Timing of long bone fracture fixation in severe traumatic brain injury

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ABSTRACT

يتطرق هذا المقال إلى مراجعه الأدلة في الأبحاث المنشورة عن التوقيت المثالي لتثبيت كسور العظام الطويلة عند المرضى الذين يعانون من إصابة الرأس الشديدة والذي لا يزال موضوع للنقاش. ولقد قمنا بدراسة 15 دراسة استرجاعية (مستوى الأدلة 2-3). وقد استنتجنا أثناء المراجعة بأن الأدلة في الأبحاث المنشورة لا تعطي إجابة قاطعة لمسألة التوقيت المثالي لتثبيت كسور العظام الطويلة في حالات إصابات الدماغ الشديدة، ونحن بحاجة إلى دراسة عشوائية مقارنة لبحث هذا الموضوع. ويقترح المؤلفان إتباع إستراتيجية تجمع بين جراحه السيطرة على التلف مع فترة مراقبة للضغط داخل القحف، وضغط التروية الدماغية، وتوفر مستوى الأوكسجين في الأنسجة الدماغية حتى يصبح وضع المريض مناسباً لعملية التثبيت.

We present a review of the published evidence on the optimal timing for long bone fracture fixation in severe traumatic brain injury (TBI); a matter that remains under debate. Fifteen retrospective articles (level II-3 evidence) were considered suitable for the review. We conclude that the published evidence does not provide a definitive answer to the optimal timing of long bone fracture surgery in severe TBI, and a randomized controlled trial is required. We recommend a safe strategy that combines damage control surgery with a period of monitoring of intracranial pressure, cerebral perfusion pressure, and if available brain tissue oxygen until the patient is considered fit for the fracture fixation.

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The timing of definitive fixation of long bone fracture in multi-trauma patients has been the subject of debate for many years. In this review, we attempt to examine the published evidence on the optimal timing for long bone fracture fixation in patients with severe traumatic brain injury (TBI). In addition, we will discuss a safe strategy for the management of long bone fractures in patients with severe TBI.

Pathophysiology. Primary TBI is usually the result of the mechanical forces applied to the brain at the time of impact that lead to neuronal damage, diffuse axonal injury, intracranial contusions, and hemorrhages (**Figure 1**). The pathophysiology of TBI is fairly complex. This is because following the trauma, several inflammatory processes and cascades are initiated with release of brain-derived proinflammatory mediators and a chain reaction leading to exacerbation of the neuroinflammation.[1] As a result, the traumatized brain becomes susceptible to secondary insults particularly hypoxia and hypotension.[1-4]

The long bone fracture (**Figure 2**) is a condition that can be associated with significant blood loss, injury to the adjacent soft tissues, systemic release of inflammatory processes that involve neutrophil "priming" and activation as well as activation of the coagulation cascade and the complement system.[1,2] Long bone fracture is usually treated by internal fixation (IF). When the operation is carried out early, it is called Early Total Care Surgery (ETCS). The IF can be carried out late after an initial conservative management using a splint, traction, or after an initial damage control surgery (DCS) with an external fixator.[1,2,5]

Arguments for and against early fracture fixation. The advantages of ETCS for long bone fractures in patients with TBI are numerous and include reduction of noxious stimuli from the fracture site, and reduction of the soft tissue damage, muscle atrophy, and joint

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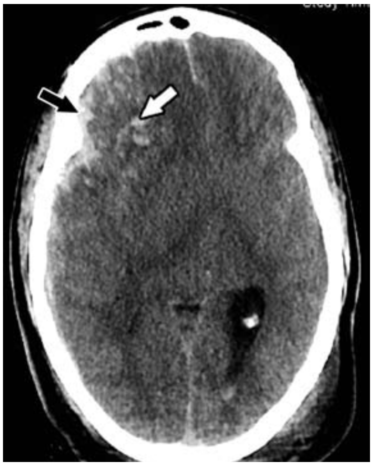

Figure 1 - A brain CT (plain) of a traumatic brain injury patient showing a right frontal acute subdural hematoma (black arrow), multiple petechial hemorrhages in the right frontal lobe (white arrow) with swelling of the right hemisphere and mass effect.

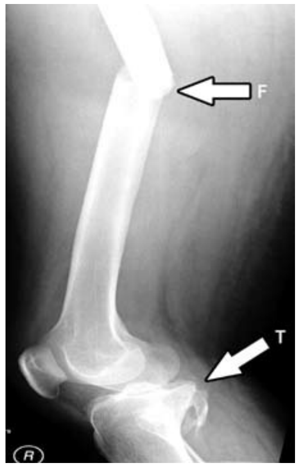

Figure 2 - Plain lateral radiograph of the right leg showing a mid shaft fracture of femur (arrow F) and a tibial plateau fracture (arrow T).

stiffness. In addition, ETCS reduces the risks of many complications including pulmonary embolism, fat embolism, gastrointestinal stasis, and pressure sores. It is also associated with easier nursing, earlier rehabilitation, and shorter hospital stay.[2,3,5] On the other hand; ETCS for long bone fractures in patients with TBI can be hazardous. It increases the risk of a secondary brain injury from cerebral ischemia due to intra-operative blood loss, hypotension, and uncontrolled rise in intracranial pressure (ICP). In addition, a secondary brain insult can be related to electrolyte imbalance and the lethal triad in trauma: coagulopathy, metabolic acidosis, and hypothermia.[1-5]

Review of published articles. We reviewed all the English language articles on TBI and long bone fractures with or without other injuries published over the last 2 decades. We selected only articles that reported patient series (not reviews), and included patient's neurological assessment and the timing of fracture surgery. The ETCS was defined as IF of a long bone fracture within the first 12-48 hours after the injury. "Late Surgery" (LS) was defined as IF any time after that. Using data from the various reports, we calculated the combined mortality rates for ETCS and LS for long bone fractures in TBI. In addition, we also calculated combined mortality rates for patients with severe TBI, patients with documented episodes of intra-operative raised ICP, and episodes of intra-operative hypotension and hypoxia.

We found 15 articles, all retrospective, suitable for inclusion.[6-20] **Table 1** summarizes the mortality rates for patients that had ETCS and LS in the various reviewed articles. The mean Injury Severity Score (ISS) in multiple trauma patients ranged from 23.3[14] to 35.[15,19] Eight articles reported patients with fractured femur only,[9,11,14-19] while 7 reported patients with fractures of any bone including the femur.[6-8,10,12,13,20] The time limit for ETCS was 24 hours in all reports except 2, which were 12 hours[6] and 48 hours.[9] The timing of LS ranged from 1-7 days for most patients.[9,12,13,15-17]

Eight articles reported patients with severe TBI (average Glasgow Coma Score [GCS] 4.4-8) only. The combined mortality rates for these patients were 11.3% in ETCS, and 20.5% in LS.[7,11,12,14-16,19,20] Seven articles

Table 1 - Mortality rates for ETCS and LS for long bone fractures in included published articles.

Author and Year	Total ETCS	Total LS	Mortality ETCS	Mortality LS
Kotwica et al,[6] 1990	51	49	7	11
Hoffman & Goris,[7] 1991	15	43	2	20
Poole et al,[8] 1992	46	26	2	0
Reynolds et al,[9] 1995	35	57	2	0
Jaicks et al,[10] 1997	19	14	2	0
McKee et al,[11] 1997	46	99	13	27
Velmhos et al,[12] 1998	22	25	1	2
Kalb et al,[13] 1998	84	39	8	3
Starr et al,[14] 1998	14	14	0	2
Townsend et al,[15] 1998	49	12	5	0
Scalea et al,[16] 2000	147	24	15	4
Brundage et al,[17] 2002	285	95	11	4
Nau et al,[18] 2003	28	120	9	42
Anglen et al,[19] 2003	10	7	1	0
Wang et al,[20] 2007	43	53	2	2
Total	**894**	**677**	**80** (8.9%)	**117** (17.3%)

*ETCS - early total care surgery, LS - late surgery included patients with a mixture of severe and moderate TBI.[6,8-10,13,17,18] The combined mortality rates for these patients were 7.5% in ETCS, and 15% in LS.

Five articles reported patients that had intra-operative episodes of raised ICP (more than 20 mm Hg).[13,15,16,19,20] The episodes were observed in 34% of patients who had ETCS, and in 28% of patients who had LS.[13,15,19,20] The combined mortality rates in the series that reported ICP monitored patients were 9% for ETCS, and 8% for LS.[13,15,16,19,20] Five articles reported patients that had intra-operative episodes of hypotension (systolic blood pressure less than 90 mm Hg) and hypoxia (oxygen saturation less than 90%).[10,12,13,15,20] The episodes were observed in 19% and 14% of patients who had ETCS, and in 18% and 11% of patients who had LS.[10,12,13,20] The combined mortality rates in the series that reported patients with intra-operative hypotension and hypoxia episodes were 8% for patients who had ETCS, and 5% for patients who had LS.[10,12,13,15,20]

Level of evidence in the literature. All the articles that compared ETCS with LS for long bone fractures in patients with TBI were retrospective, with no randomization and no controls. This indicates that the level of evidence in the literature on the subject is II-3 (US Preventive Services Task Force). The main limitation in these articles is that patients who had ETCS and LS for long bone fractures were not comparable. There was variation in their GCS and injury severity score, in the timing of LS and in the mixing of long bone fractures with other fractures.[6-20] The influence of this selection bias on mortality rates would explain the unexpected finding that the combined mortality rate in ETCS was lower than in LS for patients with TBI in general (**Table 1**) (8.9% versus 17.3%),[6-20] and for patients with severe TBI in particular (11.3% versus 20.5%).[7,11,12,14-16,19,20] However, amongst patients who had ETCS, those with severe TBI had a higher combined mortality rate than those with a mixture of moderate and severe TBI (11.3% versus 7.5%),[6-20] which is not surprising.

Based on the evidence in the literature, it is fair to say that at present there is no definitive answer to the optimal timing for long bone fracture surgery in patients with severe TBI. Results from articles that reported ICP monitored patients showed that ETCS was associated with slightly more intra-operative raised ICP episodes than LS.[13,15,16,19,20] Results from articles that reported patients who were monitored for hypotension and hypoxia during the IF showed that ETCS was associated with a slightly more intra-operative hypotension and hypoxia episodes than LS.[10,12,13,15,20] Such findings should be taken as evidence that ETCS for long bone fractures is potentially hazardous. In addition, the increase in our understanding of the TBI-related neuro-inflammation and the susceptibility of the injured brain to a second hit that can be caused by ETCS is of further support to this assumption.[1-5]

Strategy for the timing of fracture fixation. A safe approach for the management of long bone fractures in severe TBI would be to temporarily stabilize the fracture by DCS principles using an external fixator.[1,2,5,21] This procedure, compared with ETCS, is associated with reduction in operative time, in blood loss,[5] and in mortality rate.[21] In addition, following DCS the patients should undergo a period of monitoring of ICP, cerebral perfusion pressure (CPP), and if available, brain tissue oxygenation ($PbtO_2$).[22] The number of days of pre-IF monitoring is arguable, and can be tailored according to the individual case bearing in mind that in the multiply injured, the injury-hyper inflammatory response is usually reduced by 4 days.[1] Naturally, the IF can be carried out when the patient's circumstances become more optimal; normal hemodynamics, oxygenation (PaO_2/FiO_2>200), coagulation and an ICP, CPP (and if available PtO_2) remaining normal for at least 48 hours.[1,2,22] Adopting such a protocol will allow surgeons to standardize their approach to deciding on the optimal timing for long bone fracture fixation in patients with severe TBI.

In conclusion, the published evidence in the literature provides only retrospective observations of small patient cohorts, hence, the question of the optimal timing of long bone fracture fixation in patients with severe TBI cannot be definitely answered, and requires a multicentre prospective randomized controlled trial. In the mean time, modern safe neurosurgical standards necessitate that severe TBI patients should undergo initial DCS and a period of ICP, CPP (and if available $PbtO_2$) monitoring, until it is considered safe for them to undergo the IF.

References

1. Flierl MA, Stoneback JW, Beauchamp, Hak DJ, Morgan SJ, Smith WR, et al. Femur shaft fracture fixation in head injured patients: when is the right time? *J Orthop Trauma* 2010; 24: 107-114.
2. Pape HC, Tornetta P 3rd, Tarkin I, Tzioupis C, Sabeson V, Olson SA. Timing of fracture fixation in multitrauma patients: the role of early total care and damage control surgery. *J Am Acad Orthop Surg* 2009; 17: 541-549.
3. Gortz MRW, Giannoudis PV, Pape HC, Allami MK, Dinopoulos H, Krettek C. Traumatic brain injury and stabilisation of long bone fractures: an update. *Injury* 2004; 35: 1077-1086.
4. Giannoudis PV, Veysi VT, Pape HC, Krettek C, Smith MR. When should we operate on major fractures in patients with severe head injuries? *Am J Surg* 2002; 183: 261-267.

5. Tuttle MS, Smith WR, Williams AE, Agudelo JF, Hartshorn CJ, Moore EE, et al. Safety and efficacy of damage control external fixation versus early definitive stabilization for femoral shaft fractures in the multiple-injured patient. ***J Trauma*** 2009; 67: 602-605.
6. Kotwica Z, Balcewicz L, Jagodzinski Z. Head injuries coexistent with pelvic or lower extremity fractures-early or late osteosynthesis. ***Acta Neurochir (Wien)*** 1990; 102: 19-21.
7. Hoffman PA, Goris RJ. Timing of osteosynthesis of major fractures in patients with severe brain injury. ***J Trauma*** 1991; 31: 261-263.
8. Poole GV, Miller JD, Agnew SG, Griswold JA. Lower extremity fracture fixation in head-injured patients. ***J Trauma*** 1992; 32: 654-659.
9. Reynolds MA, Richardson JD, Spain DA, Seligson D, Wilson MA, Miller FB. Is the timing of fracture fixation important for the patients with multiple trauma. ***Ann Surg*** 1995; 222: 470-481.
10. Jaicks RR, Cohn SM, Moller BA. Early fracture fixation may be deleterious after head injury. ***J Trauma*** 1997; 42: 1-5.
11. McKee MD, Schemitsch EH, Vincent LO, Sullivan I, Yoo D. The effect of a femoral fracture on concomitant closed head injury in patients with multiple injuries. ***J Trauma*** 1997; 42: 1041-1045.
12. Velmhos GC, Arroyo H, Ramicone E, Cornwell EE 3rd, Murray JA, Asensio JA, et al. Timing of fracture fixation in blunt trauma patients with severe head injuries. ***Am J Surg*** 1998; 176: 324-329.
13. Kalb DC, Ney AL, Rodriguez JI, Jacobs DM, Van Camp JM, Zera RT, et al. Assessment of the relationship between timing of fixation of the fracture and secondary brain injury in patients with multiple trauma. ***Surgery*** 1998; 124: 739-745.
14. Starr AJ, Hunt JL, Chason DP, Reinert CM, Walker J. Treatment of femur fracture with associated head injury. ***J Orthop Trauma*** 1998; 12: 38-45.
15. Townsend RN, Lheureau T, Protetch J, Riemer B, Simon D. Timing of fracture repair in patients with severe brain injury (Glasgow Coma Scale <9). ***J Trauma*** 1998; 44: 977-982.
16. Scalea TM, Boswell SA, Scott JD, Mitchell KA, Kramer ME, Pollak AN. External fixation as a bridge to intramedullary nailing for patients with multiple injuries and femur fractures: damage control orthopedics. ***J Trauma*** 2000; 48: 613-621.
17. Brundage SI, McGhan R, Jurkovich GJ, Mack CD, Maier RV. Timing of femur fracture fixation: effect on outcome in patients with thoracic and head injuries. ***J Trauma*** 2002; 52: 299-307.
18. Nau T, Aldrian S, Koenig F, Vecsei V. Fixation of femoral fractures in multiple-injury patients with combined chest and head injuries. ***ANZ J Surg*** 2003; 73: 1018-1021.
19. Anglen JO, Luber K, Park T. The effect of femoral nailing on cerebral perfusion pressure in head-injured patients. ***J Trauma*** 2003; 54: 1166-1170.
20. Wang MC, Temkin NR, Deyo RA, Jurkovich GJ, Barber J, Dikmen S. Timing of surgery after multisystem injury with traumatic brain injury: effect on neurophysiological and functional outcome. ***J Trauma*** 2007; 62: 1250-1258.
21. Morshed S, Miclau T 3rd, Bembom O, Cohen M, Knudson MM, Colford Jr JM. Delayed internal fixation reduces mortality among patients with multisystem trauma. ***J Bone Joint Am*** 2009; 91: 3-13.
22. Narotam PK, Morrison JF, Nathoo N. Brain tissue oxygen monitoring in traumatic brain injury and major trauma; outcome analysis of a brain oxygen-directed therapy. ***J Neurosurg*** 2009; 111: 672-682.

Related articles

Karabekir HS, Balci C, Aktepe F, Tokyol C, Dilek H. Which is more effective in reducing secondary brain damage resulting from cyclooxygenase expression following traumatic brain injury: *calcium channel blockers or cox inhibitors?* ***Neurosciences (Riyadh)*** 2008; 13: 239-243.

Khaji A, Eftekhar B, Karbakhsh M, Ardalan KM. The use of head CT scanning in mild head injury. ***Neurosciences (Riyadh)*** 2006; 11: 248-251.

Elwatidy S. Bifrontal decompressive craniotomy for malignant brain edema. ***Neurosciences (Riyadh)*** 2006; 11: 241-247.

Jamil SA, Bhatti IH, Khan AS. Impact of prognostic factors on outcome in patients with severe head trauma. ***Neurosciences (Riyadh)*** 2003; 8: 248-249.