Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 6031 - 6039
Received 25 April 2021; Accepted 08 May 2021.

Outcome of Early Surgical Interventions for Cerebral Contusions

Dr. Mumtaz Ali Narejo[1], Muhammad Munwar Ali[2], Dr. Muhammad Sohaib Anwar[3]
[1]Assistant Professor Neurosurgery Department, Gambat Medical College, Pir Abdul Qadir Shah Jeelani Institute of Medical Sciences Gambat
[2]Assistant Professor, Neurosurgery Department, SMBBMU larkana,
[3]Associate Professor Neurosurgery, Sheikh Zayed Hospital, Rahimyarkhan

ABSTRACT

The bruising of brain tissue is cerebral contusion. It can be compared to bruises in other parts of the body only after microscopic examination. Cerebral contusions consist of areas of injured or swollen brain mixed with blood that has leaked from arteries, veins, or capillaries. Mostly contusions occur at the base of the front parts of the brain, but may occur anywhere. An intracerebral hemorrhage (ICH) describes bleeding within the brain tissue; it may be related to other brain injuries, especially contusions. The size and location of the hemorrhage helps determine whether it can be removed surgically or not.

Objectives: The main purpose of early surgical intervention for cerebral contusion is to prevent secondary brain injury. Extravagated blood is believed to be neurotoxic, leading to secondary injury that may be avoided by early surgical removal. Cerebral contusion of brain does not seem to recover and appears later as encephalomalacic brain tissue loss on convalescent phase imaging. Tissue loss is not increased by removal of irreversibly damaged brain contusion. Patients can deteriorate clinically after intracerebral hemorrhage arising and the question of early surgery to anticipate such secondary damage.

Methods & Materials: Early management of patients with TICH requires evaluation to determine whether early surgery should become part of the standard of care. This randomized patient group trial compared early surgery (within 12 h of randomization) with initial conservative treatment (subsequent surgery allowed if deemed necessary). Patients were randomized using an independent randomization service within 48 h of TBI. Patients were eligible if they had no more than two intra-parenchymal hemorrhages of 10 ml or more and did not have an extradural or subdural hematoma that required surgery.

Results: The primary outcome measure at 6 month was the traditional dichotomous split of the Glasgow Outcome Scale. Total of 170 patients were registered for this trial. From 82 patients randomized to early surgery with complete follow-up, 30 (37%) had an unfavorable outcome. Of 85 patients randomized to initial conservative treatment with complete follow-up, 40 (47%) had an unfavorable outcome (odds ratio, 0.65; 95% confidence interval, CI 0.35, 1.21; *p*=0.17), with an absolute benefit of 10.5% (CI, −4.4–25.3%). There were significantly more deaths in the first 6 months in the initial conservative treatment group (33% vs. 15%; *p*=0.006). The 10.5% absolute benefit with early surgery was consistent with the initial power calculation.

Conclusions: Use of surgical intervention for treatment of cerebral contusion varies around the world. In Asia surgical interventions are more frequent than in Europe or North America. Implementation of early referral and diagnosis with immediate treatment may reduce incidence of death and disability in this specific group of TBI patients. The occurrence of cerebral contusion is a definitive risk for higher mortality and prolonged disability. Surgical intervention at the right moment can however, change the course of this fatal condition and lead to improved outcomes in cohorts of severe traumatic brain injury.

Key words
Glasgow Outcome Scale, Intracranial pressure (ICP) monitoring; decompressive hemicraniectomy; severe traumatic brain injury (TBI) intracerebral hemorrhage (ICH).

Introduction

Brain is the most vital part of human body. All functions of body depend upon brain. A cerebral contusion is a heterogeneous zone of brain damage consisting of hemorrhage, cerebral infarction, necrosis, and edema. The normal occurrence of cerebral contusion is when brain strikes a ridge on skull or a fold in the dura mater, the tough outer covering of brain. These bruises may occur without other types of bleeding or they may occur with acute subdural or epidural hematomas.

Cerebral contusion is one of the Traumatic Brain Injury (TBI). TBI is a disruption in the normal function of the brain is disrupted due to traumatic brain injury which can be caused by a blow, bump or jolt to the head, the head suddenly and violently hitting an object or when an object pierces the skull and enters brain tissue. Symptoms of a TBI can be mild, moderate, or severe, depending on the extent of damage to the brain. Mild cases may result in a brief change in mental state or consciousness. Severe cases may result in extended periods of unconsciousness, coma, or even death.

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 6031 - 6039
Received 25 April 2021; Accepted 08 May 2021.

Treatment through surgical interventions is done upon patients with moderate to severe head injuries. Ultra early interventions, early surgical intervention and delayed surgical interventions bear different results among patients with cerebral contusions. The timely decision of surgical intervention may stop the chances of secondary injury to the brain.
Traditional neurosurgical management of patients with severe contusion is mostly based on intracranial pressure (ICP) measurement recommended by the Brain Trauma Foundation. More than 30mm Hg ICP reading would lead to surgical intervention conservative management would be done on patients with less than 20 mm Hg icp reading Patients with ICP between 20 and 30 mm Hg would be monitored closely and undergo surgery if the ICP rises. Early management of patients should be evaluated to determine whether early surgery should become part of the standard of care for cerebral contusion or not.

Methods & Materials

This study was conducted in SMBBMU larkana from January 2019 to January 2020. Written consent in the presence of witnesses and relatives were taken before the start of trial. Eligibility criteria included only patients for whose neurosurgeon was in harmony about the benefits of early surgical evacuations compared to the initial conservative treatment. Ct scan was performed to locate the size and location of the contusion. Clotting problems were corrected before randomization as per standard clinical practice. Patients who were adults within 48 h of TBI and had evidence of a TICH on CT with a confluent volume of attenuation significantly raised above that of the background white and gray matter greater than 10 mL calculated by: (length×width×height)/2 in cm were included.

The two approaches in the trial were early surgery or initial conservative treatment. Early surgery was early evacuation of the hematoma by a method of the surgeon's choice (within 12 h of randomization), combined with appropriate best medical treatment. Initial conservative treatment was best medical treatment combined with delayed (more than 12 h after randomization) evacuation if it became appropriate later. Both groups were monitored according to standard neurosurgical practice. Monitoring of ICP and management of metabolism, sodium osmotic pressure, temperature, and blood gasses could be the medical treatment included.

Operative Procedures

During surgery, the affected area of head was shaved. The removed bone was extracted in a single piece or flaps after the scalp incision, and then replaced after surgery unless contaminated. The dura mater was cut to reveal the underlying brain. After any hematoma or contusion was removed, the neurosurgeon ensured the area is not bleeding. After dura was closed the previously extracted bone was replaced, only if there was not much swelling, and the scalp was closed. The patient is returned to the ICU for observation and additional care.

During the first 5 days of their trial progress glasgow coma scale (GCS) and focal signs were collected and also ICP/CPP (cerebral perfusion pressure) were measured to describe any change in status that could conclude the outcome of early surgical interventions in comparison of conservative management treatments. a discharge/2-week form was completed(including patient's status at that time, the mechanism of injury, time of surgery if happened including reason for performing surgery or not) at 2 weeks after randomization or at discharge or death (whichever occurred first).), the GCS and localizing features for the 5 days after randomization, the occurrence of any adverse events (AEs) after randomization (including death, pulmonary embolism, deep vein thrombosis, and surgical site infection), and past medical history were also recorded in the form.

One hundred and seventy patients from SMBBMU Larkana from January 2019 to January 2020 were assigned to treatment in two groups. 1st group included 83 patients for early surgery and second group included 87 patients for initial conservative treatment. Two patients were exempted due to violation of protocols because the treatment decision was made before randomization: In one case, the patient had surgery before randomization and in the other an early decision was made not to operate. All other patients were included in the analysis, therefore first group included 82 patients and second group included 86 patients.

There were no differences in the three individual components of the GCS, handedness, or characteristics of the second hematoma.
Neurological deterioration was identified by a drop in GCS, enlargement of the hematoma or increase in mid-line shift, increase in weakness, or change in pupil size or reactivity

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 6031 - 6039
Received 25 April 2021; Accepted 08 May 2021.

Table 1

Baseline Variables			
Variables		**Early surgery**	**Initial Conservative Treatment**
Age (Years)	Median (IQR) range	57(32-63) 18-83	50(33-61) 16-77
	Mean (SD)	48 (17.7)	48 (16.9)
Age band (%)	<50	37(45)	42(49)
	50-69	34(42)	33(38)
	70+	11(13)	11(13)
Sex(%)	Male	57 (70)	65(76)
	Female	25(30)	21(24)
GCS total (%)	3	0(0)	1(1)
	4	0(0)	0(0)
	5	1(1)	2(2)
	6	6(7)	3(3)
	7	4(5)	3(3)
	8	1(1)	6(7)
	9	11(13)	8(9)
	10	11(13)	14(16)
	11	6(7)	8(9)
	12	6(7)	7(8)
	13	10(12)	8(9)
	14	14(17)	13(15)
	15	12(15)	13(15)
Pupils (%)	Both reactive	77(94)	79(92)
	One reactive	3(4)	3(3)
	Both unreactive	2(2)	4(5)
Volume of largest hematoma (ml)		25(18-37)11-96	23(15-32) 10-97
		mean=31(18.0)	mean=27(16.8)
Location of largest hemorrhage (%)	Frontal	36(44)	43(50)
	Temporal	39(48)	37(43)
	Parietal	4(5)	5(6)
	Occipital	3(4)	1(1)
Second hematoma present (%)		28(34)	33(38)
Time to randomization (h)		21(13-31)3-48	22(14-28)4-48
		mean=22(11.7)	mean=22(10.6)

For continuous variables, median (quartiles) and range are presented plus mean and SD; for categorical variables, the number of cases (percentage) is presented.

IQR, interquartile range; SD, standard deviation; GCS, Glasgow Coma Score.

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 6031 - 6039
Received 25 April 2021; Accepted 08 May 2021.

Table 2

Surgery details for early surgery patients who had surgery and initial conservative patients who required delayed surgery

		Early surgery surgical cases (N=61; 74%)	Initial conservative treatment surgical cases (N=31; 36%
Method (%)	Craniotomy	59 (97)	25 (81)
	Other	2 (3)	6 (19)
Bone flap replaced (%)		47 (77)	13 (42)
Other cranial surgery (%)		1 (2)	3 (10)
Paralyzed and sedated (%)		17 (28)	12 (39)
Any noncranial surgery (%)		1 (2)	2 (7)
Preoperative GCS–eye (%)	1	5 (8)	15 (48)
	2	18 (30)	8 (26)
	3	19 (31)	5 (16)
	4	19 (31)	3 (10)
Preoperative GCS–Verbal (%)	1	13 (21)	16 (52)
	2	15 (25)	7 (23)
	3	6 (10)	5 (16)
	4	18 (30)	0 (0)
	5	9 (15)	3 (10)
Preoperative GCS–Motor (%)	1	0 (0)	4 (13)
	2	2 (3)	1 (3)
	3	6 (10)	3 (10)
	4	4 (7)	6 (19)
	5	26 (43)	14 (45)
	6	23 (38)	3 (10)
Time randomisation to surgery (h)		3 (1–6) <1–24	25 (6–79) <1–318
		Mean: 4 (4.5)	Mean: 58 (75.6)
Surgery within 12 h of randomization (%)		57 (93)	10 (32)
Time injury to surgery (h)		23 (16–36) 4–69	45 (26–99) 9–332
		Mean 26 (13.8)	Mean 78 (79.0)
Surgery within 12 hours of injury (%)		9 (15)	3 (10)

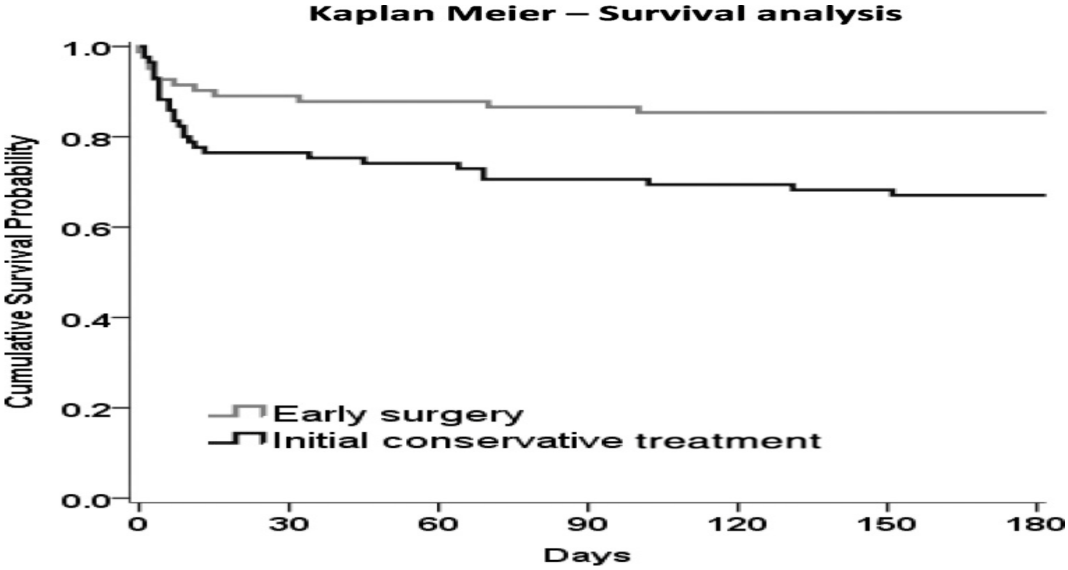
For continuous variables, median (quartiles) and range are presented plus mean and standard deviation; for categorical variables, number of cases (percentage) are presented.

GCS, Glasgow Coma Score.

Results

Primary outcome at 6 months was available for 82 early surgery patients and 85 initial conservative patients; 1 patient from the initial conservative group was lost to follow-up. 63% early surgery patients had a favorable outcome on the dichotomized GOS, compared to 53% initial conservative patients.

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 6031 - 6039
Received 25 April 2021; Accepted 08 May 2021.



In secondary outcomes at 12 months, there is a significant trend in better outcome in the early surgery group.

Table 3

OUTCOMES ANALYSIS BETWEEN EARLY SURGERY AND INITIAL CONSERVATIVE TREATMENT				
	Early surgery	Initial conservative treatment	Test and p value Absolute difference (95% CI)	
Primary outcome (%)	N = 82	N = 85		
Unfavorable	30 (37)	40 (47)	χ^2	p = 0.170
Favorable	52 (63)	45 (53)	10.5 (−4.4–25.3)	
Secondary outcomes	N = 82	N = 85		
Mortality at 6 months (%)				
Dead	12 (15)	28 (33)	χ^2	p = 0.006
Alive	70 (85)	57 (67)	18.3 (5.7–30.9)	
Rankin (%)				
Unfavorable	27 (33)	37 (44)	χ^2	p = 0.159
Favorable	55 (67)	48 (56)	10.6 (−4.0–25.3)	
GOS (%)				
Dead	12 (15)	28 (33)	χ2 trend	p = 0.047
Vegetative	0 (0)	0 (0)		
Severely dependent	18 (22)	12 (14)	POM	p = 0.153
Moderately dependent	26 (32)	18 (21)		
Good recovery	26 (32)	27(32)		
GOSE (%)				
Dead	12 (15)	28 (33)	χ^2 trend	p = 0.052
Vegetative	0 (0)	0 (0)		
Lower SD	4 (5)	8 (9)	POM	p = 0.127
Upper SD	14 (17)	4 (5)		
Lower MD	5 (6)	3 (4)		
Upper MD	21 (26)	15 (18)		
Lower GR	12 (15)	12 (14)		
Upper GR	14 (17)	15 (18)		
Rankin (%)				
0	17 (21)	18 (21)	χ^2 trend	p = 0.043
1	27 (33)	22 (26)		
2	11 (13)	8 (9)	POM	p = 0.147
3	8 (10)	4 (5)		
4	7 (9)	3 (4)		
5	0 (0)	2 (2)		
Dead	12 (15)	28 (33)		

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 6031 - 6039
Received 25 April 2021; Accepted 08 May 2021.

EuroQoL Index				
Median	0.8	0.71	M-W	p = 0.218
Quartiles	0.52–1.00	0.00–1.00		
Range	−0.33–1.00	−0.59–1.00		
Limb movement (%)				
Worst affected leg[a]				
Unaffected	50 (72)	47 (82)	χ^2	0.374
Weak	18 (26)	9 (16)		
Paralysed	1 (1)	1 (2)		
Worst affected arm[a]				
Unaffected	48 (70)	43 (75)	χ^2	0.464
Weak	21 (30)	14 (25)		
Paralysed	0 (0)	0 (0)		
Number of cases (percentage) are presented; EuroQol utility index calculated using UK weightings provided by the EuroQol Group Foundation; tests conducted were χ2 (chi-squared), χ2 trend (chi-squared for trend), POM (proportional odds model), and M-W (Mann-Whitney). For each test, the p value is given. Absolute differences with 95% confidence intervals are presented for binary outcomes.				
a One patient did not provide information about their limb movements.				
GOS, Glasgow Outcome Scale; GOSE, Glasgow Outcome Scale Extended; SD, severe disability; MD, moderate disability; GR, good recovery.				

The main causes of death were the initial head injury (5 early surgery, 14 initial conservative) and pneumonia (4 early surgery, 2 initial conservative). Other causes in the initial conservative treatment group included cachexia (2), ischemic stroke (2), meningitis (1), pulmonary embolism (2), renal (1), TBI and surgery (1), seizure (1), and unknown– sudden death in the community (1). In the early surgery group, the other causes were hypovolemic shock (1), pulmonary embolism (1), TBI and surgery (1), and unknown in the community (1). Only 8 non-death-related major AEs were recorded: seizure (3); new/enlarged hematoma (2); infection (2); and other (1).

Discussion

There were some clinically significant results. In association with early surgical interventions there was a non-significant benefit on GOS and statistically significant survival advantage (85% vs. 67%) Early management of patients with TICH is not synchronized around the world. There is no defined or universal standard for the timing of surgery in patients with cerebral contusion. Not all TICHs require removal and neither do all the contusions are associated with them. Generally, clinical weakening and expansion of the hematomas and their associated edema trigger the need for surgery. Secondary brain damage can be avoided if only the changes can be anticipated. The aim of this study was to discover whether early surgery would prevent the secondary injury to the brain, so often observed with conservative treatment. Though the primary outcome is not statistically significant, there is a strong indication that early surgery will indeed prevent second injury and save lives. This is noted in the highly significant reduction in mortality and the better outcomes in the ordinal analysis of the GOS and Rankin scales.

There were crossovers from initial conservative treatment to early surgery and vice versa, as occurs in all surgical trials. This is because surgeons perform surgical treatment to rescue the patients randomized to initial conservative treatment whose condition subsequently worsen. On the other hand, some patients who were randomized to early surgery did not have surgery because their families were no more willing. Despite these crossovers, the absolute benefit of early surgery exceeded 10% and was almost statistically significant. In addition, the patients who had delayed surgery had deteriorated to a much poorer clinical state and this was associated with a much poorer outcome this observation supports the primary hypothesis that early surgery is advantageous.

An analysis of outcome by whether patients actually had surgery or not are complex and biased because the decision for surgery was guided by the study in some cases and by a change in status in others: Some patients would have surgery before deterioration and others would only have surgery after deterioration. In the non-surgery group, some patients did not have early surgery mainly because the relative refused, whereas others did not have surgery because that was the allocation. Predicting which patients will deteriorate is complex, and the

Surgical Trial in Intracerebral Haemorrhage identified a small number of patients (GCS between 9 and 12) that may benefit from such anticipatory treatment. In general, SICH patients with a good projection (GCS between 13 and 15) can be safely observed and only require craniotomy if they deteriorate. This is because there is enough time to perform a surgery before other secondary mechanisms, such as brain edema, mass effect with herniation, and reduced CPP from elevated ICP, cause harm. This may also be true for TICH patients. In particular, those TICH patients with an initial GCS between 9 and 12 had the best outcome with early surgery. The economic analysis indicates that a strategy of early surgery is associated with a non-significant increase in health care costs.

Conclusion

There is a need of larger trial to confirm the outcomes of early surgical interventions In the meanwhile there is a strong case for operating on patients with TICH who have a GCS of 9–12. Those who are alert or just confused (GCS 13–15) can probably be watched carefully for any deterioration because there is a safety margin, which diminishes the lower down the GCS the patient descends. Once the GCS has descended below 9, surgical intervention appears to be less effective. Surgical intervention for severe TBI to prevent secondary injury sounds supporting but evidence is lacking. Large prospective randomized trials with standardization of interventions across multiple institutions are needed for the severe traumatic brain injuries, while considering the heterogeneity of various trauma systems, and establishing clinical equipoise is proving to be difficult. Even as life-saving surgical measures are taken, the ethical and socio-economic issues still remain as valued primary endpoints to consider. Occurrence of cerebral contusion is a definitive risk for higher mortality and prolonged disability. Surgical intervention at the right moment can however, change the course of this fatal condition and lead to improved outcomes in cohorts of severe traumatic brain injury.

References

[1] Joseph J. Volpe, in Volpe's Neurology of the Newborn (Sixth Edition), 2018
[2] Nitin Agarwal, MD, Rut Thakkar, Khoi Than, MD, FAANS. Traumatic-Brain-Injury. Edited on 2 March 2020 Available from: https://www.aans.org/Patients/Neurosurgical-Conditions-and-Treatments/Traumatic-Brain-Injury [Accessed 10 May 2021]
[3] David Mendelow, Barbara A. Gregson, Elise N. Rowan, Richard Francis, Elaine McColl, Paul McNamee, Iain R. Chambers, Andreas Unterberg, Dwayne Boyers, Patrick M. Mitchell, and on behalf of the STITCH(Trauma) Investigators.Journal of Neurotrauma.Sep 2015.1312-1323.http://doi.org/10.1089/neu.2014.3644
[4] Francis R., Gregson B., Mendelow A., and Rowan E. (2015). Characteristics of traumatic intracerebral haemorrhage: an assessment of screening logs from the STITCH(Trauma) Trial. (In press.) [PubMed] [Google Scholar]
[5] McGinn MJ, Povlishock JT. Pathophysiology of Traumatic Brain Injury. Neurosurg Clin N Am. 2016 Oct;27(4):397-407. [PubMed]
[6] Lalwani S, Hasan F, Khurana S, Mathur P. Epidemiological trends of fatal pediatric trauma: A single-center study. Medicine (Baltimore). 2018 Sep;97(39):e12280. [PMC free article] [PubMed]
[7] Schneider ALC, Wang D, Ling G, Gottesman RF, Selvin E. Prevalence of Self-Reported Head Injury in the United States. N Engl J Med. 2018 Sep 20;379(12):1176-1178. [PMC free article] [PubMed
[8] Fernández-Abinader JA, González-Colón K, Feliciano CE, Mosquera-Soler AM. Traumatic Brain Injury Profile of an Elderly Population in Puerto Rico. P R Health Sci J. 2017 Dec;36(4):237-239. [PubMed]
[9] Egbohou P, Mouzou T, Tchetike P, Sama HD, Assenouwe S, Akala-Yoba G, Randolph L, Tomta K. Epidemiology of Pediatric Traumatic Brain Injury at Sylvanus Olympio University Hospital of Lomé in Togo. Anesthesiol Res Pract. 2019;2019:4038319. [PMC free article] [PubMed]
[10] Cepeda S, Gómez PA, Castaño-Leon AM, Martínez-Pérez R, Munarriz PM, Lagares A. Traumatic Intracerebral Hemorrhage: Risk Factors Associated with Progression. J Neurotrauma. 2015 Aug 15;32(16):1246-53. [PubMed]
[11] Cepeda S, Castaño-León AM, Munarriz PM, Paredes I, Panero I, Eiriz C, Gómez PA, Lagares A. Effect of decompressive craniectomy in the postoperative expansion of traumatic intracerebral hemorrhage: a propensity score-based analysis. J Neurosurg. 2019 Apr 26;132(5):1623-1635. [PubMed]
[12] Gerzanich V, Stokum JA, Ivanova S, Woo SK, Tsymbalyuk O, Sharma A, Akkentli F, Imran Z, Aarabi B, Sahuquillo J, Simard JM. Sulfonylurea Receptor 1, Transient Receptor Potential Cation Channel Subfamily M Member 4, and KIR6.2:Role in Hemorrhagic Progression of Contusion. J Neurotrauma. 2019 Apr 01;36(7):1060-1079. [PMC free article] [PubMed]
[13] Jha RM, Bell J, Citerio G, Hemphill JC, Kimberly WT, Narayan RK, Sahuquillo J, Sheth KN, Simard JM. Role of Sulfonylurea Receptor 1 and Glibenclamide in Traumatic Brain Injury: A Review of the Evidence. Int J Mol Sci. 2020 Jan 09;21(2) [PMC free article] [PubMed]

[14] Moscote-Salazar LR, M Rubiano A, Alvis-Miranda HR, Calderon-Miranda W, Alcala-Cerra G, Blancas Rivera MA, Agrawal A. Severe Cranioencephalic Trauma: Prehospital Care, Surgical Management and Multimodal Monitoring. Bull Emerg Trauma. 2016 Jan;4(1):8-23. [PMC free article] [PubMed]

[15] Shetty VS, Reis MN, Aulino JM, Berger KL, Broder J, Choudhri AF, Kendi AT, Kessler MM, Kirsch CF, Luttrull MD, Mechtler LL, Prall JA, Raksin PB, Roth CJ, Sharma A, West OC, Wintermark M, Cornelius RS, Bykowski J. ACR Appropriateness Criteria Head Trauma. J Am Coll Radiol. 2016 Jun;13(6):668-79. [PubMed]

[16] Hutchinson PJ, Kolias AG, Timofeev IS, Corteen EA, Czosnyka M, Timothy J, Anderson I, Bulters DO, Belli A, Eynon CA, Wadley J, Mendelow AD, Mitchell PM, Wilson MH, Critchley G, Sahuquillo J, Unterberg A, Servadei F, Teasdale GM, Pickard JD, Menon DK, Murray GD, Kirkpatrick PJ., RESCUEicp Trial Collaborators. Trial of Decompressive Craniectomy for Traumatic Intracranial Hypertension. N Engl J Med. 2016 Sep 22;375(12):1119-30. [PubMed]

[17] Hawryluk GWJ, Rubiano AM, Totten AM, O'Reilly C, Ullman JS, Bratton SL, Chesnut R, Harris OA, Kissoon N, Shutter L, Tasker RC, Vavilala MS, Wilberger J, Wright DW, Lumba-Brown A, Ghajar J. Guidelines for the Management of Severe Traumatic Brain Injury: 2020 Update of the Decompressive Craniectomy Recommendations. Neurosurgery. 2020 Sep 01;87(3):427-434. [PMC free article] [PubMed]

[18] Carney N, Totten AM, O'Reilly C, Ullman JS, Hawryluk GW, Bell MJ, Bratton SL, Chesnut R, Harris OA, Kissoon N, Rubiano AM, Shutter L, Tasker RC, Vavilala MS, Wilberger J, Wright DW, Ghajar J. Guidelines for the Management of Severe Traumatic Brain Injury, Fourth Edition. Neurosurgery. 2017 Jan 01;80(1):6-15. [PubMed]

[19] Wang XP, Zhong J, Lei T, Wang HJ, Zhu LN, Chu S, Liu L. Epidemiology of traumatic brain injury-associated epilepsy in western China: An analysis of multicenter data. Epilepsy Res. 2020 Aug;164:106354. [PubMed]

[20] Brennan PM, Murray GD, Teasdale GM. Simplifying the use of prognostic information in traumatic brain injury. Part 1: The GCS-Pupils score: an extended index of clinical severity. J Neurosurg. 2018 Jun;128(6):1612-1620. [PubMed]

[21] Charry JD, Falla JD, Ochoa JD, Pinzón MA, Tejada JH, Henriquez MJ, Solano JP, Calvache C. External Validation of the Rotterdam Computed Tomography Score in the Prediction of Mortality in Severe Traumatic Brain Injury. J Neurosci Rural Pract. 2017 Aug;8(Suppl 1):S23-S26. [PMC free article] [PubMed]

[22] Zhou Q, Rosengart MR, Billiar TR, et al. Factors Associated With Nontransfer in Trauma Patients Meeting American College of Surgeons' Criteria for Transfer at Nontertiary Centers. JAMA Surg 2017;152:369-76. [Crossref] [PubMed]

[23] Farach SM, Walford NE, Bendure L, et al. Helicopter Transport From the Scene of Injury: Are There Improved Outcomes for Pediatric Trauma Patients? Pediatr Emerg Care 2017. [Epub ahead of print]. [Crossref] [PubMed]

[24] Carney N, Totten AM, O'Reilly C, et al. Guidelines for the Management of Severe Traumatic Brain Injury, Fourth Edition. Neurosurgery 2017;80:6-15

[25] Reith FC, Van den Brande R, Synnot A, et al. The reliability of the Glasgow Coma Scale: a systematic review. Intensive Care Med 2016;42:3-15. [Crossref] [PubMed

[26] Savitsky B, Givon A, Rozenfeld M, et al. Traumatic brain injury: It is all about definition. Brain Inj 2016;30:1194-200. [Crossref] [PubMed]

[27] Bauman ZM, Ruggero JM, Squindo S, et al. Repeat Head CT? Not Necessary for Patients with a Negative Initial Head CT on Anticoagulation or Antiplatelet Therapy Suffering Low-Altitude Falls. Am Surg 2017;83:429-35. [PubMed]

[28] Holmes JF, Siglock BG, Corwin MT, et al. Rate and Reasons for Repeat CT Scanning in Transferred Trauma Patients. Am Surg 2017;83:465-9. [PubMed]

[29] Hill EP, Stiles PJ, Reyes J, et al. Repeat head imaging in blunt pediatric trauma patients: Is it necessary? J Trauma Acute Care Surg 2017;82:896-900. [Crossref] [PubMed]

[30] Phan K, Moore JM, Griessenauer C, et al. Craniotomy Versus Decompressive Craniectomy for Acute Subdural Hematoma: Systematic Review and Meta-Analysis. World Neurosurg 2017;101:677-85.e2. [Crossref] [PubMed]

[31] Zyck S, Toshkezi G, Krishnamurthy S, et al. Treatment of Penetrating Nonmissile Traumatic Brain Injury. Case Series and Review of the Literature. World Neurosurg 2016;91:297-307. [Crossref] [PubMed]

[32] Bizhan A, Mossop C, Aarabi JA. Surgical management of civilian gunshot wounds to the head. Handb Clin Neurol 2015;127:181-93. [Crossref] [PubMed]

[33] Hutchinson PJ, Kolias AG, Timofeev IS, et al. Trial of Decompressive Craniectomy for Traumatic Intracranial Hypertension. N Engl J Med 2016;375:1119-30. [Crossref] [PubMed]

[34] Honeybul S, Ho KM, Blacker DW. ORACLE Stroke Study: Opinion Regarding Acceptable Outcome Following Decompressive Hemicraniectomy for Ischemic Stroke. Neurosurgery 2016;79:231-6. [Crossref] [PubMed]
[35] Zhao HX, Liao Y, Xu D, et al. Prospective randomized evaluation of therapeutic decompressive craniectomy in severe traumatic brain injury with mass lesions (PRECIS): study protocol for a controlled trial. BMC Neurol 2016;16:1. [Crossref] [PubMed]
[36] Honeybul S, Ho KM, Lind CRP, et al. The current role of decompressive craniectomy for severe traumatic brain injury. J Clin Neurosci 2017;43:11-15. [Crossref] [PubMed]
[37] Fong R konakondla S,Shirmer CM, Lacroix M. surgical interventions for severe traumatic brain injury. J Emerg Crit Care Med 2017;1:28.