# Una revisión sistemática del monitoreo de la presión intracraneana en adultos con trauma craneoencefálico severo

## A systematic review of intracranial pressure monitoring in adults with severe traumatic brain injury

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**Resumen**

**Objetivos:** Revisar sistemáticamente la evidencia relacionada con el monitoreo de la presion intracraneana en unidades de cuidado neurocrítico en el contexto de trauma craneoencefálico severo. **Criterios de elección:** Ensayos clínicos aleatorizados que comparen el uso del monitoreo de la presión intracraneana (PIC) que muestren un estimado de mortalidad/discapacidad a 6 meses, en pacientes mayores de 12 años de edad con trauma craneoencefálico severo (escala de Glasgow menor a 8). **Método de búsqueda**: En Medline, el Registro Central de Ensayos Controlados (CENTRAL); PubMed, HINARI, EMBASE; Grupo Cochrane de Lesiones y las listas de referencias de artículos. De acuerdo con el Manual Cochrane para meta-análisis y revisión sistemática. **Resultados:** No hubo diferencias entre el grupo de PIC y el control en el pronóstico de discapacidad (RR [Riesgo Relativo]1.01, 95% CI 0.87 to 1.18). Sin embargo, el monitoreo de la PIC reduce la estancia en UCI en comparación con otros métodos. La estancia en UCI con tratamiento cerebral específico también se redujo en comparación con grupo control. **Conclusiones:** En pacientes con trauma craneoencefálico, no hubo diferencia entre el monitoreo de la PIC y el examen clínico sin embargo, para mantener una PIC baja, hubo una sustancial reducción de requerimiento de solución salina hipertónica y un descenso en la hiperventilación trayendo consigo beneficios para pacientes en UCI.

**Palabras clave:** Presión intracraneana, Monitoreo PIC, trauma craneoencefálico, traumatismos en la cabeza, lesión cerebral traumática, cuidado neurocrítico, neurotrauma, pronostico, mortalidad.

**Abstract**

**Objectives:** To systematically review the evidence of intracranial pressure monitoring in neuro critical care unit in the context of a severe head injury. **Study eligibility criteria:** Patients were older than 12 years ,had a severe traumatic brain injury (Glasgow coma scale < 8), that compared the use of ICP monitoring with control, that presented an estimate of mortality/ disability prognosis 6 months after injury.only randomized clinical trials. **Methods:** Searched MEDLINE, the Central Register of Controlled Trials (CENTRAL); PubMed, HINARI,EMBASE; Cochrane Injuries group and the reference lists of articles. In accordance with the Cochrane handbook for meta-analysis and systematic review. **Results:** In the ICP and control groups there was no difference in the prognosis of disability (RR [Relative Risk]1.01, 95% CI 0.87 to 1.18). However, ICP monitoring reduced the duration of stay in ICU compared to other surveillance methods. The stay in the ICU with specific medical support for brain injury was also reduced compared to the control group. **Conclusions:** In patients with severe traumatic brain injury, the ICP monitoring was not difference to imaging and clinical examination. However, by keeping the ICP low there was a substantial reduction in the requirement for hypertonic saline and a decrease in hyperventilation providing benefits to the patient in the ICU.

**Key words:** Intracranial Pressure, ICP monitoring, Traumatic Brain Injury, Head trauma, Brain injury, Neurocritical care, neurotrauma, prognosis, mortality.

## Introduction

Traumatic brain injury is a global public health problem that has great importance in the socioeconomic sphere. It is estimated that 57 million people have been hospitalized around the world with some degree of craniocerebral trauma, and at least 10 million cases result in hospitalization or death each year[1]. In 1991 the USA had 5.3 million people who were living with disabilities related to cranial trauma[2]. In 2010 the estimated cost of head trauma to the US economy amounted to approximately $76.5 billion[3,13].

In the last 10 years there have been many changes in the management of patients with cranial trauma, relating to the introduction of neurointensive care units, which have shown a substantial reduction in the risk of post-trauma mortality. The application of monitoring methods for early detection of treatable ischemic complications and the prevention of secondary brain injury improves the outcome of these patients. These new technologies have resulted in considerable innovations over the years, but intracranial and mean arterial pressure remain crucial in monitoring neurointensive care[4-14]. Does monitoring the levels of intracranial ventricular pressure and CSF drainage add to neurological examination and imaging, reducing complications (mortality, functional impairment and neuropsychological) in adults with severe craniocerebral trauma? Data from randomized controlled trials that rigorously monitor intracranial pressure in the treatment of traumatic brain injury are insufficient, and few stu-dies produce high-quality data using case-controlled trials. Historically, monitoring has been confounded by several factors including the participation of intensivists and the development of the sub-specialty of neuro critical care including; major improvements in resuscitation of trauma patients (in particular those with brain injuries); the myriad of developments in the management of traumatic brain injury during pre-hospital emergency care; urgent care and rehabilitation; and notable improvements in the techniques of control and management in the intensive care unit (ICU)[5-12-17-22].

## Methods

This article reports our systematic review in accordance with the Cochrane handbook for meta-analysis and systematic review furthermore QUORUM & PRISMA declarations[24,35].

### *Search strategy*

It was systematically searched MEDLINE, the Central Register of Controlled Trials (CENTRAL); PubMed (until March 2013); HINARI (until July 2014); EMBASE (until June 2013); Cochrane Injuries group (until June 2013) and the reference lists of articles. Randomized controlled trials and controlled clinical trials describing the control of intracranial pressure compared with controls were selected for potential inclusion. We constructed search filters for intracranial pressure (ICP) monitoring and traumatic brain injury (TBI) using a combination of exploded Medical Subject Heading (MeSH) terms and text words, all combined with Booleans operators. The search strategy is shown in the Appendix.

### *Inclusion criteria*

We have searched for studies that met the following inclusion criteria 1) patients were older than 12 years; 2) had a severe traumatic brain injury (Glasgow coma scale < 8); 3) that compared the use of ICP monitoring with control; 4) that presented an estimate of mortality/ disability prognosis (95% confidence interval) 6 months after injury.

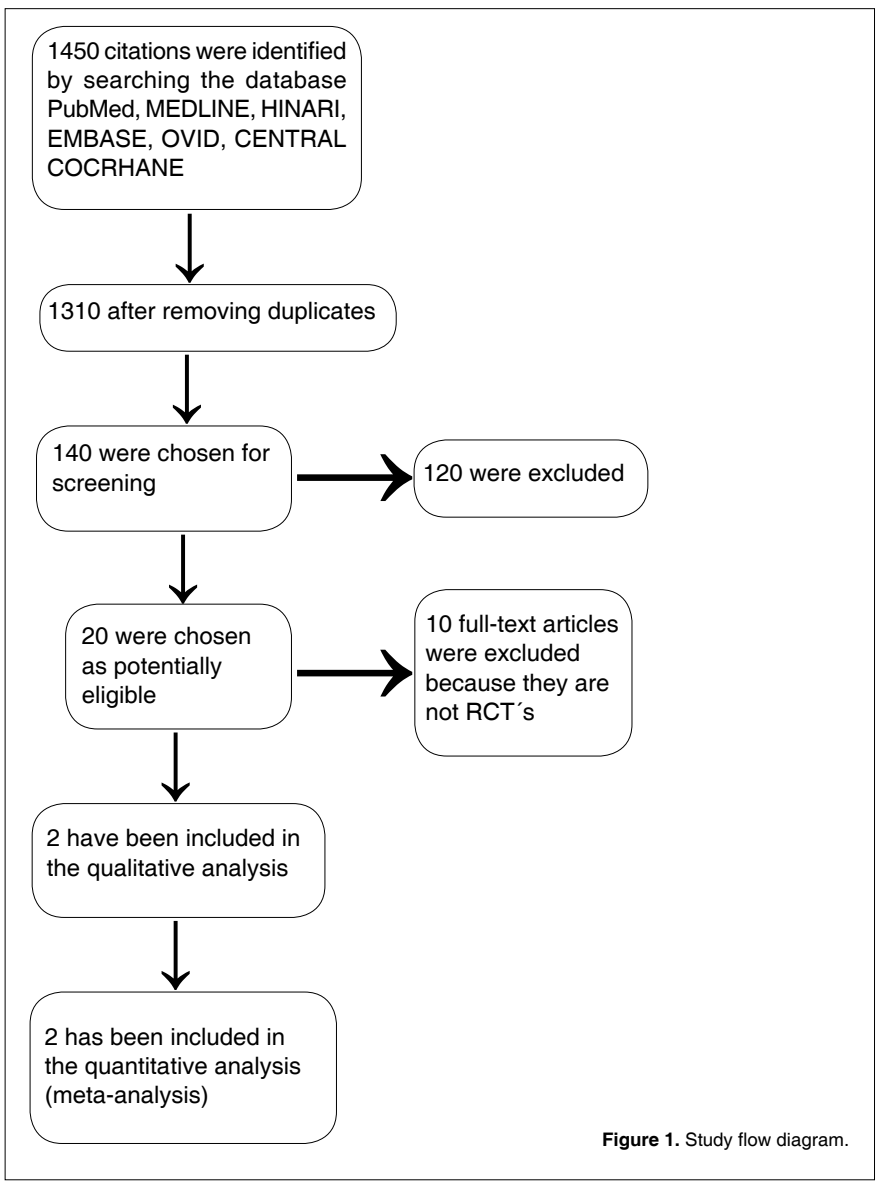


**Figure 1.** Study flow diagram.

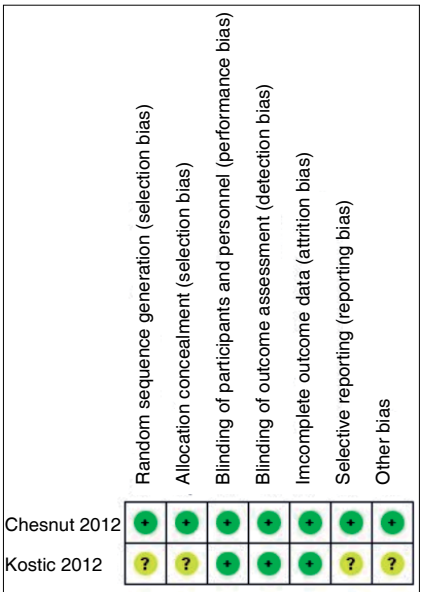


**Figure 2.** Risk of bias summary: review authors´ judgements about each risk of bias item for each included study.

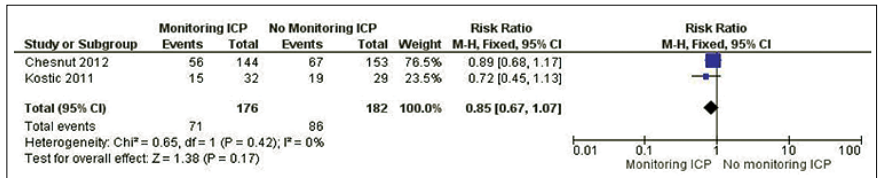


**Figure 3.** Forest plot of comparison: 1 Monitoring Intracranial Pressure (ICP) *vs* No Monitoring ICP, outcome 1.1 Mortality to six mounth.

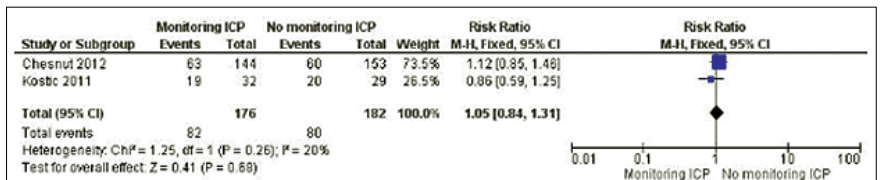


**Figure 4.** Forest plot of comparison: 1 Monitoring Intracranial Pressure (ICP) *vs* No Monitoring ICP, outcome 1.2 Good prognosis.

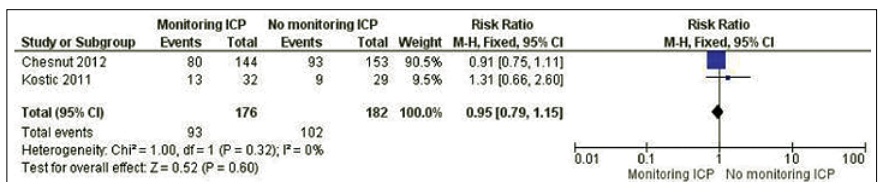


**Figure 5.** Forest plot of comparison: 1 Monitoring Intracranial Pressure (ICP) *vs* No Monitoring ICP, outcome 1.3 Poor prognosis.

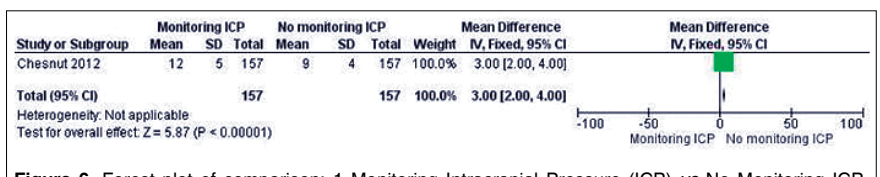


**Figure 6.** Forest plot of comparison: 1 Monitoring Intracranial Pressure (ICP) *vs* No Monitoring ICP, outcome 1.4 duration of stay in ICU.

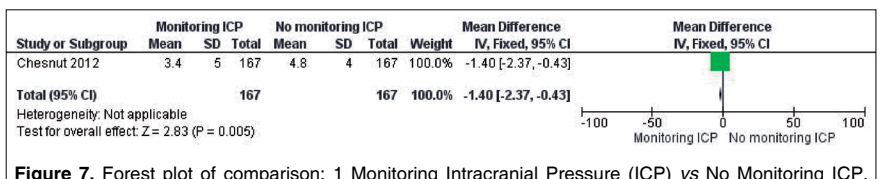


**Figure 7.** Forest plot of comparison: 1 Monitoring Intracranial Pressure (ICP) *vs* No Monitoring ICP, outcome 1.5 stay in ICU specific medical support for brain injuries.

### *Search criteria*

In duplicate and independently, two peoples screened all articles using the following inclusion criteria 1) patients were older than 12 years; 2) had a severe traumatic brain injury (Glasgow coma scale < 8); 3) that compared the use of ICP monitoring with control subjects; 4) that presented an estimate of mortality/disability prognosis (95% confidence interval) 6 months after injury.

### *Risk of bias assessment*

Risk of bias was assessed in accordance with the Cochrane handbook for meta-analysis and systematic review (Charter 10).

### *Data extraction*

In duplicate and independently the four peoples extracted the following data: mortality, duration of stay in critical care unit and the outcome at 6 months (Glasgow outcome score). The authors of the published research were contacted to obtain any missing data.

## Results

Searching the electronic databases identified 1,450 potential citations. However, 1,310 were discarded due to duplications and subject matter being out of field, leaving 140. These were screened where a further 120 were discarded. From the 20 potentially eligible publications a further 8 were discarded. The remaining 12 randomized controlled trials (RTC) were evaluated and the numbers reduced further until only two were selected for the qualitative and quantitative analysis (meta-analy-sis) (Figure 1). Study characteristics, outcome, and clinical variables are lis-ted in Table 1.

### *Assessment of methodological quality and risk bias*

The two publications selected were Chesnut (2012) and Kostic (2011). The work by Chesnut (2012) is categorized as “low risk” in all elements. The work of Kostic (2011) is categorized as “not a

**Table 1.**
**Characteristics of included studies**

| Author year, patients numbers | Study desing | Exclusion criteria | ICP monitored | Type of ICP monitor | Outcome ICP group | Evidence quality |
|---|---|---|---|---|---|---|
| Kostic 2011 N = 61 | RCT | Died before admission hospital | 32 (52,45%) | Not specified | Mortality disability | ++++ HIGH |
| Chesnut 2012 N = 324 | RCT | Dead in 24 Hours | 157 (48,45%) | EVD 100% | Mortality disability | ++++ HIGH |
| Shown study type, clinic outcome and quality of evidence form included studies. | | | | | | |

clear risk" in random sequence generation and allocation concealment, selective reporting and other bias, but "low risk" in all other items (Figure 2).

***ICP monitoring and mortality***
There was no significant reduction in mortality (RR 0.85, 95% CI 0.67 to 1.07) and no heterogeneity between the trials (I 2 = 0%, P = 0.42 $Chi^2$ P = 0.17) when comparing ICP monitoring with the controls (Figure 3).

***ICP monitoring and neuropsychological prognosis***
There were no differences in the prognosis of neuropsychological function (RR 1.01, 95% CI 0.87 to 1.18) when comparing ICP monitoring with the controls (Figures 4 and 5).

***Stay in ICU***
ICP monitoring shows greater efficacy compared to no monitoring, reducing the duration of stay in ICU (RR 3, 95% CI: 2-4), which reached statistical significance (P ≤ 0.001). The duration of stay in ICU with specific medical support for brain injuries was also reduced compared to the control group (P = 0.0001, 95% CI -1.4 -2,3 RR -0.43) (Figures 6 and 7).

## Discussion

Although conflicting results were found regarding the effect of the protocol for trauma-based ICP monitoring and clinical and imaging by reviewing the global scientific literature, overall the reports recommend the use of these procedures. The descriptive cohort studies showed a positive effect on the implementation of a strict monitoring of ICP compared to imaging and clinical monitoring alone. Balestreri et al. (2006), reported that strict monitoring of ICP or by clinical monitoring of cerebral perfusion pressure (pupils, reflections stem, fundus, mean arterial pressure led to a substantial reduction in mortality. They considered the two methods to be complementary and recommend applying both procedures. However, these studies fail to demonstrate whether these methods are preventive as the evidence is of poor quality and strength.
In two double-blind randomized clinical trials published by Kostic et al. (2011) and Chesnut et al. 2012, it was evident that ICP monitoring did not improve the prognosis of the neuropsychological function (RR 1.01; 95% CI: 0.87 1.18), but it did lead to improved efficiency compared to any other surveillance method and reduced the length of stay in the ICU (RR 3, 95% CI: 2-4), reaching statistical significance (P ≤ 0.001). Also, the duration of stay in the ICU with specific medical support for brain injury was reduced compared to the control group (P = 0.0001; RR 1.4 95 -2.3 -0.43%). Relating to complications, there were no significant differences in either group, nor were there differences in the requirement for neurosurgery (RR 0.93, 95% CI 0.81 to 1.07, P = 0.33). The group who developed intracranial hypertension had a high mortality with poor prognosis. The average value of ICP was 17.25 mmHg.
A systematic review by Shao Hua et al. (2014), was conducted in patients that had suffered severe head injuries. However, the evidence presented in their study did not include the duration of stay in the ICU, the brain specific treatment, the need for neurosurgery, the need for specific treatment or the value of the ICP[36].

## Conclusions

The monitoring of intracranial pressure no had an impact in terms of mortality. It also showed benefits in reducing polypharmacy and the number of interventions. We recommend maintaining the intracranial pressure below 16 mm Hg, but there is a lack of quality studies that provide better evidence. Further research should involve analysis of other diagnostic methods such as ultrasound or the measurement of cerebral perfusion.

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**Appendix. Search strategy**

**PUBMED**

#1Craniocerebral Trauma [mh] OR Brain Edema [mh] OR Glasgow Coma Scale [mh] OR Glasgow Outcome Scale [mh] OR Unconsciousness [mh] OR Cerebrovascular Trauma [mh] OR ((head or cranial or cerebral or brain* or intra-cranial or inter-cranial) AND (haematoma* or hematoma* or haemorrhag* or hemorrhage* or bleed* or pressure)) OR (Glasgow AND scale) OR ("diffuse axonal injury" OR "diffuse axonal injuries") or ("persistent vegetative state") OR ((unconscious* OR coma* OR concuss*) AND (injury*OR injuriesOR traumaOR damage OR damagedOR wound* OR fracture*OR contusion* OR haematoma*OR hematoma* OR haemorrhag* OR hemorrhag* OR bleed* OR pressure))
#2((randomized controlled trial[pt]OR controlled clinical trial[pt])OR (randomizedOR randomised OR randomly OR placebo[tiab]) OR (trial[ti]) OR ("Clinical Trials as Topic"[MeSH Major Topic])) NOT (("Animals"[Mesh]) NOT ("Humans"[Mesh] AND "Animals"[Mesh]))
#3(intracranial AND pressure) OR (cerebrospinal AND pressure)
#4(patient AND monitor*) OR (physiologic* AND monitor*)
#5#1 AND #2 AND #3 AND #4

COCHRANE INJURIES GROUP'S

("intracranial pressure" or "cerebrospinal pressure" or "cerebrospinal fluid") and (monitor*) and (traumatic brain injury OR head trauma OR Craniocerebral Trauma OR head injuries OR Brain injuries)

COCHRANE CENTRAL REGISTER OF CONTROLLED TRIALS

#1MeSH descriptor Craniocerebral Trauma explode all trees
#2MeSH descriptor Cerebrovascular Trauma explode all trees
#3MeSH descriptor Brain Edema explode all trees
#4(brain or cerebral or intracranial) next (oedema or edema or swell*)
#5MeSH descriptor Glasgow Coma Scale explode all trees
#6MeSH descriptor Glasgow Outcome Scale explode all trees
#7MeSH descriptor Unconsciousness explode all trees
#8glasgow next (coma or outcome) next (score or scale)
#9(Unconscious* or coma* or concuss* or 'persistent vegetative state') near5 (injur* or trauma* or damag* or wound* or fracture*)
#10"Rancho Los Amigos Scale"
#11(head or crani* or cerebr* or capitis or brain* or forebrain* or skull* or hemispher* or intra-cran* or inter-cran*) near3 (injur* or trauma* or damag* or wound* or fracture* or contusion*)
#12Diffuse next axonal next injur*
#13(head or crani* or cerebr* or brain* or intra-cran* or inter-cran*) near3 (haematoma* or hematoma* or haemorrhag* or hemorrhag*or bleed* or pressure)
#14MeSH descriptor Coma explode all trees
#15(#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #14)
#16MeSH descriptor Intracranial Pressure explode all trees
#17MeSH descriptor Cerebrospinal Fluid Pressure explode all trees
#18intracranial near3 pressure
#19cerebrospinal near5 pressure
#20(#16 OR #17 OR #18 OR #19)
#21MeSH descriptor Monitoring, Physiologic explode all trees
#22(patient near3 monitor*) or (physiologic* near3 monitor*)
#23monitor*:ti,ab
#24(#21 OR #22 OR #23)
#25(#15 AND #20 AND #24)

EMBASE

1.exp Brain Injury/
2.exp Brain Edema/
3.exp Glasgow Coma Scale/
4.exp Glasgow Outcome Scale/
5.exp Rancho Los Amigos Scale/
6.exp Unconsciousness/
7.((brain or cerebral or intracranial) adj5 (oedema or edema or swell*)).ab,ti.
8.((head or crani* or cerebr* or capitis or brain* or forebrain* or skull* or hemispher* or intra-cran* or inter-cran*) adj5 (injur* or trauma* or damag* or wound* or fracture* or contusion*)).ab,ti.

9.(Glasgow adj (coma or outcome) adj (scale* or score*)).ab,ti.
10.Rancho Los Amigos Scale.ab,ti.
11.((unconscious* or coma* or concuss* or 'persistent vegetative state') adj3 (injur* or trauma* or damag* or wound* or fracture*)).ti,ab.
12.Diffuse axonal injur*.ab,ti.
13.((head or crani* or cerebr* or brain* or intra-cran* or inter-cran*) adj3 (haematoma* or hematoma* or haemorrhag* or hemorrhag*
or bleed* or pressure)).ab,ti.
14.exp Coma/
15.or/1-14
16.exp Intracranial Pressure/
17.exp Cerebrospinal Fluid Pressure/
18.(intracranial adj3 pressure).ab,ti.
19.(cerebrospinal adj5 pressure).ab,ti.
20.16 or 17 or 18 or 19
21.exp Patient Monitoring/
22.((physiologic* adj3 monitor*) or patient* monitor*).ab,ti.
23. 21 or 22
24.23 and 20
25.exp Intracranial Pressure Monitoring/
26.24 or 25
27.26 and 15
30.exp Randomized Controlled Trial/
31.exp controlled clinical trial/
32.randomi?ed.ab,ti.
33.placebo.ab.
34.*Clinical Trial/
35.randomly.ab.
36.trial.ti.
37.28 or29 or 30 or 31 or 32 or 33 or 34
38.exp animal/ not (exp human/ and exp animal/)
39.36 not 37
40.28 and 38

MEDLINE

1.exp Craniocerebral Trauma/
2.exp Brain Edema/
3.exp Glasgow Coma Scale/
4.exp Glasgow Outcome Scale/
5.exp Unconsciousness/
6.exp Cerebrovascular Trauma/
7.((head or crani* or cerebr* or capitis or brain* or forebrain* or skull* or hemispher* or intra-cran* or inter-cran*) adj5 (injur* or trauma* or damag* or wound* or fracture* or contusion*)).ab,ti.
8.((head or crani* or cerebr* or brain* or intra-cran* or inter-cran*) adj5 (haematoma* or hematoma* or haemorrhag* or hemorrhag*
or bleed* or pressure)).ti,ab.
9.(Glasgow adj (coma or outcome) adj (scale* or score*)).ab,ti.
10."rancho los amigos scale".ti,ab.
11.("diffuse axonal injury" or "diffuse axonal injuries").ti,ab.
12.((brain or cerebral or intracranial) adj3 (oedema or edema or swell*)).ab,ti.
13.((unconscious* or coma* or concuss* or 'persistent vegetative state') adj3 (injur* or trauma* or damag* or wound* or fracture*)).ti,ab.
14.exp coma/
15.or/1-14
16.exp Intracranial Pressure/
17.exp Cerebrospinal Fluid Pressure/
18.(intracranial adj3 pressure).ab,ti.
19.(cerebrospinal adj5 pressure).ab,ti.
20.16 or 17 or 18 or 19

| |
|---|
| 21.exp Monitoring, Physiologic/<br>22.((patient adj3 monitor*) or (physiologic* adj3 monitor*)).ab,ti.<br>23.22 or 21<br>24.23 and 20 and 15<br>25.randomi?ed.ab,ti.<br>26.randomized controlled trial.pt.<br>27.controlled clinical trial.pt.<br>28.placebo.ab.<br>29.clinical trials as topic.sh.<br>30.randomly.ab.<br>31.trial.ti.<br>32.25 or 26 or 27 or 28 or 29 or 30 or 31<br>33.(animals not (humans and animals)).sh.<br>34.32 not 33<br>35.34 and 24 |
| **HINARI** |
| #1 Craniocerebral Trauma [mh] OR Brain Edema [mh] OR Glasgow Coma Scale [mh] OR Glasgow Outcome Scale [mh] OR Unconsciousness [mh] OR Cerebrovascular Trauma [mh] OR ((head or cranial or cerebral or brain* or intra-cranial or inter-cranial)<br>AND (haematoma* or hematoma* or haemorrhag* or hemorrhage* or bleed* or pressure)) OR (Glasgow AND scale) OR ("diffuse axonal injury" OR "diffuse axonal injuries") or ("persistent vegetative state") OR ((unconscious* OR coma* OR concuss*) AND (injury*OR injuriesOR traumaOR damage OR damagedOR wound* OR fracture*OR contusion* OR haematoma*OR hematoma* OR haemorrhag* OR hemorrhag* OR bleed* OR pressure))<br>#2 (randomized OR randomized OR randomly OR random order OR random sequence OR random allocation OR randomly allocated OR at random OR randomized controlled trial [pt] OR controlled clinical trial [pt] OR randomized controlled trials [mh]) NOT ((models, animal[mh] OR Animals[mh] OR Animal Experimentation[mh] OR Disease Models, Animal[mh] OR Animals, Laboratory[mh]) NOT (Humans[mh]))<br>#4 #1 and #2 |

## References


1. Alarcon JD, Rubiano AM, Chirinos MS, Valderrama A, Gich I, Bonfill X, et al. Clinical practice guidelines for the care of patients with severe traumatic brain injury: a systematic evaluation of their quality. J Trauma Acute Care Surg. 2013 Aug; 75(2): 311-319.
2. Barmparas G, Singer M, Ley E, Chung R, Malinoski D, Margulies D, et al. Decreased intracranial pressure monitor use at level II trauma centers is associated with increased mortality. Am Surg. 2012 Oct; 78(10): 1166-1171.
3. Alali AS, Fowler RA, Mainprize TG, Scales DC, Kiss A, de Mestral C, et al. Intracranial pressure monitoring in severe traumatic brain injury: results from the American College of Surgeons trauma quality improvement program. J Neurotrauma. 2013 Oct 15; 30(20): 1737-1746.
4. Balestreri M, Czosnyka M, Hutchinson P, Steiner LA, Hiler M, Smielewski P, et al. Impact of Intracranial Pressure and Cerebral Perfusion Pressure on Severe Disability and Mortality After Head Injury. Neurocrit Care. 2006; 4(1): 8-13.
5. Chesnut RM, Temkin N, Carney N, Dikmen S, Rondina C, Videtta W, et al. A trial of intracranial-pressure monitoring in traumatic brain injury. N Engl J Med. 2012 Dec 27; 367(26): 2471-2481.
6. Ponsford J, Draper K, Schönberger M. Functional outcome 10 years after traumatic brain injury: its relationship with demographic, injury severity, and cognitive and emotional status. J Int Neuropsychol Soc. 2008 Mar; 14(2): 233-242.
7. Lane PL, Skoretz TG, Doig G, Girotti MJ, Intracranial pressure monitoring and outcomes after traumatic brain injury. Can J Surg. 2000 Dec; 43(6): 442-448.
8. Saul TG, Ducker TB. Effect of intracranial pressure monitoring and aggressive treatment on mortality in severe head injury. J Neurosurg. 1982 Apr; 56(4): 498-503.
9. Narayan RK, Kishore PR, Becker DP, Ward JD, Enas GG, Greenberg RP, et al. Intracranial pressure: to monitor or not to monitor? A review of our experience with severe head injury. J Neurosurg. 1982 May; 56(5): 650-659.
10. Marshall LF, Smith RW, Shapiro HM. The outcome with aggressive treatment in severe head injuries. Part I: the significance of intracranial pressure monitoring. J Neurosurg. 1979 Jan; 50(1): 20-25.
11. Ropper AE, Chi JH. Treatment of traumatic brain injury without direct intracranial pressure monitoring. Neurosurgery. 2013 Apr; 72(4): N19-20.
12. Hesdorffer DC, Ghajar J, Iacono L. Predictors of compliance with the evidence-based guidelines for traumatic brain injury care: a survey of United States trauma centers. J Trauma. 2002 Jun; 52(6): 1202-1209.
13. Farahvar A, Gerber LM, Chiu YL, Carney N, Härtl R, Ghajar J. Increased mortality in patients with severe traumatic brain injury treated without intracranial pressure monitoring. J Neurosurg. 2012 Oct; 117(4): 729-734.
14. Griesdale DE, McEwen J, Kurth T, Chittock DR. External ventricular drains and mortality in patients with severe traumatic brain injury. Can J Neurol Sci. 2010 Jan; 37(1): 43-48.

15. Sahuquillo J,Arikan F. Decompressive craniectomy for the treatment of refractoryhigh intracranial pressure in traumatic brain injury (Review). Cochrane Database of Syst Rev, 2006 Jan 25; (1).
16. Barlow P, Mendelow AD, Lawrence AE, Barlow M, Rowan JO. Clinical evaluation of two methods of subdural pressure monitoring. J Neurosurg. 1985 Oct; 63(4): 578-582.
17. Guzmán F. Pathophysiology of traumatic brain injury. Colombia medica, vol. 39, no. 3, pp. 78-84, 2008.
18. Alted López E, Aznárez SB, Fernández MC. Updates on traumatic brain injury. Med Intensiva. 2009 Jan-Feb; 33(1): 16-30.
19. Bullock R, Chesnut RM, Clifton G, Ghajar J, Marion DW, Narayan RK, et al. Guidelines for the Management of Severe Traumatic Brain Injury. Eur J Emerg Med. 1996 Jun; 3(2): 109-127.
20. Tsang KK, Whitfield PC. Traumatic brain injury: review of current management strategies. Br J Oral Maxillofac Surg. 2012 Jun; 50(4): 298-308.
21. Stiefel MF, Spiotta A, Gracias VH, Garuffe AM, Guillamondegui O, Maloney-Wilensky E, et al. Reduced mortality rate in patients with severe traumatic brain injury treated with brain tissue oxygen monitoring. J Neurosurg. 2005 Nov; 103(5): 805-811.
22. Stendel R, Heidenreich J, Schilling A, Akhavan-Sigari R, Kurth R, Picht T, et al. Clinical evaluation of a new intracranial pressure monitoring device, Acta Neurochir (Wien). 2003 Mar; 145(3): 185-193.
23. idem, "Guidelines for the management of severe traumatic brain injury. VI. Indications or intracranial pressure monitoring" Journal of neurotrauma, 2007; 24(1): 37-44.
24. Mendelson AA, Gillis C, Henderson WR, Ronco JJ, Dhingra V, Griesdale DE. Intracranial pressure monitors in traumatic brain injury: a systematic review. Can J Neurol Sci. 2012 Sep; 39(5): 571-576.
25. Costa J, Claramunt E. Traumatismos craneanos. En: Fejerman N, Fernández-Álvarez E. Neurología pediátrica. Segunda edición. Buenos Aires, Argentina: Médica Panamericana; 1997. p. 735-738.
26. Stocchetti N, Maas AI. Traumatic intracranial hypertension. N Engl J Med. 2014 May 29; 370(22): 2121-2130.
27. Kingsley R. Concise text of Neuroscience, 2 ed. Lippincott Williams e Wilkins, Ed. 1999.
28. Nordström CH, Reinstrup P, Xu W, Gärdenfors A, Ungerstedt U. Assessment of the lower limit for cerebral perfusion pressure in severe head injuries by bedside monitoring of regional energy metabolism. Anesthesiology. 2003 Apr; 98(4): 809-814.
29. Guillaume J, Janny P. Manométrie intracrânienne continue: intérêt de la méthode et premiers résultats, Rev Neurol (Paris). 1951 Feb; 84(2): 131-142.
30. Lundberg N. Continuous recording and control of ventricular fluid pressure in neurosurgical practice. Acta Psychiatr Scand Suppl. 1960; 36(149): 1-193.
31. Bauer DF, Razdan SN, Bartolucci AA, Markert JM. Meta-analysis of hemorrhagic complications from ventriculostomy placement by neurosurgeons, Neurosurgery. 2011 Aug; 69(2): 255-260.
32. Ropper AH, Management of raised intracranial pressure and hyperosmolar therapy, Pract Neurol. 2014 Jun; 14(3): 152-158.
33. Roberts I, Sydenham E. Barbiturates for acute traumatic brain injury, Cochrane Database Syst Rev. 2012 Dec 12; 12.
34. Clifton GL, Coffey CS, Fourwinds S, Zygun D, Valadka A, Smith KR Jr. Early induction of hypothermia for evacuated intracranial hematomas: a post hoc analysis of two clinical trials. J Neurosurg. 2012 Oct; 117(4): 714-720.
35. Higgins JPT, Green S (editors). Cochrane Handbook for Systematic Reviews of Interventions. Version 5.1.0 [updated March 2011]. The Cochrane Collaboration, 2011. Available from www.cochrane-handbook.org.
36. Su SH, Wang F, Hai J, Liu NT, Yu F, Wu YF, et al. The Effects of Intracranial Pressure Monitoring in Patients with Traumatic Brain Injury. PLoS One. 2014 Feb 21; 9(2).

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