

Super early cranial repair improves the prognosis of patients with craniocerebral injury

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Abstract

Objective: Craniocerebral injury has high disability and mortality rates. The timing of cranioplasty has an important impact on patients' prognosis. This study was performed to compare the functional prognosis between super early repair and conventional repair.

Methods: This observational study included 60 patients who underwent cranioplasty after surgical treatment of severe craniocerebral trauma. The patients were divided into two groups according to the time of cranial repair after the surgical treatment of craniocerebral injury: the super early group and the conventional repair group. Sex, age, Karnofsky performance status (KPS) score, Zubrod performance status (ZPS) score, psychological function score, quality of life score, and complications were recorded.

Results: The KPS score, ZPS score, psychological function score, and quality of life score were significantly related to the intervention period. Each of these scores had a clear correlation with the performance of super early treatment.

Conclusion: Super early cranial repair does not increase the incidence of surgical complications, and it can improve the postoperative KPS, ZPS, and quality of life scores.

Keywords

Super early cranial repair, craniocerebral injury, prognosis, cranioplasty, traditional therapy, quality of life

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Introduction

Craniocerebral injury has high disability and mortality rates.^{1,2} Decompression craniectomy (DC) is a commonly used method for treating craniocerebral injury and

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intracerebral hemorrhage. Although this therapy can effectively control cranial pressure and save patients' lives, it may cause large skull defects during the operation, leading to a lack of adequate skull support of brain tissue. This may induce various types of brain dysfunction and delay patients' neurological recovery.^{3,4} However, cranioplasty (CP) is an important reconstructive surgical method with which to restore the normal anatomical structure of the skull cavity and repair the missing skull. It is also a classic surgical method.^{5,6} CP is not only a good way to correct skull deformities for cosmetic purposes, but it can also promote cerebral perfusion, improve brain function, improve quality of life, improve mood, and improve clinical symptoms and neurological dysfunction. Thus, CP is being increasingly accepted by modern neurosurgeons.⁷

The timing of CP is one of the controllable factors associated with post-CP complications and quality of life.⁸ Therefore, choosing the appropriate timing of CP is crucial and is currently a hot research topic.⁹ Because of risk factors such as infection, poor scalp growth, and brain edema, CP is traditionally recommended to be performed more than 6 months after DC.¹⁰ However, many neurosurgeons began to question this traditional CP timing recommendation because of severe adhesion of the scalp to the subcutaneous tissue and dura mater, intraoperative separation difficulties, increased blood loss, and postoperative iatrogenic complications, and some surgeons found that super early repair was more conducive to neurological rehabilitation.¹¹ They began to investigate whether early CP (1–3 months after DC) helped to reduce the complication rate, improve neurological function, and improve the prognosis. However, the most appropriate timing remains controversial.¹² The timing of surgery has a very important impact on patients' prognosis and the degree to

which they benefit from the procedure.¹³ Therefore, we performed an observational study to compare the functional prognosis, quality of life, and psychological function between super early repair and conventional repair. We also examined the process of choosing the operation timing from multiple aspects with an overall goal of improving the quality of life of patients with skull defects.

Materials and methods

Patients and groups

This prospective study involved patients who underwent CP after surgical treatment of severe craniocerebral trauma at Cangzhou Central Hospital from January 2017 to January 2020. The patients were divided into two groups according to the time of cranial repair after surgical treatment of craniocerebral injury: the super early group (4–6 weeks after the operation) and the conventional repair group (3–6 months after the operation). The patients' clinical data were then analyzed to determine the safety and feasibility of super early cranial repair (4–6 weeks after treatment of skull defect).

Indications for DC

The first indication for DC was the presence of severe contrecoup craniocerebral injury with obvious disturbance of consciousness and pupil change. The second indication was preoperative computed tomography findings of severe brain contusion and brain edema, midline shift of ≥ 0.5 cm, narrowing and disappearance of the lateral fissure cistern and basal cistern, or disappearance of the lateral fissure cistern and a decrease in the third ventricle pressure. If the intracranial pressure was high, large bone flap decompression could be performed at the same time.

Indications for CP

The cranial defect after surgical treatment of closed craniocerebral trauma was repaired based on the change in the degree of collapse of the decompression window, which helped to guide the timing of surgery. Additionally, the timing of CP was based on the patient's general condition and wound healing status, which conformed to the principle of individualized treatment and the requirements of evidence-based medicine. Surgical repair and treatment could be performed in patients with skull defects after treatment of craniocerebral trauma with mild decompression window collapse, which could not only improve the patient's neurological function and quality of life in the early stage but also reduce the occurrence of an intracranial hematoma after CP. Notably, in patients undergoing early CP, the clinician must exclude intracranial hypertension, intracranial space-occupying lesions, brain swelling, and other conditions before performing CP. We believe that the skull defect should be treated as soon as possible after healing of the original incision, restoration of normal intracranial pressure, depressurization of the window, and stability of the injury.

Ethics and consent

This study was approved by the Ethics Committee of Cangzhou Central Hospital (approval number 2017CZCH006). Written informed consent was obtained from all patients.

Inclusion and exclusion criteria

The inclusion criteria were an age of 17 to 65 years, performance of CP for skull defects after treatment of craniocerebral trauma, performance of a diagnostic nervous system examination and head computed tomography, and the presence of neurological dysfunction.

The exclusion criteria were an age of <17 or >65 years, poor wound healing or infection, other serious primary diseases, severe primary mental disorders, encephaloceles, intracranial infection, the absence of high preoperative intracranial pressure, and refusal to participate in the trial. Figure 1 shows the patient selection process for this study.

Collection of clinical indicators

The patients' sex, age, and other basic information were recorded in detail. We also compared several functional status scores between the two groups: the Karnofsky performance status (KPS) score, Zubrod performance status (ZPS) score, psychological function score, and quality of life score. Finally, we compared complications (intracranial infection, subcutaneous hydrops, scalp necrosis, and intracranial hematoma), intracranial pressure, and cerebral blood flow between the two groups.

KPS score

The KPS score is the standard for measurement of the functional status. A higher score is associated with better health, greater ability to tolerate adverse effects of

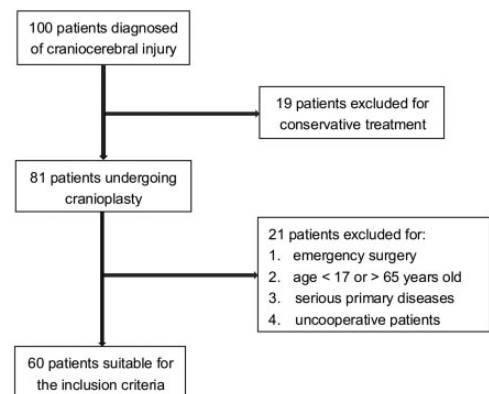


Figure 1. Patient selection process.

treatment, and a greater likelihood of receiving thorough treatment. The KPS score is classified as follows: >80, independent; 50 to <70, semi-independent; and <50, dependent.

ZPS score

The ZPS score is used to evaluate the performance status and is classified as follows: 0, normal activity; 1, mild symptoms, comfortable life, and able to engage in light physical activity; 2, able to tolerate the symptoms of the tumor and engage in self-care with <50% of the day spent in bed; 3, severe symptoms with >50% of the day spent in bed, but able to get up, stand up, and engage in some aspects of self-care; 4, completely bedridden; and 5, death.

Statistical analysis

The data are expressed as percentage of the total and percentage. Pearson's chi-square test was used to analyze associations between the clinical parameters and the intervention period. Spearman's rho test was performed to compare the clinical data and the intervention period for the correlation analysis. Univariate logistic regression analysis was used to calculate the odds ratio (OR) of the intervention period for postoperative parameters. All statistical analyses were conducted using IBM SPSS Statistics for Windows, Version 21.0 (IBM Corp., Armonk, NY, USA). A P -value of <0.05 was considered statistically significant.

Results

Associations between patients' characteristics and intervention period based on χ^2 test

Sixty patients were included in this study. The super early repair group comprised 28

patients, and the conventional repair group comprised 32 patients. Table 1 summarizes the associations between postoperative parameters and the intervention time according to Pearson's chi-square test. Significantly more patients had a KPS score of >50 in the super early repair group than in the conventional repair group ($P=0.001$). In addition, the ZPS scores, psychological function scores, and quality of life scores were significantly better in the super early repair group than in the conventional repair group ($P<0.05$). However, the intervention time was not significantly associated with age, intracranial infection, fluid accumulation, scalp necrosis, intracranial hematoma formation, intracranial pressure, or cerebral blood flow (Table 1).

Further associations between patients' characteristics and intervention period by Spearman's correlation test

A further correlation analysis was performed to confirm whether the potentially correlative characteristics after cranial defect surgery had an important association with the intervention period. Spearman's correlation coefficient indicated that the intervention period was significantly correlated with sex ($\rho=0.431$, $P=0.001$), KPS score ($\rho=-0.449$, $P=0.001$), ZPS score ($\rho=-0.449$, $P=0.001$), psychological function score ($\rho=-0.423$, $P=0.001$), and quality of life score ($\rho=-0.287$, $P=0.032$). However, there were no further associations of the intervention period with age ($\rho=-0.190$), intracranial infection ($\rho=0.033$), fluid accumulation ($\rho=0.030$), scalp necrosis ($\rho=-0.050$), intracranial hematoma formation ($\rho=-0.050$), intracranial pressure ($\rho=-0.044$), or cerebral blood flow ($\rho=-0.190$) (Table 2).

Table 1. Relationships between postoperative parameters and intervention periods.

Characteristics	n	Intervention period		P
		Conventional repair group	Super early repair group	
Sex				0.001*
Male	37	26 (43.3)	11 (18.3)	
Female	23	6 (10.0)	17 (28.3)	
Age, years				0.142
≤40	18	7 (11.7)	11 (18.3)	
>40	42	25 (41.7)	17 (28.3)	
KPS score				0.001*
>50	30	15 (25.0)	25 (41.7)	
≤50	20	17 (28.3)	3 (5.0)	
ZPS score				0.001*
Good	30	15 (25.0)	25 (41.7)	
Poor	20	17 (28.3)	3 (5.0)	
Psychological function score				0.001*
Good	36	13 (21.7)	23 (38.3)	
Poor	24	19 (31.7)	5 (8.3)	
Quality of life score				0.031*
Good	41	18 (30.0)	23 (38.3)	
Poor	19	14 (23.3)	5 (8.3)	
Intracranial infection				0.796
No	48	26 (43.3)	22 (36.7)	
Yes	12	6 (10.0)	6 (10.0)	
Fluid accumulation				0.817
No	50	27 (45.0)	23 (38.3)	
Yes	10	5 (8.3)	5 (8.3)	
Scalp necrosis				0.698
No	48	25 (41.7)	23 (38.3)	
Yes	12	7 (11.7)	5 (8.3)	
Intracranial hematoma				0.698
No	48	25 (41.7)	23 (38.3)	
Yes	12	7 (11.7)	5 (8.3)	
Intracranial pressure, mm H ₂ O				0.735
70–200	18	9 (15.0)	9 (15.0)	
<70 or >200	42	23 (38.8)	19 (31.7)	
Cerebral blood flow, mL/100 g/min				0.142
>50	18	7 (11.7)	11 (18.3)	
<50	42	25 (41.7)	17 (28.3)	

Data are presented as n (%).Pearson’s chi-squared test was used. *P < 0.05.
KPS, Karnofsky performance status; ZPS, Zubrod performance status.

Univariate logistic regression for proportional hazards analysis of correlative factors for intervention period

Finally, we used univariate logistic regression to determine the association between

correlative parameters and the intervention period [ORs and 95% confidence intervals (95% CIs)] to further define the risk associated with each intervention period. Table 3 shows the ORs and 95% CIs of the patients at the univariate level using univariate

Table 2. Relationships between patient characteristics and intervention periods.

Characteristics	Intervention period	
	ρ	<i>P</i>
Sex	0.431	0.001*
Age	-0.190	0.147
KPS score	-0.449	0.001*
ZPS score	-0.449	0.001*
Psychological function score	-0.423	0.001*
Quality of life score	-0.278	0.032*
Intracranial infection	0.033	0.800
Fluid accumulation	0.030	0.821
Scalp necrosis	-0.050	0.704
Intracranial hematoma	-0.050	0.704
Intracranial pressure	-0.044	0.740
Cerebral blood flow	-0.190	0.147

Spearman correlation test was used. * $P < 0.05$.

KPS, Karnofsky performance status; ZPS, Zubrod performance status.

logistic regression. Relative to the conventional repair group, the OR for sex was 6.697 (95% CI, 2.084–21.525; $P = 0.001$) in the super early cranial repair group. The OR for the KPS score was lower in the super early cranial repair group (OR, 0.106; 95% CI, 0.027–0.423; $P = 0.001$) than in the conventional repair group. The analysis also showed that the patients in the super early cranial repair group had a lower ZPS score (OR, 0.106; 95% CI, 0.027–0.423; $P = 0.001$), higher psychological function score (OR, 0.149; 95% CI, 0.045–0.492; $P = 0.002$), and better quality of life score (OR, 0.280; 95% CI, 0.085–0.921; $P = 0.036$) than those in the conventional repair group. However, there was no disadvantageous association between the intervention period and age (OR, 0.433; 95% CI, 0.140–1.340), intracranial infection (OR, 1.182; 95% CI, 0.333–4.192), fluid accumulation (OR, 1.174; 95% CI, 0.302–4.568), scalp necrosis (OR, 0.776; 95% CI, 0.216–2.792), intracranial hematoma formation (OR, 0.776; 95% CI, 0.216–2.792),

intracranial pressure (OR, 0.826; 95% CI, 0.273–2.496), or cerebral blood flow (OR, 0.433; 95% CI, 0.140–1.340) (Table 3).

Discussion

The present study results showed that the postoperative KPS score, ZPS score, psychological function score, and quality of life score were significantly better in the super early repair group than in the conventional repair group as indicated by Pearson's chi-square test, Spearman's correlation analysis, and univariate logistic regression analysis. Super early cranial repair can effectively improve the KPS and ZPS scores and quality of life score in patients with cranial defects after cranial injury and promote the recovery of body function; thus, it is worthy of clinical use.

Any changes in the operation timing should take into account not only the possible benefits but also the possible disadvantages to patients. Patient's postoperative quality of life is an unavoidable issue, but many studies to date have produced inconsistent findings.¹² A meta-analysis by Malcolm et al.¹² showed that the incidence of hydrocephalus is higher during super early CP than conventional CP. Furthermore, Schuss et al.¹⁴ found that super early CP might increase the risk of complications such as intracranial infection, fluid accumulation, and intracranial hematoma formation. However, other studies have shown that super early CP can shorten the operation time, reduce intraoperative blood loss, and improve the neurological function and prognosis.¹⁵ The above-mentioned meta-analysis by Malcolm et al.,¹⁶ which is the most recent to date, also demonstrated that super early (<90 days) CP significantly improved the prognosis of neurological function. Bender et al.¹⁷ conducted retrospective studies of 79 patients who underwent super early CP and 68 patients who underwent late CP,

Table 3. Assessment of postoperative characteristics with respect to intervention period by logistic regression analysis.

Characteristics	Intervention period	
	Conventional repair group	Super early repair group
Sex	OR	1
	95% CI	6.697
	P	2.084–21.525
Age	OR	0.433
	95% CI	0.140–1.340
	P	0.146
KPS score	OR	0.106
	95% CI	0.027–0.423
	P	0.001*
ZPS score	OR	0.106
	95% CI	0.027–0.423
	P	0.001*
Psychological function score	OR	0.149
	95% CI	0.045–0.492
	P	0.002*
Life quality score	OR	0.280
	95% CI	0.085–0.921
	P	0.036*
Intracranial infection	OR	1.182
	95% CI	0.333–4.192
	P	0.796
Fluid accumulation	OR	1.174
	95% CI	0.302–4.568
	P	0.817
Scalp necrosis	OR	0.776
	95% CI	0.216–2.792
	P	0.689
Intracranial hematoma	OR	0.776
	95% CI	0.216–2.792
	P	0.689
Intracranial pressure	OR	0.826
	95% CI	0.273–2.496
	P	0.735
Cerebral blood flow	OR	0.433
	95% CI	0.140–1.340
	P	0.146

* $p < 0.05$.

OR, odds ratio; 95% CI, 95% confidence interval; KPS, Karnofsky performance status; ZPS, Zubrod performance status.

respectively, and found that the neurological prognosis was significantly better in patients who underwent early (<86 days) than late (>85 days) CP.

Some scholars have pointed out that (1) if a skull defect is present, the flap will be relatively loose, and the cranial content will change with the position and regular displacement, and (2) the atmospheric pressure can function in the cerebral cortex under the skin flap. If the skull defect is close to the venous sinus, it will also affect the sinus pressure, thus causing various clinical neurological symptoms and, in severe cases, seriously affecting the recovery of neurological function.¹⁸ The optimal period for recovery of neurological function is 1 to 3 months after the injury. Therefore, CP performed on patients at this stage has a very positive effect on the recovery of neurological function and improvement in quality of life.^{19,20}

Super early repair can also effectively reduce diastolic vasoconstriction, increase the microvasodilation ability in the brain, and effectively reduce the resistance of small blood vessels. These changes can increase the cerebral blood flow and thus improve the cerebral vascular responsiveness,^{9,21,22} which might contribute to the better prognosis of patients undergoing super early CP. Long-term skull defects can cause an imbalance in the intracranial spatial structure, resulting in intracranial structural changes and neurological function damage.²³ In recent years, super early CP has been gradually applied in clinical practice.¹⁷ As noted above, the optimal period for recovery of neurological function is 1 to 3 months after the injury.²⁴ Super early CP is helpful to create favorable conditions for neurological function recovery.²⁵ Therefore, it can also create favorable conditions for improving the postoperative KPS score, ZPS score, psychological function score, and quality of life score.²⁶

The present study has two main limitations. First, the data collection method may have introduced a risk of bias. Therefore,

further studies are needed to clarify the mechanism of early CP on the prognosis of patients. Second, we only identified and analyzed the factors in choosing the operative time using the available data; we did not study the specific biological mechanism between them. We anticipate that this will be a focus of future studies. At present, many factors affect the choice of super early CP. How to effectively choose the optimal surgical treatment for patients with skull defects requires further study and discussion.

Conclusion

Early cranial repair does not increase the incidence of surgical complications and can improve the postoperative KPS score, ZPS score, and quality of life score. Early cranial repair is of great significance for reducing the area of skull defects.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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