Pediatric hydrocephalus: systematic literature review and evidence-based guidelines. Part 9: Effect of ventricular catheter entry point and position

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Object. The objective of this guideline was to answer the following question: Do the entry point and position of the ventricular catheter have an effect on shunt function and survival?

Methods. Both the US National Library of Medicine/MEDLINE database and the Cochrane Database of Systematic Reviews were queried using MeSH headings and key words specifically chosen to identify published articles detailing the use of CSF shunts for the treatment of pediatric hydrocephalus. Articles meeting specific criteria that had been delineated a priori were then examined, and data were abstracted and compiled in evidentiary tables.

Results. The search yielded 184 abstracts, which were screened for potential relevance to the clinical question of the effect of ventricular catheter entry site on shunt survival. An initial review of the abstracts identified 14 papers that met the inclusion criteria, and these were recalled for full-text review. After review of these articles, only 4 were noted to be relevant for an analysis of the impact of entry point on shunt survival; an additional paper was retrieved during the review of full-text articles and was included as evidence to support the recommendation. The evidence included 1 Class II paper and 4 Class III papers. An evidentiary table was created including the relevant articles.

Conclusion. Recommendation: There is insufficient evidence to recommend the occipital versus frontal point of entry for the ventricular catheter; therefore, both entry points are options for the treatment of pediatric hydrocephalus.

STRENGTH OF RECOMMENDATION: Level III, unclear degree of clinical certainty.
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)

KEY WORDS • practice guidelines • cerebrospinal fluid shunts • hydrocephalus • ventricular catheter • ventricular catheter placement • ventricular catheter position

SHUNT malfunction remains a significant source of morbidity in patients with shunted hydrocephalus. One variable affecting the risk of proximal shunt failure includes the entry point and position of the ventricular catheter. Entry from the skull is situated to access the ventricle without penetrating eloquent cortex. Although the optimal target is unclear, it has been suggested that positioning the tip of the ventricular catheter away from the wall of the ventricle and choroid plexus would improve shunt survival.

In general, entry points most often employed for this purpose have been frontal or occipital-parietal. The ventricular catheter most often terminates in the frontal horn, away from the choroid plexus, although a target in the atrium or occipital horn is used occasionally by some surgeons. Most ventricular catheters continue to be placed without use of a technical adjuvant to aid positioning.

Methods

Fourteen articles were identified using search criteria potentially related to this topic. Please see below for the specific search terms and strategies used in our search of the US National Library of Medicine database and the Cochrane Database of Systematic Reviews.

Search Terms

PubMed/MEDLINE
1. (“Cerebrospinal Fluid Shunts”[MeSH]) AND “Hydrocephalus”[MeSH:noexp]
2. Limit 1 to Child (0–18 years)
3. 2 and (ventricular AND (catheter OR shunt)) AND (placement OR position))
4. Limit to English and Humans
Number = 183
Part 9: Effect of ventricular catheter entry point and position

\textit{Cochrane Database}
1. MeSH descriptor Child
2. MeSH descriptor Infant
3. 1 or 2 and (MeSH descriptor Cerebrospinal Fluid Shunts)
4. 3 and (MeSH descriptor Hydrocephalus)
5. 4 and (ventricular NEAR/2 (catheter OR shunt))

\textbf{Search Strategies}

The search yielded 184 abstracts, which were screened for potential relevance to the clinical question of the effect of ventricular catheter entry site on outcome. An initial review of 183 abstracts led to the identification of 14 papers that met the inclusion criteria, and these were recalled for a full-text review. After review of these articles, only 4 papers were deemed relevant for an analysis of the effect of entry point and position of the ventricular catheter in pediatric patients; an additional paper was retrieved during the review of full-text articles. Thus a total of 5 articles were included as evidence to support the recommendation (Fig. 1). For each article included in the evidentiary table (Table 1), the study type, summary findings, and major conclusions were recorded, and a preliminary data class was assigned. The Pediatric Hydrocephalus Systematic Review and Evidence-Based Guidelines Task Force met to discuss the ranking of the evidence and the classification of data. Recommendations were then made based on the strength of the data in the evidentiary table. In these discussions, if a disagreement was encountered among members, a blinded vote was held and a consensus or majority opinion was reached.

\textbf{Results}

An initial review of the available literature indicated that an occipital entry for the ventricular catheter may be associated with longer shunt survival. In a study by Tuli and colleagues\textsuperscript{17} published in 1999, the authors performed a post hoc analysis of data collected during a randomized controlled trial of initial shunts placed in children between birth and age 18 years. The authors reviewed the characteristics of catheter tips and defined their locations as being the frontal horn, occipital horn, body of the lateral ventricle, third ventricle, embedded in brain, or unknown. The authors found that the occipital location was associated with a higher survival rate (HR 0.45; 95% CI 0.28–0.74; \(p = 0.001\)) than the frontal location (HR 0.60; 95% CI 0.39–0.91; \(p = 0.02\)).\textsuperscript{17} In a study by Bierbrauer et al.,\textsuperscript{4} a prospective analysis of catheter position revealed that 70% of shunts placed posteriorly did not require revision, compared with 59% of shunts placed in the frontal location. A life-table analysis between these groups showed a statistically significant difference in shunt survival that favored the occipital location. However, the strength of the study was diminished by the relatively weak randomization (by odd or even month of shunt placement) used to assign the treatment groups. A large retrospective study of 1719 patients conducted by Sainte-Rose et al.\textsuperscript{12} demonstrated similar findings: a lower risk of proximal occlusion in catheters whose tips were in the atrium of the ventricle than in catheters whose tips were in the frontal horn (\(p < 0.001\)). The difference in the rates of proximal occlusion primarily occurred during the 1st year after insertion.

The occipital entry point may be advantageous in infants due to the effects of skull and brain growth on final catheter position.\textsuperscript{4} Nakahara et al. demonstrated that in shunts placed in infancy, there was a higher degree of ventricular catheter shortening as well as bur hole migration, with growth relative to the ventricle when a frontal location was used. This may result in suboptimal catheter placement over time, even if the initial placement is optimal.\textsuperscript{9}

These results contrast with those of a retrospective review by Albright et al.\textsuperscript{2} published in 1988. That study indicated that the frontal entry location was advantageous with regard to shunt longevity in a series in which most patients were younger than 1 year of age and 90% of cases represented initial shunt placements. The authors noted that shunts inserted at a frontal location were more likely to be optimally placed, leading to longer function. They also analyzed optimally placed shunts inserted at both occipital and frontal entry points, finding improved shunt survival when the devices were inserted via frontal entry, compared with shunts placed with occipital entry, with a long-term function of 70% compared with 40%, respectively. These authors’ analysis was flawed, however, by a data collection in which there were many case omissions, as described in the Methods section.

Evidence suggests that having the catheter in an optimal position, surrounded by CSF, may also improve outcomes. Positioning the catheter in this manner is believed to reduce the risk of obstruction by choroid plexus, ependyma, or glial tissues.\textsuperscript{13} In the study conducted by Tuli et al.,\textsuperscript{17} the environment of the ventricular catheter tip was described as surrounded by CSF, touching brain (one side of the ventricular catheter tip in apposition to the ventricular wall), or surrounded by brain (catheter tip in the ventricle, but no visible surrounding CSF). Improved shunt survival was found in patients in whom catheters were surrounded by CSF compared with those in whom shunt tips were surrounded by brain (HR 0.21, 95% CI 0.094–0.45; \(p = 0.0001\)). This variable was found to be the greatest predictor of shunt failure, regardless of the location of the catheter tip.\textsuperscript{17}

\textbf{Excluded Articles}

Multiple papers were identified but excluded due to their lack of relevance to this specific question as well as to the population studied. Farahmand et al.\textsuperscript{3} analyzed the entry point of the ventricular catheter in adult patients as a risk factor for shunt failure, but in that study the follow-up period was only 6 months. That prospective study showed that in the first 6 months after insertion, shunts inserted through a right frontal entry point had lower rates of revision (11.6%; \(p < 0.001\)) than those inserted via occipital approaches: right occipital (26.5%; \(p = 0.003\)) and left occipital (46.7%; \(p = 0.024\)). While these results are worth noting, given the adult-only patient population, we did not include the data in the pediatric recommendations.\textsuperscript{9}

Another study that we reviewed sought to describe
the utility of endoscopic placement of the ventricular catheter, but its analysis did not include sufficient data on entry point. The authors noted in the demographic data where the entry point was located but did not separate groups for analysis. The authors did note, however, that in this patient group a greater distance between the choroid plexus and the catheter tip reduced the risk of failure.8

Finally, we reviewed a report by Albright et al. from 2010.1 While those authors did comment on entry point, their paper was a survey of pediatric neurosurgeons that sought to assess trends and was considered to contain insufficient quantitative evidence for inclusion in our recommendation.

The remaining studies3,6,7,11,14-16 were found to have no information relevant to the study question and were excluded. A report by Berry et al.3 was a retrospective multicenter study covering a large population that did not contain discrete information about entry site. Howard et al.6 presented a technical note regarding improvement of catheter positioning for occipital entry. Kast and colleagues7 discussed shunt failure, including ventricular catheter failure, without including any information about entry point. In their 2002 paper, Robinson and coworkers10 focused on the impact of valve pressure on shunt longevity without addressing variable ventricular catheter positions. Sood et al.14 presented data on the use of a ventricular reservoir at the shunt site, not ventricular catheter position; and Thomale and associates16 evaluated ventricular catheter design, not position. Finally, Steinbok et al.15 used only the occipital entry site in their practice.

Conclusions

RECOMMENDATION: There is insufficient evidence to recommend the occipital versus frontal point of entry for the ventricular catheter; therefore, both entry points are options for the treatment of pediatric hydrocephalus. STRENGTH OF RECOMMENDATION: Level III, unclear degree of clinical certainty.
**TABLE 1: The effect of ventricular catheter entry point and position: summary of evidence**

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>Study Description</th>
<th>Data Class, Quality, &amp; Reasons</th>
<th>Results &amp; Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bierbrauer et al., 1990–1991</td>
<td>Prospective, randomized by mo; study of new shunt insertion. July 1988–October 1990. n = 121, follow-up 2–30 mos.</td>
<td>Class II Randomized controlled trial; weak randomization, although both groups were statistically similar. No assurance of blinded enrollment. Chi-square analysis of data, life-table analysis of shunt survival.</td>
<td>Z = 1.74 for posterior vs anterior placement of shunts, p &lt; 0.05. Conclusion: longer shunt survival w/ posteriorly placed shunts.</td>
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<tr>
<td>Albright et al., 1988</td>
<td>Retrospective chart review. 180 records of pts treated at 2 institutions between 1978 &amp; 1981 were reviewed. 114 children included; CT scans available for 83 pts. 4 surgeons plus “others.”</td>
<td>Class III Chi-square analysis of variables, logistic regression, &amp; life-table analysis w/ time to first malfunction listed as “survival” time. Statistical significance: p ≤ 0.05.</td>
<td>2 groups were similar in age, cause of hydrocephalus, &amp; infection. Also considered was catheter position as an independent variable (Fig. 2 of paper). Conclusion: Statistically significant better long-term survival in the frontal-entry group compared to the parietal-entry group using life-table analysis (Wilcoxon: p = 0.0008; Savage: p = 0.0015).</td>
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<tr>
<td>Sainte-Rose et al., 1991–1992</td>
<td>Retrospective review of 1719 patients treated between 1974 &amp; 1983, 2 institutions.</td>
<td>Class III Retrospective, uncontrolled chart review.</td>
<td>Catheter located in the frontal horn was more likely to obstruct than catheter delivered to the atrium via the occipital route (p &lt; 0.001).</td>
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<tr>
<td>Tuli et al., 1999</td>
<td>Multicenter randomized trial, secondary data analysis. 344 pts randomized at 12 centers followed up for 2 yrs, blinded review of images. Comparability of groups commented on in prior publications.</td>
<td>Class III Secondary end points, post hoc analysis. Kaplan-Meier estimated shunt survival. Cox regression to evaluate variables.</td>
<td>Occipital location of catheter tip had the highest survival rate (HR 0.45, 95% CI 0.28–0.74; p = 0.001); compared w/ frontal location (HR 0.60; 95% CI 0.39–0.91; p = 0.02). Tip position surrounded by CSF also decreased risk of failure by half (HR 0.21; 95% CI 0.094–0.45; p = 0.0001). Conclusion: Occipital catheters may be associated w/ better long-term survival, but catheter tip location may be more important.</td>
</tr>
<tr>
<td>Nakahara et al., 2009</td>
<td>Retrospective review. Review of 130 charts. 28 charts evaluated; 102 excluded for inadequate data. Frontal entry in 9 patients; parieto-occipital in 19 patients. Mean age: 4.7 &amp; 4.5 mos, respectively. Mean follow-up: 78.6 &amp; 93.9 mos, respectively. CT scans &amp; plain skull radiographs were measured.</td>
<td>Class III No statistical analysis.</td>
<td>Mean shortening of ventricular catheter was 0.83 in frontal entry group (Group A), 0.99 in parietal-occipital group (Group B). Bur hole displacement was 1.29 axial, 1.38 lateral in Group A; it was 1.08 axial, 1.07 in Group B. Conclusion: Shortening of ventricular catheter was more pronounced when the shunt was inserted via frontal entry in this age group.</td>
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</table>

* pts = patients.

It is unclear which variable (entry point and/or catheter location) affects shunt survival. In other words, frontal versus occipital entry does not completely determine ultimate catheter position. For example, most frontally placed shunts end up in the frontal horn, but some can also end up in the body of the ventricle or the brain. Occipital placement may result in a catheter situated in the occipital horn, atrium, or frontal horn. In no study did researchers analyze patient factors such as preoperative configuration of the ventricles as a factor in the choice of entry site or shunt survival. The creation of conclusive recommendations or guidelines for the entry point or position of a ventricular catheter is impeded by the limited amount of existing evidence and, in most reports, by the lack of a multivariate analysis accounting for patient age at surgery, ventricular configuration, etiology, and other factors that might be relevant to clinical decision making. Review and evaluation of available evidence leads to the recommendation that either entry is acceptable and decisions about catheter entry site should be made based on the clinical scenario and the surgeon’s experience. The evidence would seem to support attempts to position the catheter tip so that it is surrounded by CSF and does not contact adjacent tissues. As is often the case, additional randomized controlled studies or comparative effectiveness approaches with larger data sets would provide better evidence to support a
stronger recommendation. The use of technical adjuvants to achieve that goal leads to the discussion found in Part 3.

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