Pediatr Surg Int (2006) 22: 215–218
DOI 10.1007/s00383-005-1560-0

ORIGINAL ARTICLE

Ryan E. Figg · Chadwick W. Stouffer
Wayne E. Vander Kolk · Robert H. Connors

# Clinical efficacy of serial computed tomographic scanning in pediatric severe traumatic brain injury

Accepted: 12 August 2005 / Published online: 18 November 2005


**Abstract** The purpose of this study is to determine whether serial computed tomography (CT) scans of the head lead to operative intervention in pediatric patients with severe traumatic brain injury (TBI). Serial CT scans are those done in addition to the initial CT scan and one follow up CT scan in the first 24–48 h. This study is a retrospective review from January 1990 to December 2003. The hospital course was reviewed for 942 pediatric patients with traumatic brain injuries. Of these, 40 patients were identified who met the following criteria: age less than 18, admission, Glasgow Coma Scale (GCS) ≤ 8, intra-cranial pressure (ICP) monitoring during hospitalization, no craniotomy at admission, and at least one serial CT scan after the first 48 h. One hundred fifteen serial CT scans were ordered. Eighty-seven were ordered for routine follow up, 24 were ordered for increased ICP, and 4 were ordered for neurologic change. One craniotomy and one burr hole were performed based on serial CT scans ordered for increased ICP. Serial CT scans, beyond the initial and follow-up scans, have a limited role in children with severe TBI. In this series, only serial CT scans ordered for increased ICP (21%) and neurologic deterioration (3%) led to operative interventions. Serial scans ordered for routine follow-up (76%) resulted in no operative interventions.

**Keywords** Traumatic brain injury · Computed tomography · Pediatric trauma

R. E. Figg · C. W. Stouffer (✉)
Medical Education and Research Center/MSU General Surgery Residency, 221 Michigan NE Suite 200A,
Grand Rapids, MI 49503, USA
E-mail: Stouff17@yahoo.com
Tel.: +1-616-3911691
Fax: +1-616-3918611

W. E. Vander Kolk
Department of Surgery, Michigan State University,
Grand Rapids, MI, USA

W. E. Vander Kolk
Trauma Service, Spectrum Health, 21 Michigan NE Suite 735,
Grand Rapids, MI 49503, USA

R. H. Connors
Department of Pediatric Surgery, DeVos Children's Hospital,
Michigan State University, 330 Barclay Ave. NE,
Grand Rapids, MI 49503, USA

## Introduction

Trauma is the leading cause of morbidity and mortality among children in the United States, with automobile accidents as the most common cause. Traumatic brain injury (TBI) is a very common component of pediatric trauma and results in an estimated 80% of pediatric traumatic deaths [1]. The cost of hospital care alone for pediatric TBI exceeds $1 billion per year [2].

In current trauma practice, computed tomography (CT) of the head is the initial study of choice to determine the amount and extent of intracranial damage in severe TBI (GCS ≤ 8). Adult studies have shown the presence of a CT scan abnormality has a positive predictive value of 78% with respect to unfavorable outcome in patients with severe head injury [3]. At presentation, if the patient is determined to have a nonsurgical injury, he or she is admitted to the ICU and monitored. The initial CT scan is often followed by a second follow up scan within 24–48 h of admission to monitor for acute progression of intracranial abnormality [4]. After the initial and follow up CT scans, if no neurosurgical intervention has been performed, further serial scans are ordered on a follow-up basis or because of changes in intracranial pressure (ICP) or clinical neurologic status.

The purpose of this study is to determine if serial CT scans lead to urgent neurosurgical operative intervention when performed on pediatric patients with severe TBI (GCS ≤ 8). Serial head CT scans are defined as all scans performed after the initial CT and one follow up study in the first 24–48 h after admission. The patients studied had ICP monitors placed within 48 h of admission and

were determined to be non-neurosurgical candidates based on initial workup.

## Materials and methods

This study is a retrospective review. During the period of January 1990 to December 2003, a total of 942 pediatric patients were identified from the trauma registry at our Level I trauma center as having a traumatic brain injury. From this group, 40 patients (age 2 months to 17 years) met inclusion criteria as follows: GCS score $\leq 8$, ICP monitor in place within 48 h of admission, at least one serial CT scan performed after the initial scan and follow up CT done in the first 48 h, no craniotomy as a result of the initial or follow up CT scans, and age less than 18. The subjects had all been admitted to the Pediatric Trauma service with active participation by the Neurosurgery and Pediatric Critical Care services. Each patient had a head CT at the time of admission and most had one follow up CT in the first 24–48 h of hospitalization. Age, sex, injury severity score, GCS, intensive care unit (ICU) length of stay (LOS), total hospital length of stay, days on the ventilator, mechanism of injury, and disposition were determined for each patient. Initial head CT scan interventions and diagnoses, 24–48 h follow up CT and serial CT scan timing, interventions, and results were recorded for each patient as well.

## Results

Forty patients who met inclusion and exclusion criteria were identified in the Spectrum Health level 1 trauma registry. A total of 115 serial CT scans were obtained on the 40 patients in the study (2.9 serial scans per patient). The most common cause of injury was motor vehicle collision (MVC), and the average injury severity scale score and GCS score were 30.2 and 5.1 respectively. The characteristics of the study group are listed in Table 1.

**Table 1** Patient characteristics ($n = 40$)

| Characteristics | |
|---|---|
| Gender (female:male) | 12:28 |
| Age (year) | 9.6 ± 4.4 |
| Injury severity scale | 30.0 ± 10.2 |
| Glasgow Coma Scale | 5.1 ± 1.5 |
| ICU LOS (day) | 18.7 ± 7.6 |
| Total LOS (day) | 22.3 ± 8.3 |
| Days on ventilator (day) | 14.9 ± 7.6 |
| Mechanism | |
| Fall | 2 |
| MVC | 33 |
| Other | 5 |
| Diagnosis | |
| TBI with polytrauma | 25 |
| Isolated closed head | 15 |
| Disposition | |
| Death | 2 |
| Nursing Home | 1 |
| Rehabilitation | 37 |

Quantitative data are expressed as mean ± SD

### Initial CT scan data

The diagnoses and interventions based on the initial CT scans were recorded and are listed in Table 2. The initial CT scan diagnoses were identified as follows: shear/diffuse axonal injury, intraparenchymal hematoma/contusion, subdural hematoma, and subarachnoid hemorrhage. Ninety percent of ICP monitors were placed after the initial CT scan.

### 24–48 h follow up CT scan data

The timing, intervention, and results of the 24–48 h repeat scan for each patient were recorded and are summarized in Table 3. The time to follow-up scan was recorded in days. Ten percent of ICP monitors were placed on the basis of follow-up scans. The results of the follow-up scans were recorded as improved, unchanged, or worsening.

### Serial CT scan data

The timing, reason for ordering, interventions based on, and results of the serial CT scans were recorded and are listed in Table 4. A total of 115 (average 2.9 per patient) serial CT scans were ordered.

The reasons for ordering the serial CT scans were divided as follows: increased ICP, neurologic deterioration or neurologic deficit, or planned/follow-up CT. Serial CT scans were most often ordered for routine follow-up (76% of serial scans).

Results of serial CT scans were recorded as follows: 53% of serial CT scans showed no change, 34% showed improvement, 13% showed worsening. Two (1.7%) of the serial CT scans resulted in neurosurgical operative intervention. Three (2.6%) of the serial CT scans resulted in additional ventriculostomy placements.

In our series, five patients had a surgical intervention based on the results of a serial CT scan (Table 5). Of these five scans, all were ordered based on a clinical parameter (ICP or neurologic status), not as routine

**Table 2** Initial CT scan data

| Intervention based on initial CT | |
|---|---|
| Non-surgical/ICP monitor placement | 36 |
| Non-surgical/No ICP monitor | 4 |
| Injuries diagnosed on initial CT | |
| Shear/Diffuse axonal injury | 7 |
| Intraparenchymal hematoma/contusion | 26 |
| Subarachnoid hematoma | 12 |
| Subdural hematoma | 5 |
| Epidural hematoma | 1 |

**Table 3** Twenty four to 48 h follow-up CT scan data

| Data | |
|---|---|
| Time of follow-up 24–48 h CT(d)[a] | 2.0 ± 0.5 |
| Intervention based on 24–48 h follow-up scan | |
| Non-surgical/ICP monitor placement | 4 |
| Results of 24–48 h follow-up CT | |
| Improvement | 1 |
| Unchanged | 19 |
| Worsening | 14 |

[a]Data are expressed as mean ± SD

**Table 4** Repeat (serial) CT scan data

| Data | |
|---|---|
| Time of repeat CT scans (day)[a] | 9.5 ± 5.3 |
| Reason for repeat CT scan | |
| Increased ICP | 24 |
| Neuro deterioration/Neuro deficit | 4 |
| Planned/follow-up CT | 87 |
| Interventions based on repeat CT | |
| Non-surgical/ICP monitor placement | 3 |
| Urgent operative intervention | 1 |
| Non-urgent operative intervention | 1 |
| Results of repeat CT | |
| Improvement | 39 |
| No change | 61 |
| Worsening | 15 |

[a]Data are expressed as mean ± SD

follow up. Patient one arrived with a GCS of seven and had an ICP monitor placed after the initial CT scan. On hospital day 4, a serial CT scan was performed for increased ICP. This scan led to an urgent craniotomy for increased epidural hematoma. Patient number two presented with a GCS of five and had placement of an ICP monitor after the first CT scan. A CT scan was done on day 4 due to increased ICP and resulted in the placement of a subdural drain. The third patient also had an initial GCS of 5 and an ICP monitor placed based on initial CT. On day 3, a ventriculostomy was performed based on a serial scan ordered for increased ICP. Patient four initially had a GCS of seven and a ventriculostomy placed after the repeat CT scan done 24 h after admission. On day 8, a serial scan was ordered for increased ICP and a contralateral ventriculostomy was placed based on these results. The final patient having intervention after a serial scan presented with a GCS of five and had a ventriculostomy placed initially. This was subsequently removed after a planned follow-up CT on day 7. On day 14, an urgent serial scan was ordered for neurologic deterioration and the results lead to replacement of the ventriculostomy.

The only serial CT scans that led to surgical intervention were those that were ordered based on a clinical finding-increased ICP or a change in neurologic status. The CT scans performed as planned follow up did not result in any surgical intervention.

## Discussion

Head CT scanning is considered the standard of care for pediatric trauma patients presenting with severe head injury [5–8]. On the basis of the results of the initial head CT scan, patients are either surgically managed or admitted for intensive care monitoring in the Pediatric Intensive Care Unit with Neurosurgical consultation. Multiple studies have shown that initial and follow up CT scanning within 24–48 h are sensitive for detecting intracranial lesions that have the potential to evolve toward mass lesions [8–11]. These evolving lesions consist of extraaxial hematomas and intracerebral hematomas. There have also been multiple recommendations for repeat scans after the initial head CT [8, 12, 13].

Recently Chao et al. [14] showed that with an unchanged or normal neurological examination, routine serial head CT scanning did not influence subsequent invasive neurosurgical intervention. In this study, 9 of 171 (5.3%) adult patients with blunt intracranial injury requiring invasive intervention had the intervention performed as a result of a head CT scan obtained after the initial head CT scan. Only one of the nine interventions was performed on the basis of a CT scan that was obtained after the initial and 24–48 h follow-up

**Table 5** Patients with surgical intervention based on serial CT scan

| Patient | Age | Initial GCS | Initial CT results | Day of serial CT | Reason for serial CT | Results of serial CT | Intervention |
|---|---|---|---|---|---|---|---|
| 1 | 3 | 7 | Epidural hematoma | 4 | Increased ICP | Increased epidural hematoma | Craniotomy |
| 2 | 7 month | 5 | Subarachnoid hemorrhage | 4 | Increased ICP | Increased extracerebral blood | Subdural Tap |
| 3 | 4 | 5 | Intraparenchymal hemorrhage | 3 | Increased ICP | Increased mass effect | Ventriculostomy |
| 4 | 8 | 7 | Intraparenchymal hemorrhage | 8 | Increased ICP | Increased mass effect | Ventriculostomy |
| 5 | 8 | 5 | Intraparenchymal hemorrhage | 14 | Decreased Neuro Status | Increased mass effect | Ventriculostomy |

scans in a patient with a GCS $\leq 8$ (the definition of a serial CT scan in our study). In a similar pediatric study by Tabori et al. [11], no interventions were performed after the 24–36 h repeat scan. But, 2 of 67 patients who had a third scan required a surgical intervention.

The goal of this study was to investigate whether serial CT scans beyond the initial scans performed in the first 48 h, in appropriately monitored pediatric patients, led to surgical intervention. In our patients, serial CT scans resulted in five invasive interventions, three of which were ventriculostomy placements. These results are significantly different from Chao's adult study in that a higher number of interventions were performed based on serial head CTs and the majority of serial CT scans leading to intervention were ordered for increased ICP, not for neurologic change.

In a recently published adult study from our institution [15], three serial scans which were ordered for routine-follow-up out of 117 total serial CT scans resulted in either ventriculostomy placement or hygroma drain placement. In the adult series, no interventions were performed based on serial scans ordered for increased ICP or neurologic change.

When ordering serial CT scans of the head, the risks of intrahospital transport of ICU patients and the increased cost of the scans must be considered. This is especially true in light of multiple studies that have shown dangers ranging from transient changes in hemodynamic parameters to full cardiopulmonary arrest associated directly with intrahospital transport of ICU patients [16–19]. An estimate of cost for the serial CT scans in this study was performed, taking into account the following: cost for performing the CT scan, radiologist charges, and the cost of nursing and transport personnel time. The total estimated cost for the 115 serial CT scans was $80,000. In addition, for each radiologic study, one must consider the detrimental effects of radiation exposure- especially in the pediatric population. Depending on specific technique, a non-contrast head CT delivers 2–3 rad to the patient [11].

In conclusion, in our series of pediatric traumatic brain injured patients, serial CT scans were most often ordered for routine follow up (76%). These routine serial CT scans did not result in any surgical interventions. Four serial scans ordered for increased ICP and one serial scan ordered for neurologic deterioration did result in neurosurgical intervention. Therefore, in this specific patient population, a highly selective approach to ordering serial CT scans should be practiced, with the understanding that only scans ordered for increased ICP or neurologic change are likely to lead to surgical interventions.

**Acknowledgement** This retrospective review was approved by the IRB of Spectrum health. The current study does comply with the current laws of the United States of America. No funding or grants were used for this study.

## References

1. Mayer T, Walker ML, Johnson DG et al (1981) Causes of mortality and morbidity in severe pediatric trauma. JAMA 245:719–721
2. Kraus JF, Rock A, Hemyari P (1990) Brain injuries among infants, children, adolescents and young adults. Am J Dis Child 144:684–691
3. Brain Trauma Foundation, American Association of Neurological Surgeons, Joint Section of Neurotrauma, Critical Care (2000) Computed tomography scan features. J Neurotrauma 7:597–627
4. Chin LS, Aldrich FE, DiPatri AJ, Eisenberg HM (2004) Neurosurgery. In: Beauchamp RD, Evers BM, Mattox KL (eds) Sabiston textbook of surgery, 17th edn. Elsevier, Philadelphia, pp 2152–2157
5. Committee on Trauma, American College of Surgeons (1997) Advanced trauma life support for doctors, student course manual, 6th edn. American College of surgeons, Chicago
6. Gruen JP, Weiss M (1996) Management of complicated neurologic injuries. Surg Clin North Am 76:905–922
7. Kobayashi S, Nakazawa S, Otsuka T (1983) Clinical value of serial computed tomography with severe head injury. Surg Neurol 20:25–29
8. Servadei F, Nanni A, Nasi MT et al (1983) Evolving brain lesions in the first 12 hours after head injury: analysis of 37 comatose patients. Neurosurgery 37:899–906
9. Clifton G Grossman R, Makela M, Miner M, Handl S, Sadhu V (1980) Neurological course and correlated computerized tomography findings after severe closed head injury. J Neurosurg 52:611–624
10. Cooper P (1993) Delayed traumatic intracerebral hemorrhage. Neurosurg Clin North Am 3:659–665
11. Tabori U, Kornecki A, Sofer S et al (2000) Repeat computed tomographic scan within 24–48 hours of admission in children with moderate and severe head trauma. Crit Care Med 28:840–844
12. Cope DN, Date ES, Mar EY (1988) Serial computerized tomography evaluations in traumatic head injury. Arch Phys Med Rehabit 69:483–486
13. Stein S, Spettell C (1995) Delayed and progressive brain injury in children and adolescents with head trauma. Pediatr Neurosurg 23:299–304
14. Chao C, Pearl J, Perdue P et al (2001) Utility of routine serial computed tomography for blunt intracranial injury. J Trauma 51:870–876
15. Figg RE, Burry TS, Vander Kolk WE (2003) Clinical efficacy of computed tomographic scanning in severe closed head injury patients. J Trauma 55:1061–1064
16. Evans A, Winslow EH (1995) Oxygen saturation and hemodynamic response in critically ill, mechanically ventilated adults during intrahospital transport. Am J Crit Care 4:106–111
17. Kanter RK, Boeing NM, Hannan WP, Kater DL (1992) Excess morbidity associated with intrahospital transport. Pediatrics 90:893–898
18. Smith I, Flemming S, Crenaianu A (1990) Mishaps during transport from the intensive care unit. Crit Care Med 18:278–281
19. Braman S, Dunn S, Amico C et al (1987) Complications of intrahospital transport in critically ill patients. Ann Intern Med 107:469–473