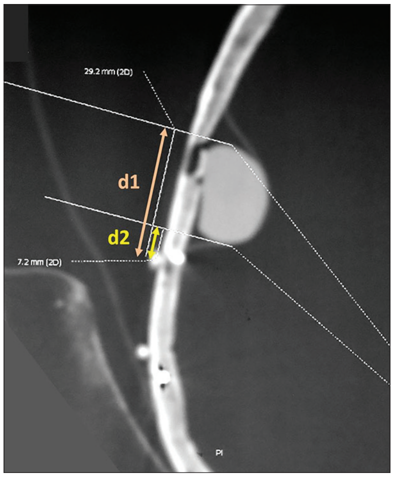

Figure 6: Axial computed tomography-scan. For each axial section/slice of interest, we specify the anterior and posterior limits of the lesion by calculating the distance of these limits compared to one of the two radio-opaque marks. In the present example, the anterior and posterior limit of the lesion correspond to "d1" (29.2 mm) and "d2" (7.2 mm), respectively, compared to the anterior radio-opaque marker (double arrows).

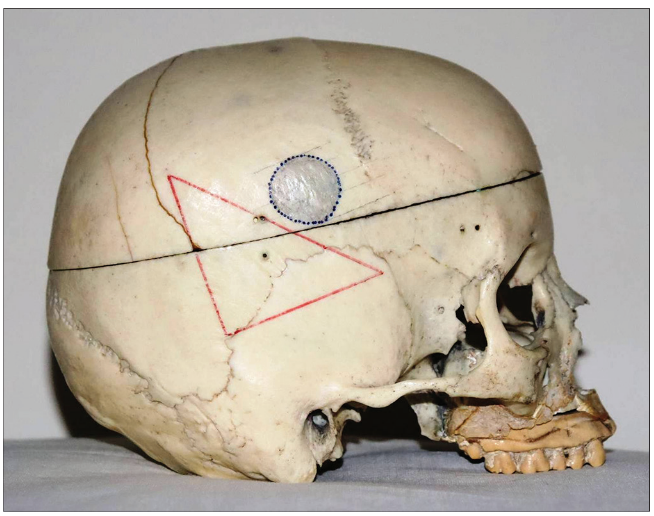

Figure 7: Lateral view of the skull showing the projection of the lesion on the cranial surface relative to the marker triangle.

HeaDax method initially requires the aid of a radiology technician, but the technique is easy to learn and can be carried out by neurosurgeons alone.

With the HeaDax procedure, some limitations and sources of error should be taken into consideration such as the possibility of a mild rotation of the skull around different axes. In addition, this technique becomes less accurate for deeper subcortical lesions and those near to the vertex. In the latter situation, additional distance from the midline must be considered on coronal plane (this plane should be perpendicular to the base of the triangle/baseline) to avoid errors in measurements which may arise due to the maximum convexity of the skull vertex. In fact, this technique is not suitable for cerebellar convexity lesions because of the significant thickness of the suboccipital muscles.

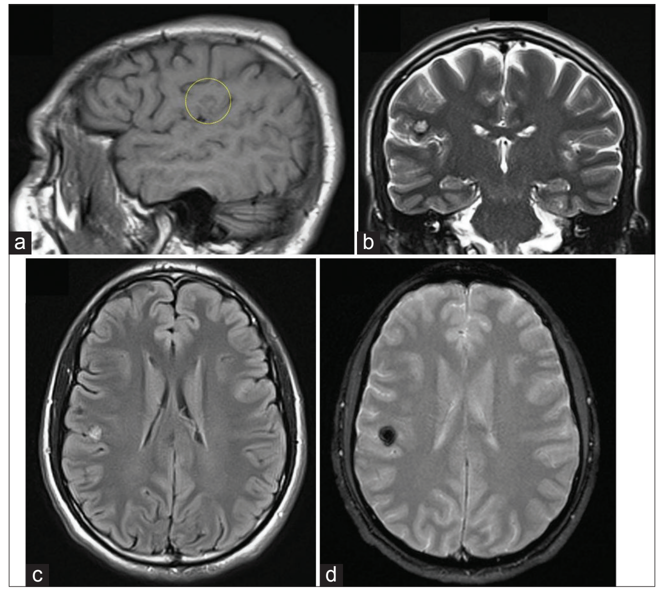

Figure 8: Brain MR imaging showing a right 10 mm subcortial supramarginal retrorolandic cavernoma. Sagittal T1-weighted magnetic resonance imaging (MRI) (a), coronal T2-weighted MRI (b), axial fluid-attenuated inversion recovery sequence (c), and axial gradient-echo imaging (d).

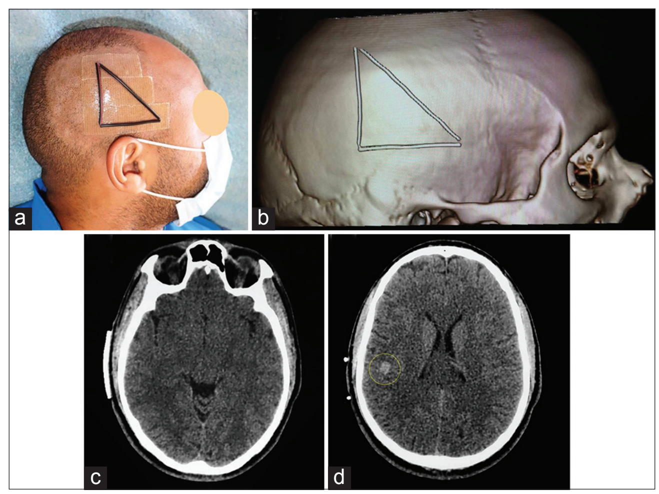

Figure 9: Surgical preplanning. Radio-opaque scalp markers on patient's head (a). Computed tomography-scan with superficial copper markers. Three-dimensional bone reconstruction (reformatted volume rendered) showing superficial markers on the right fronto-parieto-temporal area (b). Axial CT-scan showing the base of the triangle (baseline) (c) and the cavernoma (yellow circle) with the two copper markers (d).

Our procedure could also be used under traditional MRI guidance with the same principles as those made by CT-scan,

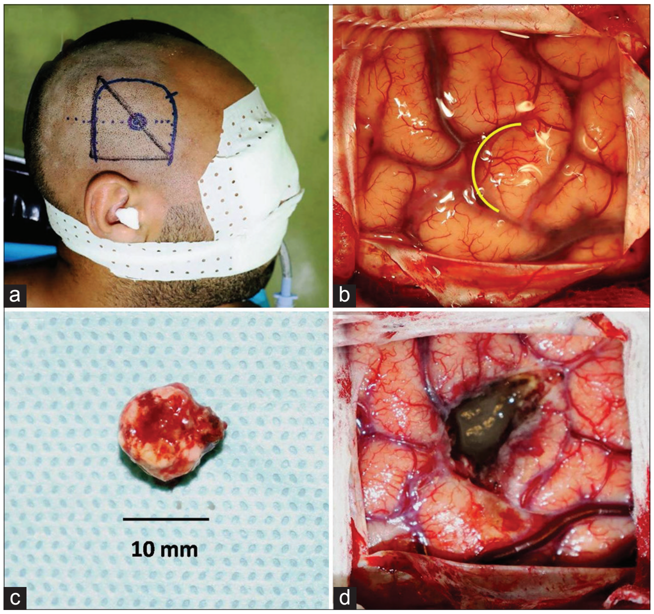

Figure 10: Lateral view of the skull showing the projection of the cavernoma on the cranial surface relative to the marker triangle (a). Note the outline of the surgical incision. Operative view showing the sulcal entry point (yellow curved line) (b). Macroscopic appearance of the complete removed cavernoma (c). Operative view following removal of the lesion (d).

but the markers should be compatible with the magnetic field.

The promising preliminary results of HeaDax applied to a phantom skull model encourage us to use it successfully for our first patient. Further, study of the application in real-time is happening to clearly evaluate the efficacy of our suggested technique. Besides localizing superficial brain lesions, such as tumor, hematoma, abscess, cyst, or cavernoma, this method could be used for localizing the entry point for ventricular shunt placement or any other cranial surgical procedure for convexity lesions requiring precision (e.g., burr hall for chronic subdural hematoma or arachnoid cyst, bone flap for acute traumatic hematomas, and craniectomy for skull bone lesion). This is a low-cost and easy technique that can be quickly learned and performed before every surgery. It helps the surgeon to plane a safe craniotomy and lesionectomy.

CONCLUSION

The HeaDax procedure is a good alternative for localizing superficial intracranial lesions on the skin scalp under CT-scan or MRI guidance. This technique is simple, practical, noninvasive, and inexpensive. It can be used as a substitute when stereotactic and neuronavigation systems are not easily available, especially in developing countries and in resource-limited environments. HeaDax has a true potential for further developments and applications in cranial surgery.

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Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Conflicts of interest

There are no conflicts of interest.

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