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Technical Notes & Surgical Techniques

The risk of ventricular catheter misplacement and intracerebral hemorrhage in shunt surgery for hydrocephalus

Linus Hultegård, Isak Michaëlsson, Asgeir Jakola, Dan Farahmand*

Department of Neurosurgery, Sahlgrenska University Hospital, Institute of Neuroscience, Sahlgrenska Academy, Gothenburg University, Sweden

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ABSTRACT

Ventricular shunt insertion is a commonly performed neurosurgical procedure but few studies evaluate the rates of ventricular catheter (VC) misplacement and postoperative intracerebral hemorrhage (ICH) after shunt surgery. In this study, we evaluated the rate of VC misplacement and ICH after shunt insertion in hydrocephalus patients.

A consecutive series of adult patients ($n = 240$) that received a ventricular shunt for hydrocephalus were included in the study. Misplacement was defined as tip of the VC located in the contralateral ventricle or intraparenchymal. The event of ICH was based on verification of intraparenchymal blood on an early (< 48 h) head CT postoperatively. The shunt revision rate within six months postoperatively was compared between patients with and without misplacement of the VC.

Misplacement of the VC tip was found in 76 patients (33%); 70 patients with the VC tip in the contralateral ventricle and six patients (3%) with the VC tip intraparenchymal.

ICH occurred in 8% of the patients. The shunt revision rate for accurately placed VCs was 17% compared to 21% for misplaced VC ($p = 0.37$). Proximal shunt failure occurred in 11% of the patients with VC misplacement compared to 5% of the patients with accurate VC placement ($p = 0.07$).

VC misplacement occurred in one third and ICH was evident in 8% of the patients. However, VC misplacement did not significantly increase the shunt revision rate. Still, measures to optimize VC placement may be important to reduce risks following ventricular shunt placement.

1. Introduction

Ventricular shunt insertion to relieve symptoms of hydrocephalus is a commonly performed neurosurgical procedure. However, the relatively high shunt revision rate of 19–33% within 6–12 months postoperatively needs consideration [1–3]. Ventricular catheter (VC) misplacement occur in 36–60% of the cases and this is a frequent cause for shunt revision [2,3–10]. Obviously, VC misplacement can cause proximal shunt obstruction due to intraparenchymal placement of the VC tip, but VC misplacement can also cause neurological impairment [11], vascular injury [12] and increased risk of intracerebral hemorrhage [12,13].

Most institutions practice a free-hand unassisted VC placement technique aiming the VC tip to the anterior part of the lateral ventricle, ipsilateral to the site of insertion [5,9,14–17]. Previously, retrospective studies have shown an association between correct VC placement and decreased risk of proximal shunt dysfunction although no difference in the overall shunt revision rate could be found [6,18].

The risk of intracerebral hematoma (ICH) after the placement of an external ventricular drainage (EVD) has in previous studies been reported to be 9–41% [19–21]. EVD placement typically occur in the acute setting or in patients treated at the neurointensive care unit, and these patients may be more prone to ICH due to acute brain injury or use of medications interfering with hemostasis. However, studies of intracerebral hemorrhage associated with the most often elective procedure of ventricular shunt placement are scarce [22].

The primary aim of this retrospective cohort study was to evaluate the association of VC misplacement and the risk of shunt revision in adult hydrocephalus patients. The secondary aims of the study were to evaluate the risk of immediate postoperative hematoma (SDH or ICH) and evaluation of ventricular catheter placement after shunt insertion.

2. Patients and methods

All ($n = 240$) adult (18 years or above) patients who underwent ventriculoperitoneal (VP) or ventriculoatrial (VA) shunt insertion

* Corresponding author at: Department of Neurosurgery, Bla straket 5, van 3, Sahlgrenska University Hospital, 413 45 Gothenburg, Sweden.
E-mail address: dan.farahmand@gmail.com (D. Farahmand).

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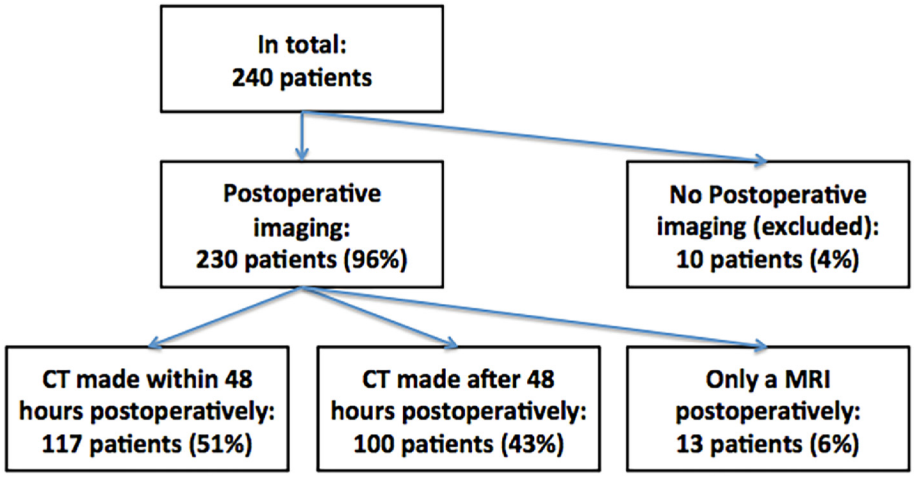

Fig. 1. The flow chart shows the proportions of the included patients undergoing imaging.

between January 2012 and December 2014 at the Department of Neurosurgery at Sahlgrenska University Hospital (Gothenburg, Sweden) were consecutively included. Patients who did not undergo postoperative imaging ($n = 10$) were excluded from the analysis (Fig. 1). Medical records were reviewed for patient characteristics and etiologies of the hydrocephalus. Preoperative imaging (CT or MRI) was used for calculation of Evans' index (EI) [23,24]. The cause of shunt revision and type of shunt revision procedure (proximal or distal/other) were acquired from a prospective database at the Swedish National Hydrocephalus Quality Registry.

In January 2012, a new postoperative routine of early (< 48 h) postoperative CT scan was introduced to evaluate potential complications like ICH and to establish the VC placement before the patients were discharged. The postoperative radiological follow-up also routinely includes an MRI three months postoperatively. Ninety-six percent of the patients underwent postoperative imaging (CT or MRI). An early head CT (non-contrast) was obtained in 117 of the patients (51%). Only patients who underwent an early CT postoperatively were evaluated for ICH (Fig. 1). Ventricular catheter placement was evaluated in all patients undergoing postoperative imaging. Baseline data for the patients in the study are presented in Table 1.

2.1. Definition of end-points

VC misplacement was defined as when the tip of the VC was located in the contralateral ventricle or intraparenchymal (Kakarla grades 2–3) [25]. The clinical impact of the misplacements is expected to differ, as a contralateral catheter in free-floating CSF is likely to be functional whereas an intraparenchymal catheter is likely to be non-functional. However, the aim of this study was to assess the frequency of misplacements as a measure of procedure accuracy. Fig. 2 shows two examples of misplacement. The assessment of the VC tip location and presence of ICH was based both on the main authors' evaluation and the radiologist's report. The maximal diameters of the ICHs were measured on the CT images.

Shunt revision within six months postoperatively was considered related to the index procedure, as has previously been shown [26]. All patients were followed up regarding shunt revision 6 months after shunt insertion and the shunt revision rates were compared between patients with and without misplacement of the VC.

Table 1
Demographic data of the patients included in the study.

Number of patients	240
Age	
Mean (SD)	63.3 (17.0)
Gender (n)	
Women	101 (42%)
Men	139 (58%)
Etiology (n)	
iNPH	114 (48%)
SAH	40 (17%)
Trauma	30 (13%)
MMC	12 (5%)
Tumor	10 (4%)
Obstructive (previously treated)	8 (3%)
Congenital	7 (7%)
CSF leakage	4 (2%)
Other	15 (6%)
Evans Index	
Mean (SD)	0.391 (0.07)

2.2. Data analysis and statistical methods

Descriptive data are presented as proportions (percent) and absolute numbers. Statistical analyses were performed using SPSS statistics version 21.0. Comparisons between groups were done using Chi-square test for categorical variables. Student's *t*-test was applied in case of normally distributed data and Mann Whitney *U* test was applied if data was skewed. Statistical significance was considered to be $p < 0.05$.

2.3. Ethics

The study was approved by the Regional Ethical Review Board (2016:542–16). All patient data were unidentified at the time of data analysis and presentation.

3. Results

Misplacement of the VC tip was found in 76 patients (33%); 70 patients with the VC tip in the contralateral ventricle and in six patients (3%) had the VC tip was placed intraparenchymal (Fig. 3).

Forty-one patients (18%) underwent shunt revision within 6 months. The shunt revision rate for patients with misplaced VC was 21% ($n = 16$) compared to 16% ($n = 25$) for patients with accurate VC placement ($p = 0.37$). Fig. 4 shows the number of shunt revisions performed in patients with correct or misplaced catheters. Proximal shunt failure occurred in eight of 76 patients (11%) with VC misplacement compared to eight of 154 patients (5%) with accurate VC placement ($p = 0.07$).

ICH occurred in nine patients (8%) who underwent an early CT scan ($n = 117$). Two of those 117 patients (2%) presented with clinical symptoms related to the hemorrhage; one patient had hemispatial

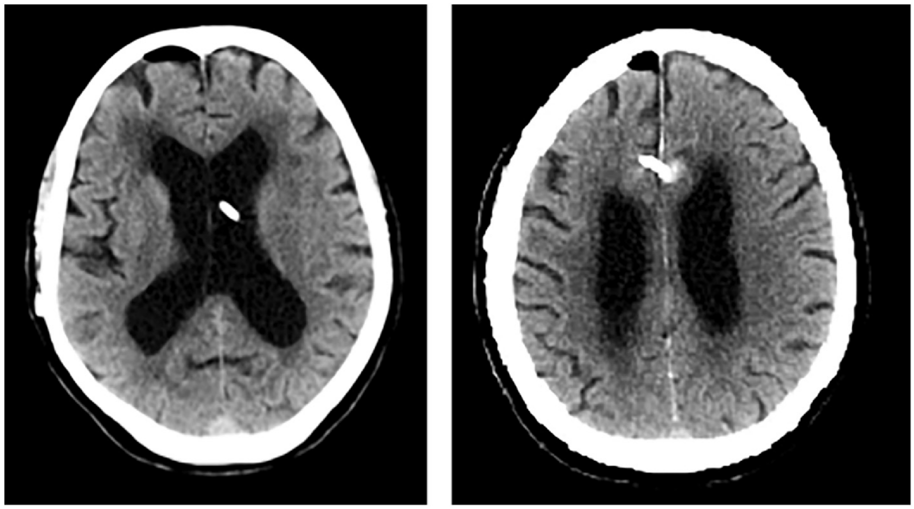

Fig. 2. Misplacement of the ventricular catheter (VC) tip illustrated by two postoperative computer tomography's of the brain. The CT image on the left shows an example of contralateral VC misplacement and the image on the right shows intraparenchymal misplacement of the VC.

neglect and hemiparesis, and the other had hemispatial neglect. ICH was observed in four of the 76 patients (5%) with correct VC tip location, compared to five of the 41 patients (12%) with a misplaced VC tip ($p = 0.18$). The median maximal diameter of the ICHs was 18 mm (range 7–61 mm).

4. Discussion

In the present study, misplacement of the VC tip was found in approximately one third of the shunt placements, which is in accordance with previous studies [6,8,9,27]. While the majority of the VC misplacements were to the contralateral ventricle, in 3% the VC tip was placed intraparenchymal leading to subsequent shunt revision. Previous studies on EVD placement have shown a rate of intraparenchymal or other extraventricular VC misplacement rate of 4–22% [8,10,13,28]. Recent studies have shown that ventricular catheter placement in patients with small ventricles with the aid of neuronavigation resulted in improved accuracy of the catheter tip position [29,30]. Measures to increase the accuracy of VC placement should be considered as it may prevent shunt revisions in patients where VCs located in brain parenchyma.

4.1. VC misplacement

Previous studies have used no generally accepted definition of VC misplacement [8,10,13,25,28]. When the ipsilateral frontal horn or third ventricle was considered as the final location of the VC tip, the inaccuracy ranged from 23 to 36% [25,28].

Wilson et al. [6] recently reported a significant improvement in proximal failure rate with stereotactic neuronavigation/ultrasonic guidance compared to freehand technique. However, no significant difference in the overall failure rate between groups was found. In the present study a higher proximal shunt revision rate was observed in the misplaced VCs (11%) compared to the correctly placed VCs (5%), however this difference was not significant.

Several studies have reported shunt revision rates of 19–32% [1,3,4]. Previously, retrospective studies have shown an association between correct VC placement and decreased risk of proximal shunt dysfunction but no difference has been shown in the overall shunt revision rate ([6,18]). The present study similarly may indicate a higher rate of proximal shunt dysfunction among patients with misplaced VCs (5% vs 11%), albeit not statistically significant ($p = 0.07$). Since we cannot exclude that the present study could have been affected by lack

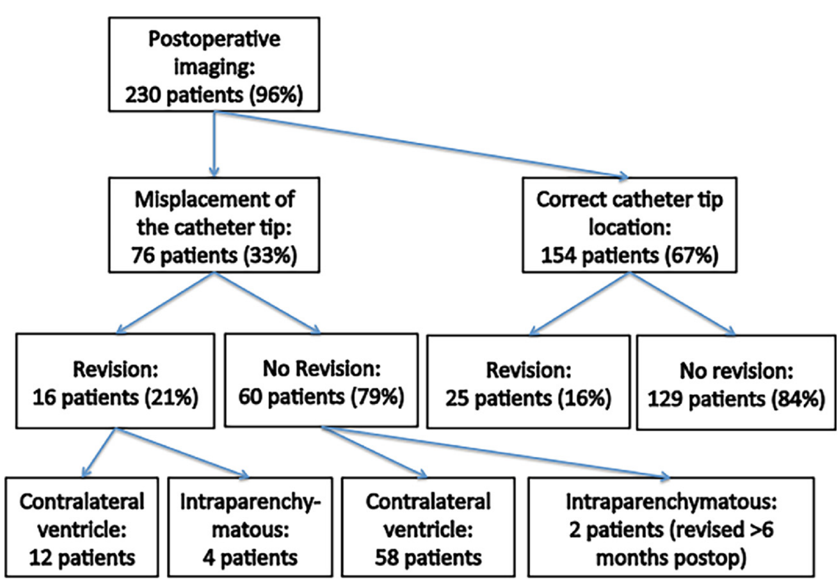

Fig. 3. Flow chart illustrating ventricular catheter (VC) tip placement and the event of shunt revision.

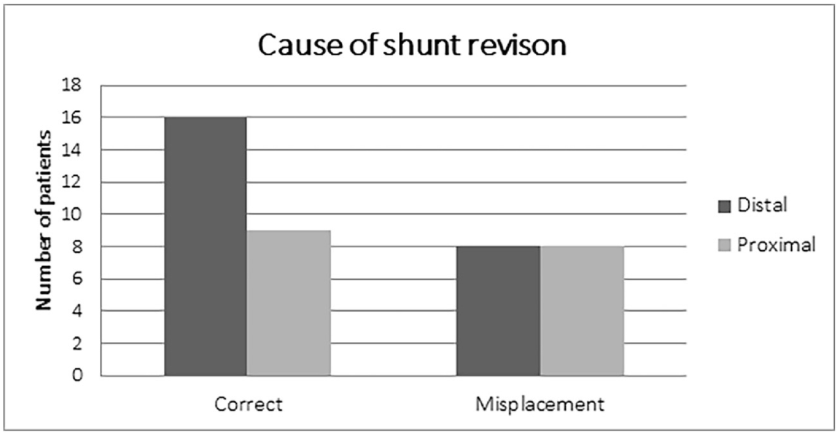

Fig. 4. Diagram illustrating the cause of shunt revisions among patients with correct (n = 25 and misplaced ventricular catheters (n = 16).

of statistical power, further studies with larger samples could be valuable in the evaluation of shunt dysfunction related to VC misplacement.

4.2. Postoperative ICH

We found that 8% of the patients experienced ICH on the postoperative CT scan, albeit only 2% of patients had symptomatic ICH. The proportion experiencing ICH following shunt placement is in accordance with previous studies on EVD (7–9%) [13,19]. However, recent publications have shown a higher rate of ICH after EVD and shunt procedures; Maniker et al. reported an EVD-related hemorrhage rate of 33% among 160 patients [20], while Ko et al. showed a ICH rate of 43% after VP-shunt placement [22]. Gardner et al. reported an ICH rate of 41% (77 of 188 patients) after EVD placement or removal [21]. It is important to point out that patients in our study underwent ventricular shunt placement in an elective setting and all presented with ventriculomegaly compared to previous studies on placement of EVDs where patients presumably have smaller ventricles and the VC placements often were performed in an acute setting.

Interestingly, we observed that 5% of correctly placed VC compared to 12% misplaced VC were associated with ICH, again this seemingly relevant difference was not statistically significant. Thus, a large-scale study is needed to settle the risks of VC misplacement in terms of shunt dysfunction and ICH. Future prospective studies evaluating the use of neuronavigation to prevent intraparenchymal VC placement leading to subsequent shunt revision would be of great value. Prospective randomized studies evaluating the correlation between optimized VC placement and the decreased risk of shunt revision would be of great interest in reducing the complication rate in shunt surgery.

4.2.1. Strengths and limitations

Even though our intention was that all patients should undergo an early postoperative CT (< 48 h), only half of the patients underwent this CT examination. Early postoperative head CT after shunt insertion was introduced at our department at the time when the present study started and therefore we believe that a gradual increase in compliance to this new routine was the major cause of the missing early postoperative CTs. However one cannot exclude that a degree of selection bias may have occurred, e.g. that a postoperative CT was made in greater extent in those cases where the surgeon was concerned about complications related to the VC placement. Since detection rate of more subtle symptoms from retrospective chart review is questionable [31], detection bias concerning symptomatic ICH remains a concern and a prospective study design with systematic pre- and postoperative neurological examination is likely to reveal a higher rate of symptomatic ICH.

5. Conclusion

Misplacement of the VC occurred in one third of the shunt insertions, however this did not increase the shunt revision rate significantly. ICH after shunt insertion occurred in 8%. Measures to optimize VC placement may be important to reduce VC misplacement following ventricular shunt placement.

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Conflict of interest

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study formal consent is not required.

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