Skin Landmarks as Ideal Entry Points for Ventricular Drainage, a Radiological Study

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Abstract

PURPOSE: Ventricular drainage remains a challenging procedure for neurosurgical trainees, particularly in healthy subjects. The objective of the study was to describe reliable skin landmarks for ideal entry points (IEPs) to catheterize brain ventricles via frontal and parieto-occipital approaches.

METHODS: We included 30 healthy subjects who underwent brain MRI and simulated the ideal catheterization trajectories of lateral ventricles using anterior and posterior approaches and localized skin surface IEPs. The optimal frontal target was the interventricular foramen and that for the parieto-occipital approach was the atrium. We measured the distances between these IEPs and easily identifiable skin landmarks.

RESULTS: The frontal IEP was localized to 114.00 ± 6.75 mm behind the nasion on the sagittal plane and to 40.04 ± 3.07 mm lateral to the midline on the coronal plane. The ideal catheter length was estimated to be 73.08 ± 4.03 mm from the skin surface to the interventricular foramen. The parieto-occipital IEP point was localized to 61.40 ± 4.44 mm above the ipsilateral tragus on the coronal plane and to 56.53 ± 6.86 mm behind the tragus on the axial plane. The ideal catheter length was estimated to be 51.65 ± 2.86 mm.

CONCLUSION: The IEP for the frontal approach was localized to 11 cm above the nasion and 4 cm lateral to the midline. The IEP for the parieto-occipital approach was 5.5 cm behind and 6 cm above the tragus. These measurements differ from the classical descriptions of Kocher's point and Keen's point and seem relevant to neurosurgical practice.

Introduction

Catheterization of the cerebral ventricles is a fundamental life-saving procedure in neurosurgery. Although numerous safe entry points to the cerebral ventricles have been described in the literature, the accuracy of free-hand catheter placement is about 77% for optimal placements.[1,2,3,4,5.6] Over the past decade, major improvements in intraoperative imaging and the increased accessibility of neuronavigation systems have changed the learning process of this procedure.[7] These devices are now widespread and considered safe and useful to access the ventricular system.

However, in emergencies, neurosurgeons are expected to perform this surgery whether or not neuronavigation is available. Therefore, every neurosurgeon must be able to identify several craniometric points to provide safe and efficient care under any circumstances.[8]

The objective of this study was to radiologically identify the shortest and safest frontal and parieto-occipital entry points on brain magnetic resonance imaging (MRI) of healthy subjects using skin landmarks and measurements.

Methods

Population

Thirty healthy adult volunteers underwent high-resolution brain MRI on a 3 Tesla scanner (Vantage Galan 3T/ZGO; Canon Medical Systems, Tochigi, Japan) with a 32-channel phased array head coil. The 3D T2 gradient echo sequences used the following parameters: repetition time (TR), 2.800 ms; echo time (TE), 262.3 ms; flip angle, 90–180°; bandwidth, 488 Hz; field of view, 22.4 × 22.4 mm; matrix, 368 × 368, and slice thickness, 0.6 mm. All participants provided written informed consent according to local regulations.

Imaging Data Analysis

Measurements were carried out after reconstructing the MRI slices in referential planes. The orbitomeatal plane, defined as running from the outer canthus of the eye to the midpoint of the external auditory meatus, was used as the axial reference. Maximal intensity projection (MIP) fusion images and multiplanar reformation were used to measure in the sagittal plane. Measurements were made on the skin surface.

Images were reconstructed and measurements were made using HorosTM software (GNU LesserGeneral Public License, Version 4.0.0 RC5) in both hemispheres of all healthy subjects.

Statistical Analysis

The Student's *t*-test was used to compare quantitative variables. A p-value < 0.05 was considered significant. The null hypothesis assumed no significant difference between the two sides, as well as between the groups of variables described below.

Radiological Measurements - Frontal Approach

The interventricular foramen (or foramen of Monro) was defined as the optimal target of the catheter. The ideal entry point (IEP) was defined as the surface skin projection of the shortest orthogonal trajectory from the skin to the optimal target. A virtual catheter was placed perpendicularly to the surface of the frontal bone in the sagittal and coronal planes and penetrated the frontal horn of the ipsilateral lateral ventricle to reach the interventricular foramen, avoiding crossing the corpus callosum.

The distance between the nasion and the entry point was measured on a MIP sagittal cut (Fig. 1A). We also measured the distance between the IEP at the surface of the skin and the midline in the coronal plane (Fig. 1B). The length of the catheter was assessed using the distance between the IEP at the surface of the skin and our objective (interventricular foramen).

Radiological Measurements – Parieto-occipital Approach

The ventricular atrium (or trigone of the lateral ventricle) was defined as the optimal target of the catheter. The IEP was spotted on the skin surface, and the catheter was introduced orthogonally to the surface of the parietal bone in the sagittal and axial planes and reached the target via the shortest trajectory (Fig. 3). The position of the IEP was measured relative to the tragus. As described previously, we used the MIP fusion cut of the axial (Fig. 3A) and coronal (Fig. 3B) planes to measure the distance between the IEP and the ipsilateral tragus. The length of the catheter was assessed by measuring the distance between the IEP at the skin surface and the optimal target of the catheter within the ventricular atrium.

Results

Frontal approach

The IEP was localized at 114.0 ± 6.7 mm behind the nasion in the sagittal plane and at 40.0 ± 3.1 mm lateral to the midline in the coronal plane. The ideal catheter length was estimated to be 73.1 ± 4.0 mm from the skin surface. No significant differences were observed between the hemispheres in any of these measurements ($p > 0.05$). Table 1 summarizes the results.

Table 1
Skin landmarks for the frontal entry point.

	Right	Left	Mean	Standard deviation	p-value
Coronal distance: frontal IEP-midline (mm)	40.4	39.7	40.0	3.1	0.73
Sagittal distance: frontal IEP-nasion (mm)	113.8	114.2	114.0	6.7	0.39
Catheter length (mm)	73.7	72.5	73.1	4.0	0.81

Parieto-occipital approach

The entry point was localized at 61.4 ± 4.4 mm above the ipsilateral tragus in the coronal plane and at 56.5 ± 6.9 mm behind the tragus in the axial plane. The ideal catheter length was estimated to be 51.6 ± 2.9 mm from the skin surface. No significant differences were observed between the hemispheres ($p > 0.05$). Table 2 summarizes the results.

Table 2
Skin landmarks for the parieto-occipital entry point.

	Right	Left	Mean	Standard deviation	p-value
Coronal distance: parieto-occipital IEP- tragus (mm)	61.3	61.5	61.4	4.4	0.41
Axial distance: parieto-occipital IEP- tragus (mm)	56.3	57.0	56.6	6.9	0.48
Catheter length (mm)	51.4	51.9	51.6	2.8	0.59

Discussion

In this study, we radiologically localized and described the IEPs to the lateral ventricle on the skin surface in 30 healthy subjects. The ideal trajectory was orthogonal to the bone and avoided the corpus callosum when possible. The optimal targets were the ipsilateral interventricular foramina for the frontal approach and the ventricular atrium for the parieto-occipital approach.

The frontal IEP has often been described as located 10–12 cm behind the nasion, which concurs with our findings.[1] However, the frontal IEP is classically described more medially, at 2–3 cm from the midline.[6,9,10] This difference was explained geometrically by the intent to describe a superficial skin surface IEP instead of a deeper bone IEP for a converging trajectory. If the described point is further from the target, it becomes further from the midline. Another reason could be the size of the ventricular system. Our subjects were young healthy volunteers and most previous studies were carried out on patients with hydrocephalus.[9,10] The difference could also be explained by the trajectory we used, as we always introduced the catheter orthogonal to the bone. The incidence angle is frequently readjusted using Kocher's point to reach the interventricular foramina using a Gahjar guide[11,12,10] or a smartphone.[13]

Localization of the parieto-occipital IEP for ventricular access has been described by numerous authors using various references, such as the meatus or the pinna of the ear.[5,9] The advantages of using the tragus as a reference are its stability and ease of identification in every patient. We found that the parieto-occipital IEP was approximately 6 cm above the tragus in the coronal plane and 5.5 cm behind the tragus in the axial plane, which is comparable to recent descriptions by other authors.[3,14] The parieto-occipital approach we describe remains similar to Frazier's point.[9]

Knowledge of these IEPs is mandatory for safe ventricular access and must be taught very early to neurosurgical trainees. These points can be found after positioning the patient, and an orthogonal trajectory can always be attempted after a failed neuronavigated puncture. More studies are necessary to evaluate the clinical relevance of this approach.

Limitations of the study

The pinna of the ear was barely identifiable on several MRI acquisitions, so we used the tragus as our reference. Our sample included only healthy subjects and the external validity of this study remains unknown.[15,16] Additionally, cranial shape and geometry play a role in localizing the entry point.[17]

Conclusion

Despite the widespread accessibility of intraoperative imagery, learning basic surface skin landmarks and IEPs is mandatory in neurosurgical practice. Although neuronavigation systems are commonly used to perform planned ventricular drainage, these devices may be erratic; thus, craniometric knowledge is required to confirm the imaging data.[18] Additional studies in a pediatric population are necessary.

Abbreviations

MRI
Magnetic Resonance Imaging
IEP
Ideal Entry Points

Declarations

FOOTNOTES

This study has not been published before; it is not under consideration for publication anywhere else; its publication has been approved by all co-authors, and at the institute where the work was carried out.

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Contributors PR and JRV had the idea for the paper. PR, PLP and VJ prepared the first draft. EL and LD prepared the draft figures. TT and JRV assisted with imaging interpretation and critically reviewed the manuscript for intellectual content. PR, VJ and JRV were involved in the clinical care of the patients and critically reviewed the manuscript for intellectual content.

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Figures

Figure 1

The interventricular foramen was identified and set as the optimal target for the catheter (red point).

Figure 2

A –The distance between the frontal ideal entry point and the midline in a coronal cut was measured.

B – The distance between the frontal ideal entry point at the skin surface and the nasion was measured on a sagittal maximal intensity projection reconstructed image.

Figure 3

A – The distance between the parieto-occipital ideal entry point at the skin surface and the tragus was measured on an axial maximal intensity projection reconstructed image.

B – The distance between the parieto-occipital ideal entry point at the skin surface and the tragus was measured on a coronal maximal intensity projection reconstructed image.

Figure 4

Three-dimensional human body model illustrating the skin landmarks for ideal entry points (IEP) for ventricular puncture.

A- Anterior-superior right-sided view illustrating the skin landmarks for the frontal IEP.

B- Right-sided posterior view illustrating the skin landmarks for the parieto-occipital IEP.