Effect of primary decompressive craniectomy on outcomes in severe traumatic brain injury with mass lesions and the independent predictors for operation decision

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Research

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Abstract

Background: Although operative indications for traumatic brain injury (TBI) have been evaluated, neurosurgeons often face a dilemma of whether or not to remove the bone flap after mass lesion evacuation, and a useful predictive scoring model for which patients should be decompressive craniectomy (DC) has yet to be developed. The aim of this study was firstly to compare the outcomes of craniotomy and DC, and secondly to determine independent predictors and develop a multivariate logistic regression equation to determine whom should perform primary DC in TBI patients with mass lesions.

Methods: A total of nine different variables were evaluated. All 245 patients with severe TBI in this study were retrospectively evaluated between June 2015 and May 2019 and all underwent decompressive craniectomy (DC) or craniotomy for mass lesion removal. The 6-month mortality and Extended Glasgow Outcome Scale (GOSE) were compared between DC and craniotomy. By using univariate, multiple logistic regression and prognostic regression scoring equations it was possible to draw Receiver Operating Characteristic curves (ROC) to predict the decision for DC.

Results: The overall 6-month mortality in the entire cohort was 11.43% (28/245). DC patients had a lower mean preoperative Glasgow Coma Scale (GCS) ($p = 0.01$); more patients with GCS of 6 ($p=0.007$);more unresponsive pupillary light reflex ($p< 0.001$); more closed basal cisterns ($p< 0.001$); and more patients with diffuse injury ($p=0.025$) than craniotomy patients. Given the greater severity, patients undergoing primary DC had higher 6-month mortality than the remainder of the cohort. However, in the surviving patients, the favorable GOSE rate was similar in two groups. We found that pupillary light reflex and basal cisterns were independent predictors for DC decision. Using ROC curve to predict the probability of DC, the sensitivity was 81.6% and the specificity was 84.9%.

Conclusion: Our preliminary findings showed that the primary DC may benefit subgroups of sTBI with mass lesions, and unresponsive pre-op pupil reaction, and closed basal cistern to predict the DC decision were useful. These sensitive variables can be used as a referential guideline in our daily practice to decide to perform or avoid primary DC.

Introduction

Traumatic brain injury (TBI) presents a great challenge to public health worldwide[1]. In China, TBI is a problem primarily of young and middle aged adults and the proportion of patients with severe TBI is as high as around 20%, leading to huge losses in health and labor capacity[2, 3]. Although most small parenchymal lesions do not require surgical evacuation[4], the development of mass effect from larger lesions may result in secondary brain injury, placing the patient at risk of progressive neurological deterioration, refractory intracranial hypertension, herniation, and death[5]. Craniotomy with evacuation of the hematoma is the standard surgical treatment for these patients. A significant proportion of patients, especially severe TBI patients, however, have intractable intracranial hypertension after standard craniotomy, which necessitates craniectomy, and these patients have the worst outcome[6]. However, there is a paucity of evidence in the literature regarding the best surgical strategy (primary decompressive craniectomy or craniotomy) for this group of patients and surgical decision making is often haphazard[7].

Decompressive craniectomy (DC) is a surgical procedure in which a large component of the bony skull is removed and the underlying dura mater is opened[8].Primary DC refers to leaving a large bone flap out after the evacuation of an intracranial hematoma in the early phase after a TBI[9]. DC holds the promise of reduced mortality, but long term neurological outcomes and indications remain controversial[10]. However, the indications for DC remain difficult to define for the surgeon in the emergency setting[11]. The current debate centers on patient selection and clinical indications[12].Intracranial pressure monitoring is widely used to evaluate the intracranial status of patients with TBI[1]. In the two decades, the addition of intracranial pressure monitoring has markedly improved decision making and management of patients with severe TBI[13]. However, in China, most patients admitted to the intensive care unit (ICU) with severe TBI did not receive an intracranial pressure (ICP) monitoring device[2], reflect the role of clinical assessment and imaging in making treatment decisions ,or economic constraints in case of non-reimbursement[14]. In contrast, computed tomography (CT) scans are done for patients with TBI in all hospitals with departments of neurosurgery in China[13].Moreover, we found that decompressive craniectomy (DC) in refractory ICP was performed in Chinese centers more often than that in European centers[15]. This procedure is recommended (level II A evidence) in the Brain Trauma Foundation guidelines[16].

We had performed craniectomy as the primary procedure for TBI patients with clear operative indications to prevent expected postsurgical increases in ICP and hypothesized that there are subpopulations of patients who need surgical intervention will benefit from primary DC. However, the precise characteristics of these subpopulations are not, as yet, clearly defined. The primary purpose of this study is to assess the impact of DC on subgroups of sTBI by comparing the 6-month mortality between primary DC and standard craniotomy. And also, to determine independent predictors and develop a multivariate logistic regression equation to predict who should undergo and benefit from the primary DC.

Methods

Study Description

This is a retrospective cohort study which includes 245 adult patients (age of 18 to 65) of severe TBI (Glasgow Coma Scale 6 to 8) with mass lesions admitted to a medical center in China (Tangdu Hospital) from June 2015 through May 2019. This study was approved by the ethics committee of our hospital (No. TDLL2015105). Given the study design of a retrospective chart review, patient consent was not required. All clinical data, including medical records, brain imaging examinations, operation reports, intensive care nursing records, and outpatient visit reports were retrospectively reviewed.

Operative Indications

All sTBI patients with a score of 6 to 8 on the GCS undergoing craniotomy or primary DC following head injury during this period were included in the study. The key indications for operation were as follows: Frontal or temporal cerebral contusions greater than 20 cm^3 in volume with midline shift of at least 5 mm and/or cisternal compression of CT scan. Any lesion greater than 50 cm^3 in volume[17]. Some patients received simple craniotomy with evacuation of hematoma. Whereas others received primary DC in whom were left with the “bone-off” after mass lesion evacuation. The decision for primary DC was based on neurosurgeon discretion, some patients were decided to DC before in the operating room, some of them the bone flap was not repositioned due to the presence of major intraoperative brain swelling during operation, there was no fixed protocol.

Surgical Technique

For analysis, patients were divided in two groups: craniotomy group and DC group. Selection of initial surgical procedure was nonrandomized, and the choice of surgical approach was at the discretion of the attending neurosurgeon. All surgeries were conducted by a well-trained surgical team. Briefly, patients in craniotomy group underwent either large unilateral frontotemporoparietal craniectomy (hemicraniectomy), which was recommended for patients with unilateral hemispheric swelling, or bifrontal craniectomy, which was recommended for patients with diffuse brain swelling that affected both hemispheres according to the position of hematomas on imaging studies. The exact type of craniectomy was left to the discretion of the surgeons. And a frontotemporoparietal bone flap was created in DC group. In both groups, the dura was coagulated and widely opened. A relaxation suture duraplasty was performed by synthetic material or by a periosteal patch. An ICP microsensor was placed in the parenchyma of the ipsilateral frontal lobe of each patient.

Treatment

All patients were managed in the intensive unit with standard medical treatment and critical care according to the guideline for the Management of Severe Traumatic Brain Injury 4th Edition by Brian Trauma Foundation[16]. CT scans, biochemical examinations, routine blood tests, and routine coagulation studies were performed immediately when the patients were admitted to the emergency department. The medical history and results of the neurologic physical examination were recorded immediately after admission. Vital signs were monitored. Treatment protocols target cerebral perfusion pressure (CPP) >60 mm Hg，ICP <20 mm Hg , PaO_2 80–120 mmHg, $PaCO_2$ 35–40 mmHg, hemoglobin >90 g/L, temperature <37.5 C, and sodium >140 mmol/ L. Patients were appropriate sedation and analgesia with a continuous intravenous infusion of midazolam and fentanyl. If needed, hypertonic saline (3%) or mannitol was used.

Data Collection

The patient’s basic information (age, gender, the mode of injury, the initial GCS score, etc) was recorded and retrospectively from our hospital’s computerized electronic database. GCS, length of stay, time to various procedures, and all other vital signs were collected daily from admission until the removal of ICP monitor or death. ICP mean values were recorded each hour. The patients were followed up by telephone by three trained assessors to record their prognostic information at 6 months after surgery. The outcome of patients at 6 months after injury was categorized according to the GOSE that ranges from 1 to 8, with lower scores indicating a poorer functional outcome[18]. A score of 5–8 was considered a favorable outcome (moderate disability or less) and a score of 1–4 was considered unfavorable (severe disability or death).

The midline shift at the Foramen of Monro on the CT scan was defined as the absolute distance (cm) that the septum pellucidum of the brain was displaced away from the midline, which was determined as an average by calculating the distance between both inner tables inside the skull[19].For convenience of data analysis, the presence of a fixed pupil was defined as unresponsive (< 1 mm) to a light stimulus. The pupillary light reflex was divided into three categories including one pupil fixed, both pupils fixed and both pupils reactive[20].

Cerebrospinal fluid cisterns around the midbrain are divided into three limbs. Basal cisterns were also dived into three categories: open (all limbs open), partially closed (one or two limbs obliterated), and completely closed (all limbs obliterated)[17].

Statistical Analysis

Primary analysis was to compare 6-month mortality and functional outcomes between groups. The GOSE score was dichotomized as poor outcome (GOSE 1–4) and favorable outcome (GOSE 5–8). The data were analyzed using version 17.0 of SPSS (SPSS, Chicago, IL, USA) software. Variables were classified as continuous or categorical. Independent Student's *t*-tests were used for continuous variables between the two groups. Fisher's exact test or Pearson's $\chi 2$ test was used for comparison of categorical variables among groups. Multiple logistic regression models were used for correlation between two continuous or categorical variables and the independent risk factors for DC. Finally, logistic regression analysis was then used to establish a prognostic model and a ROC curve was then drawn based on the prognostic scoring model [21]. A two-tailed P value <0.05 was considered statistically significant.

Results

Patients

From June 2015 to May 2019, a total of 947 adult consecutive patients with TBI admitted to our hospital were reviewed retrospectively. Of these, 245 patients with a score of 6 to 8 o the GCS who underwent craniotomy or DC were retrospectively evaluated in this study. Patients were divided into two groups: craniotomy group and DC group (Table 1). There were 152 patients in the DC group and 93 patients in the craniotomy group. The mean age was 48.29±14.59 years in the DC group, while 47.98±14.72 years in the craniotomy group, there was no significant difference (p=0.874, t=0.159). Male patients were significantly predominant at 76.97% (117/152) and 80.64% (75/93) in the DC group and craniotomy group, respectively, with no difference between two groups (p=0.527, $\chi 2$=0.498). The mean systolic blood pressure was 136.98±26.84 mmHg and 133.67±20.33 mmHg in the DC group and craniotomy group, respectively, without significant difference between two groups ($p=0.276$, $t=1.09$). The proportion of patients with systolic blood pressure higher than 140mmHg was similar between the two groups ($p=0.893$, $\chi^2=0.034$), 38.81% (59/152) in the DC group and 37.63% (35/93) in the craniotomy group, respectively. Patient in the DC group had a lower mean GCS than that in the craniotomy group($p=0.01$, $t=2.603$), the mean GCS was 6.75±0.8 in the DC group and 7.04±0.88 in the craniotomy group, respectively. Although, the median GCS was same and both were 7 in two groups, there were much more patients with GCS 6 in the DC group than that in the craniotomy group ($p=0.007$, $\chi2=9.78$). Both the mean midline shift and the proportion of midline shift more than 0.5cm were similar in two groups, the mean midline shift was 0.43±0.33 cm in the DC group in which 43.42% was more than 0.5cm, while the mean midline shift in the craniotomy group was 0.38±0.28 cm in which 39.78% was more than 0.5cm. The mean time from injury to surgery was similar in the two groups, that was 15.06±15.27 hours and 16.32±14.86 hours for the DC group and the craniotomy group, respectively. The pre-operation pupillary light reflex was significantly different in the two groups ($p=0.000$, $\chi^2=71.67$), there were much more patients with one or both pupillary fixed in the DC group than that in the craniotomy group. Similarly, there were much more patients with closed basal cisterns in the DC group than that in the craniotomy group ($p=0.000$, $\chi^2=54.54$). For pre-operation CT imaging, there were much more patients with diffuse injury in the DC group than that in the craniotomy group ($p=0.025$, $\chi^2=5.53$). Patients and their clinical characteristics are summarized in Table 1.

Outcomes

The overall 6-month mortality in the entire cohort was 11.43% (28/245). The 6-month mortality in the DC group was 15.13% (23/152) which was higher than that in the craniotomy group (5.37%, 5/93) ($p=0.022$, $\chi^2=5.42$). However, in the surviving patients, the favorable GOSE rate was similar in two groups($p=0.061$), the favorable GOSE rate in the DC group was 78.29% and in the craniotomy group was 87.5%. The 6-month mortality and GOSE are summarized in Table 2.

To test the hypothesis that there are subpopulations of patients who need surgical intervention will benefit from primary DC. Since there were significantly varies in GCS, pupillary light reflex, basal cisterns, and CT imaging in the two groups which might have different associations to the patient's outcomes, subgroup analysis was also performed. Patients were further divided into several subgroups according to GCS, pupillary light reflex, basal cisterns, and CT imaging, respectively. The mortality and the favorable GOSE rate were compared in subgroups.

Although there were more patients with GCS 6 in the DC group than in the craniotomy group, the mortality and the favorable GOSE rate in DC group was similar with the craniotomy group (Table 3). That were similar situations for patients with GCS 7 or GCS 8, the mortality was higher, and the favorable GOSE rate was lower in the DC group than the craniotomy group without significantly difference.

For patients with at least one pupillary light reflex present, the mortality was same in the DC group and the craniotomy group, and the favorable GOSE rate was similar in the two groups (Table 4). However, for patients with both pupillary light reflex absent, the mortality was lower in the DC group and the favorable GOSE rate was significantly higher in the DC group than the craniotomy group which indicated that this subgroup of patients might be benefit from the DC operation.

There were significantly less patients with basal cisterns open in the DC group than the craniotomy group, while significantly more patients with closed basal cisterns in the DC group ($p=0.000$, $\chi^2=54.54$) which consistent with the fact that more severe TBI patients were more likely to choose DC (Table 5). For patients with basal cisterns open, the mortality was significantly higher in the DC group than in the craniotomy group, and the favorable GOSE rate was significantly lower in the DC group. However, for patients with closed basal cisterns, the mortality was lower in the DC group and the favorable GOSE rate was significantly higher in the DC group than the craniotomy group which indicated that this subgroup of patients might be benefit from the DC operation. For patients with partial closed basal cisterns, the mortality and the favorable GOSE rate was similar in the two groups.

There were significantly more patients with diffuse injury showed by CT imaging in the DC group than the craniotomy group ($p=0.025$, $\chi^2=5.53$). For patients with diffuse injury, the mortality and the favorable GOSE rate was similar in the two groups (Table 6). The mortality in patients with mass lesion in the DC group tended to increase, but there was not significantly difference. However, the favorable GOSE rate was significantly lower in the DC group than the craniotomy group ($p=0.011$, $\chi^2=7.11$) which indicated that this subgroup of patients might not be benefit from the DC operation.

Multivariate logistic regression was then performed on the significant variables extracted from the previous step to determine the independent associations of each variable with the choice of DC (Table 7). Thus, the final model contained two variables: pupillary light reflex and basal cisterns. These results showed pupillary light reflex (OR = 7.51, CI = 2.34-24.07; p <0.001), and basal cisterns (OR = 4.22, CI =1.42-12.59; p =0.01) were independent of associations to the choice of DC.

At the same time, a predicted probability (P) of choosing DC was estimated by the multiple logistic regression model: Ln(P/1−P)=)=-2334+1.44×(basal cisterns)+2.016×(pupil reaction). The predictors of the model were selected by stepwise procedure. Using ROC curve analysis based on the prognostic model scoring, a cut off point for prediction of choosing DC of p was defined as a value=3.19. The sensitivity of the equation was 81.6%, and specificity 84.9% in predicting the choice of DC for operation after TBI (AUC=0.811, 95% CI=0.75-0.87, Figure 1).

Discussion

In this study, we evaluated the impact of primary DC and craniotomy on sTBI with mass lesions. As expected (given the greater severity), patients undergoing primary DC had higher 6-month mortality than the remainder of the cohort. However, in the surviving patients, the favorable GOSE rate was similar in primary DC patients and craniotomy patients indicated that primary DC might improve outcomes of subgroup patients of sTBI. We further identified that patients either with both pupillary light reflex absent or with closed basal cisterns, the primary DC decreased the mortality and increased the favorable GOSE proportion. Furthermore, we developed a multivariate logistic regression equation for decision making and to determine whether the primary DC should be done or not for sTBI with mass lesion.

TBI is one of the leading causes of death and disability worldwide, with a global annual incidence of more than 50 million cases[22]. With a population of 1.4 billion, the number of patients with TBI in China exceeds that of most other countries, causing an enormous burden to society and families[1]. Among patients who are hospitalized with severe TBI, 60% either die or survive with severe disability[18]. In China, the proportion of patients with severe TBI is around 20%,and the mortality of sTBI is also around 20%[2, 13].

After severe TBI, medical and surgical therapies are performed to minimize secondary brain injury[18]. The treatment goal of severe TBI is to reduce and prevent intracranial hypertension (ICH), a pathologic increase in ICP can lead to brain ischemia by reducing CPP and lead to neurologic deficit and fatal brain herniation syndromes. To achieve this goal, several medical and surgical therapies can be performed, including head-of-bed elevation, pharmacologic sedation and analgesic, improved blood flow, external ventricular drain, surgical evacuation of hemorrhagic lesions, and DC[23]. Despite recommendations by the Brain Trauma Foundation supporting the use of these therapies for sTBI, there is no level I evidence demonstrating improvement in patient outcomes through definitive, surgical management of TBI [17, 24]. DC has been performed for the purpose of relieving elevated intracranial pressure with outcome improvement in specific TBI patients[25].DC holds the promise of reduced mortality, but long term neurological outcomes and indications remain controversial[10].

Recently, in *The Lancet Neurology*, the results of the Chinese sister study—the CENTER-TBI China registry study including 13138 patients from 52 centers showed that surgical interventions, including insertion of the intracranial pressure device, decompression, external ventricular drainage, and hematoma removal show therapeutic benefits in patients with signs of brain herniation[2]. Moreover, this finding probably reflects the high proportion of patients with severe injury, but from a clinical perspective preemptively treating impending brain herniation is preferable, rather than waiting for the condition’s full development[2]. The effectiveness of these surgical interventions in this cohort is of particular relevance given the lack of benefit reported in the overall TBI population in previous clinical trials[26-28]. The identification of subgroups who are most likely to benefit from these interventions should be a priority[2].

In China, the indications for unilateral or bilateral large DC include progressive neurological deterioration, intracerebral hematoma, contusion or edema with midline shift more than 5 mm and cisternal compression on CT, and intracranial pressure higher than 30 mm Hg for longer than 30 min[13]. However, these indication variables alone do not define the patient who should undergo DC intervention. Although, intracranial pressure monitoring is widely used to evaluate the intracranial status of patients with TBI. And, in the past two decades, the addition of ICP monitoring has markedly improved decision making and management of patients with severe TBI[13]. But, most patients admitted to the ICU with severe TBI in China did not receive an ICP monitoring device, thus implying that in many centers treatment decisions are made on the basis of clinical and radiological findings[2]. Instead, in China, CT scans are done for patients with TBI in all hospitals with departments of neurosurgery[1]. Primary DC is most often performed for clinical and radiographic evidence of herniation, rather than for refractory ICP elevation[29].Moreover, we found that DC in TBI was performed in Chinese centers more often than that in European centers[2, 15].

Most sTBI patients with intracranial hypertension attribute to mass lesions, such as contusion and acute subdural hematoma (ASDH)[17]. Severe primary injury and worsening condition necessitate emergent surgical intervention. The available type of operation is either craniotomy or DC. Generally, there are three distinct scenarios in which DC is performed for TBI: firstly, as a “primary” procedure following evacuation of a mass lesion; secondly, as emergent treatment for neurological deterioration attributable to worsening mass effect in patients who previously were not considered to have an indication for ICP monitoring; and thirdly, as treatment for raised ICP that is refractory to medical therapy[29].

In this study, in contrast to DECRA and RESCUE-ICP[18, 27], we performed DC as primary procedure following evacuation of a mass lesion. Our data supported the hypothesis that some specific TBI patients would benefit from primary DC. Our results in line with some studies which suggesting primary DC proposed that early aggressive intervention could mitigate the secondary damages of increased ICP[30]. In Europe, a retrospective study of 729 patients revealed that one-third of patients with STBI who received emergency surgery still needed DC even after hematoma evacuation[31]. In a retrospective cohort comparison study of 91 patients who had an operation for an ASDH, 56% received a primary DC, while the rest a craniotomy[32]. This study supports the hypothesis that a primary DC (i.e. bone flap left out after ASDH evacuation) may lead to better outcomes compared to a craniotomy (i.e. bone flap is replaced) due to better control of brain swelling and intracranial hypertension in the post-operative period. This hypothesis is also supported by a two-center non-experimental comparative effectiveness research (CER), which found that post-operative ICP was better controlled and patient outcomes were better in the center with greater utilization of primary DC[33, 34]. Given the potential benefit from primary DC on TBI, there are several prospective randomized trials are going on. The primary DC for patients with ASDH is being systematically evaluated in the context of the RESCUE-ASDH trial in UK[33]. And, the effect of primary DC in sTBI with mass lesions is being evaluated in a prospective, randomized, assessor-blind, single center clinical trial named prospective, randomized evaluation of therapeutic decompressive craniectomy in sTBI with mass lesions (PRECIS) in China[35].

When comparing DC with craniotomy patients, it shows DC patients have a lower mean preoperative GCS (p = 0.01); more patients with GCS of 6 (p=0.007);more unresponsive pupillary light reflex (p< 0.001); more closed basal cisterns (p< 0.001); and more patients with diffuse injury (p=0.025). These results seem to support the notion that the perioperative neurological status in decompressive craniectomy patients is more severe than in craniotomy. To explore the factors involved in decision marking for DC, in addition to the single factor analysis and multi-factorial prognostic analysis, in our study, we further combined an ROC curve and the multivariate logistic regression equation to evaluate the predictive accuracy of two variables in choosing of DC. In line with previous reports demonstrated that the effacement of the basal cisterns and the absent of pupil reaction are strongly associated with poor outcomes and that calling for DC[36]. These results disclosed two variables, which had previously been shown to be related to survival, as having strong accuracy in prognostic judgment with sensitivity 81.6% and specificity 84.9% in predicting of DC. Since these two variables in the scoring model are clinically simple to attain in the acute stage after TBI, we consider therefore, that the derived equation is clinically useful to make decision on whether DC or not in daily practice.

There are limitations of the present study must be considered because of the nature of the retrospective, nonrandomized design of this study. It is a retrospective analysis of a 5-year cohort of sTBI patients with mass lesion requiring primary DC or craniotomy. The decision of operation procedure was nonrandom that may be affected by experience of surgeons and patients' condition. The perioperative neurological status in patients with DC is more severe than in craniotomy. This issue needs to be addressed in prospective studies. Another limitation of this study is lacking preoperative ICP monitoring. Although, all the patients in this study need operation, without preoperative ICP, we could not analyze the ICP factors in decision making. Additional limitation of the present study includes the heterogeneity of the patient population. Despite all patients in present study with mass lesions, the different types of TBI such as epidural hematoma, subdural hematoma and contusion hemorrhage will result in different outcomes and might vary in operation style. In future, the subgroup analysis of an enriched population of different types of TBI patients is needed to clarify the issue.

Conclusion

Based on our findings, we confirm that the primary DC may benefit subgroups of sTBI with mass lesions. We conclude that two factors: unresponsive pre-op pupil reaction, and closed basal cistern are associated with primary DC chosen in patients with sTBI with mass lesions. These factors can be used as independent predictors in assessing the decision making on DC in TBI patients. The two variables derived multivariate logistic equation is also clinically useful for predicting utilization of DC or not in daily practice.

Declarations

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Authors' contributions

CY and JRZ designed, analyzed, wrote, processed, and reviewed the manuscript. GZ, HG, FG, BW, WXC, YWS and YD helped in concept, data collection, materials, and literature search. ZHL and LW helped in resources, materials, data collection and literature search. LTM, YQ and SNG designed, supervised, analyzed, and reviewed the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

Data and materials in the report is collected from our own cases. All the data supporting the conclusions of this article is included in the present article.

Ethics approval and consent to participate

Although the study was in the category of noninterventional clinical research with its retrospective nature, we did apply for ethics committee approval. The ethics committee approved the study (No. TDLL2015105) and formal consent in addition to what the patients had given prior to hospitalization was waived.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Abbreviations

ASDH: acute subdural hematoma; CPP: cerebral perfusion pressure; CT: Computed tomography; DC: Decompressive craniectomy; GCS: Glasgow Coma Scale; GOSE: Extended Glasgow Outcome Scale; ICH: intracranial hypertension; ICP: Intracranial pressure; ICU: Intensive Care Unit; ROC: Receiver operating characteristic curves; TBI: Traumatic brain injury.

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Tables

Table 1. Characteristics of severe traumatic brain injury patients with mass lesions undergoing decompressive craniectomy or craniotomy

Characteristics	**DC (n=152)**	**craniotomy (n=93)**	**p**
Age (years)	48.29±14.59	47.98±14.72	0.874
Male	117（76.97%）	75（80.64%）	0.527
Systolic blood pressure(mmHg)	136.98±26.84	133.67±20.33	0.276
>140mmHg	59（38.81%）	35（37.63%）	0.893
GCS(median)	6.75±0.80(7)	7.04±0.88(7)	**0.01**
6	72	33	**0.007**
7	45	21	
8	35	39	
midline shift(cm)	0. 43±0.33	0.38±0.28	0. 22
>0.5	66(43.42%)	37(39.78%)	0.596
Time from injury to surgery(hours)	15.06±15.27	16.32±14.86	0.432
Pupillary light reflex			**0.000**
Both present	23(5.13%)	62(66.66%)	
One absent	64(42.10%)	23(24.73%)	
Bth absent	65(42.76%)	8(8.60%)	
basal cisterns			**0.000**
Open	32(21.05%)	57(61.29%)	
Partial closed	41(26.97%)	27(29.03%)	
Closed	79(51.97%)	9(12.12%)	
CT imaging			
With diffuse injury	84(55.26%)	37(39.78%)	**0.025**
Mass lesion only	68(44.74%)	56(60.22%)	

Table 2. The 6-month mortality and GOSE

GOSE	DC (n=152)	craniotomy (n=93)	p
1(dead)	23 (15.13%)	5 (5.37%)	0.022
2	4 (2.63%)	2 (2.15%)	
3	19 (12.5%)	4 (4.3%)	
4	3 (1.97%)	3 (3.22%)	
5	11 (7.23%)	8 (8.6%)	0.061*
6	20 (13.15%)	10 (10.75%)	
7	40 (26.31%)	23 (26.88%)	
8	32 (21.05%)	36 (38.7%)	

*In the surviving patients (GOSE of 2 to 8), the favorable GOSE rate (GOSE of 5 to 8) was similar in two groups(p=0.061), the favorable GOSE rate in the DC group was 78.29% and in the craniotomy group was 87.5%.

Table 3. The mortality and the favorable GOSE rate were compared in subgroups according to preoperative GCS

	DC (n=152)	craniotomy (n=93)	p
GCS	6.75±0.80(7)	7.04±0.88(7)	0.01
6	72(47.37%)	33(35.48%)	
Dead	14(19.44%)	5(15.15%)	0.786
Favorable	42(58.33%）	22(66.67%）	0.519
7	45(29.61%)	21(22.58%)	
Dead	6(13.33%)	0	0.166
Favorable	30(66.67%）	16(76.19%）	0.569
8	35(23.03%)	39(41.94%)	
Dead	3(8.57%)	0	0.101
Favorable	31(88.57%)	37(94.87%)	0.413

Table 4. The mortality and the favorable GOSE rate were compared in subgroups according to preoperative pupillary light reflex

	DC (n=152)	craniotomy (n=93)	p
Pupillary light reflex			0.000
Both present	23(15.13%)	62(66.66%)	
Dead	0	0	
Favorable	23(100%)	59(95.16%)	0.56
One absent	64(42.10%)	23(24.73%)	
Dead	0	0	
Favorable	54(84.37%)	18(78.26%)	0.529
Both absent	65(42.76%)	8(8.60%)	
Dead	23(35.38%)	5(62.5%)	0.246
Favorable	24(36.92%)	0	**0.047**

Table 5. The mortality and the favorable GOSE rate were compared in subgroups according to preoperative basal cisterns

	DC (n=152)	craniotomy (n=93)	p
Basal cisterns			0.000
Open	32(21.05%)	57(61.29%)	
Dead	4(12.5%)	0	**0.015**
Favorable	23(71.87%)	52(91.22%)	**0.031**
Partial Closed	41(26.97%)	27(29.03%)	
Dead	4(9.75%)	0	0.146
Favorable	33(80.48%)	24(88.88%)	0.506
Closed	79(51.97%)	9(9.67%)	
Dead	15(18.98%)	5(55.55%)	**0.026**
Favorable	45(56.96%)	1(11.11%)	**0.012**

Table 6. The mortality and the favorable GOSE rate were compared in subgroups according to preoperative CT imaging

	DC (n=152)	craniotomy (n=93)	p
CT imaging			0.025
With diffuse injury	84(55.26%)	37(39.78%)	
Dead	16(19.04%)	4(10.81%)	0.302
Favorable	52(61.90%)	26(70.27%)	0.416
Mass lesion only	68(44.74%)	56(60.22%)	
Dead	7(10.29%)	1(1.78%)	0.069
Favorable	49(72.05%)	51(91.07%)	**0.011**

Table 7. The final model of multiple logistic regression was constructed using the forward stepwise procedure, the adjusted odds ratio in predicting the choice of decompressive craniectomy

	β	OR	95%CL	p
Pupillary light reflex	2.016	7.51	2.34-24.07	p <0.001
Basal cisterns	1.441	4.22	1.42-12.59	p =0.01
Constant	-2.334			

Figures

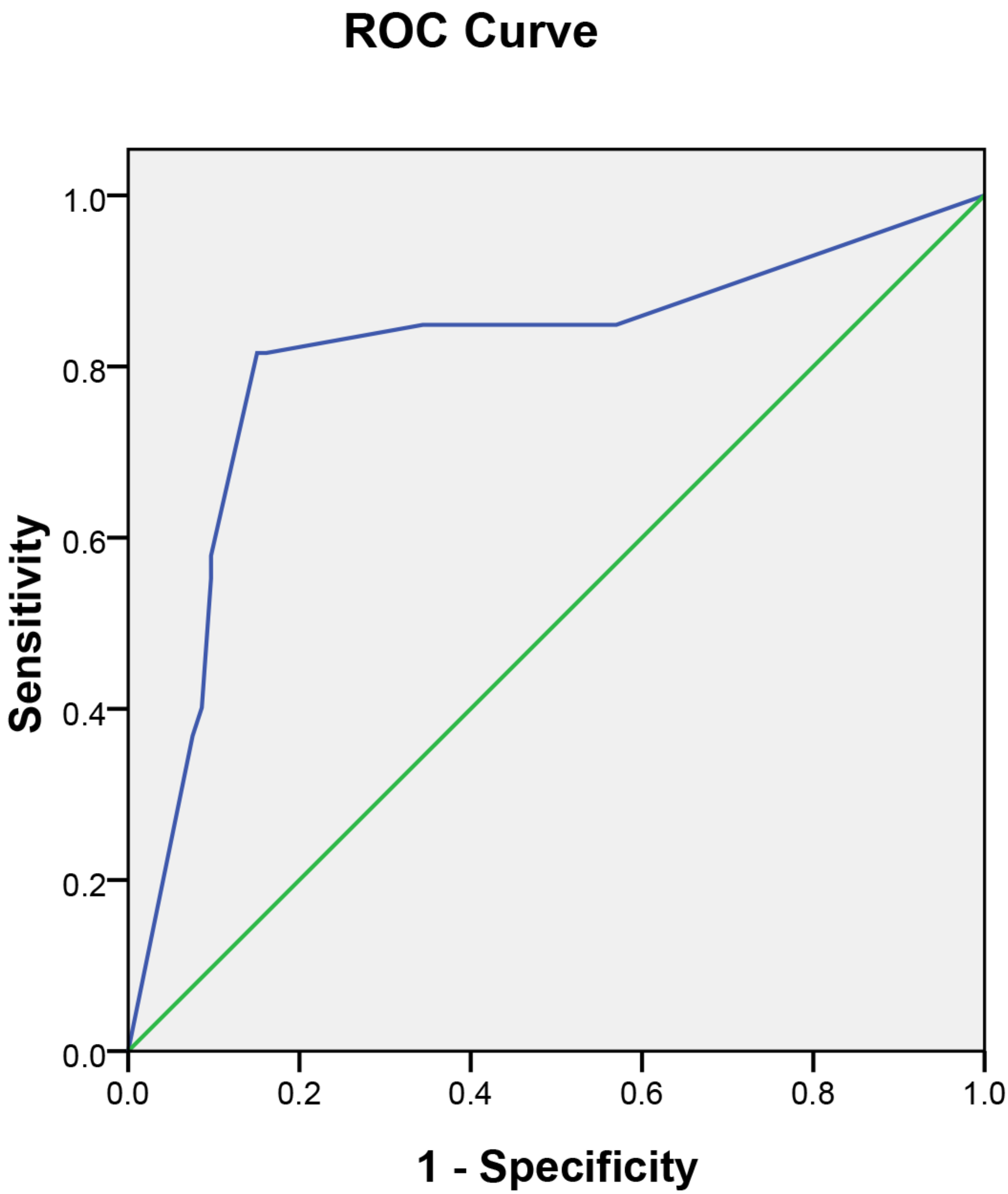

Figure 1

ROC curve. Receiver-operating characteristic curve was drawn based on the prognostic scoring model, logistic = Ln(p/(1-p)=-2334+1.44×(basal cisterns)+2.016×(pupil reaction）where, basal cisterns, open=1; partial closed=2; closed=3; pupil reaction, both reactive=0, at least one reactive = 1, both fixed = 2.