54 Guidelines for Treatment of Patients with Severe Traumatic Brain Injury

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Recommendations

Level I

There are insufficient data to support a Level I recommendation of a single treatment algorithm and a specific guideline for TBI patients.

Level II

There is no Level II evidence supporting the hypothesis that one of the described guidelines is superior to another.

Level III

There is Level III evidence supporting that care of patients should be performed in a specialized neurointensive care unit. There is Level III evidence from two smaller randomized studies giving support for the Lund therapy and one study giving support for the US guidelines.

54.1 Overview of Guidelines

54.1.1 Comparing Guidelines for the Adult

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	US guideline, 2016, updated version from 2007	European guidelines (EBIC)	Addenbrooke guidelines	Rosner protocol	Lund concept
CPP, blood pressure	CPP 60–70 mmHg	CPP > 60–70 mmHg MAP > 90 mmHg	CPP > 70 mmHg	CPP >70 mmHg	Optimal CPP 60–70 mmHg and min 50 mmHg in selected cases if normovolaemia. Blood pressure-reducing therapy is a recommended option
Ventilation	Volume-controlled normoventilation. Moderate hyperventilation at raised ICP	Volume-controlled hyperventilation to 4.0–4.5 kPa in OBS. May be intensified at high ICP	Volume-controlled hyperventilation at a raised ICP to 3.5–4.0 kPa in OBS if SjO2 > 55%	Hyperventilation accepted	Volume-controlled normoventilation
Oxygenation	PaO_2 > 8 kPa	PaO_2 12–13 kPa	Not specified	Not specified	PaO_2 12–13 kPa
Analgesics, sedatives	Not specified Barbiturate and propofol at high ICP	Yes. Not specified	Propofol, midazolam, fentanyl	Not specified	Deep sedation (midazolam, fentanyl,α_2 agonist). No wake-up tests Propofol in the weaning phase
ICP monitoring	If abnormal CT scan and unconscious	If considered desirable	All patients with severe TBI	All patients with severe TBI	All patients with severe TBI
ICP treatment initiated	ICP > 22 mmHg	ICP > 20–25 mmHg	ICP > 20–25 mmHg	Not specified	Early, independent of ICP
High-dose barbiturates	To control a high ICP if haemodynamically stable	To control a refractory high ICP	Burst suppression pattern to control a refractory high ICP	Not used	Not used. Low dose (1–3 mg/kg/h) for at most 2 days can be used at refractory significantly raised ICP
Hyperosmolar therapy	Mannitol to control a raised ICP, 0.25–1 g/kg Hypertonic saline is an option	Mannitol to control a raised ICP, S-Osm < 315 mosm	Mannitol to control a raised ICP, S-Osm < 320 mosm	Mannitol to control a raised ICP if CPP < 70 mmHg	Not used except to prevent acute brain stem herniation and to offer space during brain operation
CSF drainage	Not specified	Can be used	An option	Can be used to control CPP	Via ventricular drain from a relatively high drainage level to prevent ventricular collapse. CT control of ventricular size
Fluids/fluid balance, erythrocyte transfusion	Normovolaemia Fluids not specified	Normovolaemia. Fluids not specified. Hb > 110 g/L recommended	Normovolaemia. Fluids and optimal Hb values not discussed	Normovolaemia to moderate hypervolaemia Hct 30–35%	Normovolaemia with albumin 20% to be given slowly (s-alb 33–38 g/L) and erythrocytes (leucocyte-depleted blood) to Hb > 110 g/L (Hct 33%) Crystalloids 1–1.5 L/day

Vasopressors/ inotropy	Can be used to maintain CPP	Recommended to maintain CPP	Recommended to maintain CPP	Recommended to maintain a high CPP	If used, in lowest possible doses
Nutrition	Enteral or parenteral nutrition, full supply after 1 week	Early enteral feeding	Early enteral feeding	Not specified	Mainly enteral feeding. Full replacement (15–20 kcal/kg/d) from day 2
Antiseizure prophylaxis	Not recommended, but may be used in patients with high risk of seizure	Not recommended	Can be used	Not discussed	Not used
Surgical therapy		Evacuation of epidural/ subdural haematomas. Craniectomy in exceptional in exceptional cases			Evacuation of haematomas. Decompressive craniectomy when indicated to prevent brainstem herniation
Temp control	Active cooling is not recommended	Not discussed	Active cooling to 33 °C if CPP <70 mmHg and ICP > 25 mmHg	Not discussed	Normothermia. High fever treated pharmacologically. No active cooling

Comparison between various guidelines for treatment of severe isolated TBI in adults in terms of the latest updated version of US guidelines from 2016 (The Brain Trauma Foundation; The American Association of Neurological Surgeons; Congress of Neurological Surgeons 2016), the European Brain Injury Consortium's (EPIC) guidelines (Maas et al. 1997), the Addenbrooke guidelines from Cambridge (Menon 1999), the Rosner protocol (Rosner et al. 1995) and the Lund concept (Grände 2006, 2017)

54.1.2 The Brain Trauma Foundation Guidelines (US Guidelines) and the Lund Concept for Treatment of the Paediatric Population

There are two paediatric guidelines available. The Brain Trauma Foundation Guidelines from 2010, the principles later also published by Bell and Kochanek (2013), here called US guideline, and the Lund concept (Grände 2006, 2017). The US guidelines are mainly based on a meta-analytic approach, while the Lund concept has more of a physiological base.

54.1.2.1 Blood Pressure, CPP and Oxygenation

US guidelines: CPP = 40–65 mmHg. Min SBP 70 mmHg + $(2 \times \text{age})^2$, up to 1 year. Min systolic blood pressure (SBP) 90 mmHg + $(2 \times \text{age})^2$ above 1 year. $PaO_2 > 8$ kPa.

Lund concept: CPP > 38–50 mmHg depending on age from newborn up to 18 years of age. These values provide a normovolaemic condition. SBP not discussed. PaO_2 12–13 kPa.

54.1.2.2 Initiation of ICP Treatment

US guidelines: At an ICP > 20–22 mmHg.

Lund concept: Early independent of ICP to counteract an increase in ICP.

54.1.2.3 Use of Hyperventilation

US guidelines: No prophylactic hyperventilation. Mild hyperventilation 4.0–4.5 kPa at a raised ICP. More aggressive hyperventilation (OBS < 4.0 kPa) may be considered at resistant intracranial hypertension.

Lund concept: Normoventilation, preferably volume controlled.

54.1.2.4 CSF Drainage

US guidelines: An option at a refractory intracranial hypertension.

Lund concept: Intermittently with caution at a high ICP with drainage from a relatively high drainage level via ventricular drainage. CT control to detect and prevent ventricular collapse.

54.1.2.5 Hyperosmolar Therapy

US guidelines: Options for mannitol 0.25–1 g/kg to serum osmol <320 mosm/L and for hypertonic saline to serum osmol <360 mosm/L.

Lund concept: Not recommended. Exceptionally it can be used to prevent acute brainstem herniation, e.g. under transportation, and to offer space during brain operation.

54.1.2.6 Fluid/Fluid Balance and Erythrocyte Therapy

US guidelines: Normovolaemia. Type of fluids and how to verify normovolaemia is not specified.

Lund concept: Normovolaemia. Moderate crystalloid infusions combined with albumin 20% as the main plasma volume expander resulting in an albumin concentration of 32–38 g/L. The albumin infusion should be given slowly. Erythrocyte transfusion (leucocyte-depleted blood) to maintain a haemoglobin concentration of above 110 g/L.

54.1.2.7 Vasopressors

US guidelines: Vasopressors can be used to increase CPP and SPB.

Lund concept: Vasopressors should be used in lowest possible dose.

54.1.2.8 Sedation, Analgesics and Musculorelaxation

US guidelines: Sedation, analgesics and muscle relaxation not specified and left to the treating physician. No propofol.

Lund concept: Midazolam and fentanyl in doses adapted to the age and individually preventing stress and pain. No neuromuscular blockade and no propofol.

54.1.2.9 High-Dose Barbiturates

US guidelines: Can be used at a refractory high ICP.

Lund concept: Not recommended, but lower doses <2–3 mg/kg/h for at most 2 days can be used at a refractory raised ICP.

54.1.2.10 Steroids

US guidelines: Not used.

Lund concept: Not used. One moderate bolus dose of methylprednisolone can be accepted to reduce a life-threatening high fever.

54.1.2.11 Temperature Control

US guidelines: Active cooling to subnormal temperature may be used as brain protection. Hyperthermia should be avoided.

Lund concept: Active cooling should not be used. High fever treated pharmacologically.

54.1.2.12 Antiseizure Prophylaxis

US guidelines: May be used in patients with a high risk of seizure.

Lund concept: Not used.

54.1.2.13 Surgical

US guidelines: Decompressive craniectomy an option to control a refractory high ICP. Surgical evacuation of haematomas and contusions not discussed.

Lund concept: Evacuation of large haematomas and surgical available contusions. Decompressive craniectomy as a last measure to counteract a refractory high ICP.

Tips, Tricks and Pitfalls

- All guidelines for treatment of severe head injury should be looked upon with humbleness, and there must be an individual evaluation of the treatment to choose.

54.2 Background

54.2.1 Guidelines for the Adult

Various guidelines have been presented during the last 25 years for treatment of an isolated severe traumatic brain injury in the adult, of which the most important are presented in the table above. The Rosner protocol (Rosner et al. 1995) and the Lund concept (Asgeirsson et al. 1994) were presented in 1992–1995. The US guideline was presented in its first version in 1996 (Bullock et al. 1996). Other guidelines are the European guideline presented in 1997 (Maas et al. 1997) and the Addenbrooke guideline from Cambridge, England, presented in 1999 (Menon 1999). Elucidatory versions of the Lund concept have been published (Grände 2006, 2017) as well as several updated versions of the US guideline, the latest in 2007 and 2016 (The Brain Trauma Foundation; The American Association of Neurological Surgeons; Congress of Neurological Surgeons 2007, 2016). In addition, national guidelines such as the Danish (Welling et al. 2010) have been published. All guidelines except the Lund concept can be characterized as cerebral perfusion pressure (CPP)-targeted guidelines and show similarities with the US guidelines and are mainly based on meta-analytic surveys. The Lund concept instead is based on basal physiological principles for brain volume and perfusion control and can be characterized as an intracranial pressure (ICP) and perfusion-targeted therapy. While most traditional guidelines including US guidelines are based only on clinical studies, the Lund concept also finds support from experimental studies. None of the published guidelines have been tested in larger randomized controlled studies, but numerous investigations, some with historical controls, have been published both for the Lund concept and more conventional guidelines (Grände 2006; Gerber et al. 2013). Modified versions of the Lund therapy have been compared with more conventional treatments in two smaller randomized studies, showing better outcome with the Lund therapy (Liu et al. 2010; Dizdarevic et al. 2012). Also recent studies with the US guideline have shown good outcome results (Gerber et al. 2013). By now we cannot tell, however, that a specific guideline is better than another.

All guidelines recommend continuous measurement of arterial pressure and ICP as well as the use of artificial ventilation. No guideline recommends treatment with steroids, except that the Lund concept accepts one bolus dose of Solu-Medrol (0.25–0.5 g to the adult) to reduce a life-threatening critically raised body temperature (>39.5 °C). Active cooling is an option in some conventional guidelines, but not in the Lund concept (see Chap. 58). Normal potassium and sodium concentrations are generally recommended. A shift in the treatment paradigm has

emerged recently in many "non-Lund centres" by accepting a lower CPP, indicating that the guidelines have approached the Lund concept in some respects, even though the means to reach the goal are different (see Sect. 55.2 for details). Sedation should be sufficient to ameliorate the stress response. Wake-up tests are controversial, but still used in some centres.

There is a general recommendation that patients with severe head injury as soon as possible should be transferred to a neurosurgical unit. The patient should be intubated and receive intensive care treatment as recommended in the guidelines. There are some differences, though, regarding the intensive care treatment, as can be seen from the different guidelines in the table above. One difference is that US guidelines recommend that ICP treatment should not start before ICP is above 20–22 mmHg, while the Lund concept recommends that it should start as soon as possible after arrival to the neurointensive care unit independent of ICP. Focus should be to prevent hypovolaemia, avoidance of hypoxia, avoidance of hyper- or hypoglycaemia and avoidance of hyper- and hypoventilation. Enteral feeding is the goal. The intensive care should endeavour to ensure normality in most areas of the field, such as important physiological parameters.

54.3 Guidelines for the Paediatric Population

Little substantial research has been performed for the paediatric population, defined as <18 years of age. The paediatric brain injury remains poorly investigated. Treatment of children and adolescents therefore is mainly based on deductions from guidelines developed for adults. Important differences from the adult are lower blood pressure and lower peripheral resistance in the whole body, including the brain. This means that perfusion of various organs and the brain is maintained at blood and CPP pressures lower than those recommended for the adult. Like for the adult, enteral feeding is to be preferred. The need of energy/kg is much higher for children than for the adult. Specific recommendations for children and adolescents according to US guidelines are presented by the The Brain Trauma Foundation, Pediatric Guidelines (2010) and Bell and Kochanek (2013) and for the Lund concept (Wahlström et al. 2005; Grände 2006), while the other guidelines do not specifically address the paediatric population. As for the adult, the US paediatric guidelines are based on meta-analytic surveys of clinical studies and are a CPP-targeted therapy, and the Lund therapy is based on physiological principles for brain volume and brain perfusion regulation and is more of an ICP and perfusion-targeted therapy. The Lund concept also considers results from experimental studies.

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