Korean J Neurotrauma. 2021 Oct;17(2):100-107
https://doi.org/10.13004/kjnt.2021.17.e20
pISSN 2234-8999·eISSN 2288-2243

KJNT

Clinical Article

Check for updates

Comparison of Postoperative Complications between Simultaneous and Staged Surgery in Cranioplasty and Ventriculoperitoneal Shunt Placement after Decompressive Craniectomy

Jong Han Gill, Hyun Ho Choi, Shin Heon Lee, Kyoung Min Jang, Taek Kyun Nam, Yong Sook Park, and Jeong Taik Kwon

Department of Neurosurgery, Chung-Ang University Hospital, Chung-Ang University College of Medicine, Seoul, Korea

OPEN ACCESS

Received: Mar 2, 2021
Revised: Jul 12, 2021
Accepted: Jul 29, 2021

Address for correspondence:
Hyun Ho Choi
Department of Neurosurgery, Chung-Ang University Hospital, Chung-Ang University College of Medicine, 102 Heukseok-ro, Dongjak-gu, Seoul 06973, Korea.
E-mail: ayohyunho@naver.com

ORCID iDs
Jong Han Gill
https://orcid.org/0000-0003-1891-6466
Hyun Ho Choi
https://orcid.org/0000-0003-1170-6829
Shin Heon Lee
https://orcid.org/0000-0002-5424-1374
Kyoung Min Jang
https://orcid.org/0000-0002-0452-4595
Taek Kyun Nam
https://orcid.org/0000-0003-3151-631X
Yong Sook Park
https://orcid.org/0000-0003-1152-6844
Jeong Taik Kwon
https://orcid.org/0000-0002-7889-7634

Conflict of Interest
The authors have no financial conflicts of interest.

ABSTRACT

Objective: Cranioplasty (CP) and ventriculoperitoneal shunt (VPS) are required procedures following decompressive craniectomy (DC) for craniofacial protection and to prevent hydrocephalus. This study assessed the safety and efficacy of simultaneous operation with CP and VPS after DC, and determined the preoperative risk factors for postoperative complications.
Methods: Between January 2009 and December 2019, 81 patients underwent CP and VPS in simultaneous or staged operations following DC. Cumulative medical records and radiologic data were analyzed using univariate analysis to identify factors predisposing patients to complications after CP and VPS.
Results: CP and VPS were performed as simultaneous or staged operations in 18 (22.2%) and 63 (77.8%) patients, respectively. The overall postoperative complication rate was 16.0% (13/81). Patients who underwent simultaneous CP and VPS were significantly more likely to experience complications when compared with patients who underwent staged operations (33.3% vs. 9.6%, $p<0.01$). Univariate analysis revealed that simultaneous CP and VPS surgery was the only significant predictor of postoperative complications ($p=0.031$).
Conclusion: This study provided detailed data on surgical timing and complications for CP and VPS after DC. We showed that simultaneous procedures were a significant risk factor for postoperative complications.

Keywords: Cranioplasty; Ventriculoperitoneal shunt; Craniectomy; Complications

INTRODUCTION

Decompressive craniectomy (DC) is a critical treatment option for refractory intracranial hypertension. It is caused by traumatic brain injury (TBI), subarachnoid hemorrhage (SAH), intracerebral hemorrhage (ICH), and cerebral infarction.[2,7-9] Cranioplasty (CP) is required after DC for craniofacial protection, cosmesis, and improving neurologic outcomes.[4,20]
DC is performed with a large cranial defect for decompression; therefore, it can lead to

secondary hydrocephalus due to interruptions in cerebrospinal fluid (CSF) circulation and cerebral blood perfusion. Furthermore, 5%–15% of patients with DC require an additional ventriculoperitoneal shunt (VPS).[3,6,19]

The correct timing for the CP and VPS is not well established; neurosurgeons decided this by considering the patient's condition, prognosis, and economic situation. Simultaneous surgery occurs when CP and VPS are performed in one stage. This is advantageous because it shortens patient hospital stays, reduces hospitalization costs, and increases hospital resource efficiency.[23] However, recent studies have reported controversial complication rates when the simultaneous approach is used.[12,18,22,24] Therefore, the purpose of this study was to compare the postoperative complication rates and preoperative risk factors in patients who underwent simultaneous or staged operations with CP and VPS.

MATERIALS AND METHODS

Study population and surgical procedures

Between January 2009 and December 2019, 81 patients were treated with CP and VPS in simultaneous or staged operations following DC in our institution. DC was performed for refractory intracranial hypertension despite the best medical treatment. Medical records were retrospectively reviewed for patient variables including gender, age, hypertension, diabetes mellitus, hyperlipidemia, antiplatelet medication, smoking or alcohol use, clinical presentation (TBI, SAH, ICH, cerebral infarction, arteriovenous malformation [AVM]), cranial defect size, brain bulging before CP, and hydrocephalus index.

Patients were divided into the simultaneous or staged operation groups based on their surgical treatment. Of the 81 patients, 18 patients underwent simultaneous VPS and CP, and 63 patients underwent staged VPS and CP. Among the patents with staged operations, 37 patients received the CP after VPS and 26 patients underwent VPS after CP. Autologous bone, which had been stored in our bone bank, was placed during CP in 79 patients. Two patients received custom-made titanium mesh (Cusmedi, Suwon, Korea). We inserted a Codman Hakim programmable valve (Codman/Johnson & Johnson, Raynham, MA, USA) in 57 patients, 9 received the Strata adjustable valve (Medtronic, Minneapolis, MN, USA), 7 received a CSF-Flow Control valves (Medtronic), 6 received the Miethke proGAV Programmable Shunt System (Aesculap, Tuttlingen, Germany), and 2 received Codman Certas programmable valve (Codman/Johnson & Johnson). We typically set the shunt valve pressure with 70–100 mmH_2O according to the initial CSF pressure, which was later adjusted with reference to the computed tomography (CT) data within 24 hours of all operations. We selected the CSF-Flow Control valves with reference to the EVD pressure that patients had undergone before the VPS.

We shaved all patient hair the day before VPS and CP, and draped their head and abdomen with alcohol and povidone-iodine using sterile towels. Prophylactic antibiotics were administered before the skin incision. Radiographic images of chest, abdomen, and skull were checked routinely. CT was performed within 24 hours of all operations, and one week, 2 weeks, and one month after DC. Any neurological deterioration after surgery was immediately assessed via brain CT.

https://doi.org/10.13004/kjnt.2021.17.e20

Assessment of hydrocephalus, cranial defects, and brain bulging

If ventricular enlargement was showed on brain CT, we suspected hydrocephalus. This was defined using the following criteria: bifrontal index (the ratio of maximum width of the frontal horn to the width of the inner table) >0.3 on brain CT; increasing ventricular size compared with immediate post-operative brain CT; and improvement of neurological status after lumbar drainage. Cranial defect size was classified into 2 groups based on the maximum diameter. A small unilateral cranial defect was defined as a maximum diameter that was less than half the hemispheric diameter. A large cranial defect was defined as a maximum diameter greater than half the hemispheric diameter. Brain bulging was classified into 2 types: flaccid concave and tense convex cranial defect. The flaccid concave cranial defect was defined as the brain being completely beneath the plane of the cranium. Tense concavity was defined as the brain being completely or partly above the plane of the cranium.

Post-operative complications were classified into epidural abscess, brain abscess, shunt infection, epidural hemorrhage, intraventricular hemorrhage, and pneumocephalus. Furthermore, any complications that triggered severe neurological impairment and caused reoperation were recorded.

Statistical analysis

Continuous variables were expressed as mean±standard deviation (range) and categorical data were expressed as frequencies and percentages. To evaluate risk factors predisposing complications after VPS and CP, univariate analysis was applied and a 2-tailed p-value <0.05 was considered statistically significant. Data were analyzed using and Statistical Package for the Social Sciences (SPSS, Version 25; IBM, Armonk, NY, USA).

RESULTS

Baseline patient characteristics

A total of 81 patients (39 female, 48.1%; mean age 61.3±14.6; age range 24–84 years) were included in this study. VPS and CP were performed in 29 patients (35.8%) with TBI, 31 patients (38.3%) with SAH, 11 patients (13.6%) with ICH, 7 patients (8.6%) with cerebral infarction, and 3 patients (3.7%) with cerebral AVM. Most of the cranial defects were larger than half of the hemisphere (86.4%). In the last brain CT before the CP operation, tense convex and flaccid concave accounted for 90.1% and 9.9% of brain bulging, respectively. The mean hydrocephalus index was 0.36±0.07. Six patients underwent bilateral craniectomy (7.4%). Baseline characteristics between staged and simultaneous groups were similar except incidence of TBI and hydrocephalus index. Detailed characteristics are described in **TABLE 1**.

Timing of surgery and post-operative complications

The number of patients who underwent VPS after CP was 26 (32.1%), CP after VPS was 37 (45.7%), and simultaneous surgery was 18 (22.2%). Total complications of simultaneous group were significantly higher than those of staged group (33.3% vs. 9.6%, p<0.01). Among the 13 (16.0%) patients with complications that required an additional surgery, 4 (30.8%) were in the VPS after CP group, 3 (23.1%) were in the CP after VPS, group and 6 (46.1%) were in the simultaneous group. The mean interval time (days) from DC to CP was 93.9±74.7, 115.4±94.5, and 59.8±29.4, respectively, in the staged VPS after CP, CP after VPS, and simultaneous groups. The interval times (days) from DC to VPS were 270.4±300.5, 76.7±72.6, and 59.8±29.4 respectively. The mean CP surgery times (minutes) were 149.0±52.6,

https://doi.org/10.13004/kjnt.2021.17.e20

TABLE 1. Comparison of baseline characteristics of patients with CP and VPS

Variables	Total (n=81)	Simultaneous surgery (n=18)	Staged surgery (n=63)	*p*-value
Mean age (years)	61.3±14.6	60.9±15.3	62.5±12.4	0.68
Female	39 (48.1)	12 (66.7)	27 (42.9)	0.13
Smoking	26 (32.1)	3 (16.7)	23 (36.5)	0.15
Alcohol	35 (43.2)	5 (27.8)	30 (47.6)	0.22
Antiplatelet medication	20 (24.7)	5 (27.8)	15 (23.8)	0.97
Hypertension	39 (48.1)	7 (38.9)	32 (50.8)	0.53
Diabetes mellitus	14 (17.3)	1 (5.6)	13 (20.6)	0.17
Hyperlipidemia	7 (8.6)	2 (11.1)	5 (7.9)	0.65
Initial presentation				
TBI	29 (35.8)	2 (11.1)	27 (42.9)	0.01
SAH	31 (38.3)	10 (55.6)	21 (33.3)	0.15
ICH	11 (13.6)	2 (11.1)	9 (14.3)	1.00
Cerebral infarction	7 (8.6)	3 (16.7)	4 (6.3)	0.18
AVM	3 (3.7)	1 (5.6)	2 (3.2)	0.53
Cranial defect size				
Less than half hemisphere	11 (13.6)	4 (22.2)	7 (11.1)	0.25
More than half hemisphere	70 (86.4)	14 (77.8)	56 (88.9)	0.25
Brain bulging before CP				
Tense convex	73 (90.1)	18 (100)	55 (87.3)	0.19
Flaccid concave	8 (9.9)	0 (0)	8 (12.7)	0.19
Hydrocephalus index	0.36±0.07	0.37±0.08	0.34±0.03	0.01
Bilateral craniectomy	6 (7.4)	1 (5.6)	5 (7.9)	1.00

Values are presented as mean±standard deviation or number (%).
CP: cranioplasty, VPS: ventriculoperitoneal shunt, TBI: traumatic brain injury, SAH: subarachnoid hemorrhage, ICH: intracerebral hemorrhage, AVM: arteriovenous malformation.

142.5±39.7, 180.8±47.1, and VPS surgery times (minutes) were 67.1±32.1, 62.1±27.6, 180.8±47.1, respectively. The VPS and CP sites were on the same and opposite sides in 22 (27.2%) and 59 (72.8%) of the patients (**TABLES 2** & **3**).

Risk factors analysis for complications

The overall postoperative complication rate was 16.0% (13/81). Intracranial abscesses (epidural and brain abscesses) developed in 7 patients (8.6%) and mechanical infection in

TABLE 2. Comparison of complications between staged and simultaneous surgery

Complications	Staged surgery (n=63)	Simultaneous surgery (n=18)	*p*-value
Total	7 (11.1)	6 (33.3)	<0.01
Epidural abscess	4 (6.3)	1 (5.6)	
Brain abscess	1 (1.6)	1 (5.6)	
Shunt infection	2 (3.2)	0 (0)	
Epidural hemorrhage	0 (0)	2 (11.1)	
Intraventricular hemorrhage	0 (0)	1 (5.6)	
Pneumocephalus	0 (0)	1 (5.6)	

Values are presented as number (%).

TABLE 3. Comparison of characteristics and complications according the surgical timing

Variables	VPS after CP (n=26)	CP after VPS (n=37)	Simultaneous surgery (n=18)
Interval from DC to CP	93.9±74.7	115.4±94.5	59.8±29.4
Interval from DC to VPS	270.4±300.5	76.7±72.6	59.8±29.4
CP surgery time	149.0±52.6	142.5±39.7	180.8±47.1*
VPS surgery time	67.1±32.1	62.1±27.6	180.8±47.1*
Surgery site			
Same side	8 (30.8)	7 (18.9)	7 (38.9)
Opposite side	18 (69.2)	30 (81.1)	11 (61.1)

DC: decompressive craniectomy, CP: cranioplasty, VPS: ventriculoperitoneal shunt.
*The sum of the time of CP and VPS.

https://doi.org/10.13004/kjnt.2021.17.e20

TABLE 4. Risk factor analysis for complication after CP and VPS

Variables	Complication		Univariate analysis	
	(–) (n=68)	(+) (n=13)	OR (95% CI)	*p*-value
Female	31 (45.6)	8 (61.5)	1.910 (0.567–6.436)	0.297
Age (>60 years)	35 (51.5)	8 (61.5)	1.509 (0.448–5.081)	0.505
Hypertension	31 (45.6)	8 (61.5)	1.910 (0.567–6.436)	0.297
Diabetes mellitus	11 (16.2)	3 (23.1)	1.555 (0.367–6.579)	0.549
Smoking	22 (32.4)	4 (30.8)	0.929 (0.258–3.351)	0.911
Alcohol	30 (44.1)	5 (38.5)	0.792 (0.235–2.670)	0.706
Antiplatelet medication	16 (23.5)	4 (30.8)	1.444 (0.392–5.323)	0.581
TBI	26 (38.2)	3 (23.1)	0.485 (0.122–1.926)	0.303
SAH	26 (38.2)	5 (38.5)	1.010 (0.298–3.419)	0.988
ICH	8 (11.8)	3 (23.1)	2.250 (0.509–9.946)	0.285
Cerebral infarction	5 (7.4)	2 (15.4)	2.291 (0.394–13.222)	0.356
Cranial defect size (>half hemisphere)	60 (88.2)	10 (76.9)	0.444 (0.101–1.965)	0.285
Brain bulging before CP (flaccid concave)	6 (8.8)	2 (15.4)	1.879 (0.335–10.534)	0.473
Bilateral craniectomy	5 (7.4)	1 (7.7)	1.050 (0.112–9.804)	1.000
Surgery site (same side)	18 (26.5)	4 (30.8)	1.235 (0.338–4.508)	0.750
Simultaneous surgery	12 (17.6)	6 (46.2)	4.000 (1.139–14.047)	0.031

Values are presented as number (%).
CP: cranioplasty, VPS: ventriculoperitoneal shunt, OR: odds ratio, CI: confidence interval, TBI: traumatic brain injury, SAH: subarachnoid hemorrhage, ICH: intracerebral hemorrhage.

2 (2.5%). Intracranial hemorrhage (epidural and intraventricular hemorrhage) developed in 3 patients (3.7%) and pneumocephalus in one patient. The risk factors for VPS and CP complications were evaluated using the following variables: sex, age, hypertension, diabetes mellitus, hyperlipidemia, antiplatelet medication, smoking or alcohol use, clinical presentation (TBI, SAH, ICH, cerebral infarction, AVM), cranial defect size, brain bulging before CP, location of surgery site, and simultaneous surgery. The univariate analysis revealed that simultaneous surgery was indicated as the sole significant risk factor of postsurgical complication after VPS and CP (p=0.031) (**TABLE 4**).

DISCUSSION

DC is one of the important neurosurgical practice controlling intracranial pressure for traumatic and hemorrhagic patients with refractory intracranial hypertension. However, some of these patients also have post-hemorrhagic or port-traumatic hydrocephalus and VPS is required for patients undergone DC in 8%–10% after all acute phases of management.[10] Additionally, CP is required after DC for brain protection, to improve brain perfusion, and stabilize CSF hydrodynamics.[5,20] However, VPS and CP remain a concern for neurosurgeons because of the risk of unexpected complications (such as surgical site infection, intracranial hemorrhage, and mechanical malfunction). Furthermore, the proper timing of these 2 procedures relies on the surgeon's individual preferences and policies due to the lack of evidence or comprehensive guidelines. Many factors are associated with an increased risk of postoperative complications. In line with the results of this study, previous reports have shown that patients who underwent simultaneous VPS and CP had a higher rate of complications when compared with the staged group.

Traditionally, a prolonged time interval between DC and CP is used to reduce the incidence of complications.[11] However, early CP within 3 months after DC has been reported.[13,21] Several studies have shown a similar postoperative complication rate between early CP and prolonged CP groups.[1,13]

https://doi.org/10.13004/kjnt.2021.17.e20

Complication rates are related to many factors, such as cranial defect size and surgical materials. Park et al.[16] have reported that a large cranial defect can cause insufficient blood supply to the end of the skin flap, which increases complications, and the infection rate of the autogenous bone is reported as 0%–33%.[14,15] In this study, the autogenous bone was placed during CP in 79 patients and 2 received custom-made titanium mesh. All of 13 patients with complication were autogenous bone.

Hydrocephalus is the most common morbidity in post-traumatic or post-hemorrhagic patients with DC. It affects intracranial pressure, CSF circulatory, and cerebral blood perfusion. VPS is required to manage hydrocephalus in patients with progressive ventricular dilation on serial CT, and the complications of VPS include intracranial hemorrhage, surgical site infection, wound healing problems, and mechanical valve malfunction.[17]

Simultaneous surgery of CP and VPS is associated with a higher incidence rate than staged surgery. Heo et al.[12] have retrospectively reviewed 51 patients who underwent CP and VPS procedures. The overall complications rates after CP and VPS are 56% and 21% in the simultaneous and staged groups, respectively, including a significantly higher rate of infection (19% vs. 5%). The authors suggest that the difficulty of adjusting shunt pressure during the simultaneous procedure could have caused subdural fluid collection and subdural hematoma. Moreover, Schuss et al.[18] have reported 100 patients with similar results and reveal that simultaneous CP and VPS has a higher risk of complications than staged surgery (47% vs. 12%). Furthermore, patients have a significantly higher rate of infection in the simultaneous group (41% vs. 0%). In the present study, we retrospectively reviewed 81 patients who had undergone VPS and CP. The complication rate of simultaneous vs. staged CP and VPS was analyzed. We found significantly different complication rates of 33.3% and 11.1% in the simultaneous and staged groups, respectively. Interestingly, the infection rate was 11.1% in both groups. The rate of non-infective complications, such as epidural hemorrhage, intraventricular hemorrhage, and pneumocephalus was 22.2% and 0% in the simultaneous and staged groups, respectively. Compared with other studies, our study showed a higher rate of non-infective complications than infective complications.

The advantages of simultaneous surgery include shortening the patient hospital stay, reducing hospitalization costs, and increasing hospital resource efficiency; however, the safety of these procedures is an important consideration. Both CP and VPS are vulnerable to infection caused by the materials used, such as autogenous bone and mechanical shunt valves. Our results showed that simultaneous surgery may increase the incidence of complications, which should aid the surgeon in their decision for such operations.

The limitations of this study include its retrospective design and confinement to a single institution with a small sample size. The treatment decision was based on the patient's clinical status and the preference of neurosurgeons, which potentially introducing bias. However, we believe that our data can be used to support treatment decisions. Simultaneous CP and VPS surgery was associated with higher non-infection complication rates than infections, which is different from other studies. Further, prospective studies are required to definitively evaluate complication rates of CP and VPS patients.

https://doi.org/10.13004/kjnt.2021.17.e20

CONCLUSION

Simultaneous surgery was the sole significant risk factor of postsurgical complication after CP and VPS. We conclude that simultaneous surgery should be avoided, and staged operations should be performed when possible after DC.

REFERENCES

1. Annan M, De Toffol B, Hommet C, Mondon K. Sinking skin flap syndrome (or syndrome of the trephined): a review. **Br J Neurosurg 29**:314-318, 2015
PUBMED | CROSSREF
2. Bullock MR, Chesnut R, Ghajar J, Gordon D, Hartl R, Newell DW, et al. Surgical management of acute subdural hematomas. **Neurosurgery 58:**S16-S24, 2006
PUBMED
3. de Oliveira JG, Beck J, Setzer M, Gerlach R, Vatter H, Seifert V, et al. Risk of shunt-dependent hydrocephalus after occlusion of ruptured intracranial aneurysms by surgical clipping or endovascular coiling: a single-institution series and meta-analysis. **Neurosurgery 61**:924-933, 2007
PUBMED | CROSSREF
4. Feroze AH, Walmsley GG, Choudhri O, Lorenz HP, Grant GA, Edwards MS. Evolution of cranioplasty techniques in neurosurgery: historical review, pediatric considerations, and current trends. **J Neurosurg 123**:1098-1107, 2015
PUBMED | CROSSREF
5. Fodstad H, Love JA, Ekstedt J, Fridén H, Liliequist B. Effect of cranioplasty on cerebrospinal fluid hydrodynamics in patients with the syndrome of the trephined. **Acta Neurochir (Wien) 70**:21-30, 1984
PUBMED | CROSSREF
6. Gooch MR, Gin GE, Kenning TJ, German JW. Complications of cranioplasty following decompressive craniectomy: analysis of 62 cases. **Neurosurg Focus 26**:E9, 2009
PUBMED | CROSSREF
7. Güresir E, Raabe A, Setzer M, Vatter H, Gerlach R, Seifert V, et al. Decompressive hemicraniectomy in subarachnoid haemorrhage: the influence of infarction, haemorrhage and brain swelling. **J Neurol Neurosurg Psychiatry 80**:799-801, 2009
PUBMED | CROSSREF
8. Güresir E, Schuss P, Seifert V, Vatter H. Decompressive craniectomy in children: single-center series and systematic review. **Neurosurgery 70**:881-888, 2012
PUBMED | CROSSREF
9. Güresir E, Schuss P, Vatter H, Raabe A, Seifert V, Beck J. Decompressive craniectomy in subarachnoid hemorrhage. **Neurosurg Focus 26**:E4, 2009
PUBMED | CROSSREF
10. Güresir E, Vatter H, Schuss P, Oszvald A, Raabe A, Seifert V, et al. Rapid closure technique in decompressive craniectomy. **J Neurosurg 114**:954-960, 2011
PUBMED | CROSSREF
11. Schimidek H. Operative neurosurgical technique: cranio-plasty: indications, technique and prognosis, ed 4. Singapore: Elsevier Science, 2000
12. Heo J, Park SQ, Cho SJ, Chang JC, Park HK. Evaluation of simultaneous cranioplasty and ventriculoperitoneal shunt procedures. **J Neurosurg 121**:313-318, 2014
PUBMED | CROSSREF
13. Liang W, Xiaofeng Y, Weiguo L, Gang S, Xuesheng Z, Fei C, et al. Cranioplasty of large cranial defect at an early stage after decompressive craniectomy performed for severe head trauma. **J Craniofac Surg 18**:526-532, 2007
PUBMED | CROSSREF
14. Moreira-Gonzalez A, Jackson IT, Miyawaki T, Barakat K, DiNick V. Clinical outcome in cranioplasty: critical review in long-term follow-up. **J Craniofac Surg 14**:144-153, 2003
PUBMED | CROSSREF
15. Nagayama K, Yoshikawa G, Somekawa K, Kohno M, Segawa H, Sano K, et al. Cranioplasty using the patient's autogenous bone preserved by freezing--an examination of post-operative infection rates. **No Shinkei Geka 30**:165-169, 2002
PUBMED

https://doi.org/10.13004/kjnt.2021.17.e20

16. Park JS, Lee KS, Shim JJ, Yoon SM, Choi WR, Doh JW. Large defect may cause infectious complications in cranioplasty. **J Korean Neurosurg Soc 42**:89-91, 2007
17. Pollack IF, Albright AL, Adelson PD. A randomized, controlled study of a programmable shunt valve versus a conventional valve for patients with hydrocephalus. **Neurosurgery 45**:1399-1408, 1999
PUBMED | CROSSREF
18. Schuss P, Borger V, Güresir Á, Vatter H, Güresir E. Cranioplasty and ventriculoperitoneal shunt placement after decompressive craniectomy: staged surgery is associated with fewer postoperative complications. **World Neurosurg 84**:1051-1054, 2015
PUBMED | CROSSREF
19. Sobani ZA, Shamim MS, Zafar SN, Qadeer M, Bilal N, Murtaza SG, et al. Cranioplasty after decompressive craniectomy: an institutional audit and analysis of factors related to complications. **Surg Neurol Int 2**:123, 2011
PUBMED | CROSSREF
20. Winkler PA, Stummer W, Linke R, Krishnan KG, Tatsch K. The influence of cranioplasty on postural blood flow regulation, cerebrovascular reserve capacity, and cerebral glucose metabolism. **Neurosurg Focus 8**:e9, 2000
PUBMED | CROSSREF
21. Xu H, Niu C, Fu X, Ding W, Ling S, Jiang X, et al. Early cranioplasty vs. late cranioplasty for the treatment of cranial defect: a systematic review. **Clin Neurol Neurosurg 136**:33-40, 2015
PUBMED | CROSSREF
22. Yang XF, Wang H, Wen L, Huang X, Li G, Gong JB. The safety of simultaneous cranioplasty and shunt implantation. **Brain Inj 31**:1651-1655, 2017
PUBMED | CROSSREF
23. Zhou Q, Zhang SZ, Xu RX, Wang JQ, Tu YY. One-stage operation of ventriculo-peritoneal shunt and cranioplasty: analysis of 54 cases. **Di Yi Jun Yi Da Xue Xue Bao 25**:254-255, 2005
PUBMED
24. Jung H, Jang KM, Choi HH, Nam TK, Park YS, Kwon JT. Comparison of postoperative surgical site infection and symptomatic intracranial hemorrhage between staged and simultaneous cranioplasty with ventriculoperitoneal shunt placement: a meta-analysis. **Korean J Neurotrauma 16**:235-245, 2020
PUBMED | CROSSREF