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Intraventricular Shunt Catheter Placement of Adult Normal Pressure Hydrocephalus Using an AxiEM™ Electromagnetic Neuronavigation System: A Single-Center Experience

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ABSTRACT

AIM: To prove the superiority of the electromagnetic (EM) neuronavigation technique to increase shunt accuracy and reduce accompanying complications.

MATERIAL and METHODS: A total of 21 patients with hydrocephalus (age, 53–84) were studied. All of them had undergone thin-slice, navigation-compatible, computed tomography (CT) preoperatively. Shunt surgery was performed under the guidance of EM neuronavigation technology. All patients underwent follow-up CT the next day to evaluate catheter tip placement and were followed up at 1, 3, 6, and 12 months.

RESULTS: All catheter tips were placed properly in front of the foramen of Monro in the desired position, except in one case in which the tip migrated to the perimesencephalic cistern and underwent reoperation in the early postoperative period. No complications due to infection and obstruction were observed in the medium- and long-term follow-ups. The complication rate due to the incorrect catheter positioning was 4.76% of the total cases.

CONCLUSION: The placement of the ventricular catheter under EM-guided navigation technology reduces the proximal-end failure caused by malpositioning, obstruction, and infection.

KEYWORDS: AxiEM, Ventriculoperitoneal shunting, Electromagnetic neuro navigation, EM guided catheter placement

ABBREVIATIONS: EM neuronavigation: Electromagnetic neuronavigation, **CT:** Computed tomography, **3D:** three-dimensional, **CSF:** Cerebrospinal fluid

INTRODUCTION

The use of navigation technology in medical science has a lengthy history. The term navigation was used for the first time in the 1700s by Pierre de Fermat, referring to the Cartesian coordinate system (27). In 1905, the first frame-based stereotaxic surgery technique was devised. It was used in experimental animal studies, and the procedure was performed on humans successfully for the first time in 1947. Stereotaxic systems were developed later on. These frame-based stereotaxic techniques were invasive and painful, and the areas where it could be utilized were restricted; thus, real-time imaging data could not be synchronized.

More modern navigation technologies were developed and launched in the late 1990s. Following this historic development, the use of neuronavigation systems has become popular in the field of neurosurgery. Its indications has expanded in various surgical procedures, ranging from cranial to spinal surgery, as it is less invasive and achieves the target with more accuracy (7,10,16,28).

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Although ventricular catheter placement appears to be a simple operation, even in the most experienced hands, there can be complications. Ventricular catheter proximal-end failure has many causes, such as infection and obstruction. Obstruction may be caused by debris or adherence to the choroid plexus, ventricular wall, or clogging the brain tissue. In addition, the placement of the catheter in the contralateral ventricle or third ventricle may cause malfunction (3,4,23).

The AxiEM (Medtronic, Minneapolis, USA); is a novel navigation technology that is not invasive and does not require head fixation unlike optical systems; thus, it is comfortable to use. After the registration, the surgeon can move the patient's head freely. Frameless electromagnetic-navigated (AxiEM™) functions by creating a magnetic field using an apparatus that is placed near the patient's head (9,31).

In EM technology, we can follow the tip of the catheter by inserting a thin probe into it, which helps track the trajectory accurately. It also helps follow the catheter tip, which allows the surgeon to place the catheter at the target location as was planned preoperatively. As a result, it reduces complications and undesired revision surgeries.

MATERIAL and METHODS

We evaluated our experience in EM-guided neuronavigation technology for ventricular catheterization. A total of 21 patients who had undergone ventriculoperitoneal shunt placement with EM-guided neuronavigation were prospectively evaluated (Table I). Patients who needed surgery and diagnosed with normal pressured hydrocephalus were included in the study. Patients with a previous history of shunting and the cases with a history of previous bleeding or infection were not included in the study. 1-mm thin-sectioned neuronavigational compatible cranial computed tomography (CT) was taken preoperatively.

CT was performed because the accuracy during recording was better than that with magnetic resonance imaging. CT images were uploaded to the Medtronic Stealth Station S8 navigation station with shunt insertion mode selection. Then, in the planning screen, the surgeon selected the entry and target points to create a surgical plan on the radiological images and three-dimensional (3D) model generated by the system. At this point, the probe eye function was used in the navigation menu to simulate the catheter trace virtually. Care was taken to ensure that there was no vascular structure in the area where the catheter would pass avoiding the sulcal anatomy. The Medtronic magnetic emitter was then mounted near the patient's head with a Vertek arm. A Medtronic noninvasive patient tracker was attached to the patient's head in a nonsterile fashion and connected with wires to the EM portable controller. In the software, the surgeon switched to the registration screen and registered the patient with the Medtronic EM Tracer Pointer connected to the EM portable controller. An error of <1.5 mm appeared acceptable during registration. Registration verification was performed by touching the Tracer Pointer at the proper anatomical points (tip of the nose, glabella etc.). After these steps, the entry point was marked with the tip of the AxiEM marker, and the system was ready to use. The surgical site was sterilized and draped. After burr-hole opening and dural incision, Medtronic AxiEM Stylet was placed into the ventricular catheter and the aid of the stylet. Before ventricular placement, we aligned the catheter with a stylet on the trajectory line on the trajectory windows in the navigation monitor and aligned with the target point. The surgeon monitored the movement of the tip of the ventricular catheter on the navigation screen when advancing the catheter toward the target. When the catheter tip reached the accurate target on the screen, the stylet was removed. The catheter was placed on the measured depth in the frontal horn of the lateral ventricle, and standard ventriculoperitoneal shunting procedure was completed. All patients underwent CT the next day. Patients were followed for 1 year in 1, 3–6, and 6–12 months at regular intervals to assess whether revision was required.

Table I: Demographic Characteristics, Diagnoses and Occurence of Complications in the Treated Patients

Patient no	Sex	Age	Pathology	Complication
1	M	61	NPH	(–)
2	M	74	NPH	(–)
3	F	81	NPH	(–)
4	M	75	NPH	(–)
5	F	54	NPH	(–)
6	F	72	NPH	(–)
7	F	70	NPH	(–)
8	M	76	NPH	(–)
9	F	81	NPH	(–)
10	M	65	NPH	(–)
11	M	77	NPH	(–)
12	M	69	NPH	(–)
13	M	84	NPH	(–)
14	M	73	NPH	(+)
15	F	63	NPH	(–)
16	M	78	NPH	(–)
17	M	66	NPH	(–)
18	F	53	NPH	(–)
19	M	61	NPH	(–)
20	M	70	NPH	(–)
21	M	75	NPH	(–)

***NPH:** normal pressure hydrocephalus.*

RESULTS

CT was performed the day after surgery, which showed that all catheters, except one, were placed in the desired location planned before surgery without touching the ventricular walls or vascular structures (Figure 1). We encountered a case in which early revision surgery was performed due to the entry of the catheter tip into the perimesencephalic cistern (Figure 2). No complications due to infection and obstruction were observed in the medium and long-term follow-ups. The complication rate due to incorrect positioning of catheter was 4.76% of the total cases (Table II).

DISCUSSION

This study aimed to show the precision and accuracy of using the AxiEM neuronavigation technique in ventriculo-peritoneal shunting. We decided to calculate the precision of catheter insertions by measuring the distance of the catheter tip from the foramen of Monro using early postoperative cranial topographies. The results of our study showed how this technology significantly reduces the occurrences of malfunctioning and the need for revision surgery.

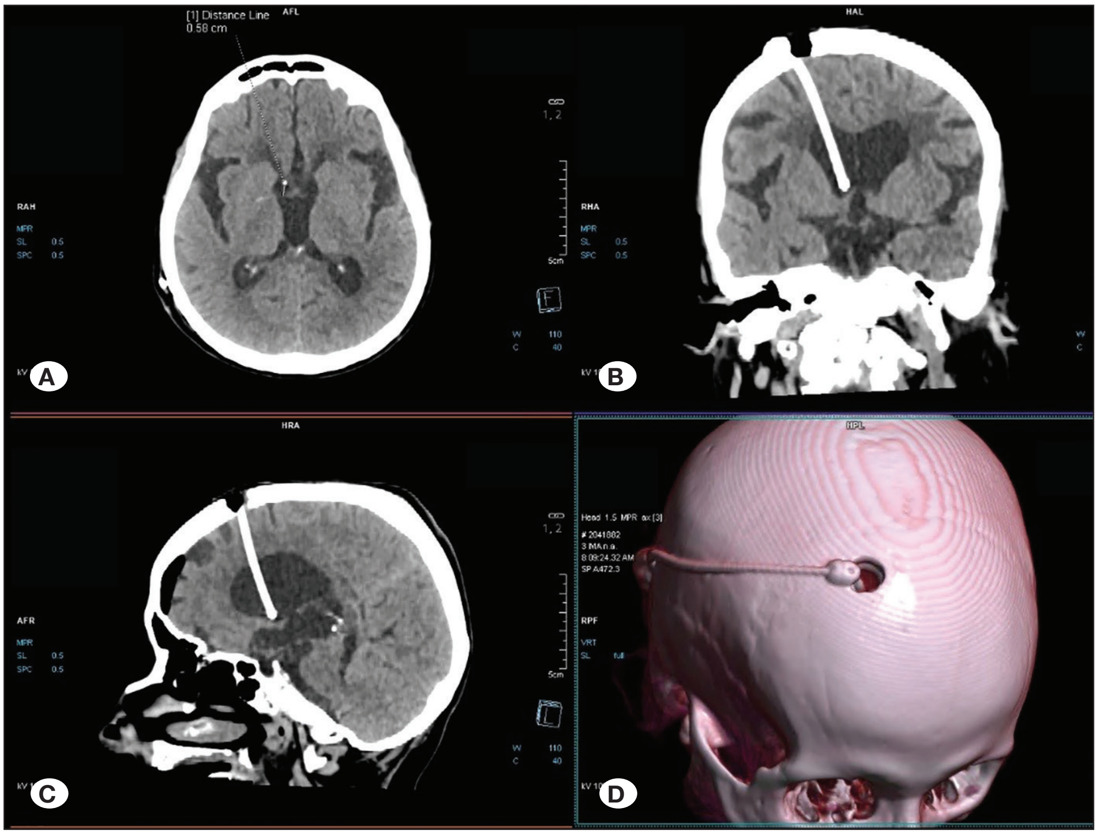

Figure 1: Postoperative axial **(A)**, coronal **(B)**, sagittal **(C)** and 3-D **(D)** computed tomography scans. We can see AxiEM guidance ventricular catheter placement on the desired location just behind to foramen of Monro.

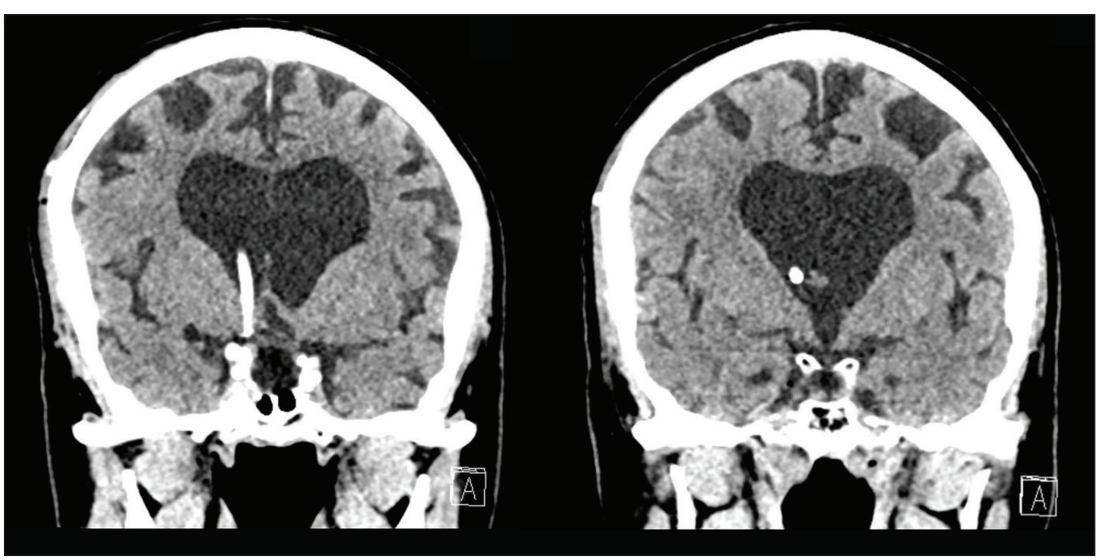

Figure 2: Postoperative coronal computed tomography scans of the patient that underwent early revision surgery due to misplacement of the catheter into the perimesencephalic cistern. Care must be taken during the insertion of catheter even using the neuronavigational device.

In recent years, the tendency to use neuronavigation technology in the field of neurosurgery has increased. The adoption of this method has significantly reduced complications that arise in surgery**.** Ventriculoperitoneal shunting should not be considered a simple procedure. In all types of hydrocephalous, in any age, even under experienced hands, revision surgery may be needed (14,25). Revision surgeries are very expensive and carry certain risks**.** Infections and mechanical occlusion are the main causes of revision, with proximal catheter misplacement and/or occlusion (19,29,30).

Importantly, CSF (Cerebrospinal fluid) drainage during catheter insertion is not always indicative of a successful operation, as proper placement is the most important (2,13). The proper location for the catheter tip is just beside the foramen of Monro (6,18,21). Thus, it is important to insert the catheter to the desirable location in one trial: the higher the number of attempts, the higher the risk of damaging eloquent areas and the infection rate.

Catheter malposition is one of the main causes of early shunt dysfunction and needs revision (15,24). Catheter misplacement, placement in the contralateral ventricle or sidewall of the ventricle, and stretching toward the third ventricle are the main causes. Rates could go as high as 20.8%–24.4% in some reports, and up to 16.7% may require for revision (1,15). In the later periods, shunt infection or obstruction due to debris may cause revision surgeries (17,24).

In the freehand shunting method, unguided and blind advancing of the shunt into the ventricular space may lead to some inadvertent results. In addition, the operation may take longer because it may not be successful in just one attempt. The possibility of damaging deep structures may increase due to the surgeon's loss of 3D imagination. The catheter may touch the ventricular wall and adhere to the neural parenchyma or choroid plexus.

Table II: Proper Location (PL) (The desired location for the tip of the shunt, the location that leads to less malfunctioning, obstruction, and infection, is close to the foramen of monro, away from the lateral ventricle's walls and other important areas such as the choroid plexus)

Patient No.	Distance to the foramen of Monro/proper location	Early postoperative complication/need for revision (<1 month)	1–3 month postoperative complication/need for revision	Late postoperative complication/need for revision (6–12 months)
1	(+)	(–)	(–)	(–)
2	(+)	(–)	(–)	(–)
3	(+)	(–)	(–)	(–)
4	(+)	(–)	(–)	(–)
5	(+)	(–)	(–)	(–)
6	(+)	(–)	(–)	(–)
7	(+)	(–)	(–)	(–)
8	(+)	(–)	(–)	(–)
9	(+)	(–)	(–)	(–)
10	(+)	(–)	(–)	(–)
11	(+)	(–)	(–)	(–)
12	(+)	(–)	(–)	(–)
13	(+)	(–)	(–)	(–)
14	(–)	(+)	(–)	(–)
15	(+)	(–)	(–)	(–)
16	(+)	(–)	(–)	(–)
17	(+)	(–)	(–)	(–)
18	(+)	(–)	(–)	(–)
19	(+)	(–)	(–)	(–)
20	(+)	(–)	(–)	(–)
21	(+)	(–)	(–)	(–)

Neuronavigation-guided surgical procedures can decrease such unwanted incidents. It helps decrease the surgical time and reach the target in the shortest and safest trajectory, as a result of the careful preplanning. The surgeon can evaluate the whole alternative approach preoperatively to maintain maximum confidence and comprehension regarding the anatomic structures (20). These devices could provide instantaneous intraoperative answers to the questions in the case of disorientation (20,22). The possibility of misplacement and infections are lower in navigation-guided technology than in conventional techniques that can cause damage to the neural structures and cause hemorrhaging or infection due to several insertion trials (13). In addition, the overall surgical time can be significantly reduced because of one-time catheterization attempt and accuracy in the shunt placement procedure; therefore, the rate of short- and long-term revision surgery reduces by decreasing the risk of infections, intracerebral hemorrhages, and ventricular floating particles. All of which result in a better prognosis (11,20).

Despite these advantages of neuronavigation, tearing the scalp using pins during the insertion of the skull clamp, sticking into the brain tissue, and epidural or intracerebral hemorrhage is probable, especially in pediatric patients, since their skulls are thin. To eliminate these drawbacks, EM-guided systems have emerged, providing the benefits of being less invasive with high reliability and accuracy (12). This technology emits an EM field around the patient's head that allows the surgeon to track their progress in real time through the instruments attached to the balls, even in advancing the deep brain structures. The patient's head can move freely despite the led-based navigation techniques.

In ventriculoperitoneal shunting procedure, the accuracy of EM-guided catheter placement is higher than the LED-dependent navigational technique (31).

In our experience, the use of neuronavigation devices is not just about keeping these devices close to the patient and watching the progress of the catheter from the screen. The fact that the surgeon must be trained in the use of neuronavigation devices and has sufficient experience in this field will seriously affect the results because today's technologies can be beneficial only if the user has sufficient knowledge of how to operate. Otherwise, there will be nothing but a crowd of devices in the operating room. As the surgeon's skill and experience in the use of neuronavigation increase, the operation time can be established quickly and ultimately shortened due to the placement of the shunt in one trial.

In our series, one patient underwent early revision surgery due to catheter malposition. In the postoperative CT, the catheter was far ahead and entered the perimesencephalic cistern. It was corrected with a second surgery (Figure 2). When we reexamined the cause of the error, we learned that after placing the catheter at the targeted point under EM guidance while pulling the stylet, the surgeon should hold the catheter with his finger over the burr hole until it is fixed to the galea to prevent it from slipping into the brain. Otherwise, the catheter may be accidentally pushed in, and all efforts may be wasted.

In our series, there was no case of infection during the 1-year follow-up period, and we did not encounter upper-end obstruction of the shunt during the medium- and long-term follow-ups. Probably, the cases with a history of previous bleeding or infection were not included in the study. On the contrary, because of catheterization in one attempt, debris and bleeding did not occur, which is known as the cause of catheter proximal-end occlusion (8). Finally, it may be due to our use of pressure-regulating valves that can regulate the discharge of CSF even under alternating pressure conditions (5,24).

This study has some limitations. First, there were no control groups of freehand techniques to enable comparison of the results of our navigational technique and obtain more meaningful statistical information. Second, our study included mostly patients with dilated ventricles, and the number of patients with narrow ventricles was limited, which decreases the generalizability of the study. We believe that the insertion of the catheter in a slit ventricle under EM guidance also can be performed with more precision. Third, this review does not focus on a longer-term follow-up that may alter parameters and complication rates (26,29). Finally, there were not enough participants who needed shunt surgeries; having merely 21 cases to investigate decreased the amount of data we needed to collect.

Notably, the main inadequacy of navigational technology is that it does not provide real-time data, and preoperative imaging may not reflect the true localization because the brain shifts after CSF drainage and scalp draping (20). In addition, the magnetic resonance produced can affect nearby metallic equipment, which decreases the precision of the neuronavigational system.

CONCLUSION

The placement of the ventricular catheter under EM-guided navigation technology reduces the proximal-end failure caused by malpositioning, obstruction, and infection. Essentially, we should never rely too much on technology; surgeon experience is always superior.

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AUTHORSHIP CONTRIBUTION

Study conception and design: TK
Data collection: MH
Analysis and interpretation of results: MH
Draft manuscript preparation: MH
Critical revision of the article: TK
All authors (TK, MH) reviewed the results and approved the final version of the manuscript.

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