# Chapter 6. Threshold for treatment of intracranial hypertension

## I. RECOMMENDATIONS

*A. Standards.* There are insufficient data to support a treatment standard for this topic.

*B. Guidelines.* There are insufficient data to support a treatment guideline for this topic.

*C. Options.* Treatment for intracranial hypertension, defined as a pathologic elevation in intracranial pressure (ICP), should begin at an ICP ≥20 mm Hg.

Interpretation and treatment of intracranial hypertension based on any ICP threshold should be corroborated by frequent clinical examination, monitoring of physiologic variables (e.g., cerebral perfusion pressure), and cranial imaging.

*D. Indications From Adult Guidelines.* There are insufficient data to support a treatment standard for this topic (1).

Treatment for intracranial hypertension should be initiated at an ICP upper threshold of 20–25 mm Hg.

Interpretation and treatment of intracranial hypertension based on any ICP threshold should be corroborated by frequent clinical examination and cerebral perfusion pressure (CPP) data.

## II. OVERVIEW

The effect of intracranial hypertension, or pathologically elevated ICP, on outcome after severe head injury in children appears to be related to both the absolute peak and duration of elevated ICP and the inverse relation between ICP and cerebral physiologic variables (e.g., cerebral perfusion and compliance). Quantitative guidelines for intracranial hypertension threshold values are needed for management of elevated ICP in children.

## III. PROCESS

We searched Medline and Healthstar from 1966 to 2001 by using the search strategy for this question (see Appendix A) and supplemented the results with literature recommended by peers or identified from reference lists. Of 62 potentially relevant studies, five were used as evidence for this question (Table 1).

## IV. SCIENTIFIC FOUNDATION

Specific thresholds of ICP for institution of therapy in children with severe traumatic brain injury (TBI) have not been established. However, it is clear that prolonged periods of intracranial hypertension or large increases in ICP are associated with poor outcome as evidenced in the following studies. It should be noted that in none of the cited studies did the authors prospectively address ICP treatment thresholds.

Pfenninger et al. (2) retrospectively reviewed the monitoring of ICP in 24 patients with severe TBI. They used a definition of ICP elevation as "persistently" >20–25 mm Hg. The goal of the treatment regimen they followed was to maintain ICP ≤20 mm Hg and abolish ICP elevations that were >25–30 mm Hg that lasted for >3 mins. They reported that extremely high, sustained ICP (>40 mm Hg) was associated with death ($p < .001$); ICP between 20–40 mm Hg was associated with moderate outcome (one dead, two severely disabled, 13 moderate or good); and ICP <20 mm Hg was associated with good outcome (one severely disabled, three moderate or good).

Esparza et al. (3) performed a retrospective review of 56 pediatric patients with severe TBI (defined as Glasgow Coma Scale score <8 for ≥6 after injury). They used a treatment threshold of ICP >20 mm Hg. Surgical evacuation of mass lesions was performed as needed, but no decompressive craniotomy was done. They found that the group of patients with ICP >20–40 mm Hg had a mortality rate of 28%, whereas the group with an ICP >40 mm Hg had a mortality rate of 100%.

Cho et al. (4) performed a retrospective review of 23 infants (mean age = 5.8 months) with TBI due to abusive head trauma. They found that outcome was worse with ICP >30 mm Hg compared with ICP <20 mm Hg or ICP >30 mm Hg treated with surgical decompression. They suggested that patients with ICP <30 mm Hg may be treated successfully with medical treatment only and that there is a role for decompressive craniotomy in patients with ICP >30 mm Hg.

Two additional studies described physiologic derangements associated with an ICP threshold >20 mm Hg. In a prospective study of 21 pediatric patients (mean age = 8 yrs) with severe TBI (Glasgow Coma Scale score <8), Sharples et al. (5) documented an inverse relation between elevations in ICP >20 mm Hg for ≥10 mins and cerebral blood flow (CBF) in 18 patients with ICP monitoring ($r = -.24$, $p = .009$). In only two cases was ICP >20 mm Hg associated with CBF equal to or above the normal range. In 66 simultaneous measurements of ICP and CBF, the authors found that the mean CBF = 0.57 $mL \cdot g^{-1} \cdot min^{-1}$ when the ICP was <20 mm Hg, whereas in 56 measurements the CBF was 0.47 $mL \cdot g^{-1} \cdot min^{-1}$ when the ICP was >20 mm Hg ($p = .037$). Shapiro and Marmarou (6) reported a retrospective, nonrandom case series of 22 children with TBI and ICP monitoring to determine a predefined "pressure-volume index" (PVI; i.e., a measure of cerebral compliance) produced by bolus withdrawal or injection into a ventriculostomy catheter. They defined intracranial hypertension as either an ICP >20 mm Hg for ≥10 mins or the presence of plateau waves or spot elevations >30 mm Hg in the ICP waveform with noxious stimulation. They found that ICP <20 mm Hg was associated with a PVI >80% of predicted; an ICP 21–40 mm Hg was associated with a PVI 60–80%; and ICP >40 mm Hg correlated with a PVI <60%. They concluded that elevated ICP >20 mm Hg was inversely correlated with PVI, supporting a relationship between intracranial hypertension and impaired cerebral compliance.

### Key Elements From the Adult Guidelines Relevant to Pediatric TBI

Initiation of ICP treatment at an upper threshold of 20–25 mm Hg was sup-

Table 1. Evidence table

| Reference | Description of Study | Data Class | Conclusion |
|---|---|---|---|
| Pfenninger et al. (2), 1983 | Retrospective review of 24 patients. Treatment threshold set at ICP persistently elevated >20–25 mm Hg. Severely sustained ICP >40 was associated with death. Moderately sustained or acute ICP elevations were not associated with outcome. | III | Supports using ICP >20–25 mm Hg as treatment threshold. |
| Esparza et al. (3), 1985 | Retrospective review of 56 patients with GCS <8. MVA (n = 40), fall (n = 14), child abuse (n = 2). Treatment protocol called for anti-intracranial hypertensive therapies at ICP >20. Mortality rate was 28% in ICP 20–40 mm Hg group vs. 100% in ICP >40 mm Hg group. Outcome was better in ICP <20 group (27 good, two poor) compared with ICP 20–40 (10 good and four poor) and ICP >40 (0 good and 13 poor). | III | Outcome was better if ICP <20 compared with ICP 20–40.<br>Poor outcome related to ICP >20–40 mm Hg.<br>Suggests that ICP >20 mm Hg is a valid treatment threshold. |
| Cho et al. (4), 1995 | Retrospective, single-center study of outcome following shaken baby syndrome in patients <2 yrs old. Patient groups were as follows:<br>(A) ICP <30 with medical treatment only (n = 6)<br>(B) ICP >30 with medical treatment only (n = 7)<br>(C) ICP >30 with surgical decompressive craniotomy (n = 10). Outcome was worse with ICP >30 mm Hg compared with ICP <20 mm Hg or ICP >30 mm Hg treated with surgical decompression. | III | Outcome was worse with ICP >30 mm Hg compared with ICP <20 mm Hg. |
| Shapiro and Marmarou (6), 1982 | Prospective nonrandom case series of 22 patients. ICP treatment threshold defined as ICP ≥20 × 10 min, plateau waves or spot elevations >30 mm Hg with noxious stimuli, or progressive increases in ICP >20 mm Hg. ICP <20 mm Hg was associated with PVI of >80% of predicted; ICP 21–40 mm Hg was associated with PVI 60–80%; and ICP >40 mm Hg correlated with PVI <60%. | III | Elevated ICP >20 mm Hg is inversely correlated with PVI.<br>Clinical signs of increased ICP >20 mm Hg are not always apparent. |
| Sharples et al. (5), 1995 | Prospective, descriptive study of 18 patients. Treatment threshold used was ICP >20 mm Hg for ≥10 min. Authors found an inverse relationship between CBF and ICP. In only two cases of ICP >20 mm Hg was CBF equal to or greater than the normal range. | III | CBF inversely related to ICP.<br>CBF data support use of ICP treatment threshold of >20 mm Hg to prevent cerebral ischemia. |

ICP, intracranial pressure; GCS, Glasgow Coma Scale; MVA, motor vehicle accident; PVI, pressure-volume index; CBF, cerebral blood flow.

ported as a treatment guideline (1). No prospective, randomized clinical trial directly compared ICP treatment thresholds and outcome. The largest study using prospectively collected, observational data, controlling for a large number of confounding prognostic variables, associated the mean ICP, in 5 mm Hg steps, with outcome in a logistic regression model and found 20 mm Hg to be the optimal threshold value predicting poor outcome. Multiple, small, noncontrolled reports suggested a range of 15–25 mm Hg of ICP. Only one prospective, double blind, multiple-center, placebo-controlled study in 73 patients demonstrated improved outcome when ICP could be controlled by using a threshold of 20 mm Hg (7). This study was class II with respect to outcome.

Patients may herniate at intracranial pressures <20–25 mm Hg. However, the likelihood of herniation depends on the location of an intracranial mass lesion. Thus, the choice of any threshold must be closely and repeatedly corroborated with the clinical examination and computed tomography imaging in an individual patient. The "Guidelines for the Management of [Adult] Severe Traumatic Brain Injury" (1) concluded that adequate CPP may be maintained in adults with intracranial pressures of >20–25 mm Hg. Thus, in select cases, a higher limit of acceptable ICP may be chosen as long as an adequate CPP can be maintained.

## V. SUMMARY

Current pediatric data support defining intracranial hypertension as pathologically elevated ICP ≥20 mm Hg and a treatment option setting an ICP of 20 mm Hg as an upper threshold above which treatment to lower ICP generally should be initiated. There have been some suggestions that lower values for younger children may be used, although there are no data to support this. Intracranial hypertension with pathologically elevated ICP following severe TBI in children increases morbidity and mortality.

## VI. KEY ISSUES FOR FUTURE INVESTIGATION

Specific threshold values of ICP for institution of therapy in pediatric age groups need to be clearly defined. Defining age-specific and injury-mechanism-specific ranges for ICP and CPP is vital for determining future treatment recommendations. For example, should a lower ICP treatment threshold of 15–20 mm Hg be used for infants? The critical value of ICP and its interaction with other cerebral physiologic variables are major unanswered questions.

As we recognize the importance of CPP and improve our ability to safely maintain an adequate CPP somewhat independent of ICP, the issue of an absolute value for ICP appears to be most closely related to the risk of herniation, which

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seems to vary between patients and within patients over the course of their therapy. A method to estimate this "herniation pressure" needs to be developed, and the range of values where CPP is independent of mean arterial and intracranial pressures needs to be determined.

Large, coordinated, multiple-center, randomized clinical trials are the best means of addressing many of these unanswered issues. A national database for severe TBI in children would be useful and provide important information.

## REFERENCES


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# APPENDIX: LITERATURE SEARCH STRATEGIES

### SEARCHED MEDLINE AND HEALTHSTAR FROM 1966 TO 2001

### Chapter 6. ICP Threshold

1. exp craniocerebral trauma/
2. head injur$.tw.
3. brain injur$.tw.
4. 1 or 2 or 3
5. intracranial pressure/ or "intracranial pressure".mp.
6. intracranial hypertension/ or "intracranial hypertension".mp.
7. 5 or 6
8. 4 and 7
9. limit 8 to (newborn infant <birth to 1 month> or infant <1 to 23 months> or preschool child <2 to 5 years> or child <6 to 12 years> or adolescence <13 to 18 years>)