Skin landmarks as ideal entry points for ventricular drainage, a radiological study

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Abstract

Purpose Ventricular drainage remains a usual but challenging procedure for neurosurgical trainees. 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 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 116.8 ± 9.3 mm behind the nasion on the sagittal plane and to 39.7 ± 4.9 mm lateral to the midline on the coronal plane. The ideal catheter length was estimated to be 68.4 ± 6.4 mm from the skin surface to the interventricular foramen. The parieto-occipital point was localized to 62.9 ± 7.4 mm above the ipsilateral tragus on the coronal plane and to 53.1 ± 9.1 mm behind the tragus on the axial plane. The ideal catheter length was estimated to be 48.3 ± 9.6 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 lightly differ from the classical descriptions of Kocher’s point and Keen’s point and seem relevant to neurosurgical practice while using an orthogonal insertion.

Keywords Surface landmarks · Neurosurgical anatomy · Ventricular shunt

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Abbreviations
MRI  Magnetic resonance imaging
IEP  Ideal entry points

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 [3, 4, 10, 11, 13]. Over the past decade, major improvements in intraoperative imaging and the increased accessibility of neuronavigation systems have changed the learning process of this procedure [22]. 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 the neuronavigation is available or not. Therefore, every neurosurgeon must be able to identify several craniometric points to provide safe and efficient care under any circumstances [5, 15, 21]. Even though we strongly believe that most of these procedures, especially the parieto-occipital approach to the ventricular atrium, must be performed under neuronavigation assistance in most cases [7]. Nevertheless, every neurosurgeon should be able to perform these procedures in case of neuronavigation failure. For this purpose, skin landmarks related to optimal orthogonal trajectories seem, in our opinion, to be a safer option than most angled trajectories previously described in the literature [6, 12]. This study aimed to validate our previous results upon a cadaveric study [17].

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 using an orthogonal insertion.

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 twice by two authors, a senior and a junior practician together (PR and PLP) 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 Lesser General 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.

Intraobserver analysis was assessed using Pearson’s correlation coefficient analysis (R-value) to assess the correlation between all the measures.

Radiological measurements—frontal approach

The interventricular foramen (or foramen of Monro) was defined as the optimal target of the catheter (Fig. 1). 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 intro-
duced orthogonally to the surface of the parietal bone in the
sagittal and axial planes and reached the target via the shortest trajectory (Fig. 2). The position of the IEP was measured relative to the tragus. As described previously, we used the MIP fusion cut of the axial and coronal planes to measure the distance between the IEP and the ipsilaterial tragus. The length of the catheter was assessed by measuring the dis-
tance 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 $116.8 \pm 9.3$ mm behind the nasion in the sagittal plane and at $39.7 \pm 4.9$ mm lateral to the midline in the coronal plane. The ideal catheter length was estimated to be $68.4 \pm 6.4$ mm from the skin surface. No sig-
nificant differences were observed between the hemispheres ($p > 0.05$). Table 1 summa-
rizes the results.

**Parieto-occipital approach**

The entry point was localized at $62.9 \pm 7.4$ mm above the ipsilateral tragus in the coronal plane and at $53.1 \pm 9.1$ mm behind the tragus in the axial plane. The ideal catheter length was estimated to be $48.3 \pm 9.6$ mm from the skin surface. No significant differences were observed between the hemi-
spheres ($p > 0.05$). Table 2 summarizes the results.

**Intrarater reliability**

Intrarater reliability results using the Pearson technique for the mean measures were, respectively, 0.43 for the coronal distance between the frontal IEP and the midline (0.56 for

![Fig. 1 The interventricular foramen was identified and set as the optimal target for the catheter (yellow point) on brain magnetic resonance imaging T2-weighted sequences on a coronal cut (A), a sagittal cut (B), and an axial cut (C) (colour figure online)](image1)

![Fig. 2 The parieto-occipital ventricular atrium was identified and set as the optimal target for the catheter (yellow point) on brain magnetic resonance imaging T2-weighted sequences on a coronal cut (A), a sagittal cut (B), and an axial cut (C)](image2)

| Table 1 Skin landmarks for the frontal entry point |
|-----------------------------------------------|
| Right | Left | Mean | Standard deviation | $p$-value |
|-------|------|------|---------------------|----------|
| Coronal distance: frontal IEP–midline (mm) | 39.7 | 39.8 | 39.7 | 4.9 | 0.86 |
| Sagittal distance: frontal IEP–nasion (mm) | 116.5 | 117.1 | 116.8 | 9.3 | 0.72 |
| Catheter length (mm) | 68.9 | 67.8 | 68.4 | 6.4 | 0.33 |
the right side, and 0.67 for the left side), 0.77 for its sagittal distance from the nasion (respectively, 0.86 and 0.86), 0.85 for the ideal length of the frontal catheter (respectively, 0.92 and 0.91), 0.78 for the coronal distance between the tragus and the atrial IEP (respectively, 0.86 and 0.84), 0.80 for the axial distance between the tragus and this IEP (respectively, 0.83 and 0.85), and 0.90 for the ideal length of the atrial catheter (respectively, 0.94 and 0.94).

### 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 as described in Figs. 1 and 2.

The frontal IEP has often been described as located 10–12 cm behind the nasion, which concurs with our findings [13]. However, the frontal IEP is classically described more medially, at 2–3 cm from the midline [10, 13, 16]. 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 [13, 16]. 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 Ghajar guide [14, 24], or a smartphone [20].

In this study, we described normal anatomy of healthy subjects to avoid the interindividual variability of ventricular anatomy in case of hydrocephalus. The use of a population might explain the difference between our results and previous published results upon a cadaveric study [17]. The main difference is the distance from the midline to the frontal IEP in the coronal plane (33 mm in the cadaveric study, and 39 mm in this study). Indeed, the age of the patient and especially the ventricular anatomy should be considered before any ventricular shunt with or without neuronavigation assistance. These results are summarized in Fig. 3.

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 [11, 13]. 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 6.3 cm above the tragus in the coronal plane and 5.3 cm

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

|                  | Right | Left | Mean | Standard deviation | p-value |
|------------------|-------|------|------|--------------------|---------|
| Coronal distance: |       |      |      |                    |         |
| parieto-occipital | 62.6  | 63.2 | 62.9 | 4.4                | 0.62    |
| IEP–tragus (mm)  |       |      |      |                    |         |
| Axial distance:  | 52.7  | 53.4 | 53.1 | 9.1                | 0.68    |
| parieto-occipital |       |      |      |                    |         |
| IEP–tragus (mm)  |       |      |      |                    |         |
| Catheter length  | 48.1  | 48.4 | 48.3 | 9.6                | 0.70    |
| (mm)             |       |      |      |                    |         |

![Fig. 3](image-url)
behind the tragus in the axial plane, which is comparable to recent descriptions by other authors, and concordant with our previous cadaveric study [17, 19]. The parieto-occipital approach we describe remains similar to Frazier’s point [13].

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. However, a neurosurgical trainee who would be using these landmarks should remember these measures have been performed on healthy young volunteers and might differ in some clinical situations.

**Limitations of the study**

The pinna of the ear was barely identifiable on several MRI acquisitions, so we used the tragus as our reference which seemed to be anatomically intact but can be distorted by the positioning of the wedge on MRI. Our sample included only healthy subjects and the external validity of this study remains unknown [2, 9]. In addition, cranial shape and geometry play a role in localizing the entry point [8].

The estimated lengths of the catheters as described were the shortest ways to perform these CSF shunt techniques. However, using these IEP, neurosurgeons should be aware that the catheter lengths are probably not ideal and could be increased using a neuronavigation device. Nevertheless, our results seem consistent with previous measures [1, 23].

**Conclusion**

Despite the widespread accessibility of intraoperative imaging, learning basic surface skin landmarks and IEPs is mandatory for 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]. These landmarks might be used while using an orthogonal insertion when neuronavigation devices are unavailable. Additional studies in a pediatric population are necessary.

**Author contributions** 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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**Availability of data and materials** PR had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Data are available on request to the corresponding author.

**Code availability** Not applicable

**Declarations**

**Conflict of interest** All the authors declare: no support from any organization for this study; no financial relationships with any organizations that might have an interest in the submitted work.

**Ethical approval** Approval was obtained from the institutional ethics board (2016-A00434-47).

**Consent to participate** All the participants provided a written informed consent.

**Consent for publication** Not applicable.

**References**

1. Abdoh MG, Bekaert O, Hodel J, Diarra SM, Le Guerinel C, Nseir R, Bastuji-Garin S, Decq P (2012) Accuracy of external ventricular drainage catheter placement. Acta Neurochir (Wien) 154:153–159. https://doi.org/10.1007/s00701-011-1136-9
2. Aitken AR (1995) Neuroanatomical and cranial geometry of the frontal horn of the lateral ventricle. J Clin Neurosci 2:329–332. https://doi.org/10.1016/0967-5868(95)90054-3
3. Aitken AR (1996) A ventricular catheter guide for rapid and accurate ventricular access. J Clin Neurosci 3:257–260. https://doi.org/10.1016/s0967-5868(96)90061-2
4. Amoo M, Henry J, Javadpour M (2021) Common trajectories for freehand frontal ventriculostomy: a systematic review. World Neurosurg 146:292–297. https://doi.org/10.1016/j.wneu.2020.11.065
5. Austerman R, Rajendran S, Lee J, Britz G (2020) The July effect and its impact on external ventricular drain placement by neurosurgical trainees-analysis of the national inpatient sample. World Neurosurg 142:e81–e88. https://doi.org/10.1016/j.wneu.2020.06.057
6. Beckett JS, Gaonkar B, Babayan D, Mathew J, McArthur D, Salamon N, Martin N, Yang I, Macyszyn L (2018) Autonomous trajectory planning for external ventricular drain placement. Oper Neurosurg (Hagerstown) 15:433–439. https://doi.org/10.1093/ons/opx285
7. Craven CL, Pradini-Santos L, Goel A, Thorne L, Watkins LD, Toma AK (2020) Approach to slitlike ventricles: parieto-occipital versus frontal burr catheter entry sites. World Neurosurg 135:e447–e451. https://doi.org/10.1016/j.wneu.2019.12.030
8. Deora H, Pruthi N, Rao KVLN, Saini J, Dikshit P (2020) Predicting the ideal ventricular freehand pass trajectory using osirix software and the role of occipital shape variations. World Neurosurg 141:e341–e357. https://doi.org/10.1016/j.wneu.2020.05.146
9. Ikeda K, Asahi T, Iida T, Yamamoto J, Tsukada T, Yamamoto N, Takeuchi F, Munemoto S, Sato S-J, Akaike S, Shoin K (2017) Why a catheter can be correctly placed in the anterior horn of lateral ventricle by inserting perpendicular to the frontal bone on...
the ventricular drainage? Demonstration of the accuracy of an inserting path by computed tomographic image study and clinical practices. Neurol Med Chir (Tokyo) 57:225–230. https://doi.org/10.2176/nmc.oa.2016-0175

10. Kakarla UK, Kim LJ, Chang SW, Theodore N, Spetzler RF (2008) Safety and accuracy of bedside external ventricular drain placement. Neurosurgery 63:162–166. https://doi.org/10.1227/NEU.0b013e318287072d

11. Keen WW (1890) Surgery of the lateral ventricles of the brain. Lancet 136:553–555. https://doi.org/10.1016/S0140-6736(00)48676-9

12. Lind CRP, Tsai AMC, Law AJJ, Lau H, Muthiah K (2008) Ventricular catheter trajectories from traditional shunt approaches: a morphometric study in adults with hydrocephalus. J Neurosurg 108:930–933. https://doi.org/10.3171/JNS/2008/108/5/0930

13. Morone PJ, Dewan MC, Zuckerman SL, Tubbs RS, Singer RJ (2020) Craniometrics and ventricular access: a review of Kocher’s, Kaufman’s, Paine’s, Menovsky’s, Tubb’s, Keen’s, Frazier’s, Dandy’s, and Sanchez’s points. Oper Neurosurg (Hagerstown) 18:461–469. https://doi.org/10.1093/ons/opz194

14. Park J, Son W, Park K-S, Kim MY, Lee J (2016) Calvarial slope affecting accuracy of Ghajar Guide technique for ventricular catheter placement. J Neurosurg 124:1429–1433. https://doi.org/10.3171/2015.5.JNS15226

15. Pishjoo M, Khattibi K, Etemadrezaie H, Zabihyan S, Ganjeifar B, Safdari M, Baharvahdat H (2021) Determinants of accuracy of freehand external ventricular drain placement by neurosurgical trainees. Acta Neurochir (Wien) 163:1113–1119. https://doi.org/10.1007/s00701-020-04671-5

16. Rehman T, ur Rehman A, Ali R, Rehman A, Bashir H, Ahmed Bhimani S, Tran H, Khan S (2013) A radiographic analysis of ventricular trajectories. World Neurosurg 80:173–178. https://doi.org/10.1016/j.wneu.2012.12.012

17. Roblot P, David R, Lefevre E, Gimbert É, Liguro D, Jecko V (2021) Skin landmarks to main cerebral structures: how to identify the main cerebral sulci? An anatomical study. Surg Radiol Anat. https://doi.org/10.1007/s00276-021-02760-3

18. Stieglitz LH, Fichtner J, Andres R, Schucht P, Krähenbühl A-K, Raabe A, Beck J (2013) The silent loss of neuronavigation accuracy: a systematic retrospective analysis of factors influencing the mismatch of frameless stereotactic systems in cranial neurosurgery. Neurosurgery 72:796–807. https://doi.org/10.1227/NEU.0b013e318287072d

19. Tayebi Meybodi K, Hoseinzadeh E, Ahmadi M, Taghvaei M, Saberi H (2017) Reevaluation of classic posterior ventricular puncture sites using a 3-dimensional brain simulation model. World Neurosurg 107:22–27. https://doi.org/10.1016/j.wneu.2017.07.134

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