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Does CT wand guidance improve shunt placement in patients with hydrocephalus?

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ABSTRACT

Object: To evaluate the effectiveness of stereotactic navigation in enhancing the accuracy of ventricular shunt placement in patients with hydrocephalus.
Methods: A retrospective cohort study at a single institution by a single surgeon was performed. Consecutive patients who underwent implantation of a ventricular shunt for the management of hydrocephalus between July 2001 and December 2011 were included in the study, totaling 535 patients. Patients were classified as either having optimal or sub-optimal placement of the shunt into the ventricle. Multiple logistic regression analysis was used.
Results: Overall, 93.8% of patients were found to have optimal shunt placement. On multivariate analysis, navigation use was not significantly associated with improved accuracy of shunt placement (odds ratio [OR] = 0.54; 95% confidence interval [CI] = 0.19–1.54; $p = 0.25$). Pseudotumor cerebri diagnosis was significantly associated with increased odds of sub-optimal shunt placement (OR = 6.41; 95% CI = 1.90–21.59; $p = 0.003$).
Conclusions: CT guided navigation did not significantly improve the accuracy of ventricular shunt placement in adults with hydrocephalus for an experienced surgeon. Further studies are required to assess the utility of CT guided navigation for less experienced surgeons and patients with small or dysmorphic ventricles.

1. Introduction

Hydrocephalus, an imbalance between the production and absorption of cerebrospinal fluid (CSF) inside the brain, has an estimated prevalence of 0.9–1.2 per 1000 persons in developed countries [11]. Hydrocephalus has a variety of etiologies, ranging from obstructive hydrocephalus, caused by intracranial lesions or aqueductal stenosis, to non-obstructive hydrocephalus, such as idiopathic normal pressure hydrocephalus (iNPH). CSF diversion with shunting is the most common treatment for hydrocephalus, but has a high complication and revision rate, particularly in patients with small ventricles. For instance, in the pseudotumor cerebri (PTC) population, McGirt et al. found that 75% of all shunts failed within 24 months of shunting [9].

It has been suggested that age and preoperative size of the ventricles are most strongly associated with sub-optimal catheter placement [14]. Additionally, in a recent study, using the freehand approach, optimal placement only was achieved in 85% of parietal, 64% of frontal, and 42% of occipital approaches [8]. Furthermore, it was recently shown that sub-optimal placement of the ventricular catheter had a 57% increased risk of failure with sub-optimal placement, and a 66% increased risk with poor placement relative to sub-optimal placement [6]. Therefore, there is a need for a technology that could increase the accuracy of ventricular catheter placement.

Frameless stereotactic navigation has been increasingly utilized in the field of neurosurgery, and it has recently been adopted in ventricular catheter placement to enable more optimal shunt positioning particularly in patients with slit ventricles [1,18]. Ultrasound guidance has also been used in an effort to increase the accuracy of shunt placement and thereby potentially reduce

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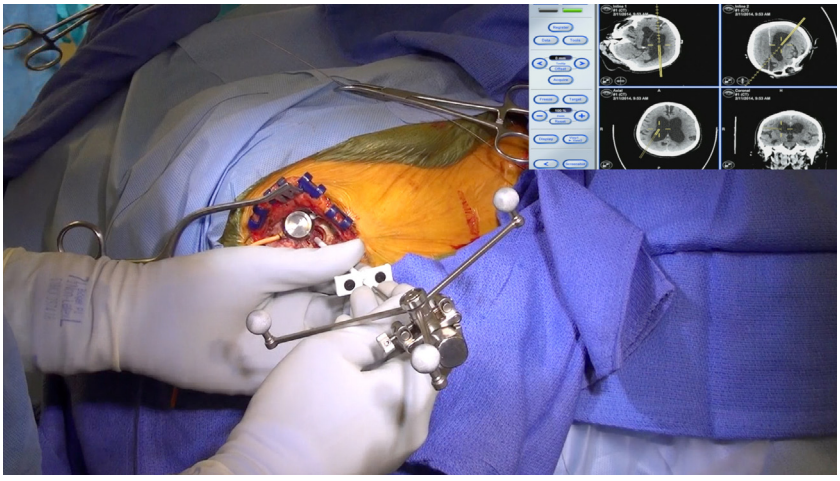

Fig. 1. Use of CT wand during shunt placement with navigation screen.

shunt failure rate. While ultrasound has the advantage of limiting radiation exposure, it is limited in that generally a larger trephination is required. Also, the resolution is sub-optimal compared to CT stereotactic navigation especially when there is thicker cortex to penetrate before entering the ventricles [10]. In a recent study, both ultrasound guidance and stereotactic navigation led to significantly reduced proximal shunt failure rates compared to the freehand technique [16]. However, another study demonstrated that ultrasound guidance did not lead to increased accuracy of shunt placement over the freehand technique [15]. Another approach is to limit the use of stereotactic navigation to patients with small ventricles, such as is the case in patients with PTC. This strategy has been demonstrated to be safe and effective [12,17,18].

However, the prior studies have had small numbers of patients or have involved multiple surgeons. Therefore, with a large number of patients and a single surgeon's experience, the objective of this study was to evaluate the effectiveness of stereotactic navigation in enhancing the accuracy of ventricular shunt placement in patients with hydrocephalus and to determine the factors associated with sub-optimal placement.

2. Materials and methods

Following Institutional Review Board approval, the patient records at a single institution were retrospectively reviewed for adult patients with hydrocephalus who underwent surgery for the placement of a ventricular shunt from July 2001 to December 2011 by the senior author. A parietal approach was used in general, while a frontal approach was typically used for those with PTC. Stereotactic navigation was used in a subset of the patients (Fig. 1). Optimal shunt placement was evaluated by examining postoperative CT images and reviewing radiology reports. A shunt was deemed to be sub-optimally placed if the tip of the catheter was placed in the brain parenchyma or the tip of the catheter was not completely surrounded by CSF. Placement of the catheter tip in the proximity of, or in contact with choroid, was not classified as sub-optimal placement because a revision would not be recommended for this in adult patients unless there was evidence of proximal obstruction.

For each patient, basic demographic information was recorded. Additionally, patients were classified as "PTC" or "non-PTC hydrocephalus," use of navigation, type of shunt, optimal vs. sub-optimal catheter positioning, number of prior revisions, and occurrence of clinically significant intracranial hemorrhage were also recorded.

The early patients in the series were treated without stereotactic navigation, while the later patients in the series were treated with navigation after it became commonly used in our department. Stereotactic navigation was used in all of the later patients in the series unless there was a technical issue with the equipment.

In our protocol, a navigation wand is inserted as the stylet into a peel-away sheath. The peel-away sheath is used to decrease the risk of proximal shunt occlusion [7]. The wand and peel-away sheath are then passed through the cortex and into the ventricle. The wand is removed from the sheath and CSF flow is confirmed. The ventricular catheter is then passed through the peel-away sheath to the appropriate depth based on the navigation measurement, and the peel-away catheter is stripped and removed. The same procedure is performed when navigation is not used, except a standard stylet is used when passing the peel-away sheath rather than the wand.

2.1. Statistics

Demographic and clinical characteristics were summarized using frequencies and percentages for categorical measures and medians and interquartile ranges (IQRs) for continuous measures as most of the continuous measures, e.g., hospital stay, days until revision, were not normally distributed. Wilcoxon's rank–sum test was used to assess the association between shunt placement outcome and the continuous measures. Fisher's exact test was used to assess the association of shunt placement outcome with pathology, race, shunt type, and navigation use. Demographic and clinical variables, except for shunt type, which was insignificant for placement outcome, were included in a multiple exact logistic regression model to determine the independent effect of each. Asian ($n = 4$) and Hispanic ($n = 1$) patients were dropped from the logistic regression because there were so few and none had sub-optimal placement. Hydrocephalus type (non-PTC or PTC) was significantly associated with both age and outcome, so separate models stratifying by pathology were also tested. All analyses were performed using SAS version 9.3 (SAS Institute, Inc., Cary, NC, USA). All reported p-values are two-sided and statistical significance was set at $p < 0.05$.

3. Results

A total of 528 patients were included in the study. Mean (SD) age of the patients at the time of shunt placement was 69.8 (18.0) years. 50.8% of the patients were male and 15.2% had a diagnosis of PTC. Navigation was used in 224 (42.4%) cases. Many of the 304 cases without navigation were performed prior to its widespread use in shunt placement at our institution. Optimal shunt placement was achieved in 95.4% of all patients using the freehand method, and