Long-Term Pediatric Outcomes of Decompressive Craniectomy after Severe Traumatic Brain Injury

Claudia M. Ocasio-Rodríguez, MD, FAAP; Anabel Puig-Ramos, PhD, FCCP;
Ricardo García-De Jesús, MD, FCCM, FCCP, FAAP

Objective: There is no consensus on the use of decompressive craniectomy (DC) to manage severe traumatic brain injury (sTBI). We evaluated the profile of pediatric patients admitted with sTBI and assessed functional outcomes, 6 months post-trauma, in patients who had a DC and in those who had not, and the functional outcomes of early versus late DCs.

Patients and Methods: This case-control observational study evaluated pediatric patients admitted for sTBI in Puerto Rico (June 2016-October 2018); we included patients admitted within 24 hours of injury and had a Glasgow Coma Scale (GCS) of 8 or lower. 6-month post-trauma outcomes were measured with the Glasgow Outcome Scale-Extended Pediatric (GOS-E Peds).

Results: 20 patients were included; 15 underwent a DC and 5 comprised the control group. We found no differences in terms of sex, age, GCS score, Pediatric Risk of Mortality score, or Pediatric Trauma Score. However, in the DC group, a higher percentage of patients presented significant cerebral herniation in the initial computed tomography scan (CT) (DC: 73%; control: 0%; *P* = .005). No differences were found regarding intracranial pressure (ICP), cerebral perfusion pressure, mean arterial pressure, PaCO2, or temperature. Patients in the DC group had longer hospital stay (DC: 41; control: 17 days; *P* = .0005). All patients with DC survived, with an early procedure being associated with favorable outcomes.

Conclusion: As determined 6 months post-trauma, this study showed that early DC increased survival and improved functionality. [*P R Health Sci J 2023;42(2):152-157*]

Key words: Decompressive craniectomy, Long-term outcome, Pediatric, Severe traumatic brain injury

Traumatic brain injury (TBI) is an acute head injury caused by a blunt or penetrating trauma and acceleration/deceleration forces, excluding degenerative and congenital problems (1). This remains a significant pediatric health problem, worldwide, with particularly devastating neurological outcomes in severe cases (1,2). The goals of management are to optimize intracranial pressure (ICP), cerebral perfusion pressure (CPP), and brain oxygenation/perfusion; avoid secondary insults; and create the best possible environment for brain recovery (3–5). Therapies to meet these goals are organized by tiers. The 2012 guidelines for the *Acute Medical Management of Severe Traumatic Brain Injury in Infants, Children, and Adolescents* state that "decompressive craniectomy (DC) with duroplasty, leaving the bone flap out, may be considered for pediatric patients with traumatic brain injury (TBI) who are showing early signs of neurologic deterioration or herniation or are developing intracranial hypertension refractory to medical management during early stages of treatment" (6). Various therapies, such as DC, lack evidence of consistent outcomes to meet the criteria for a stronger level of recommendation. Even more, to our knowledge, outcomes of severe TBI (sTBI) have not been studied in the pediatric population of Puerto Rico (PR). Therefore, our primary objective was to describe functional outcomes, 6 months post-trauma, in sTBI patients admitted to our pediatric intensive care unit (PICU) and compare those who had a DC with those who had not. As a secondary objective, we also wanted to compare the functional outcomes in relation to early versus late DC.

Methodology

Patient population

In this case-control observational study, we evaluated our admissions database to identify pediatric trauma patients admitted with a sTBI diagnosis from June 1, 2016 to October 31, 2018, at the only PICU and Level 1 trauma center in PR.

Department of Pediatrics Critical Care, School of Medicine, University of Puerto Rico Medical Sciences Campus, San Juan, Puerto Rico

The authors have no conflict of interest to disclose.

Address correspondence to: Ricardo García-De Jesús, MD, FCCM, FCCP, FAAP, University of Puerto Rico School of Medicine, Department of Pediatrics-Critical Care Section, PO Box 191079, San Juan, PR 00919-1079. Email: ricardo.garcia@upr.edu

This is a 16-bed medical/surgical PICU in the University Pediatric Hospital, a teaching hospital in San Juan, PR. Because it is a teaching hospital, every parent and caregiver receive an informed consent document for possible contact for research purposes. Only patients who, during admission, consented to participate in studies conducted at the hospital were evaluated for to determine whether they met the additional inclusion criteria. We included all the trauma patients who were admitted within 24 hours of injury, were less than 21 years old, and had an acute head injury classified as an sTBI, defined as having a GCS score of 8 or lower on admission. We excluded patients who died within the first 24 hours after their TBI, were more than 21 years old, had a GCS score greater than 8, for whom ICP monitoring was not available or had a previous diagnosis related to neurodevelopmental delay. The case patients were those who had undergone a DC, and those who had not made up the control group. An early DC was one that was defined as having been performed within the first 12 hours of admission, whereas a procedure that took place after 12 hours of a given patient's having been admitted was considered a late DC. The decision as to whether to perform a DC, and when to do so, was at the discretion of the attending neurosurgeon.

Variables and data collection process

We evaluated patients' demographic data and baseline characteristics including age, sex, weight, GCS score, Pediatric Risk of Mortality (PRISM) score, Pediatric Trauma Score (PTS), cause of injury, and head computed tomography (CT) scan findings on admission (7). Also, we reviewed physiological variables such as ICP (mmHg), CPP (mmHg), mean arterial pressure (MAP, mmHg), and oxygen saturation. These variables were extracted from the daily nursing flow sheets, and daily averages were calculated for each patient. The nursing staff manually entered physiological variables every hour. The cerebral hypoperfusion index, oxygen saturation index, and ICP index were calculated for the first 24 hours of admission. The intracranial hypertension index was calculated by dividing the number of end-hourly measures of ICP of more than 20 mmHg by the total number of measurements, multiplied by 100. We calculated the cerebral hypoperfusion index using the number of events of end-hourly measurements of CPP below the age reference (≤ 4 years old, < 40 mmHg threshold; > 5 years old, < 50 mmHg threshold), divided by the total number of measurements, and then multiplied by 100. Lastly, the oxygen saturation index was calculated by dividing the number of end-hourly measures of oxygen saturation of under 98% by the total number of measurements, multiplied by 100. An analysis was performed not only with means but also with episodes surpassing given thresholds (index) since we believe this reflects the frequency of critical events and our most accurate data. Other therapies used were evaluated, such as cerebrospinal fluid drainage, inotropes, hyperosmolar solution (saline 3%), neuromuscular blockage and treatment goal values such as normocapnia ($PaCO_2$, mmHg), serum sodium, and body temperature.

Outcomes were measured in both groups: survival, days of mechanical ventilation, days of PICU stay, and length of hospital stay. We used the pediatric version of the Glasgow Outcome Scale-Extended (GOS-E Peds) to determine functional outcomes (8). The GOS-E Peds is an interview that has been modified to include developmentally appropriate questions for pediatric patients; it evaluates the patient's intellectual and physical functions. The questionnaire was administered to a given patient's caregiver by phone after an informed consent was taken. Outcome categories of the GOS-E Peds were simplified with a numerical value of 1 to 8, in which a score of 1 to 4 was considered a favorable outcome and included mild to moderate disability. A score of 5 to 8 was considered an unfavorable outcome and included severe disability to death. During the interview, we also collected physical rehabilitation referrals and explored patient access to such services. The Institutional Review Board of the University of PR School of Medicine and the University Pediatric Hospital Ethics Committee approved this study (protocol A9400117). There is no conflict of interest to disclose.

Statistical analysis

The data were expressed as medians and interquartile ranges (IQRs) for continuous variables and as percentages for discrete variables. To compare percentages among patients with and without DC, Fisher's exact test was conducted. For continuous data, a Mann–Whitney test was conducted. A P value of less than .05 was established as statistically significant. Data analysis was performed with GraphPad Prism 9.2 for Windows, GraphPad Software (San Diego, California, USA, HYPERLINK "http://www.graphpad.com"www.graphpad.com).

Results

Phase 1: Clinical data and management

During the study period, 37 patients diagnosed with sTBI were admitted to our PICU, representing 2.1% of the total admissions during this period. Seventeen patients were excluded from the analysis: 12 did not receive ICP monitoring and brain death evaluations had been initiated for 3 of them in the first 24 hours; 1 had a history of cerebral palsy and the transfer of 1 had been delayed, with the patient arriving at our hospital more than 24 hours after the trauma. This left 20 patients that met the inclusion criteria for data analysis. Fifteen patients underwent a DC procedure, and 5 patients were in the control group (Figure 1).

A general description of our patients' demographic data and trauma characteristics appears in Table 1. Our sample was composed mostly of % males (65%) ; its members had a median age of 12.5 years and a mortality of 10% (2/20). The mechanisms of trauma were variable, with sports-related, pedestrian, and motor vehicle accidents (MVA) being the most frequent.

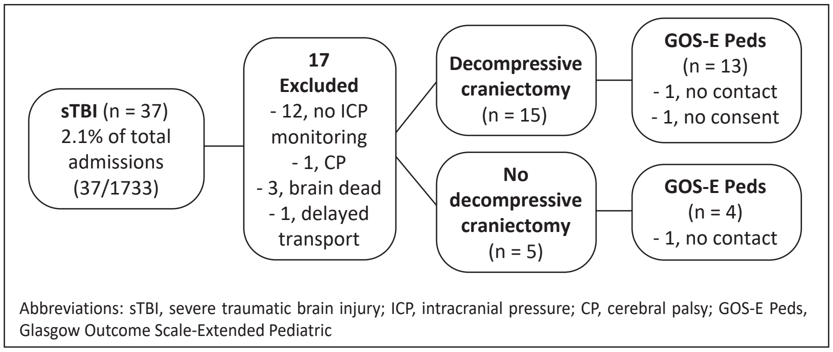

Figure 1. Sample population inclusion and exclusion criteria flowchart

Clinical characteristics were compared between the control (N = 5), and the DC group (N = 15), and we found that there were no differences between age, male predominance, GCS score, PRISM score, or PTS score. However, DC patients did have a significant presentation of cerebral herniation in the initial CT scan compared to the control group (DC: 11 [73%]; control: 0 [0%]; *P* = .005) (Table 2).

The physiological parameters and the different interventions used for the management of ICP during the first 24 hours following a TBI are summarized in Table 2. There were no significant differences between the groups regarding their median or index ICP, CPP, MAP, $PaCO_2$, temperature, or percentage use of hypertonic saline. Inotropes were significantly employed in the treatment of the DC group, most likely to ensure perfusion prior to DC procedure. However, the ICP index (DC: 14 [IQR: 0–41]; control: 25 [IQR: 2–90.5]) and mean (DC: 12.7 [IQR: 10–19]; control: 17 [IQR: 12.8–26]) proved to be lower in the patients with DC versus those in the control group (Table 2).

Comparing intrahospital clinical outcome measurements, we found a significant increase in hospital length of stay in the DC group versus the control group (DC: 41 [IQR: 36–69]; control: 17 [IQR: 12.5–23]; *P* = .01) (Table 3). This finding was not supported by a significant increase in mechanical ventilation days or PICU length of stay in the former group. However, the DC patients were more likely to undergo a procedure such as a tracheostomy, a gastrostomy, or the placing of a ventriculoperitoneal shunt than were the patients in the control group.

In terms of mortality outcomes, as of 30 days, post-trauma, no one in the DC group had died (DC: 0/15 [0%]; control: 2/5 [40%]; *P* = .05). Two members of the study sample did not survive. Both deceased were in the control group; 1 died on day 9, being declared brain dead, and the other died on day 26 after a cardiac arrest, most likely caused by a massive pulmonary embolism (Table 3).

Phase 2: Parent and/or guardian follow-up questionnaire and GOS-E Peds Score

Seventeen questionnaires were performed, 13 in the DC group and 4 in the control group; 2 parents/guardians were unable to be contacted, and 1 did not consent to taking the questionnaire (Figure 1). The GOS-E Peds outcomes in our population admitted with sTBI were favorable for 7 (41%) patients and unfavorable for 8 (47%), and 2 (12%) of the patients, as detailed above, died (Table 1). The median time after admission for caregiver interviews was 9 months (IQR: 2–14 months).

Upon comparing GOS-E Peds scores in patients who underwent a DC and in those who did not (the control group), we found there was no significant difference in functional scores between them (Table 4). In this comparison we included death, with a GOS-E Peds score of 8, as an unfavorable outcome.

All DCs were unilateral and used an opening in the dura. The mean time for surgical intervention was 12 hours after admission. Those DCs performed in the first 12 hours after admission were associated with a median GOS-E Peds score indicating a favorable outcome compared to those performed later. Even though the timing of the intervention did not reach statistical significance, DCs performed 12 hours (or more) after admission were more likely to have unfavorable outcomes than were those performed earlier.

Table 1. Demographic data and baseline characteristics of pediatric patients with severe traumatic brain injury

Characteristic	Median (IQR)/Percentage
Number of patients	20
Age in years (median, IQR)	12.5 (8.2–15.7)
Sex (% males)	13 (65%)
Mortality (%)	2 (10%)
GCS score on admission (median)	4 (3–5.7)
PRISM score (median, IQR)	7 (5–8)
PTS (median)	3 (2–3)
GOS-E Peds (N = 17)	
Favorable	7 (41%)
Unfavorable (but still living)	8 (47%)
Death	2 (12%)
Cause of injury (%)	
Sports-related	5 (25%)
Pedestrian	5 (25%)
MVA	5 (25%)
Fall	3 (15%)
GSW	2 (10%)
Head CT Findings (%)	
Epidural hemorrhage	3 (15%)
Intracerebral hemorrhage	19 (95%)
Cerebral herniation	11 (55%)
Cerebral edema	11 (50%)

Data were expressed as medians (IQR) or percentiles. Abbreviations: CT, computed tomography; DC, decompressive craniectomy; IQR, interquartile range; GCS, Glasgow Coma Scale; GSW, gunshot wound; MVA, motor vehicle accident; PRISM, Pediatric Risk of Mortality; PTS, Pediatric Trauma Score; GOS-E Peds, Glasgow Outcome Scale-Extended Pediatric

Table 2. Comparison of clinical characteristics, physiological variables and interventions used for management of intracranial pressure in patients without and with decompressive craniectomy during the first 24 hours after severe traumatic brain injury

Characteristic	Control	DC	*P* value
Number of patients	5	15	
Age in years, median	16 (IQR: 13–17)	10 (IQR: 7–14)	.05
Sex (% males)	2 (40%)	11 (73%)	.20
GCS score on admission, median	6 (IQR: 3–7.5)	4 (IQR: 3–5)	.33
PRISM score, median	7 (IQR: 5.5– 13.7)	7 (IQR: 5–8)	.82
PTS, median	3 (IQR: 2–3)	3 (IQR: 1.5–3)	.95
Head CT findings			
Epidural hemorrhage	0 (0%)	3 (20%)	.54
Intracerebral hemorrhage	5 (100%)	14 (93%)	1.0
Cerebral herniation	0 (0%)	11 (73%)	.005
Physiological and Clinical Management Variables			
ICP in mmHg, median	17 (12.8–26)	12.7 (10–19)	.24
CPP in mmHg, median	70 (58–73.3)	58 (53.7–75)	.54
MAP in mmHg, median	86 (80–88.5)	77 (74–84)	.08
ICP index	25 (2–90.5)	14 (0–41)	.34
CPP index	0 (0–22.8)	4 (0-20.8)	.74
MAP index	0 (0)	0 (0–4)	.42
Hypertonic saline	4/5 (80%)	15/15 (100%)	.09
$PaCO_2$, median	34 (28–36)	38 (33–40)	.07
Temperature in °C, median	36.8 (36.2–38)	36.4 (34.9–37.5)	.45
Inotropes	2/5 (40%)	13/15 (87%)	.04

The control group consisted of patients who had undergone a craniectomy that was not a decompressive craniectomy. Fisher's exact test was used to compare percentages among patients with and without a DC. A Mann–Whitney test was conducted to evaluate differences among groups in continuous variables: age, GCS score, PRISM score, PTS, ICP, CPP, MAP, PaCO2, and temperature. Abbreviations: CT, computed tomography; DC, decompressive craniectomy; IQR, interquartile range; GCS, Glasgow Coma Scale; PRISM = Pediatric Risk of Mortality; PTS, Pediatric Trauma Score; CPP, cerebral perfusion pressure; ICP, intracranial pressure; MAP, mean arterial pressure

Patients that survive a significant traumatic event are likely to have a residual physical disability; therefore, during the caregiver interview, we determined whether a given patient was receiving any kind of rehabilitation service. We found that 82% (14/17) of the patients had received or were receiving rehabilitation either at home or at an institution. Accessibility is a big concern in some parts of the island, especially for disabled patients, and even though 2 of the interviewed parents/guardians did not answer the question exploring this issue, we found that 75% (9/12) found rehabilitation services to be accessible to their needs.

Discussion

In this study, we aimed to determine whether DC would reduce mortality but add to an increase in severe disability outcomes compared to non-surgical medical management, as was presented in a recent randomized control trial with adult and pediatric samples (9). The pediatric population has been studied for decades, now, and it has been reported that head injuries in adults appear to be different from those in children, in whom the skull and brain are more compressible, resulting in fewer mass lesions and more white matter shear injuries (10); diffuse brain swelling occurs twice as often in children as it does in adults (11). Our study data were derived exclusively from a pediatric population, and our findings are consistent with those described by Josan and Aldrich, in that intracerebral hemorrhage, cerebral herniation, and cerebral edema predominated over mass lesions. Also, we documented a significant presentation of cerebral herniation in the DC group, which was expected, as herniation a key indication for DC. The clinical characteristics and physiological variables were similar between the groups. However, we did observe a significantly increased use of inotropes in the DC group, most likely to treat low MAP and promote adequate cerebral perfusion prior to DC procedure. As mentioned previously, we found no significant differences in the physiological variables between the groups; however, the median ICP and ICP index were both found to be lower in the DC group, demonstrating a survival rate of 100% in patients with sTBI treated with DC. The improved control of ICP with surgery may have accounted for a higher survival rate than that observed with medical management. Meanwhile, we found no differences in functional outcome scores between the groups at 6 months post-trauma, suggesting that functional outcomes may be influenced by multiple factors.

Some centers may still consider cranial decompression as a last-tier therapy to control refractory ICP. However, several pediatric studies have suggested that the benefits of

Table 3. Comparison of clinical outcomes in pediatric patients with severe traumatic brain injury with and without decompressive craniectomy

Clinical outcome	Control	DC	*P* value
Number of patients	5	15	
Mortality	2/5 (40%)	0/15 (0%)	.052
MV days, median	9 (IQR: 4.5–15)	11 (IQR: 7–19)	.17
PICU LOS (days), median	12 (IQR: 9–19)	17 (IQR: 12–24)	.15
Hospital LOS (days), median	17 (IQR: 12.5–23)	41 (IQR: 36–69)	.0005
Tracheostomy	0 (0%)	4 (27%)	.53
Gastrostomy tube	1 (20%)	6 (40%)	.43
Ventriculoperitoneal shunt	1 (20%)	2 (13%)	1.00

The control group consisted of patients who had undergone a craniectomy that was not a decompressive craniectomy. Fisher's exact test was used to compare percentages among patients with and without a DC. A Mann–Whitney test was conducted to evaluate differences among groups in continuous variables: MV days, PICU LOS, hospital LOS. Abbreviations: DC, decompressive craniectomy; IQR. interquartile range; MV, mechanical ventilation, PICU, pediatric intensive care unit, LOS, length of stay

Table 4. Comparison of GOS-E Peds outcomes in pediatric patients with and without decompressive craniectomy, 6 months post-trauma

GOS-E Peds Outcome	Control	DC	*P* value
Number of patients	4	13	
GOS-E Peds, median	5.5 (IQR: 2–8)	4.2 (IQR: 2–6)	.43
GOS-E Peds, favorable	1 (25%)	6 (46%)	.46
GOS-E Peds, unfavorable	3 (75%)	7 (54%)	.47

The control group consisted of patients who had undergone a craniectomy that was not a decompressive craniectomy. Fisher's exact test was used to compare percentages among patients with and without a DC. A Mann–Whitney test was conducted to evaluate differences among groups in GOS-E Peds score. Abbreviations: DC, decompressive craniectomy; IQR, interquartile range; P GOS-E Peds, Glasgow Outcome Scale-Extended Pediatric

decompressive surgery are related to the time that elapses between the traumatic event and the procedure, with the greatest benefits accruing when the procedure is performed earlier (12). Operative decompression seems to be most successful if performed within 24 hours of the start of the elevated ICP (12). As a secondary aim, we wanted to compare early versus late DC patients' functional outcomes. Our study's DC procedures were performed at a mean time of 12 hours from admission. Fifty-seven percent of the patients with DC had favorable outcomes when the procedure took place in the first 12 hours compared with those whose DCs were performed later, in which latter group, 67% of the patients had outcomes that were considered unfavorable. Although the results were not significant, they did show a tendency for better outcomes with early DC when the patients were evaluated 6 months post-trauma.

Rutigliano et al reported that patients who were operated on earlier (less than 10 hours after the original trauma) had shorter ICU and hospital stays (12). We were surprised to find that the members of our DC group had a significant increase (2.5-fold) in their hospital lengths of stay compared to those in the control group. This finding is not supported by an increase in mechanical ventilation days or PICU length of stay; however, a procedure such as a tracheostomy, a gastrostomy, or the placing of a ventriculoperitoneal shunt was required in up to 80% of the DC group, suggesting the need for more complex discharge planning involving education and follow-up. However, the patients' clinical courses outside the PICU were not evaluated in this study, and our findings should encourage an investigation of these patients while they are still in the ward, as the prolonged length of stay might have limited DC patient outcomes.

Table 5. Association of GOS-E Peds with time of decompressive craniectomy surgery at 6 months post-trauma

GOS-E Peds Outcome	≤12 hours for DC	>12 hours for DC	*P* value
Number of patients	7	6	
GOS-E Peds, median	4 (IQR: 2–6)	6 (IQR: 1–6)	.89
GOS-E Peds, favorable	4 (57%)	2 (33%)	.41
GOS-E Peds, unfavorable	3 (43%)	4 (67%)	.40

The control group consisted of patients who had undergone a craniectomy that was not a decompressive craniectomy. Fisher's exact test was used to compare percentages among patients with and without a DC. A Mann–Whitney test was conducted to evaluate differences among groups in GOS-E Peds score. Abbreviations: DC, decompressive craniectomy; IQR, interquartile range; P GOS-E Peds, Glasgow Outcome Scale-Extended Ped

Jagannathan et al, in their 2-year follow-up study, suggested that developmental immaturity in pediatric patients may contribute to the favorable long-term outcomes that have been observed in pediatric TBI patients compared with their adult counterparts (13). We found, at 6 months post-trauma, severe disability in up to 47% of the patients diagnosed with sTBI, and we can reasonably believe that this finding may change with adequate stimulation through rehabilitation resources. Though the resources on the island of PR are limited, we nevertheless found that up to 80% of our population received rehabilitation and that three-fourths of them considered the services to be accessible. Those findings suggest that further rehabilitation awareness may improve the services for the pediatric population in PR and subsequently may positively impact their functional outcomes.

On a final note, accidents can be prevented, and it was eye-opening to realize that it took us only 2 years and 3 months to obtain a study population of 20 patients, whereas Taylor et al required 7 years to reach a sample of 27 patients (14). Our study describes a prevalence of 2.1% for sTBI, and this finding should encourage road safety campaigns that would promote awareness on speed limits, avoiding driving under influence of alcohol or drugs, the use of compulsory sport helmets, and educating the public on the correct use of car seats and seatbelts.

This study had several limitations. First, data regarding intrahospital management of sTBI patients were collected, retrospectively, and missing data were encountered in the paper-based records. Second, 12 patients with sTBI were excluded as they did not have ICP monitoring devices for further data collection. This resulted in a small case-control study, so the interpretation of the results is somewhat limited due to the sample size. Third, when and whether to perform a DC was decided by the neurosurgeon on call; in the absence of institutional protocols, this kind of decision could differ between providers. However, neurologic deterioration, herniation, and intracranial hypertension refractory to medical management were strongly considered in the process of deciding on a surgical approach for ICP control.

Conclusion

Although primary brain injury can be prevented only through increased public awareness and education, preventing secondary brain injury is the most important thing we can do for a patient within the acute hospital setting. The importance of maintaining an adequate environment of perfusion for brain recovery cannot be overstressed. In contrast to what is recommended for adults, our study supports the use of early

DC for the management of refractory increased ICP in pediatric patients with sTBI, as this procedure increases survival rates and improves functional outcomes, according to evaluations made 6 months post-trauma.

Resumen

Objetivos: No existe un consenso en el uso de la craniectomía descompresiva (CD) para manejar el trauma a cabeza severo (TCs). Se evaluó el perfil de pacientes pediátricos admitidos con TCs, 6 meses post trauma, se compararon los hallazgos funcionales de los que tuvieron CD y los que no la tuvieron y la CD temprana versus tardía. Pacientes y métodos: En este estudio observacional caso-control se evaluaron pacientes pediátricos ingresados por TCs en Puerto Rico (junio 2016 - octubre 2018), en 24 horas post trauma y con escala inicial de coma Glasgow (GCS, por sus siglas en inglés) de 8 o menor. Los resultados de funcionalidad, 6 meses post trauma, se evaluaron usando la Escala Pediátrica Extendida de Glasgow (GOS-E Peds, por sus siglas en inglés). Resultados: Se evaluaron 20 pacientes; 15 con CD y 5 del grupo de control. No hubo diferencias entre sexo, edad, puntuación GCS, riesgo de mortalidad pediátrica y de trauma pediátrico. Un por ciento mayor de pacientes con CD presentó herniación cerebral en su CT inicial (CD: 73%, control: 0%, P = .005). No hubo diferencias en presión intracraneal, de perfusión cerebral, de presión arterial promedio, $PaCO_2$ o temperatura. La estadía hospitalaria fue mayor en el grupo de CD (CD: 41, control: 17 días, P = .0005). Todos los pacientes con CD sobrevivieron y los pacientes con CD temprana tuvieron resultados favorables. Conclusiones: A 6 meses luego del TCs, se demostró que la CD temprana aumentó la sobrevida y mejoró la funcionalidad.

Acknowledgments

Special mention goes to the contributors in the acquisition of data: Paola Flores-Arroyo, University of Puerto Rico, Rio Piedras Campus; Paola Vega Labrador, University of Puerto Rico, Cayey Campus; Giulianna Betancourt, BS, San Juan Bautista School of Medicine; and Sandra Ríos-Meléndez, BS, University of Puerto Rico School of Medicine. Part of this work was presented in abstract form at the 49th Society of Critical Care Medicine Congress in San Diego, California, on February 18, 2019.

References

1. Kochanek PM, Bell MJ, Bayir H, et al. Severe Traumatic Brain Injury in Infants and Children. In: Fuhrman BP, Zimmerman JJ, eds. Pediatric Critical Care. 5th ed. Elsevier; 2017:1613-1637.
2. Catroppa C, Anderson VA, Morse SA, Haritou F, Rosenfeld JV. Outcome and predictors of functional recovery 5 years following pediatric traumatic brain injury (TBI). J Pediatr Psychol. 2008;33(7):707-718. doi:10.1093/jpepsy/jsn006
3. Cruz J, Nakayama P, Imamura JH, Rosenfeld KG, de Souza HS, Giorgetti GV. Cerebral extraction of oxygen and intracranial hypertension in severe, acute, pediatric brain trauma: preliminary novel management strategies. Neurosurgery. 2002;50(4):774-780. doi:10.1097/00006123-200204000-00017
4. Stiefel MF, Udoetuk JD, Storm PB, et al. Brain tissue oxygen monitoring in pediatric patients with severe traumatic brain injury. J Neurosurg. 2006;105(4 Suppl):281-286. doi:10.3171/ped.2006.105.4.281
5. Grinkeviciūte DE, Kevalas R, Matukevicius A, Ragaisis V, Tamasauskas A. Significance of intracranial pressure and cerebral perfusion pressure in severe pediatric traumatic brain injury. Medicina (Kaunas). 2008;44(2):119-125.
6. Kochanek PM, Carney N, Adelson PD, et al. Guidelines for the acute medical management of severe traumatic brain injury in infants, children, and adolescents--second edition [published correction appears in Pediatr Crit Care Med. 2012 Mar;13(2):252]. Pediatr Crit Care Med. 2012;13 Suppl 1:S1-S82. doi:10.1097/PCC.0b013e31823f435c
7. Tepas JJ 3rd, Mollitt DL, Talbert JL, Bryant M. The pediatric trauma score as a predictor of injury severity in the injured child. J Pediatr Surg. 1987;22(1):14-18. doi:10.1016/s0022-3468(87)80006-4
8. Beers SR, Wisniewski SR, Garcia-Filion P, et al. Validity of a pediatric version of the Glasgow Outcome Scale-Extended. J Neurotrauma. 2012;29(6):1126-1139. doi:10.1089/neu.2011.2272
9. Cooper DJ, Rosenfeld JV, Murray L, et al. Decompressive craniectomy in diffuse traumatic brain injury [published correction appears in N Engl J Med. 2011 Nov 24;365(21):2040]. N Engl J Med. 2011;364(16):1493-1502. doi:10.1056/NEJMoa1102077
10. Josan VA, Sgouros S. Early decompressive craniectomy may be effective in the treatment of refractory intracranial hypertension after traumatic brain injury. Childs Nerv Syst. 2006;22(10):1268-1274. doi:10.1007/s00381-006-0064-0
11. Aldrich EF, Eisenberg HM, Saydjari C, et al. Diffuse brain swelling in severely head-injured children. A report from the NIH Traumatic Coma Data Bank. J Neurosurg. 1992;76(3):450-454. doi:10.3171/jns.1992.76.3.0450
12. Rutigliano D, Egnor MR, Priebe CJ, et al. Decompressive craniectomy in pediatric patients with traumatic brain injury with intractable elevated intracranial pressure. J Pediatr Surg. 2006;41(1):83-87. doi:10.1016/j.jpedsurg.2005.10.010
13. Jagannathan J, Okonkwo DO, Yeoh HK, et al. Long-term outcomes and prognostic factors in pediatric patients with severe traumatic brain injury and elevated intracranial pressure. J Neurosurg Pediatr. 2008;2(4):240-249. doi:10.3171/PED.2008.2.10.240
14. Taylor A, Butt W, Rosenfeld J, et al. A randomized trial of very early decompressive craniectomy in children with traumatic brain injury and sustained intracranial hypertension. Childs Nerv Syst. 2001;17(3):154-162. doi:10.1007/s003810000410