Manual Occipital Ventricular Puncture for Cerebrospinal Fluid Shunt Surgery: Can Aiming Be Standardized?

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Abstract

The manual occipital ventricular puncture is a standard surgical procedure, but specific targeting has not received sufficient attention despite the experience of anatomical disorientation. This study tried to identify an exact site for the ideal trajectory with this method, especially in the sagittal plane, which avoids contact with the choroid plexus that may be the major source of complications. A total of 44 consecutive adult cases undergoing cerebrospinal fluid shunting through the occipital route for hydrocephalus were retrospectively reviewed for the following: correlations between burr hole site, direction of puncture, and location of the ventricular catheter based on postsurgical radiological studies; calculation of the ideal trajectory to place the catheter tip in the anterior horn of the lateral ventricle without contact with the choroid plexus through the standard occipital burr hole. In addition, the relationships between the location of the ventricular structure, the cranial base line connecting the nasion and inion, and the size of the ventricle were evaluated. Incorrect catheter emplacement was found in five cases, which suggested that this procedure using the standard burr hole site and aim point might result in incorrect catheter placement. The ideal external aim points were widely distributed because of the variable heights of ventricular structures from the cranial baseline. No correlation between the locations of the anatomical points and ventricular size was found. The present study could not define a standard external aim point. Tailored preoperative planning of the trajectory is recommended.

Key words: hydrocephalus, shunt, ventricular catheter, puncture

Introduction

Ventricular catheter emplacement still relies on manual puncture because of its simplicity, although neuroimaging guidance has been introduced. Cerebrospinal fluid shunting requires placement of the catheter in the anterior horn of the lateral ventricle,^{1-3,6)} for maintenance of shunt function and prevention of complications, mainly related to the choroid plexus, a vascular rich and fragile tissue. These complications include intraventricular hemorrhage (IVH) due to direct injury by ventricular catheter insertion,¹⁷⁾ obstruction of the catheter by hypertrophic tissue as a foreign body reaction,^{8,19)} and IVH⁵⁾ or more rarely pseudoaneurysm formation caused by avulsion of the anterior choroidal artery²⁰⁾ on removal of an obstructed catheter.

Avoidance of the choroid plexus must be considered with manual ventricular puncture, especially

using the occipital route, where there is a tendency for wrong emplacement of the catheter. The present study analyzed the ideal trajectory for this procedure.

Materials and Methods

A total of 63 adolescent and adult patients underwent ventriculoperitoneal or ventriculoatrial shunt placement through the occipital route for treatment of hydrocephalus at Kitasato University Hospital and International Goodwill Hospital, between January 1996 and March 2002. Nineteen patients with marked ventricular deformity caused by mass lesion, external or internal decompression surgery, or secondary focal brain atrophy, or insufficient surgical records and radiological studies including problems with identifying the cranial landmarks mentioned later were excluded. Therefore, 44 patients, 15 men and 29 women aged from 14 to 82 years (mean 58.9 years), were retrospectively studied. No patient had any apparent anomalies of the

cranium, i.e., platybasia or basilar impression. The causes of hydrocephalus were subarachnoid hemorrhage in 34 cases, intraventricular hemorrhage due to intracerebral hemorrhage in two, tumor in three, and trauma in five.

The correlations were evaluated between the burr hole site (distance between the inion and the center of the burr hole), the direction of puncture, and the location of the ventricular catheter tip, as assessed by postsurgical computed tomography (CT) and radiography, and the ideal trajectory was calculated. Geometrical parameters were used to evaluate the anatomical relationships between external cranial landmarks (nasion and inion) and the ventricular structure (Fig. 1). Outlines of the targeted lateral

Fig. 1 Diagram showing the ideal location of the occipital ventricular puncture and the geometric relationships between external cranial landmarks and ventricular structures. BH: burr hole (60 mm above the I), C: anterosuperior margin of the choroid plexus, D_{CV} : distance between C and V (height of the lateral ventricle), D_{N-BH-C} (*) or $D_{N-BH-1/2CV}$ (**): distance between N and the cross point on the BH-C line or the BH-1/2CV line on the forehead, respectively, D_{NI-C} : distance between NI line and C, I: inion, N: nasion, V: upper margin of the lateral ventricle.

ventricle and choroid plexus, identifiable on slices parallel to the orbitomeatal line at 10 mm of thickness, were plotted on presurgical lateral views of the skull based on CT scout views.

A cranial base line connecting the nasion (N) and inion (I) was drawn (NI line), and the distance to the anterosuperior margin of the choroid plexus (C) was measured (D_{NI-C}). The height of the lateral ventricle (D_{CV}) was also measured. Two trajectories through the standard burr hole site, 60 mm above the inion, were considered: the lowest trajectory to pass the choroid plexus passing the C point; and the trajectory to obtain safe clearance from the choroid plexus, taking into account the arcuate bulge, passing the halfway point of the D_{CV} . The distances between the N and the cross points of the two trajectories on the surface of the skull in the forehead were measured (D_{N-BH-C} and $D_{N-BH-1/2CV}$), respectively. The cross-points were defined as the aim points and a bicaudate cerebroventricular index (CVI), the ratio of the width of the lateral ventricles to the width of the brain, at the level of the mid portion of the head of the caudate nucleus (normal value $15 \pm 3\%$),¹²⁾ was established to determine whether the size of the ventricle and the height of the aim point were related.

Results

Correct catheter emplacement, with the tip lying in the anterior horn of the lateral ventricle, was achieved in 39 cases (88.6%), using burr holes located 50 to 110 mm (mean 68.6 mm) above the inion. The external aim points, defined by the cross point of the extended line of the catheter axis on the skull forehead, were distributed from the medial canthus to 40 mm above the nasion in the sagittal plane, and from the midline to ipsilateral medial canthus in the axial plane. Four cases required multiple attempts due to medially located burr holes.

Incorrect catheter emplacement occurred in five cases (11.4%) (Table 1, Fig. 2). The catheter tip was located in the third ventricle in three cases, the thalamus in one, and the inferior horn of the lateral

Table 1 Cases of incorrect ventricular catheter emplacement

Age/Sex	Burr hole location above the inion (mm)	Aim point (sagittal plane)	Location of the catheter tip	Complications
73/F	78	nasion	thalamus	none
76/F	75	medial canthus	third ventricle	IVH
72/M	74	glabella	third ventricle	none
48/F	60	glabella	third ventricle	none
59/M	55	below the medial canthus	inferior horn	none

IVH: intraventricular hemorrhage.

Fig. 2 Postoperative computed tomography scan (A) and scout view (B) in a case of incorrect ventricular catheter emplacement. The catheter was inserted through the burr hole about 60 mm above the inion (arrow), in a line extending along the axis of the catheter into the glabella (arrowheads), but the tip was located in the third ventricle.

Table 2 Geometrical parameters related to ventricular catheter emplacement

Parameters	Range (mean)
D_{N-C} (mm)	30–54 (40.8)
D_{CV} (mm)	10–43 (22.7)
D_{N-BH-C} (mm)	0–53 (24.1)
$D_{N-BH-1/2CV}$ (mm)	19–69 (45.2)
CVI (%)	16.3–37.8 (25.6)

CVI: cerebroventricular index. See Fig. 1 for the definition of the geometrical parameters.

ventricle in one. The burr hole location ranged from 60 to 78 mm above the inion, and the external aim points in the sagittal plane were the glabella, nasion, medial canthus, and below the medial canthus. The patient with the catheter tip emplaced in the thalamus underwent revision of the catheter immediately after the initial surgery. Single cases of small IVH were observed in both correct and incorrect catheter emplacement groups.

The measurements relating to ventricular catheter placement are shown in Table 2. The external aim points were widely distributed because of variable heights of ventricular structures from the cranial baseline (Table 3). D_{N-BH-C} ranged from 0–53 mm (mean 24.1 mm) and $D_{N-BH-1/2CV}$ from 19–69 mm (mean 45.2 mm). No case had an aim point below the N. No definite correlation between the location of these anatomical points and bicaudate CVI was found (Fig. 3).

Table 3 Distribution of aim points for each trajectory

Distance from N (mm)	Aim points	
	N-BH-C	N-BH-1/2CV
60–69	0	8
50–59	2	11
40–49	3	8
30–39	10	13
20–29	12	3
10–19	11	1
0–9	6	0

See Fig. 1 for the definition of the aim points.

Discussion

The geometric factors for selecting the trajectories for manual ventricular punctures are the burr hole location and the external aim point. In the occipital route, the burr hole location is established in a standard fashion, located 60–80 mm above the inion and 30–40 mm lateral to the midline.^{4,7,10,11,14,18)} On the other hand, the external aim point has been variously described in surgical textbooks, especially with reference to the sagittal plane, as the nasion,¹⁸⁾ the tip of the top of the ear,¹¹⁾ or not specified¹⁴⁾ for cerebrospinal fluid sampling or temporary drainage; and the middle of forehead,^{10,16)} 10 mm above the nasion,⁴⁾ and the medial canthus^{7,10,15)} for shunt placement. This situation is confusing for trainee neurosurgeons and standard manual puncture sometimes results in incorrect ventricular catheter placement.

The present study generated two major findings. First, puncture using the standard puncture site and external aim point was used in four of the five incorrect emplacements. Second, no definite correlation was found between the ventricular size and location (height) of the anterosuperior margin of the choroid plexus superior to the NI line. Therefore, no standard external aim point could be established. Guidance tools have earlier been proposed.^{9,13)} Investigation of a posterior ventricular catheter burr hole localizer employing the normally located superior orbital rim and superior attachment point of the ear as reference points showed that localization of the burr hole relative to the inion should not be applied because of the variations in this landmark.⁹⁾ The present retrospective analysis also showed that the described conventional standard occipital puncture might result in incorrect catheter emplacement and the ideal external aim points could not be standardized because of the wide varia-

Fig. 3 Scatterplots showing the relationships between the cerebroventricular index (CVI) and four geometrical parameters; D_{NI-C} (A), D_{CV} (B), D_{N-BH-C} (C), and $D_{N-BH-1/2CV}$ (D), respectively. See Fig. 1 for the definition of the geometrical parameters.

tion in the landmarks. We believe that the aim point should be decided based on preoperative individual radiological measurements, although this primitive process takes time. The experience of the surgeon is very important in manual occipital ventricular catheter placement, but relying solely on experience is not recommended.

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Commentary on this paper appears on the next page.

Commentary

All blind procedures relying on external landmarks carry a considerable risk of mistakes. This holds true also for manual occipital ventricular puncture. The authors analyze their experience with this procedure and find that a sizeable number of catheters had been misplaced (around 12%). I believe that this is also the experience of most neurosurgical centers, especially because in many hospitals this maneuver is carried out by young residents at the beginning of their training. The suggestion of the authors of planning manual occipital ventricular puncture based on the radiology of the individual patient is to be supported; use either plain skull x-rays (AP and lateral) or CT. This is what I was taught to do at the beginning of my residency, and it is what I still teach my residents to do. The measurements and the figures produced by the authors may help to reduce the number of misplaced catheters.

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Shimizu et al. present a retrospective study on the results in occipital placement of ventricular catheters. The actual location of the catheter is analyzed. After placing a burrhole 3 cm from the midline 6 cm above the inion, the trajectory and possible landmarks as target points are determined from CT scans. The purpose of this was to avoid placement of the catheters in the choroid plexus or in the thalamus or caudate nucleus. The individual CT scan was obtained prior to surgery. The results are obviously surprising, as reliance on "experience" or landmarks proved to be treacherous. The individual differences of the size and location of the ventricles in relation to

landmarks is apparently so variable, that targeted placement of these catheters is warranted. As it is our fundamental task to avoid unnecessary lesions, this contribution should lead to routine CT and appropriate evaluation prior to placement of occipital ventricular catheters.

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Cerebrospinal fluid shunt surgery is a common operation in neurosurgery. Manual occipital ventricular puncture is more simple and easier than other neurosurgical management, but involves some problems for routine puncture, incorrect location of the ventricular and celiac catheter, and increased complications caused by the shunt, because hydrocephalus for various reasons often causes transfiguration of the ventricular system, and even skull and brain development abnormality.

The authors have mapped the puncture sites and tracks by individual, and sum up the operations from 44 consecutive adult cases undergoing cerebrospinal fluid shunting through the occipital route for hydrocephalus. We believe that this tailored preoperative planning was mostly based on applying radiological techniques, combined with the state of different patients, using various puncture schemes, then operating. This method ensures the veracity of puncture and exact location of catheter in the ventricle. It is worthy of recommending and applying because of its simplicity and easy manipulation.

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