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Comparison of the decompressive craniectomy results in patients with ischemic stroke and acute subdural hematoma and determination of prognostic markers

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ABSTRACT

Aims: This study aimed to investigate the therapeutic effectiveness of decompressive craniectomy in patients with traumatic acute subdural hematoma and stroke patients and to determine the parameters that could predict the risk of mortality in these patients.

Methods: Patients diagnosed and operated on with acute subdural hematoma (ASH) or stroke between January 2022 and September 2023 were grouped into the ASH group and the CVO group. The patients were also divided into DEAD and SURVIVED groups according to mortality. Age, gender, anisocoria, the area of the craniectomy field, length of stay in the intensive care unit (ICU), length of stay in the hospital, and Glasgow Outcome Scale scores were recorded. In addition, Glasgow Coma Scale (GCS) scores, the amount of midline shift, and the blood biochemistry results were recorded pre-and postoperatively.

Results: This study consisted of 11 (5 male and 6 female) patients. Sex, preoperative GCS score, anisocoria, postoperative sedation anesthesia time, postoperative GCS score, duration of stay in the ICU, preoperative serum blood urine nitrogen, preoperative serum C-reactive protein (CRP), postoperative neutrophil-to-lymphocyte ratio, and postoperative CRP values were different between the ASH and CVO groups ($p<0.05$). Furthermore, the preoperative GCS score, postoperative GCS score, postoperative sedation anesthesia duration, postoperative serum aspartate aminotransferase (AST), and postoperative serum CRP level values were different between the DEAD and SURVIVED groups ($p<0.05$). The correlation analysis results revealed a positive correlation between mortality and preoperative GCS score and a negative correlation between mortality and anisocoria ($p<0.05$). The ROC-curve analysis revealed that preoperative GCS and postoperative GCS score, postoperative serum AST level value, and postoperative serum CRP level value could predict mortality risk ($p<0.05$). However, Logistic Regression analysis showed that any study parameter could be used as the best marker for prediction of the postoperative mortality risk ($p>0.05$).

Conclusion: This study showed that decompressive craniectomy may offer more satisfactory results in severe head trauma patients. It was also argued that preoperative and postoperative GCS scores, postoperative midline shift values, and postoperative serum AST and CRP level values could be used to predict mortality risk.

Keywords: Decompressive craniectomy, acute subdural hematoma, stroke, mortality risk

INTRODUCTION

Decompressive craniectomy is currently applied to reduce increased intracranial pressure in cases of traumatic acute subdural hemorrhage and severe cerebral ischemia (stroke). Studies have shown that the mortality occurring in these patients may be related to age, the type and severity of the injury, the time the patient was taken to surgery, the planned surgical intervention, and the duration of postoperative intensive care stay.[1] Considering all these factors, the necessity of determining predictive factors of patient prognosis to improve the neurological condition and reduce mortality rates in these patients has begun to be discussed in the literature.[2-5] Many studies in the literature regarding this discussion have examined many factors and parameters for the prediction of prognosis, but many different results have been reported.[6]

This study aimed to investigate the therapeutic effectiveness of decompressive craniectomy in patients with

traumatic acute subdural hematoma and stroke patients and to determine the parameters that could predict the mortality risk in the hospital in these patients.

METHODS

Ethics

This prospective clinical research study was done after approval by the Kırıkkale University Clinical Researches Ethics Committee (Date: 02.09.2021, Decision number: 12/01). We obtained an informed consent form from all patients for the procedure. All procedures were carried out according to the ethical rules and the principles of the Declaration of Helsinki.

In addition, this study was supported by the Kırıkkale University Scientific Research Projects Coordination Unit within the scope of "Directed Project" (Project acceptance date: 08.11.2021, Project number: 2021/105).

Patients

Data of patients diagnosed with acute subdural hematoma (ASH) or stroke on brain computed tomography (CT) between January 2022 and September 2023 were recorded.

The patients were then grouped as follows:

- ASH group (consisting of patients with ASH, n=6).
- CVO group (consisting of patients with stroke, n=5)

The patients were divided into two groups according to mortality:

- DEAD group (consisted of patients who died in the hospital after surgical treatment, n=5)
- SURVIVED group (consisted of patients who survived after surgical treatment and were discharged from the hospital, n=6)

The patients were also divided into the male group (n=5) and female group (n=6) according to gender.

Medical treatment consisted of sedation and analgesia or barbiturate coma, bed elevation, and hyperosmolar therapy. Prophylactic anticoagulation was started 48-72 hours after surgical treatment, provided that intracranial hemorrhagic lesions were stable.

Those patients who died in the emergency department after a diagnosis of stroke or ASH, who had a combination of head and general body trauma or a life-threatening major organ injury, who had another intracranial hemorrhage secondary to trauma (e.g. epidural hematoma, subarachnoid hemorrhage, spontaneous intracerebral hemorrhage, etc.), secondary to trauma patients with non-existent subdural hematoma, subacute/chronic subdural hematoma, missing data, or patients in the pediatric age group (<16 years) were not included in the study.

Materials

For each patient, age, gender, Glasgow Coma Scale (GCS) scores at admission, pupil dilation/reactivity findings (i.e., anisocoria), length of stay in the intensive care unit, length of hospital stay, GCS scores at hospital discharge after surgery, and Glasgow Outcome Scale (GOS) scores were recorded. Higher scores on these scales indicated a better neurological status.[7,8] In addition, the brain CT images obtained during admission to the hospital and after the surgical intervention were examined and the amount of preoperative and postoperative midline shift, and area of the craniectomy field were recorded (Figure 1, Figure 2, Figure 3).[9] Finally, the first blood biochemistry results at the time of admission to the hospital and the last biochemistry analysis results obtained before discharge from the hospital or death were also recorded.

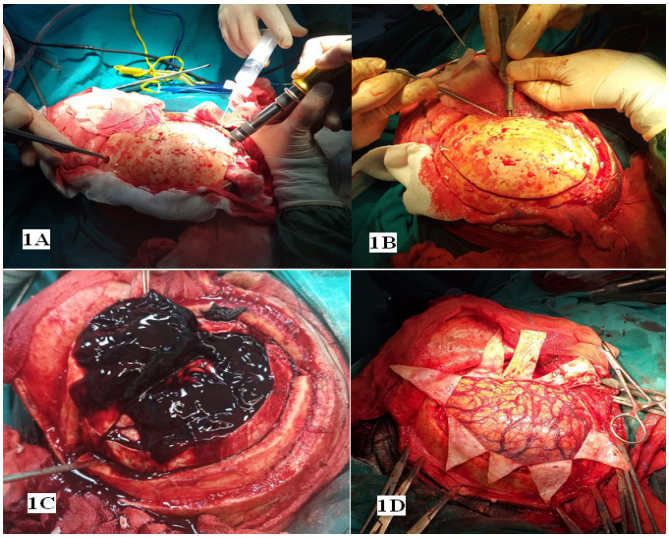

Figure 1. After the multiple burr-hole openings (1A), a wide craniectomy flap was removed (1B), and the dura mater was opened appropriately in the traumatic acute subdural hematoma side (1C) or stroke side (1D)

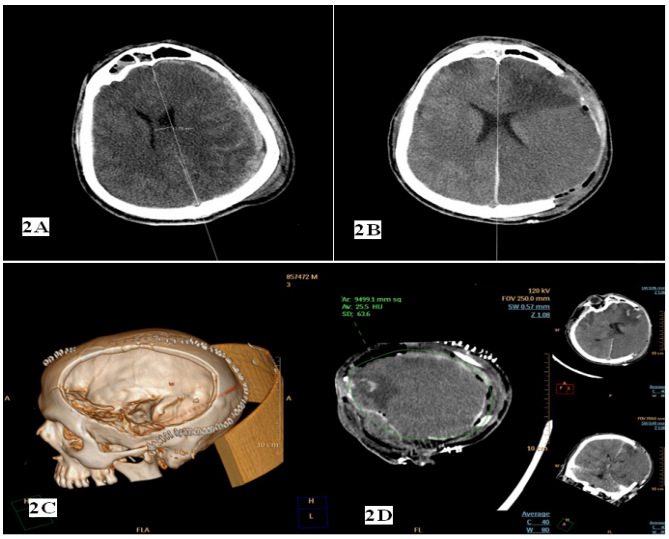

Figure 2. Photographs show the preoperative (2A) and postoperative (2B, 2C) cranial CT images of a patient with traumatic acute subdural hematoma. Photographs also show the measurement technique of the craniectomy area in sagittal, coronal, and axial CT images of this patient (2D)

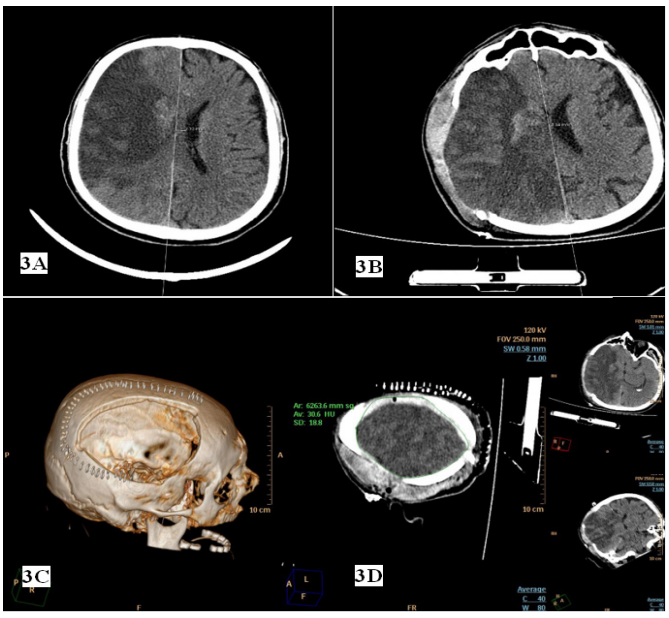

Figure 3. Photographs show the preoperative (3A) and postoperative (3B, 2C) cranial CT images of a patient with stroke. Photographs also show the measurement technique of the craniectomy area in sagittal, coronal, and axial CT images of this patient (4D)

Surgery

After general anesthesia was administered to all patients, wide fronto-temporo-parietal craniectomy was performed by the surgeon (M.O., U.Y., and B.B.) using a high-speed craniotome (AESCULAP®, ELAN 4 Electro Craniotome & Attachments, Braun, Germany) on the ASH or stroke side. In the CVO group, after the craniectomy flap was lifted, the dura mater was opened in a "star" shape and duraplasty was performed using a large graft taken from the cranial periosteum. In the ASH group, after the craniectomy flap was lifted, the dura was opened in a "C" shape, the hematoma was evacuated, and then duraplasty was performed after hemostasis using a large graft taken from the cranial periosteum (Figure 1). No patient underwent lobectomy. Surgical folds were closed anatomically. In patients whose brains were severely swollen during the surgery, the craniectomy bone flap was left on the abdominal fascia or tensor fascia lata, and the surgical area on that side was anatomically closed and the surgery was terminated. Then, intubated patients were observed under sedation anesthesia in the intensive care unit for at least 48 hours.

Biochemical Analysis

In venous blood samples taken from patients, hemoglobin level values (reference range: 10-18 g/dl) and leukocyte (reference range: 4400-11300 uL), neutrophil (reference range: 110-9600 uL), lymphocyte (reference range: 500-6000 uL), monocyte (reference range: 100-1400 uL), eosinophil (reference range: 0-1000 uL), basophil (reference range: 0-300 uL) and platelet (reference range: 150.000-500.000 uL) counts were obtained using an automatic analyzer device (Mindray BC-6800, Shenzen, China). In addition, preoperative and postoperative neutrophil-to-lymphocyte ratio, platelet-to-lymphocyte ratio, and monocyte-to-lymphocyte ratio values were also recorded. Furthermore, in the same blood samples, serum glucose (reference range: 74-109 mg/dl), BUN (reference range: 17-43 mg/dl), creatinine (reference range: 0.84-1.24 mg/dl), ALT (reference range: 5-41 u/L), AST (reference range: 5-40 u/L), CRP (reference range: 0.15-5 mg/dl), sodium (reference range: 136-146 mmol/L) and potassium (reference range: 3.5-5.1 mmol/L) level values were obtained using an automatic device with their original kits (COBAS c501, Roche).

Statistical Analysis

SPSS v.20.0 software was used for statistical analysis. The Kolmogorov-Smirnov test was used to test the normal distribution of the study data.

Independent Samples t-test was used for parametric study findings ($p<0.05$). Mann-Whitney U test was used for statistical analysis of non-parametric study findings ($p<0.05$). Spearman's rho correlation test was used to determine the existence of a correlation between the parameters of the patients ($p<0.05$). The ROC-Curve test was applied to determine the predictive properties of the study parameters for prognosis and mortality level. Additionally, a Logistic Regression test was used to determine which of these parameters could be the "best parameter" ($p<0.05$).

RESULTS

This study consisted of 11 (5 male and 6 female) patients. Before the surgery, it was determined that 4 (36.4%) of the patients had anisocoria and 2 (18.2%) of the patients had fixed dilated pupils. Additionally, 5 (45.5%) patients were found to be unconscious. Before surgery, the GCS score in the ASH group was approximately 14 (3-15) and the midline shift was 8.66±6.99 mm. In the CVO group, the GCS score was approximately 3 (3-3) and the midline shift was 13.07±3.98 mm. Postoperatively, the GCS score in the ASH group was approximately 15 (3-15) and the midline shift was 3.01±2.78 mm. In the CVO group, the GCS score was found to be approximately 3 (3-3) and the midline shift was 4.90±3.79 mm. It was observed that 2 patients in the ASH group died after the surgery due to the very low GCS score. Furthermore, 4 patients in the CVO group died after the surgery due to congestive heart failure (1 patient) or pneumonia (3 patients). The average duration of hospital stay after surgery was found to be 8.00±5.76 days in the ASH patient group and 13.60±8.99 days in the CVO group.

Sex ($X^2=4.412$, $p=0.036$), preoperative GCS score ($Z=-2.128$, $p=0.033$), anisocoria sign ($X^2=7.773$, $p=0.021$), postoperative sedation anesthesia application time ($t=-2.304$, $p=0.047$), postoperative GCS score ($Z=-2.128$, $p=0.029$) and duration of stay in the ICU ($Z=-2.401$, $p=0.016$) were found to be different between the ASH and CVO groups. Additionally, between the two groups, preoperative BUN ($t=-3.124$, $p=0.012$), preoperative CRP ($Z=-2.309$, $p=0.021$), postoperative NLR ($t=-3.486$, $p=0.008$), and postoperative CRP ($t=-3.960$, $p=0.003$) values were also found to be different (Table 1, Table 2, Figure 4).

When the preoperative and postoperative data of the ASH patient group were compared, hemoglobin levels ($t=3.383$, $p=0.020$) and ALT values ($t=-4.008$, $p=0.010$) were found to be different. When the preoperative data of the CVO group were compared with the postoperative data, it was seen that the hemoglobin levels ($t=7.214$, $p=0.002$) and serum sodium level values ($t=-2.935$, $p=0.043$) were found to be different (Table 3).

When the patients were divided into SURVIVED and DEAD groups, the preoperative GCS score ($Z=-2.553$, $p=0.011$), postoperative GCS score ($Z=-2.619$, $p=0.009$), postoperative sedation anesthesia duration ($t=2.927$, $p=0.017$), postoperative serum AST ($Z=-2.191$, $p=0.028$), and postoperative CRP ($t=2.515$, $p=0.033$) level values were found to be different between groups (Table 4, Table 5, Figure 5).

When the preoperative data and postoperative data of the DEAD group were compared, the midline shift values ($t=3.380$, $p=0.020$), hemoglobin levels ($t=7.243$, $p=0.001$), neutrophil counts ($Z=-2.023$, $p=0.043$), AST ($Z=-2.023$, $p=0.043$) and CRP ($Z=-2.023$, $p=0.043$) levels were found statistically different. On the other hand, when the preoperative data and postoperative data of the SURVIVED group were compared, serum potassium ($t=-3.058$, $p=0.038$) and BUN ($t=3.334$, $p=0.029$) values were found to be different (Table 6).

When the patients included in the study were divided into male and female groups according to gender, no statistical difference was detected between the two groups in terms of any study parameter.

The correlation analysis results revealed a positive correlation between mortality and preoperative GCS score ($r=0.807$, $p=0.003$). Additionally, a negative correlation was found between mortality and anisocoria ($r=-0.654$, $p=0.029$). However, no statistical relationship was found between other study parameters and mortality risk.

Table 1. The descriptive table shows the demographic, clinical, and radiological findings of the ASH and CVO groups

		ASH	CVO		
Preoperative variables		**Mean± SD/ Median (min-max) n (%)**	**Mean± SD/ Median (min-max)/ n (%)**	**t/Z/X²**	**p**
Age (year)		47.50 (25-75)	66 (60-76)	-1.281†	0.200
Gender	Male Female	5 (45.5%) 1 (9.1%)	1 (9.1%) 4 (36.4%)	4.412‡	0.036
Glasgow Coma Scale score		14 (3-15)	3 (3-3)	-2.128†	0.033
Midline shift level (mm)		8.66±6.99	13.07±3.98	-1.246*	0.244
Pupillary dilatation	No	4 (36.4%)	1 (9.1%)	7.773‡	0.021
	Yes	0 (0.0%)	4 (36.4%)		
	Fixed	2 (18.2%)	0 (0.0%)		
Consciousness	Worse	2 (18.2%)	3 (27.3%)	0.782‡	0.376
	Well	4 (36.4%)	2 (18.2%)		
Hematoma thickness (mm)		12.09±6.33	0.00±0.00	-	-
Postoperative variables					
Decision time for DC		6 (4-24)	24 (5-72)	-1.784†	0.074
DC site	Left	3 (27.3%)	2 (18.2%)	0.110‡	0.740
	Right	3 (27.3%)	3 (27.3%)		
DC area (cm²)		69.94±32,31	86.66±13.69	-1.072*	0.311
Sedation anesthesia time (day)		1.66±1.86	4.40±2.07	-2.304*	0.047
Midline shift level (mm)		3.01±2.78	4.90±3.79	-0.953*	0.365
Glasgow Coma Scale score		15 (3-15)	3 (3-3)	-2.182†	0.029
Duration of stay in ICU (day)		1.50 (0-5)	12 (2-26)	-2.401†	0.016
Duration of stay in hospital (day)		8.00±5.76	13.60±8.99	-1.254*	0.241
Glasgow Outcome Scale score		1.50 (1-5)	5 (4-5)	-1.812†	0.070
Mortality rate	Survived	4 (36.4%)	1 (9.1%)	2.396‡	0.122
	Exitus	2 (18.2%)	4 (36.4%)		

(*) t value, Independent Samples t-test; (†) Z value, Mann Whitney U test; (‡) X2 value Pearson's chi-square test, p<0.05
(SD: standard deviation, min: minimum, max: maximum, N: number of patients, DC: decompressive craniotomy, ICU: intensive care unit)

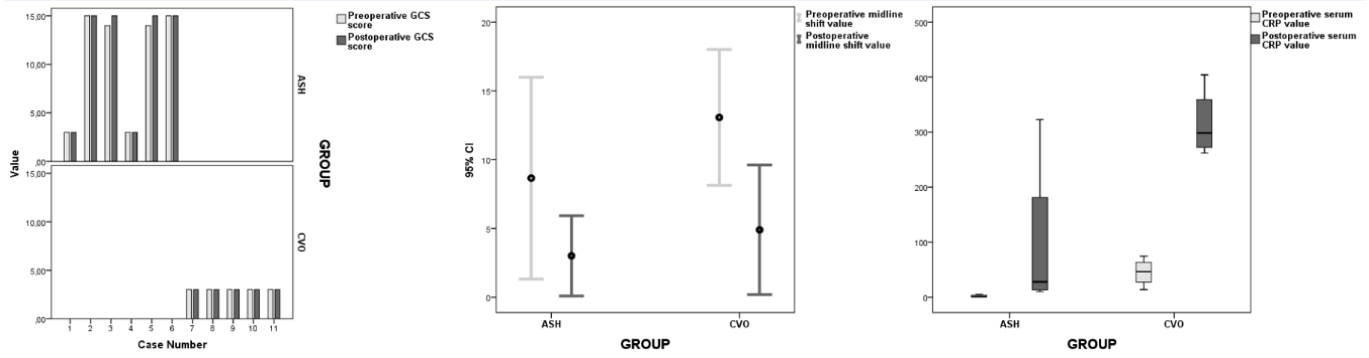

Figure 4. Graphics show the preoperative and postoperative Glasgow Coma Scale (GCS) scores, midline shift values, and serum C-reactive protein (CRP) level values of the ASH and CVO groups' patients.

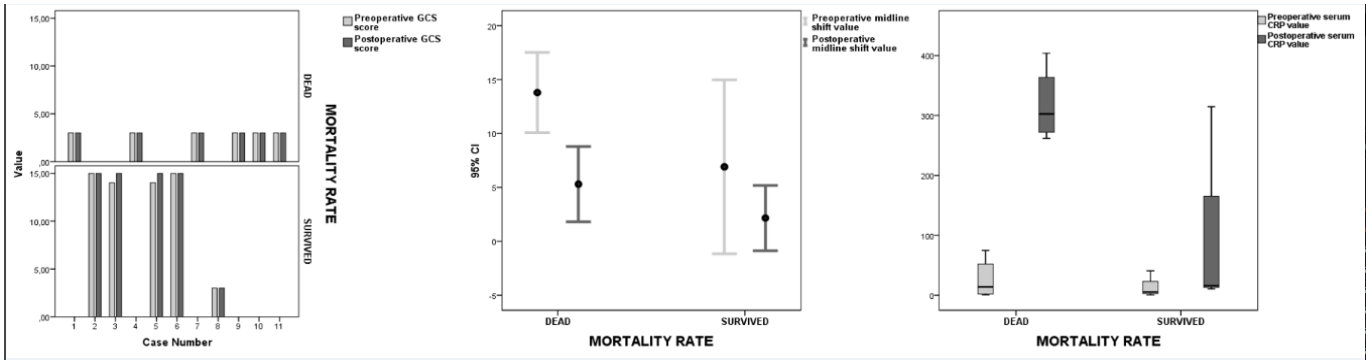

Figure 5. Graphics show the preoperative and postoperative Glasgow Coma Scale (GCS) scores, midline shift values, and serum C-reactive protein (CRP) level values of the DEAD and SURVIVED groups' patients.

Table 2. Table shows the preoperative and postoperative blood biochemistry results of the patients with acute subdural hematoma or stroke

		ASH	CVO		
	Variable	Mean ± SD/ Median (min-max)	Mean ± SD/ Median (min-max)	t / Z	p
PREOPERATIVE	Hemoglobin level (g/dl)	14.27±2.03	15.40±2.06	-0.916*	0.384
	Leukocyte count (uL)	9812±3435.25	13000±7064.88	-0.982*	0.352
	Neutrophil count (uL)	5868±2337.11	11050±7085.38	-1.700*	0.123
	Lymphocyte count (uL)	2715±2369.35	1260±1105.35	1.256*	0.241
	Monocyte count (uL)	373±239.39	434±500.58	-0.265*	0.797
	Eosinophil count (uL)	50 (0-330)	10 (0-60)	-1.488†	0.137
	Basophil count (uL)	22±19.41	24±18.17	-0.204*	0.843
	Platelet count (uL)	205333±73888.20	220400±54187.64	-0.378*	0.714
	Neutrophil to lymphocyte ratio	1.75 (1-15)	18.53 (1.77-20.80)	-1.826†	0.068
	Platelet to lymphocyte ratio	130.11±98.43	234.53±96.51	-1.767*	0.111
	Monocyte-to-lymphocyte ratio	0.18 (0.01-0.93)	0.41 (0.02-1.39)	-0.730†	0.465
	Glucose (mg/dLl)	127.50±22.60	201.80±90.61	-1.957*	0.082
	Sodium (mmol/L)	140.50±2.34	142.60±7.13	-0.685*	0.511
	Potassium (mmol/L)	3.78±0.33	4.40±0.86	-1.628*	0.138
	Blood urea nitrogen (mg/dl)	12.77±3.63	28.32±11.65	-3.124*	**0.012**
	Creatinin (mg/dl)	0.77±0.17	1.01±0.21	-2.149*	0.060
	Aspartate aminotransferase (u/L)	24.33±5.96	23.50±9.98	0.167*	0.871
	Alanine aminotransferase (u/L)	16.00±3.35	17.25±8.77	-0.323*	0.755
	C-reactive protein (mg/dl)	1.22 (0.38-5.40)	46.50 (13.90-74.80)	-2.309†	**0.021**
POSTOPERATIVE	Hemoglobin level (g/dl)	11.98±1.79	10.14±3.29	1.186*	0.266
	Leukocyte count (uL)	8969.45±5658.03	15368.00±8076.45	-1.545*	0.157
	Neutrophil count (uL)	6440 (5840-13880)	16700 (5490-21790)	-1.461†	0.144
	Lymphocyte count (uL)	1277±636.32	665±304.90	-1.279*	0.201
	Monocyte count (uL)	580.00±253.54	452.50±509.08	0.533*	0.609
	Eosinophil count (uL)	5 (0-180)	60 (0-290)	-0.866†	0.386
	Basophil count (uL)	12±11.69	32±28.64	-1.600*	0.144
	Platelet count (uL)	186333±74004.50	116800±104834.15	1.290*	0.229
	Neutrophil to lymphocyte ratio	7.31±3.53	19.83±7.86	-3.486*	**0.008**
	Platelet to lymphocyte ratio	153.48±41.38	198.77±86.05	-1.131*	0.291
	Monocyte-to-lymphocyte ratio	0.48±0.18	0.54±0.52	-0.280*	0.787
	Glucose (mg/dl)	116.17±25.90	145.60±58.17	-1.122*	0.291
	Sodium (mmol/L)	140.67±10.88	153.00±6.63	-2.206*	0.055
	Potassium (mmol/L)	4.10±0.47	4.35±1.31	-0.438*	0.672
	Blood urea nitrogen (mg/dl)	20.24±10.63	38.14±17.95	-2.059*	0.070
	Creatinin (mg/dl)	0.70 (0.41-3)	1 (0.50-2.23)	-1.100†	0.271
	Aspartate aminotransferase (u/L)	21.50 (13-233)	41 (21-77)	-1.095†	0.273
	Alanine aminotransferase (u/L)	30.17±10.17	38.60±38.71	-0.518*	0.617
	C-reactive protein (mg/dl)	66.45±126.37	309.46±56.10	-3.960*	**0.003**

(*) t value, Independent Samples t-test; (†) Z value, Mann Whitney U test; p<0.05
(SD: standard deviation, min: minimum, max: maximum)

The ROC-curve analysis results revealed that the preoperative GCS score (area=0.100, p=0.028, cut-off value <8, 100% sensitivity, 80% specificity), postoperative GCS score (area=0.100, p=0.028, cut-off value <9, 100% sensitivity, 80% specificity), postoperative serum AST level value (area=0.900, p=0.028, cut-off value >31 u/L, 83% sensitivity, 80% specificity), and postoperative serum CRP level value (area=0.867, p=0.045, cut-off value >151 mg/dl, 80% sensitivity, 80% specificity) could predict mortality risk (Table 7, Figure 6). However, Logistic Regression analysis showed that any study parameter could be used as the best marker for prediction of the postoperative mortality risk.

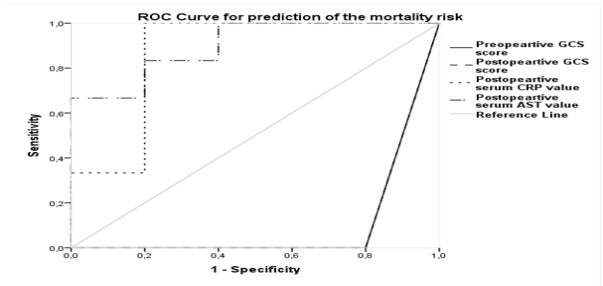

Figure 6. The ROC-Curve analysis revealed that preoperative and postoperative Glasgow Coma Scale (GCS) scores, postoperative serum alanine aminotransferase (AST), and C-reactive protein (CRP) level values could predict mortality risk in both groups.

Table 3. Table shows the comparison results of the preoperative and postoperative clinical and blood biochemistry findings of each group

		PREOPERATIVE	POSTOPERATIVE		
	Variable	Mean ± SD/ Median (min-max)	Mean ± SD/ Median (min-max)	t / Z	P
ASV	Glasgow Coma Scale score	14 (3-15)	15 (3-15)	-1.414†	0.157
	Midline shift level (mm)	8.66±6.99	3.01±2.78	2.876*	0.035
	Hemoglobin level (g/dl)	14.27±2.03	11.98±1.79	3.383*	**0.020**
	Leukocyte count (uL)	9812±3435.25	8969.45±5658.03	0.591*	0.580
	Neutrophil count (uL)	5868±2337.11	6440 (5840-13880)	-1.483†	0.138
	Lymphocyte count (uL)	2715±2369.35	1277±636.32	1.491*	0.196
	Monocyte count (uL)	373±239.39	580.00±253.54	-1.510*	0.192
	Eosinophil count (uL)	50 (0-330)	5 (0-180)	-1.214†	0.225
	Basophil count (uL)	22±19.41	12±11.69	1.118*	0.314
	Platelet count (uL)	205333±73888.20	186333±74004.50	1.208*	0.281
	Neutrophil to lymphocyte ratio	1.75 (1-15)	7.31±3.53	-0.944†	0.345
	Platelet to lymphocyte ratio	130.11±98.43	153.48±41.38	-0.493*	0.643
	Monocyte-to-lymphocyte ratio	0.18 (0.01-0.93)	0.48±0.18	-0.944*	0.345
	Glucose (mg/dl)	127.50±22.60	116.17±25.90	0.918*	0.401
	Sodium (mmol/L)	140.50±2.34	140.67±10.88	-0.040*	0.970
	Potassium (mmol/L)	3.78±0.33	4.10±0.47	-1.652*	0.160
	Blood urea nitrogen (mg/dl)	12.77±3.63	20.24±10.63	-1.705†	0.149
	Creatinin (mg/dl)	0.77±0.17	0.70 (0.41-3)	-0.674†	0.500
	Aspartate aminotransferase (u/L)	24.33±5.96	21.50 (13-233)	-0.736†	0.462
	Alanine aminotransferase (u/L)	16.00±3.35	30.17±10.17	-4.008*	**0.010**
	C-reactive protein (mg/dl)	1.22 (0.38-5.40)	66.45±126.37	-1.254†	0.299
CVO	Glasgow Coma Scale score	3 (3-3)	3 (3-3)	0.000†	1.000
	Midline shift level (mm)	13.07±3.98	4.90±3.79	2.667*	0.056
	Hemoglobin level (g/dl)	15.40±2.06	10.14±3.29	7.214*	**0.002**
	Leukocyte count (uL)	13000±7064.88	15368.00±8076.45	-0.564*	0.603
	Neutrophil count (uL)	11050±7085.38	16700 (5490-21790)	-0.674†	0.500
	Lymphocyte count (uL)	1260±1105.35	665±304.90	1.303*	0.283
	Monocyte count (uL)	434±500.58	452.50±509.08	0.041*	0.970
	Eosinophil count (uL)	10 (0-60)	60 (0-290)	-1.461†	0.144
	Basophil count (uL)	24±18.17	32±28.64	-0.749*	0.495
	Platelet count (uL)	220400±54187.64	116800±104834.15	1.884*	0.133
	Neutrophil to lymphocyte ratio	18.53 (1.77-20.80)	19.83±7.86	-1.826†	0.068
	Platelet to lymphocyte ratio	234.53±96.51	198.77±86.05	0.400*	0.716
	Monocyte-to-lymphocyte ratio	0.41 (0.02-1.39)	0.54±0.52	-0.365†	0.715
	Glucose (mg/dl)	201.80±90.61	145.60±58.17	2.284*	0.084
	Sodium (mmol/L)	142.60±7.13	153.00±6.63	-2.935*	**0.043**
	Potassium (mmol/L)	4.40±0.86	4.35±1.31	0.092*	0.931
	Blood urea nitrogen (mg/dl)	28.32±11.65	38.14±17.95	-1.066*	0.346
	Creatinin (mg/dl)	1.01±0.21	1 (0.50-2.23)	-0.730†	0.465
	Aspartate aminotransferase (u/L)	23.50±9.98	41 (21-77)	-1.826†	0.068
	Alanine aminotransferase (u/L)	17.25±8.77	38.60±38.71	-1.291*	0.287
	C-reactive protein (mg/dl)	46.50 (13.90-74.80)	309.46±56.10	-1.681†	0.191

(*) t value, Paired Samples t-test; (†) Z value, Wilcoxon Signed Ranks test; p<0.05 (SD: standard deviation, min: minimum, max: maximum)

DISCUSSION

The aim of decompressive craniectomy, which is currently used in the treatment of various neurological emergencies, is to provide extra space for the edematous brain tissue due to the injury and/ or ischemia to expand.[10,11] Therefore, the logic of decompressive craniectomy is to prevent life-threatening cerebral/cerebellar herniation and improve cerebral perfusion by reducing intracranial pressure.[12,13] There is good evidence that surgical decompression in ischemic stroke can control intracranial hypertension, which is strongly associated with mortality.[5,13] However, in one study, no difference was found in terms of in-hospital mortality and length of hospital stay between patients who underwent surgery between 4 and 24

Table 4. The descriptive table shows the demographic, clinical, and radiological findings of the DEAD and SURVIVED groups

		DEAD	SURVIVED		
Preoperative variables		**Mean± SD/ Median (min-max) n (%)**	**Mean± SD/ Median (min-max)/ n (%)**	**t/Z/X²**	**P**
Age(year)		63 (43-76)	66 (25-75)	-0.091†	0.927
Gender	Male	3 (27.3%)	3 (27.3%)	0.110‡	0.740
	Female	3 (27.3%)	2 (18.2%)		
Glasgow Coma Scale score		3 (3-3)	14 (3-15)	-2.553†	**0.011**
Midline shift level (mm)		13.79±3.54	6.91±6.50	2.240*	0.052
Pupillary dilatation	No	1 (9.1%)	4 (36.4%)	4.748‡	0.093
	Yes	3 (27.3%)	1 (9.1%)		
	Fixed	2 (18.2%)	0 (0.0%)		
Consciousness	Worse	4 (36.4%)	1 (9.1%)	2.396‡	0.122
	Well	2 (18.2%)	4 (36.4%)		
Hematoma thickness (mm)		4.70±7.34	8.87±8.40	-0.881*	0.401
Postoperative variables					
Decision time for DC (hour)		24 (4-72)	6 (4-24)	-0.939†	0.348
DC site	Left	3 (27.3%)	2 (18.2%)	0.110‡	0.740
	Right	3 (27.3%)	3 (27.3%)		
DC area (cm2)		86.41±16.66	66.90±32.81	1.281*	0.232
Sedation anesthesia time (day)		4.33±1.86	1.20±1.64	2.927*	**0.017**
Midline shift level (mm)		5.30±3.32	2.16±2.44	1.753*	0.113
Glasgow Coma Scale score		3 (3-3)	15 (3-15)	-2.619†	**0.009**
Duration of stay in ICU (day)		7.50 (0-26)	2 (0-18)	-1.016†	0.310
Duration of stay in hospital (day)		9.17±9.43	12.20±5.12	-0.641*	0.537
Glasgow Outcome Scale score		5 (5-5)	1 (1-4)	-3.019†	**0.003**

(*) t value, Independent Samples t-test; (†) Z value, Mann Whitney U test; (‡) X2 value Pearson's chi-square test, p<0.05
(SD: standard deviation, min: minimum, max: maximum, N: number of patients, DC: decompressive craniotomy, ICU: intensive care unit)

hours after admission and patients who underwent surgery within 4 hours.[2] Depending on the size of the bone to be removed, the literature indicates that the larger the defect, the better results are achieved with a minimum bone flap diameter of 11 to 12 cm.[14] Interestingly, in recent studies, it is recommended to replace the bone flap loosely after decompression in both acute subdural hematoma and stroke patients.[1,15] In addition, no difference in disability and quality of life outcomes has been reported between patients with traumatic acute subdural hematoma who underwent craniotomy or decompressive craniectomy.[16]

In this study, it was observed that the ASH group consisted mostly of male patients and the CVO group consisted mostly of female patients. It was determined that the preoperative and postoperative GCS scores of the patients in the ASH group were higher than those in the CVO group. On the other hand, it was found that anisocoria was detected more in patients in the CVO group, these patients received postoperative sedation and anesthesia for a longer time, and these patients stayed in the intensive care unit for a longer time. There was no difference in preoperative and postoperative midline shift values, GOS scores, and mortality rates between the two groups. With these results, it was argued that both patient groups were decompressed adequately. Although there was no difference between the two groups in terms of the time taken to decide on surgical treatment for the patients, when the numerical data were examined, it was seen that surgical treatment was performed earlier in the ASH group. It was thought that this was due to the transfer of CVO patients by the Neurology department.

On the other hand, preoperative and postoperative CRP values were found to be higher in the CVO group. Although there was no statistical difference between the two groups in terms of leukocyte, neutrophil, and lymphocyte values, it was observed that leukocyte and neutrophil count values in the CVO group were above normal laboratory values and lymphocyte values were lower than the ASH group values. With these findings, it was thought that the preoperative CRP elevation in the CVO group occurred more as an inflammatory response. However, when postoperative CRP values were examined, it was seen that CRP values were much higher than normal laboratory values in both groups. Although there was no statistical difference between the leukocyte, neutrophil, and lymphocyte count values of the groups, numerically, the leukocyte and neutrophil count values of the patients in the CVO group were seen to be much higher than normal laboratory values and the lymphocyte values were very low. With these findings, it was argued that the high serum CRP level values and high neutrophil count values measured in the CVO group occurred as an inflammatory response to pneumonia, while in the ASH group, the CRP elevation increased mostly as a response to trauma and or surgical intervention.

When the preoperative data of the ASH group was compared with their postoperative findings, it was determined that there was a significant decrease in the hemoglobin levels of these patients and a significant increase in AST values after the surgery. Similarly, in the CVO group, there was a significant decrease in hemoglobin

Table 5. The table shows the preoperative and postoperative blood biochemistry results of the patients who survived or died

		DEAD	SURVIVED		
	Variable	Mean ± SD/ Median (min-max)	Mean ± SD/ Median (min-max)	t / Z	p
PREOPERATIVE	Hemoglobin level (g/dl)	15.10±2.08	14.40±2.13	0.550*	0.596
	Leukocyte count (uL)	2048±2283.86	2060±1778.31	0.019*	0.985
	Neutrophil count (uL)	8098±5086.47	8374±6553.22	-0.079*	0.939
	Lymphocyte count (uL)	2048±2283.86	2060±1778.31	-0.009*	0.993
	Monocyte count (uL)	302±248.15	520±463.95	-1.001*	0.343
	Eosinophil count (uL)	5 (0-27)	20 (10-330)	-1.302†	0.193
	Basophil count (uL)	25±22.58	20±12.25	0.441*	0.669
	Platelet count (uL)	183167±65076.62	247000±42936.00	-1.872*	0.094
	Neutrophil to lymphocyte ratio	5.90 (1-20.18)	1.78 (1.35-20.80)	-0.183†	0.855
	Platelet to lymphocyte ratio	169.25±112.18	187.56±113.56	-0.268*	0.795
	Monocyte-to-lymphocyte ratio	0.21 (0.02-0.60)	0.23 (0.01-1.39)	-0.548†	0.584
	Glucose (mg/dl)	188.00±86.49	129.20±30.07	1.438*	0.184
	Sodium (mmol/L)	142.50±6.38	140.20±2.49	0.754*	0.470
	Potassium (mmol/L)	4.33±0.82	3.74±0.23	1.550*	0.156
	Blood urea nitrogen (mg/dl)	0.93±0.24	0.82±0.20	0.771*	0.460
	Creatinin (mg/dl)	24.21±12.82	14.59±6.95	1.497*	0.169
	Aspartate aminotransferase (u/L)	25.80±9.55	22.20±4.49	0.763*	0.468
	Alanine aminotransferase (u/L)	18.40±7.09	14.60±3.65	1.065*	0.318
	C-reactive protein (mg/dl)	13.90 (0.38-74.80)	5.40 (0.43-40.90)	-0.447†	0.655
POSTOPERATIVE	Hemoglobin level (g/dl)	10.50±2.99	11.92±2.13	-0.886*	0.399
	Leukocyte count (uL)	14775±7400.21	8401±6083.46	1.537*	0.159
	Neutrophil count (uL)	13655 (5490-21790)	6640 (5480-13880)	-1.095†	0.273
	Lymphocyte count (uL)	774±133.53	1290±784.92	-1.449*	0.185
	Monocyte count (uL)	528±408.74	530±342.64	-0.008*	0.994
	Eosinophil count (uL)	30 (0-290)	10 (0-180)	-0.289†	0.773
	Basophil count (uL)	27±28.75	14±11.40	0.920*	0.382
	Platelet count (uL)	128167±86066.06	186600±97700.05	-1.056*	0.319
	Neutrophil to lymphocyte ratio	14.95±6.47	9.68±4.40	0.999*	0.347
	Platelet to lymphocyte ratio	195.07±72.85	148.12±47.33	1.208*	0.261
	Monocyte-to-lymphocyte ratio	0.64±0.42	0.37±0.15	1.319*	0.224
	Glucose (mg/dl)	144.50±52.06	111.60±26.22	1.277*	0.234
	Sodium (mmol/L)	150.67±7.66	141.00±12.59	1.573*	0.150
	Potassium (mmol/L)	4.16±1.24	4.27±0.32	-0.192*	0.852
	Blood urea nitrogen (mg/dl)	32.47±15.86	23.47±17.67	0.891*	0.396
	Creatinin (mg/dl)	1.25 (0.50-3.00)	0.70 (0.41-1.00)	-1.742†	0.081
	Aspartate aminotransferase (u/L)	51.50 (21-233)	17 (13-41)	-2.191†	**0.028**
	Alanine aminotransferase (u/L)	26.00±15.97	43.60±33.86	-1.139*	0.284
	C-reactive protein (mg/dl)	265.93±121.64	70.08±136.83	2.515*	**0.033**

(*) t value, Independent Samples t-test; (†) Z value, Mann Whitney U test, p<0.05
(SD: standard deviation, min: minimum, max: maximum)

levels after surgery. It was thought that these changes might be related to the surgery and or the anesthesia applied.

In the study group, it was observed that the midline shifts of the deceased patients decreased significantly after the surgery. However, when the data of these patients were examined, it was seen that the preoperative GCS values of two patients who died in the ASH group were 3 and these values did not change at all in the postoperative period. On the other hand, it was seen that the preoperative GCS values of all patients who died in the CVO group were 3 and that these values did not change at all in the postoperative period. These patients were followed under sedation anesthesia for a longer time and therefore it was thought that they did not benefit from decompression. In addition, it was observed that serum CRP and neutrophil count values in the CVO group increased significantly after surgery, and three of the four patients who developed pneumonia in the postoperative period died due to sepsis despite medical treatment. However, it was determined that there was no significant difference between living patients and deceased patients in terms of biochemical data.

When the data of the SURVIVED group were examined, it was argued that GOS values were on average 1 except for one patient and they were able to show enough neurological

Table 6. Table shows the comparison results of the preoperative and postoperative clinical and blood biochemistry findings of each group

		PREOPERATIVE	POSTOPERATIVE		
	Variable	Mean ± SD/ Median (min-max)	Mean ± SD/ Median (min-max)	t / Z	P
DEAD	Glasgow Coma Scale score	3 (3-3)	3 (3-3)	0.000†	1.000
	Midline shift level (mm)	13.79±3.54	5.30±3.32	3.380*	**0.020**
	Hemoglobin level (g/dl)	15.10±2.08	10.50±2.99	7.243*	**0.001**
	Leukocyte count (uL)	2048±2283.86	14775±7400.21	-1.700*	0.150
	Neutrophil count (uL)	8098±5086.47	13655 (5490-21790)	-2.023†	**0.043**
	Lymphocyte count (uL)	2048±2283.86	774±133.53	1.432*	0.226
	Monocyte count (uL)	302±248.15	528±408.74	-1.541*	0.198
	Eosinophil count (uL)	5 (0-27)	30 (0-290)	-0.365†	0.715
	Basophil count (uL)	25±22.58	27±28.75	-0.143*	0.892
	Platelet count (uL)	183167±65076.62	128167±86066.06	1.567*	0.178
	Neutrophil to lymphocyte ratio	5.90 (1-20.18)	14.95±6.47	-1.826†	0.068
	Platelet to lymphocyte ratio	169.25±112.18	195.07±72.85	-1.745*	0.156
	Monocyte-to-lymphocyte ratio	0.21 (0.02-0.60)	0.64±0.42	-1.826†	0.068
	Glucose (mg/dl)	188.00±86.49	144.50±52.06	1.877*	0.119
	Sodium (mmol/L)	142.50±6.38	150.67±7.66	-2.381*	0.063
	Potassium (mmol/L)	4.33±0.82	4.16±1.24	0.401*	0.705
	Blood urea nitrogen (mg/dl)	0.93±0.24	32.47±15.86	-1.410*	0.218
	Creatinin (mg/dl)	24.21±12.82	1.25 (0.50-3.00)	-1.219†	0.223
	Aspartate aminotransferase (u/L)	25.80±9.55	51.50 (21-233)	-2.023†	**0.043**
	Alanine aminotransferase (u/L)	18.40±7.09	26.00±15.97	-1.880*	0.133
	C-reactive protein (mg/dl)	13.90 (0.38-74.80)	265.93±121.64	-2.023†	**0.043**
SURVIVED	Glasgow Coma Scale score	14 (3-15)	15 (3-15)	-1.414†	0.157
	Midline shift level (mm)	6.91±6.50	2.16±2.44	2.203*	0.092
	Hemoglobin level (g/dl)	14.40±2.13	11.92±2.13	2.259*	0.087
	Leukocyte count (uL)	2060±1778.31	8401±6083.46	0.877*	0.430
	Neutrophil count (uL)	8374±6553.22	6640 (5480-13880)	-0.135†	0.893
	Lymphocyte count (uL)	2060±1778.31	1290±784.92	1.202*	0.296
	Monocyte count (uL)	520±463.95	530±342.64	-0.029*	0.978
	Eosinophil count (uL)	20 (10-330)	10 (0-180)	-0.948†	0.343
	Basophil count (uL)	20±12.25	14±11.40	0.739*	0.501
	Platelet count (uL)	247000±42936.00	186600±97700.05	1.203*	0.295
	Neutrophil to lymphocyte ratio	1.78 (1.35-20.80)	9.68±4.40	-0.674†	0.500
	Platelet to lymphocyte ratio	187.56±113.56	148.12±47.33	0.613*	0.573
	Monocyte-to-lymphocyte ratio	0.23 (0.01-1.39)	0.37±0.15	-0.405†	0.686
	Glucose (mg/dl)	129.20±30.07	111.60±26.22	1.211*	0.293
	Sodium (mmol/L)	140.20±2.49	141.00±12.59	-0.150*	0.888
	Potassium (mmol/L)	3.74±0.23	4.27±0.32	-3.058*	**0.038**
	Blood urea nitrogen (mg/dl)	0.82±0.20	23.47±17.67	3.334*	**0.029**
	Creatinin (mg/dl)	14.59±6.95	0.70 (0.41-1.00)	-1.826†	0.068
	Aspartate aminotransferase (u/L)	22.20±4.49	17 (13-41)	-0.135†	0.892
	Alanine aminotransferase (u/L)	14.60±3.65	43.60±33.86	-1.875*	0.134
	C-reactive protein (mg/dl)	5.40 (0.43-40.90)	70.08±136.83	-1.604†	0.109

(*) t value, Paired Samples t-test; (†) Z value, Wilcoxon Signed Ranks test; p<0.05
(SD: standard deviation, min: minimum, max: maximum)

recovery to sustain their daily lives and these patients could benefit from decompression. However, when looked at in general terms, it was seen that the mortality rate in all patients was 54.6% (5 patients) and most of these deceased patients (4 patients) were in the CVO group. On the other hand, correlation analysis revealed no relationship between the area of the craniectomy bone flap and neurological impairment and/ or mortality rate. Therefore, it was thought that decompressive craniectomy could offer more satisfactory results in traumatic acute subdural hematoma patients rather than ischemic stroke patients.

On the other hand, the correlation analysis applied to the findings of all patients revealed that the GCS scores obtained during the patient's admission to the hospital may be significantly related to the risk of mortality, and the risk of mortality may increase in patients with low GCS scores.

Table 7. The table shows the parameters that can predict the mortality risk in patients with traumatic acute subdural hematoma or stroke

ROC-Curve test for mortality risk						
Group	**Variable**	**Area**	**p**	**Cut-off value**	**Sensitivity**	**Specificity**
All patients	Preoperative GCS	0.100	**0.028**	<8	100%	80%
	Postoperative GCS	0.100	**0.028**	<9	100%	80%
	Postoperative AST	0.900	**0.028**	>31 u/ L	83%	80%
	Postoperative CRP	0.867	**0.045**	>151 mg/ dL	80%	80%

ROC-Curve test, p<0.05.
(GCS: Glasgow Coma Scale, AST: aspartate aminotransferase, CRP: C-reactive protein)

In addition, it was thought that the risk of mortality might be high if anisocoria was detected in the preoperative period. However, no statistical relationship was found between midline shift and/or neurological impairment and mortality risk. Additionally, no relationship was found between the mortality risk and the blood biochemistry examination results obtained during hospital admission. As a result of the ROC analysis, it was found that the preoperative GCS score could predict the mortality risk. Furthermore, postoperative GCS score and serum AST and CRP level values could predict the mortality risk. With these results, it could be said that preoperative and/or postoperative GCS values and serum AST and CRP level values could be used as predictive markers for the mortality risk of these patients. However, the regression analysis results suggested that none of the study parameters could be used as good markers in predicting the risk of mortality in patients.

Study Limitations

This study had some limitations. First, since this study was a single-center study, the study population was quite small. Secondly, the long-term follow-up results of the patients were not included in the study as per the hypothesis of the study. Thirdly, due to technical and financial limitations, the preoperative and postoperative intracranial pressure measurement values of the patients were not included in the study. Fourthly, because the number of patients included in this study was small, the results of patients who underwent craniotomy could not be compared with the results of patients who underwent craniectomy. Finally, due to technical inadequacies, radiological imaging examination results that could show the patients' brain metabolism in the preoperative and postoperative periods were not available in this study. Therefore, it was thought that it would be appropriate to conduct this study in a larger population and use more advanced imaging methods (such as ICP monitoring, SPECT, etc.).

CONCLUSION

At the end of this study, it was thought that decompressive craniectomy may offer more satisfactory results in traumatic acute subdural hematoma patients. It was also argued that preoperative and postoperative GCS scores, and postoperative serum AST and CRP level values could be used to predict mortality risk.

ETHICAL DECLARATIONS

Ethics Committee Approval: This prospective clinical research study was done after approval by the Kırıkkale University Clinical Researches Ethics Committee (Date:02.09.2021, Decision No: 12/01).

Informed Consent: All patients signed and free and informed consent form.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: There is no "conflict of interest" among the authors. Furthermore, through any of the products used in this research, no financial engagement has been established with any company that makes and/or markets these products or with any corporation that produces and/or markets a competing product.

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Author Contributions: All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

REFERENCES

1. Mohan M, Layard Horsfall H, Solla DJF, et al. Decompressive craniotomy: an international survey of practice. *Acta Neurochir (Wien).* 2021;163(5):1415-1422.
2. Ahmed N. Impact of early decompressive craniectomy following blunt traumatic brain injury on mortality: propensity matched analysis. *J Neurol Surg A Cent Eur Neurosurg.* 2017;78(5):453-459.
3. Bruno A, Paletta N, Verma U, et al. Predicting functional outcome after decompressive craniectomy for malignant hemispheric infarction: clinical and novel imaging factors. *World Neurosurg.* 2022;158:e1017-e1021.
4. Daou B, Kent AP, Montano M, et al. Decompressive hemicraniectomy: predictors of functional outcome in patients with ischemic stroke. *J Neurosurg.* 2016;124(6):1773-1779.
5. Honeybul S, Ho KM. Decompressive craniectomy for severe traumatic brain injury: the relationship between surgical complications and the prediction of an unfavourable outcome. *Injury.* 2014;45(9):1332-1339.
6. Kalaycı M, Aktunç E, Gül S, et al. Decompressive craniectomy for acute subdural haematoma: an overview of current prognostic factors and a discussion about some novel prognostic parametres. *J Pak Med Assoc.* 2013;63(1):38-49.
7. Teasdale G, Jennett B. Assessment of coma and impaired consciousness. a practical scale. *Lancet.* 1974;2(7872):81-84.
8. McMillan T, Wilson L, Ponsford J, Levin H, Teasdale G, Bond M. The Glasgow outcome scale-40 years of application and refinement. *Nat Rev Neurol.* 2016;12(8):477-485.
9. Missori P, Morselli C, Domenicucci M, et al. Measurement of bone flap surface area and midline shift to predict overall survival after decompressive craniectomy. *World Neurosurg.* 2016;96:11-14.
10. Hatamleh MM. Contemporary review on craniectomy and cranioplasty; part 1: decompressive craniectomy. *J Craniofac Surg.* 2022;33(3):838-841.
11. Honeybul S, Ho KM, Gillett GR. Reconsidering the role of decompressive craniectomy for neurological emergencies. *J Crit Care.* 2017;39:185-189.
12. Li LM, Kolias AG, Guilfoyle MR, et al. Outcome following evacuation of acute subdural hematomas: a comparison of craniotomy with decompressive craniectomy. *Acta Neurochir (Wien).* 2012;154(9):1555-1561.
13. Pilato F, Pellegrino G, Calandrelli R, et al. Decompressive hemicraniectomy in patients with malignant middle cerebral artery infarction: a real-world study. *J Neurol Sci.* 2022;441:120376.

14. Wang YS, Wang Y, Shi XW, Zhang JD, Ma YY. Size of bone flap and bone window area may impact the outcome of decompressive craniectomy using standard bone flap. *Eur Rev Med Pharmacol Sci*. 2016;20(17):3679-3682.
15. Tsermoulas G, Shah O, Wijesinghe HE, Silva AHD, Ramalingam SK, Belli A. Surgery for acute subdural hematoma: replace or remove the bone flap? *World Neurosurg*. 2016;88:569-575.
16. Hutchinson PJ, Adams H, Mohan M, et al. Decompressive craniectomy versus craniotomy for acute subdural hematoma. *N Engl J Med*. 2023;388(24):2219-2229.

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