Cranioplasty and Ventriculoperitoneal Shunt Placement after Decompressive Craniectomy: Staged Surgery Is Associated with Fewer Postoperative Complications

Patrick Schuss, Valeri Borger, Ági Güresir, Hartmut Vatter, Erdem Güresir

**OBJECTIVE:** Decompressive craniectomy (DC) requires later cranioplasty (CP) in survivors. However, if additional ventriculoperitoneal shunt (VPS) placement due to shunt-dependent hydrocephalus is necessary, the optimal timing of both procedures still remains controversial. We therefore analyzed our computerized database concerning the optimal timing of CP and VPS regarding postoperative complications.

**METHODS:** From 2009–2014, 41 cranioplasty procedures with simultaneous or staged VPS placement were performed at the authors’ institution. Patients were stratified into two groups according to the time from CP to VPS (“simultaneous” and “staged”). Patient characteristics, timing of CP and VPS, as well as procedure-related complications, were assessed and analyzed.

**RESULTS:** Overall CP and VPS were performed simultaneously in 41% and in staged fashion in 59% of the patients. The overall complication rate was 27%. Patients who underwent simultaneous CP and VPS suffered significantly more often from complications compared with patients who underwent staged CP and VPS procedures (47% vs. 12%; \( P = 0.03 \)). Patients with simultaneous CP and VPS had a significantly higher rate of infectious postoperative complications compared with patients with staged procedures \( (P = 0.003) \). On multivariate analysis, simultaneous CP and VPS procedure was the only significant predictor of postoperative complication after CP and VPS \( (P = 0.03) \).

**CONCLUSION:** We provide detailed data on surgical timing and complications for cranioplasty and ventriculoperitoneal shunt placement after DC. The present data suggest that patients who undergo staged CP and VPS procedures might benefit from a lower complication rate. This might influence future surgical decision making regarding optimal timing of CP and VPS placement.

**OBJECTIVE**

Decompressive craniectomy (DC) is a life-saving procedure in patients suffering from elevated intracranial pressure (ICP) caused by a number of underlying pathologies (2, 10-13, 17, 19, 20). As a consequence of this broader range of indications for DC, the number of subsequent cranioplasty (CP) procedures increases. Furthermore, patients with DC may also suffer from posthemorrhagic hydrocephalus. Therefore approximately 27% of patients undergoing CP are in the need of long-term cerebrospinal fluid (CSF) diversion leading to the necessity of a ventriculoperitoneal shunt (VPS) placement (13). We previously found that the presence of VPS in patients undergoing CP is significantly associated with a higher rate of postoperative complications (18). However, there is no consensus on the optimal timing of CP and VPS in patients who need both operative procedures. Nevertheless, in some patients CP itself might change CSF hydrodynamics and therefore alter the necessity of VPS during the treatment course (6, 7). Because of lack of data, some patients undergo both procedures simultaneously.
simultaneously, and the others are staged. We therefore analyzed our computerized database of consecutive patients who underwent DC and subsequent CP and VPS with special attention on timing of both procedures and associated postoperative complications.

METHODS

From January 2009 to September 2014, we performed 41 cranioplasty procedures with simultaneous or subsequent VPS placement in patients who previously underwent DC. Information including patient characteristics on admission and during the course of treatment; radiological features; mean duration of DC and CP procedure; modality of DC; mean time among DC, CP, and VPS procedure; complications of DC, CP, and VPS; and the specific indication for DC were entered into a computerized SPSS-database (version 22, IBM Corporation, Armonk, New York, USA). Initial DC was performed for intractably elevated ICP (>20 mm Hg, despite extensive medical therapy) primarily or secondary during the course of intensive care treatment. Size of DC was at least 11 × 16 cm. The site of DC was determined on the basis of the location of the main pathology and/or mydriasis. During DC, the dura was opened in a stellate fashion but no watertight duraplasty was applied as previously reported in detail elsewhere (13).

In case of shunt-dependent hydrocephalus during the treatment course, a VPS was placed, primarily in the right frontal horn. However, if VPS was performed before CP, VPS was placed at the opposite site according to the previous DC. Cranioplasty was considered after resolution of brain edema and was applied as previously reported elsewhere (18). The timing of CP and VPS varied according to the treating neurosurgeon, due to unclear literature data, between a simultaneous and a staged fashion. In case of shunt-dependent hydrocephalus during the treatment course, a VPS was placed, primarily in the right frontal horn. However, if VPS was performed before CP, VPS was placed at the opposite site according to the previous DC. Cranioplasty was considered after resolution of brain edema and was applied as previously reported elsewhere (18). The timing of CP and VPS varied according to the treating neurosurgeon, due to unclear literature data, between a simultaneous and a staged fashion.

Timing of CP and VPS

In 17 of 41 patients (41%) CP and VPS were performed simultaneously. In 24 of 41 patients (59%) CP and VPS were performed in a staged fashion. In patients with staged CP and VPS procedures, mean time between both operations was 61 ± 35 days (median 64 days).

RESULTS

Patient Characteristics

Patient characteristics, including age, sex, and data on the CP and VPS procedures according to the primary admission diagnosis, are shown in Table 1.

Cranioplasty and VPS were performed in 19 patients (46%) with previous subarachnoid hemorrhage (SAH), 15 patients (37%) with previous traumatic brain injury (TBI), 4 patients (10%) with previous intracerebral hemorrhage (ICH), 1 patient (2%) with previous cerebral infarction, and 2 patients (5%) with other primary diagnoses. The mean time from DC to CP was 120 ± 81 days. The mean surgical time for CP was 139 ± 44 minutes when treated simultaneously and 114 ± 38 minutes when treated in staged fashion (P = 0.06). The mean surgical time for VPS was 53 ± 15 minutes when treated simultaneously and 57 ± 20 minutes when treated in staged fashion (P = 0.5; see Table 1).

Table 1. Patient Characteristics in Present Series*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Simultaneous CP and VPS Procedures</th>
<th>Staged CP and VPS Procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients</td>
<td>17</td>
<td>24</td>
</tr>
<tr>
<td>Mean age in years</td>
<td>52 ± 13</td>
<td>53 ± 18</td>
</tr>
<tr>
<td>Female sex</td>
<td>10 (59)</td>
<td>14 (58)</td>
</tr>
<tr>
<td>Time from DC to CP in days (Median)</td>
<td>115</td>
<td>107</td>
</tr>
<tr>
<td>Mean duration of CP in minutes</td>
<td>139 ± 44</td>
<td>114 ± 38</td>
</tr>
<tr>
<td>Mean duration of VPS in minutes</td>
<td>53 ± 15</td>
<td>57 ± 20</td>
</tr>
<tr>
<td>Underlying pathologies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAH</td>
<td>9 (53)</td>
<td>10 (42)</td>
</tr>
<tr>
<td>TBI</td>
<td>5 (29)</td>
<td>10 (42)</td>
</tr>
<tr>
<td>ICH</td>
<td>2 (12)</td>
<td>2 (8)</td>
</tr>
<tr>
<td>Cerebral infarction</td>
<td>1 (6)</td>
<td>2 (8)</td>
</tr>
<tr>
<td>Complications</td>
<td>8 (47)</td>
<td>3 (12)</td>
</tr>
</tbody>
</table>

CP, cranioplasty; VPS, ventriculo-peritoneal shunt; DC, decompressive craniectomy; min, minutes; SAH, subarachnoid hemorrhage; TBI, traumatic brain injury; ICH, intracerebral hemorrhage.

*Values represent number of patients unless otherwise indicated (%). Means are given with SDs.

1P = 0.03, OR 5.9, 95% CI 1.2–29.8.

STATISTICS

Data analyses were performed using the computer software package SPSS (version 22, IBM Corporation, Armonk, New York, USA). An unpaired t-test was used for parametric statistics. Categorical variables were analyzed in contingency tables using Fisher’s exact test. Results with P < 0.05 were considered statistically significant. In a second step a multivariate analysis was performed to find independent predictors for postoperative complications after CP and VPS using a binary logistic regression analysis and to find confounding factors between potentially independent predictors. Variables with significant P values in univariate analyses or that had been considered to be clinically relevant were considered as potentially independent variables in the multivariate analysis. A backward stepwise method was used to construct multivariate logistic regression models with the inclusion criterion of a P value < 0.05.
The Effect of Timing of CP and VPS on Postoperative Complications

Overall, postoperative complications after CP and/or VPS procedures occurred in 11 of 41 patients (27%).

CP and VPS were performed simultaneously in 17 patients (41%) and staged in 24 patients (59%) after DC. Stratified according to the timing of both procedures, bleeding complications occurred in 1 out of 17 patients with simultaneous procedures and in 1 out of 24 patients with staged procedures (6% vs. 4%, \( P = 1.0 \)). Postoperative infections and/or wound healing disturbances occurred in 7 out of 17 patients with simultaneous procedures compared with none of 24 patients with staged procedures (41% vs. 0%; \( P = 0.03 \), OR 5.9, 95% CI 1.2–29.6). Postoperative mechanical VPS problems (e.g., occlusion) occurred in none of 17 patients with simultaneous procedures and in 1 out of 24 patients with staged procedures (0% vs. 4%, \( P = 1.0 \)). Furthermore, postoperative hygroma occurred in none of 17 patients with simultaneous procedures and in 1 out of 24 patients with staged procedures (0% vs. 4%; \( P = 1.0 \); Table 2).

Considering only patients with staged CP and VPS procedures, VPS was inserted before the CP procedure in 21 of 24 patients (87%) and inserted during the time period after previous CP in 3 of 24 patients (12%). Between these two groups, postoperative complications rate was higher in patients with VPS placement during the time period after previous CP procedure; however, differences did not differ significantly (33% vs. 10%; \( P = 0.3 \)).

Overall, simultaneous procedures were associated with a significantly higher rate of postoperative complications compared with staged procedures (47% vs. 12%; \( P = 0.03, \text{OR} \ 6.2, \text{95}\% \text{CI} \ 1.33–29.0; \text{see Table 2} \).

Multivariate Analysis

We performed a multivariate logistic regression analysis of those variables significantly associated with complications after CP and VPS. We also included the variable “timing of CP after DC” into further analysis, to determine any possible association with higher postoperative complications as previously reported (18). In the multivariate regression model the variable “simultaneous procedure” \( (P = 0.03, \text{OR} \ 5.9, \text{95}\% \text{CI} \ 1.2–29.6) \) was the only significant and independent predictor for the occurrence of postoperative complications after CP and VPS (Nagelkerke \( R^2 = 0.28 \)).

DISCUSSION

Cerebrospinal fluid hydrodynamics are often disturbed after DC with possible subsequent improvement after CP (7, 21). However, several diseases that led to DC are known predictors of shunt dependency (e.g., subarachnoid hemorrhage) (5, 15, 22). Therefore VPS is necessary in approximately 27% of patients after DC throughout the treatment course (13). However, the optimal timing of VPS and CP procedures after DC is still unclear. We therefore analyzed patients who underwent DC and subsequent CP and VPS with special attention on timing of both procedures and associated postoperative complications. Previous reports stated that the overall postoperative complication rate of CP is much higher than in other elective cranial procedures (4, 8, 13, 18). Furthermore, we previously reported that the presence of VPS at the time of CP is associated with a higher postoperative complication rate (18). A recent publication stated that simultaneous CP and VPS procedures have a higher postoperative complication rate when compared with patients with a median time interval of >2 months between both procedures (14). In the present series, the median time between CP and VPS procedures in patients with staged procedures was likewise approximately 2 months. Despite the impact on everyday clinical practice, data on effects of simultaneous versus staged CP and VPS procedures are scarce.

In the present series, patients with simultaneous CP and VPS procedures suffered significantly more often from postoperative complications with the necessity of surgical revision \( (P = 0.03) \). Therefore staged CP and VPS procedures might be preferable in order to avoid postoperative complications.

Furthermore, only patients with simultaneous CP and VPS procedure suffered from postoperative infections when compared with patients with staged CP and VPS procedures. Several studies suggest the use of antibiotic-impregnated shunt systems in patients with shunt-dependent hydrocephalus (1, 9). Nevertheless, critically ill patients who initially underwent DC might suffer more often from concurrent infections and medical comorbidity that might place their VPS at risk for postoperative infectious complication (16). This might lead to preference of simultaneous CP and VPS procedure in order to avoid possible complications of a second operation in these patients.

On the other hand, due to several variables like concurrent infections and other comorbidities, simultaneous CP and VPS procedure might not be possible in these critical ill patients. A recent study identified higher Hunt and Hess grade and surgical clipping in patients suffering from SAH as independent predictors of VPS infection (3). This again might overrule potential advantages of avoiding a second operation in patients with simultaneous CP and VPS. Therefore a staged method of CP and VPS procedures

| Table 2. Timing of Cranioplasty and Ventriculoperitoneal Shunt Placement* | Number of complications According to the Time to CP and VPS |
|---|---|---|
| | Simultaneous \( (n = 17) \) | Staged \( (n = 24) \) |
| Overall complications | 8 \( (47\% \) | 3 \( (12\%) \) |
| Bleeding | 1 \( (6\%) \) | 1 \( (4\%) \) |
| Infection/wound Healing disturbance | 7 \( (41\% \) | — |
| Hygroma | — | 1 \( (4\%) \) |
| Other | — | 1 \( (4\%) \) |

CP, cranioplasty; VPS, ventriculo-peritoneal shunt.

*Values represent number of complications (%).

\( |P = 0.03, \text{OR} \ 5.9, \text{95}\% \text{CI} \ 1.2–29.6. \)

\( |P = 0.003, \text{OR} \ 27.7, \text{95}\% \text{CI} \ 1.4–535. \)
might be favored to give these patients the chance to recover with support of intermediate rehabilitation between both procedures.

Summarizing, the multivariate analysis of the present study revealed “simultaneous procedure” as the only independent and significant predictor for postoperative complications (P = 0.03, OR 5.9, 95% CI 1.2–29.0).

Therefore if procurable, a time interval between CP and VPS procedure should be considered in the treatment course of patients with DC and shunt-dependent hydrocephalus.

**Limitations**

The present study has several limitations. Due to retrospective data analysis, the study suffers from shortcomings of a retrospective analysis. The heterogeneity of the underlying pathologies that led to DC might have biased complication rate after CP or VPS. Furthermore, these results represent only a single-center experience and prospective studies with larger patient population are needed.

**CONCLUSION**

We provide detailed data on surgical timing and complications for cranioplasty and ventriculo-peritoneal shunt placement after decompressive craniectomy. The present data suggest that simultaneous CP and VPS procedures are associated with a significantly higher risk of postoperative complications. Therefore VPS and CP procedures should be performed in a staged fashion whenever possible.

**REFERENCES**


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