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Safety Analysis of Simultaneous Cranioplasty and Ventriculoperitoneal Shunt Placement

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ABSTRACT

AIM: To investigate the safety of combined cranioplasty (CP) and ventriculoperitoneal shunt (VPS) placement. Furthermore, we investigated whether the sequence of these procedures affects the postoperative complication rates associated with staged CP and VPS placement.

MATERIAL and METHODS: We retrospectively investigated patients who developed communicating hydrocephalus after decompressive craniectomy and subsequently underwent VPS placement and CP at the hospital at which this study was performed between January 2009 and December 2019. Patients were categorized into group 1 (simultaneous CP and VPS placement) and group 2 (CP and VPS placement performed separately). Group 2 was subcategorized into subgroup 2a (CP performed before VPS placement) and subgroup 2b (VPS placement performed before CP). The Student's t and Chi square tests were used to analyze intergroup differences.

RESULTS: This study included 86 patients; 22 in group 1 and 64 in group 2 (24 patients in subgroup 2a and 40 patients in subgroup 2b). No statistically significant difference was observed in the overall complication rates between groups 1 and 2 (36.4% vs. 28.1%, P=0.591). However, the incidence of infections was significantly higher in group 1 than in group 2 (22.7% vs. 4.7%, P=0.024). Subgroup analysis showed that the overall complication rate was significantly lower in subgroup 2a than in subgroup 2b (12.5% vs. 37.5%, P=0.031).

CONCLUSION: Simultaneous CP and VPS placement is associated with a high incidence of infections. Moreover, compared with initial CP, initial VPS placement is associated with a significantly higher risk of overall complications in patients who undergo a staged procedure.

KEYWORDS: Decompressive craniectomy, Cranioplasty, Ventriculoperitoneal shunt, Complication

ABBREVIATIONS: CP: Cranioplasty, **CSF:** Cerebrospinal fluid, **DC:** Decompressive craniectomy, **SSFS:** Sinking skin flap syndrome, **VPS:** Ventriculoperitoneal shunt

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INTRODUCTION

Decompressive craniectomy (DC) is a life-saving emergency measure for patients with malignant intracranial hypertension that occurs after traumatic brain injury, intracerebral hemorrhage, and subarachnoid hemorrhage (1,10). A post-DC cranial defect may trigger turbulence in the cerebrospinal fluid (CSF) and circulation hydrodynamics (15,28), and patients require cranioplasty (CP) as a protective, therapeutic, and cosmetic procedure. Reportedly, approximately 5–15% of patients who undergo DC may develop communicating hydrocephalus (HCP) that necessitates long-term CSF diversion (20). Consequently, ventriculoperitoneal shunt (VPS) placement is also needed in these patients.

There is lack of consensus regarding the optimal timing of CP and VPS placement in patients who require both surgeries (12,20,24,25,29,36). Usually, these operations are performed separately, although some neurosurgery centers currently attempt both procedures during a single session. Although this is a cost-effective approach for patients and shortens the length of hospitalization, its safety remains unclear. Several studies have reported an increased risk of infections and overall complications following simultaneous CP and VPS placement (12,29); however, a few studies have observed no differences in postoperative complication rates between simultaneous and staged procedures (19,20).

In this study, we compared postoperative complication rates associated with simultaneous vs. staged CP and VPS placement to investigate the safety of this combined approach. We also investigated whether the sequence of procedures (CP performed before VPS placement vs. VPS placement performed before CP) was associated with complication rates of staged surgery.

MATERIAL and METHODS

Participants

This retrospective comparative study was approved by the Institutional Review Board of the hospital at which this study was performed. Data were retrospectively obtained from patients' electronic medical records. We enrolled patients who developed communicating HCP after DC and subsequently underwent CP and VPS placement between January 2009 and December 2019. We excluded patients who were lost to follow-up within 3 months.

Based on the sequence of CP and VPS placement, patients were non-randomly categorized as follows: patients who underwent CP and VPS placement simultaneously (group 1) and those who underwent CP and VPS placement as separate procedures (group 2). Patients in the staged group were subcategorized as follows: patients who underwent CP before VPS placement (subgroup 2a) and those who underwent VPS placement before CP (subgroup 2b). Patient characteristics and postoperative complication rates were compared between groups 1 and 2, as well as between subgroups 2a and 2b.

Procedures

The sequence of CP and VPS placement differed across groups based on the neurosurgeons' experience and patients' condition because no standard criteria are available in this regard. All procedures were performed by the associate chief surgeon or a surgeon of a higher grade with similar experience. VPS placement was considered in patients with HCP and progressively worsening clinical symptoms, in those with a sustained increase in ventricular size (observed on computed tomography/magnetic resonance imaging) or in patients who showed neurological improvement after CSF drainage (via lumbar puncture). A programmable (Medtronic, Minneapolis, USA/Sophysa, Orsay, FRA) or conventional (Medtronic, Minneapolis, USA) VPS was selected based on surgeons' and patients' preference. Patients' family members were consulted in unconscious patients. The VPS was placed to ensure that the proximal end of the catheter was away from the skull repair site and the distal end of the catheter was located in the middle upper abdomen.

CP was performed only in patients in whom the brain tissue was completely under the skull line. Patients from subgroup 2a who showed persistent brain bulging (the brain tissue was partially or completely above the plane of the skull) underwent lumbar or external ventricular drainage before CP to ensure that the bone flap was placed smoothly without resistance; external drainage was discontinued postoperatively (29,30). We inserted a custom-made titanium mesh in all patients who underwent CP. All patients were administered vancomycin (antibiotic) prophylactically and underwent computed tomography within 24 hours postoperatively.

Statistical Analysis

Quantitative variables were expressed as means±standard deviation or median quartiles (25^{th}–75^{th} percentile) and were compared using the Student's t or Mann-Whitney test. Categorical variables were expressed as frequencies (%) and compared using the Chi-square or Fisher's exact test. A logistic regression model was used to identify the risk factors associated with infections and overall complications. A p value <0.05 was considered statistically significant. All statistical tests were performed using the SPSS software, version 22.0 (SPSS Inc., Chicago, IL).

RESULTS

This cohort study included 86 patients; 22 patients underwent simultaneous CP and VPS placement (group 1), and 64 patients underwent staged CP and VPS placement (group 2). Among those who underwent staged surgery, 24 patients underwent CP before VPS placement (subgroup 2a), and 40 patients underwent VPS placement before CP (subgroup 2b).

Table I shows a comparison of patient characteristics between groups 1 and 2. No statistically significant difference was observed between groups 1 and 2 with regard to age, sex, underlying pathological conditions, comorbidities, and the Glasgow Coma Scale score recorded before the initial procedure performed in patients. No statistically significant intergroup difference was observed in the degree of brain bulging and bilateral craniectomy, location of the proximal end of the catheter, and time interval between the DC and the initial

Table I: Baseline Characteristics of Patients in Group 1 and Group 2

	Group 1 (n=22)	Group 2 (n=64)	p
Age (years)	50.0 (43.0, 57.0)	43.5 (33.0, 53.0)	0.088
Gender (male/female)	18/4	53/11	1.000
Underlying pathologies			0.973
TBI	13 (59.1)	37 (57.8)	
SAH	3 (13.6)	8 (12.5)	
ICH	6 (27.3)	19 (29.7)	
GCS score before the first procedure			0.723
≤8	2 (9.1)	10 (15.6)	
>8	20 (90.9)	54 (84.4)	
Time from DC to the first procedure (month)	3.4 (2.0, 6.0)	4.0 (2.5, 5.0)	0.575
Shunt valve type			**0.023**
Programmable	13 (59.1)	53 (82.8)	
Conventional	9 (40.9)	11 (17.2)	
Location of proximal catheter			0.139
Frontal horn	15 (68.2)	32 (50)	
Occipital horn	7 (31.8)	32 (50)	
Brain bulging	19 (86.4)	54 (84.4)	1.000
Previous bilateral craniectomy	2 (9.1)	11 (17.2)	0.501
Diabetes	0 (0)	4 (6.3)	0.568
Hypertension	5 (22.7)	24 (37.5)	0.206

TBI: *Traumatic brain injury,* ***SAH:*** *Subarachnoid hemorrhage,* ***ICH:*** *Intracerebral hemorrhage,* ***GCS:*** *Glasgow Coma Scale,* ***DC:*** *Decompressive craniectomy.*

procedure performed in patients. However, programmable shunt valve placement was more common in patients in group 2 than in group 1 (82.8% vs. 59.1%, p=0.023).

Table II shows a comparison of patient characteristics between subgroups 2a and 2b. The mean age in subgroup 2a was 47.7 ± 18.2 years and that in subgroup 2b was 39.2 ± 11.6 years (p=0.026). The time interval between DC and the initial procedure performed in subgroup 2a was 5.2 (3.5–7.0) months and in subgroup 2b was 2.2 (1.6–4.0) months (p=0.001). Brain bulging was more commonly observed in patients in subgroup 2b than in patients in subgroup 2a (97.5% vs. 62.5%, p<0.001). No significant intergroup differences were observed with regard to other characteristics.

As shown in Table III, postoperative complications occurred in 26 of 86 patients (30.2%), including infection in 8 patients (5 in group 1, 3 in group 2), obstruction in 3 patients (group 2), seizure in 3 patients (1 in group 1, 2 in group 2), epidural hemorrhage in 3 patients (group 2), epidural hygroma in 8 patients (3 in group 1, 5 in group 2), and sinking skin flap syndrome (SSFS)/paradoxical herniation in 6 patients (group 2). The overall complication rate (the number of patients who developed at least a single complication) was higher in group 1 than in group 2; however, this difference was statistically nonsignificant (36.4% vs. 28.1%, p=0.591). The infection rate was significantly higher in group 1 than in group 2 (22.7% vs. 4.7%, p=0.024).

As shown in Table IV, among the 64 patients included in group 2, 18 patients (28.1%) developed at least a single complication as follows: infection in 3 patients (2 in subgroup 2a, 1 in subgroup 2b), obstruction in 3 patients (1 in subgroup 2a, 2 in subgroup 2b), seizure in 2 patients (subgroup 2b), epidural hemorrhage in 3 patients (subgroup 2b), epidural hygroma in 5 patients (1 in subgroup 2a, 4 in subgroup 2b), and SSFS/paradoxical herniation in 6 patients (subgroup 2b). The overall complication rates were 12.5% and 37.5% in subgroups 2a and 2b, respectively, and this difference was statistically significant (p=0.031).

Logistic regression analysis performed for all patients who underwent CP and VPS placement showed that simultaneous procedures were significantly associated with infections

Table II: Baseline Characteristics of Patients in Subgroup 2a and Subgroup 2b

	Subgroup 2a (n=24)	Subgroup 2b (n=40)	p
Age (years)	47.7±18.2	39.2±11.6	**0.026**
Gender (male/female)	17/7	36/4	0.084
Underlying pathologies			0.289
TBI	17 (70.8)	20 (50.0)	
SAH	2 (8.3)	6 (15.0)	
ICH	5 (20.8)	14 (35.0)	
GCS score before the first procedure			0.297
≤8	2 (8.3)	8 (20.0)	
>8	22 (91.7)	32 (80.0)	
Time from DC to the first procedure (month)	5.2 (3.5, 7.0)	2.2 (1.6, 4.0)	**0.001**
Time interval between two procedures (month)	3.5 (1.3, 9.2)	3.9 (2.0, 6.2)	0.760
Shunt valve type			1.000
Programmable	20 (83.3)	33 (82.5)	
Conventional	4 (16.7)	7 (17.5)	
Location of proximal catheter			0.606
Frontal horn	11 (45.8)	21 (52.5)	
Occipital horn	13 (54.2)	19 (47.5)	
Brain bulging	15 (62.5)	39 (97.5)	**<0.001**
Previous bilateral craniectomy	5 (20.8)	6 (15.0)	0.734
Diabetes	2 (8.3)	2 (5.0)	0.627
Hypertension	6 (25.0)	18 (45.0)	0.110

TBI: *Traumatic brain injury,* ***SAH:*** *Subarachnoid hemorrhage,* ***ICH:*** *Intracerebral hemorrhage,* ***GCS:*** *Glasgow Coma Scale,* ***DC:*** *Decompressive craniectomy.*

Table III: The Distribution of Postoperative Complications in Group 1 and Group 2

	Group 1 (n=22)	Group 2 (n=64)	p
Infection	5 (22.7)	3 (4.7)	**0.024**
Obstruction	-	3 (4.7)	0.567
Seizure	1 (4.5)	2 (3.1)	1.000
Bleeding	-	3 (4.7)	0.567
Hygroma	3 (13.6)	5 (7.8)	0.416
SSFS/paradoxical herniation	-	6 (9.3)	0.331
Overall complications*	8 (36.4)	18 (28.1)	0.591

SSFS: *Sinking skin flap syndrome.* ****Definition:*** *the number of patients who experienced at least one complication.*

(odds ratio [OR] 5.980, 95% confidence interval [CI] 1.296–27.590, p=0.022), and the use of a conventional shunt valve was significantly associated with overall postoperative complications (OR 3.125, 95% CI 1.103–8.857, p=0.032). Among patients who underwent CP and VPS placement as separate procedures, performing VPS placement before CP was significantly associated with the overall complication rate (OR 4.200, 95% CI 1.069–16.506, p=0.040) (Tables V–VII).

DISCUSSION

This study showed no statistically significant differences in overall complication rates between simultaneous and staged CP and VPS placement. However, the incidence of infections was significantly higher in patients who underwent simultaneous procedures.

With regard to the safety of combined CP and VPS placement, Heo et al. reported that patients who underwent simultaneous CP and VPS placement showed a significantly higher rate of overall complications than those who underwent a staged procedure (56% and 21%, respectively). Moreover, the authors observed that the rate of infectious complications was significantly higher in those who underwent simultaneous procedures than in those who underwent a staged procedure (19% and 5%, respectively) (12). Similarly, Schuss et al. reported a postoperative complication rate of 47% in patients who underwent simultaneous CP and VPS placement and 12% in patients who underwent CP and VPS placement as separate procedures; notably, this difference was statistically significant. Additionally, the rate of infections/wound healing disturbances was as high as 41% in patients who underwent a simultaneous procedure, whereas no infections were

Table IV: The Distribution of Postoperative Complications in Subgroup 2a and Subgroup 2b

	Subgroup 2a (n=24)	Subgroup 2b (n=40)	p
Infection	2 (8.3)	1 (2.5)	0.551
Obstruction	1 (4.2)	2 (5.0)	1.000
Seizure	-	2 (5.0)	0.524
Bleeding	-	3 (7.5)	0.286
Hygroma	1 (4.2)	4 (10.0)	0.642
SSFS/paradoxical herniation	-	6 (15.0)	0.076
Overall complications*	3 (12.5)	15 (37.5)	**0.031**

SSFS: *Sinking skin flap syndrome.* ****Definition:*** *The number of patients who experienced at least one complication.*

Table V: Logistics Regression Analysis of Risk Factors for Infections in all Patients

Variables		OR (95%CI)	p
Age		0.998 (0.941-1.037)	0.617
Gender	male/female	-	0.999
Underlying pathologies	TBI/SAH+ICH	5.698 (0.669-48.537)	0.111
GCS score before the first procedure	≤8/>8	1.149 (0.129-10.270)	0.901
Time from DC to the first procedure		0.979 (0.879-1.090)	0.697
Timing of CP and VPS	simultaneous/staged	5.980 (1.296-27.590)	**0.022**
Shunt valve type	programmable/ conventional	2.153 (0.467-9.932)	0.326
Location of proximal catheter	frontal/occipital	0.700 (0.156-3.134)	0.641
Brain bulging	yes/no	1.273 (0.143-11.301)	0.829
Previous bilateral craniectomy	yes/no	0.786 (0.088-6.976)	0.829
Diabetes	yes/no	-	0.999
Hypertension	yes/no	0.255 (0.030-2.181)	0.212

TBI: *Traumatic brain injury,* ***SAH:*** *Subarachnoid hemorrhage,* ***ICH:*** *Intracerebral hemorrhage,* ***GCS:*** *Glasgow Coma Scale,* ***DC:*** *Decompressive craniectomy,* ***CP:*** *Cranioplasty,* ***VPS:*** *Ventriculoperitoneal shunt.*

Table VI: Logistics Regression Analysis of Risk Factors for Overall Complications in All Patients

Variables		OR (95%CI)	p
Age		0.984 (0.953-1.015)	0.310
Gender	male/female	3.319 (0.692-15.919)	0.134
Underlying pathologies	TBI/SAH	5.152 (0.608-43.666)	0.133
Underlying pathologies	ICH/SAH	4.706 (0.511-43.361)	0.172
GCS score before the first procedure	≤8/>8	0.370 (0.107-1.283)	0.117
Time from DC to the first procedure		1.003 (0.958-1.050)	0.912
Timing of CP and VPS	simultaneous/staged	1.460 (0.524-4.072)	0.469
Shunt valve type	programmable/conventional	3.125 (1.103-8.857)	**0.032**
Location of proximal catheter	frontal/occipital	1.048 (0.416-2.638)	0.921
Brain bulging	yes/no	2.694 (0.553-13.128)	0.220
Previous bilateral craniectomy	yes/no	1.548 (0.454-5.278)	0.485
Diabetes	yes/no	0.760 (0.075-7.668)	0.816
Hypertension	yes/no	1.349 (0.517-3.520)	0.541

TBI: *Traumatic brain injury,* ***SAH:*** *Subarachnoid hemorrhage,* ***ICH:*** *Intracerebral hemorrhage,* ***GCS:*** *Glasgow Coma Scale,* ***DC:*** *Decompressive craniectomy,* ***CP:*** *Cranioplasty,* ***VPS:*** *Ventriculoperitoneal shunt.*

Table VII: Logistics Regression Analysis of Risk Factors for Overall Complications in Staged CP and VPS

Variables		OR (95%CI)	p
Age		0.983 (0.947-1.020)	0.359
Gender	male/female	4.722 (0.558-39.937)	0.154
Underlying pathologies	TBI/SAH	2.962 (0.325-27.016)	0.336
Underlying pathologies	ICH/SAH	3.231 (0.321-32.477)	0.319
GCS score before the first procedure	≤8/>8	3.154 (0.787-12.633)	0.105
Time from DC to the first procedure		1.003 (0.957-1.052)	0.891
Time interval between two procedures		0.921 (0.803-1.065)	0.239
Timing of CP and VPS	CP before VPS/VPS before CP	4.200 (1.069-16.506)	**0.040**
Shunt valve type	programmable/conventional	4.100 (1.063-15.815)	**0.041**
Location of proximal catheter	frontal/occipital	1.364 (0.456-4.076)	0.579
Brain bulging	yes/no	4.135 (0.484-35.298)	0.194
Previous bilateral craniectomy	yes/no	1.592 (0.404-6.276)	0.507
Diabetes	yes/no	0.843 (0.082-8.681)	0.886
Hypertension	yes/no	1.500 (0.494-4.552)	0.474

TBI: *Traumatic brain injury,* ***SAH:*** *Subarachnoid hemorrhage,* ***ICH:*** *Intracerebral hemorrhage,* ***GCS:*** *Glasgow Coma Scale,* ***DC:*** *Decompressive craniectomy,* ***CP:*** *Cranioplasty,* ***VPS:*** *Ventriculoperitoneal shunt.*

observed in patients who underwent a staged procedure (29). In contrast, Meyer et al. and Wan et al. observed no difference in the overall and specific complication rates between patients who underwent simultaneous and staged CP and VPS placement (19,20). Currently, limited data are available regarding the safety of combined CP and VPS placement; most studies have included a small number of patients (Heo et al. [51 patients], Schuss et al. [41 patients], Meyer et al. [50 patients] and Wan et al. [56 patients]). In our study, we observed that infectious complications were a major risk factor associated with simultaneous CP and VPS placement; however, this finding differs from those reported by previous studies.

Reportedly, complications such as intracranial hematoma and subdural hygroma observed in patients who undergo simultaneous CP and VPS placement were associated with the VPS-induced sunken down effect of the brain (12,14). Temporary occlusion of the distal shunt catheter during a simultaneous procedure is considered an effective preventive measure against these complications, while the risk of infection persists in such cases (14). The longer duration and greater number of surgical processes performed during a combined procedure serve as risk factors for infection. Moreover, the simultaneous introduction of two types of heterogeneous materials into the body predisposes patients to infections secondary to a higher risk of bacterial contamination. The bacteria that colonize the surface of the heterogeneous material can result in recurrent infections (35). Tsang et al. reported that CP can theoretically increase the risk of CSF shunt infection through direct contamination or hematogenous bacterial colonization (32). Other authors have observed that shunt infections can spread via CSF circulation leading to post-CP infections (22,35). The higher risk of infections associated with simultaneous CP and VPS placement could be attributed to the aforementioned factors.

After cranioplasty, the infection of any surgical site may lead to incision healing disturbance, and part of them may be subject to the removal of material in the end (21,36). During ventriculoperitoneal shunt system, it may probably be removed when infected intracranially. Serious intracranial infection can also lead to death (12,36). Therefore, for patients who require both CP and VPS placement, it may be prudent to perform these as separate procedures.

Interestingly, in this study, we observed that the overall complication rate was significantly higher in patients who underwent VPS placement before CP than in patients who underwent VPS placement after CP. In our opinion, the significantly higher occurrence of post-DC SSFS observed in the former group could have contributed to this condition.

It is well known that DC, which involves the removal of a bone flap and opening of the dura, effectively reduces elevated intracranial pressure (2). However, a post-DC skull defect exposes the intracranial cavity directly to the atmospheric pressure. During the recovery phase following craniectomy, the atmospheric pressure combined with the effect of gravity may overwhelm the intracranial pressure, leading to sinking of the skin flap (2,13,27,33,34). Patients who develop post-DC HCP may require additional VPS placement for CSF diversion. However, performing VPS placement before CP paradoxically increases the risk of SSFS by reducing the intracranial pressure (Figure 1A-C) (2,3,26,27). Zheng et al. have reported that the rate of occurrence of SSFS in such cases is as high as 76.9% (38). Based on their definition of a sunken skin flap, in our study, we observed that 75.0% of patients in subgroup 2b developed a concavity in the skin flap, whereas only 20.8% of patients in subgroup 2a showed a depression at the surgical site.

Cranial defects combined with a sunken skin flap are known to reduce cerebral blood flow over the site of the craniectomy and may result in neurological symptoms, including epilepsy, headaches, dizziness, and language or motor deficits (2,3,4,27,34). This phenomenon is referred to as the SSFS, which is a common complication associated with VPS placement (34). Moreover, excessive depression of a skin flap may lead to a midline shift and consequent compression of the brain stem resulting in life-threatening respiratory and/or respiratory disorders. This severest form of SSFS is referred to as “paradoxical herniation” (6,23,31). In this study, 6 patients

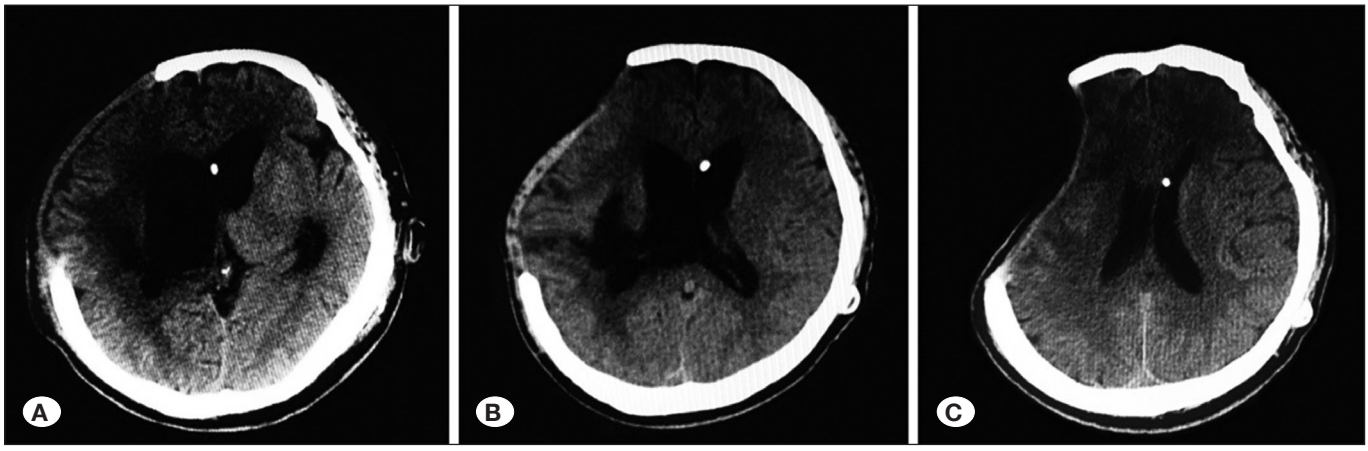

Figure 1: Head computed tomography images (axial view) obtained on days 1, 3 and 7 (**A, B** and **C**, respectively) after ventriculoperitoneal shunt insertion showing a sunken skin flap secondary to CSF diversion.

in subgroup 2b who underwent VPS placement before CP developed SSFS postoperatively, and 2 of these patients developed paradoxical herniation.

Notably, CP is complicated in patients with a sunken skin flap, which can increase the risk of postoperative complications (11,13,38). For example, separation of the subcutaneous tissue and dura becomes challenging in such cases, which could predispose the patient to dural injury, resulting in a high risk of epidural hygroma. Moreover, elimination of the epidural dead space is difficult, which may increase the risk of hematoma formation (11). Reportedly, epidural fluid collection and hematoma are associated with an increased rate of surgical infection; CP-associated infection may necessitate removal of the implant materials in patients with VPS placement, which could precipitate SSFS (37-39). Therefore, prevention of a sunken skin flap is a prerequisite for safe CP.

CP performed before VPS placement can avoid the development of a sunken skin flap that occurs secondary to CSF diversion with early stabilization of intracranial pathophysiology (13,18), which can effectively reduce postoperative complications. Previous studies have reported that initial CP may reverse the DC-induced alterations in CSF dynamics and obviate the need for a subsequent shunt operation (8,25,26). Kutty et al. reported a reverse rate as high as 91% in asymptomatic patients with HCP without papilledema but with ventriculomegaly (16). Therefore, initial CP further reduces the overall postoperative complications, although we did not observe this phenomenon in our study. Moreover, theoretically a programmable shunt valve is recommended because this device allows progressive "dialing up" of the shunt resistance and decreases the possibility of craniectomy site depression (5,7,17). In this study, both an initial CP procedure and the use of a programmable shunt valve served as protective factors against postoperative complications.

CP can be performed before VPS placement in all patients with DC-induced HCP. For patients with severe brain edema, preoperative CSF drainage (lumbar or ventricular) can ensure smooth insertion of the bone flap. This management strategy was introduced by Alexiou et al. and Giese et al., and the feasibility and safety of this approach has been confirmed by other studies (9,25,29,35). In our study, we did not observe the drainage-induced (lumbar or ventricular) complications in patients who underwent additional CSF drainage.

Following are the limitations of this study: (a) The retrospective design of this cohort study is a drawback; a randomized controlled trial is warranted to gain a deeper understanding regarding the safety and feasibility of CP and VPS placement performed as separate procedures. (b) Further multivariate logistic regression analysis could not be performed owing to the small sample size of this study. (c) The results of this single-center study are representative of only the Northern Chinese population.

CONCLUSION

Simultaneous CP and VPS placement is associated with an increased risk of infections; therefore, CP and VPS placement should preferably be performed as separate procedures. Furthermore, in patients who undergo staged procedures, it is recommended that CP be performed before VPS placement, based on the current data which indicate a significantly higher risk of complications in those who undergo VPS placement before CP.

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AUTHORSHIP CONTRIBUTION

Study conception and design: XZ, XF, HL, FH

Data collection: AG, DG, CG, SW, YC

Analysis and interpretation of results: AG, BZ, KY

Draft manuscript preparation: XZ, XF, EH

Critical revision of the article: HL, FH

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All authors (XZ, XF, AG, DG, CG, SW, YC, BZ, KY, EH, HL, FH) reviewed the results and approved the final version of the manuscript.

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