Evaluation of the Standardized Assessment of Concussion in a Pediatric Emergency Department
Joseph A. Grubenhoff, Michael Kirkwood, Dexiang Gao, Sara Deakynae and Joe Wathen
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Evaluation of the Standardized Assessment of Concussion in a Pediatric Emergency Department

WHAT’S KNOWN ON THIS SUBJECT: Mild traumatic brain injury (mTBI) is common among children, but there are no evidence-based tools that systematically quantify cognitive deficits and symptom severity for those in this age group. Better instruments to quantify severity and monitor recovery are needed.

WHAT THIS STUDY ADDS: Results of this study reveal that the graded symptom checklist in the SAC systematically quantifies the severity of symptoms of mTBI. They also reveal the interplay between somatic complaints and other measures of severity.

abstract

OBJECTIVE: The Standardized Assessment of Concussion (SAC) is a validated tool for identifying the effects of mild traumatic brain injury (mTBI). Previous research focused on sport-related sideline evaluation of adolescents and adults. Our goal was to evaluate performance of the SAC among subjects with and without head injury in a pediatric emergency department (ED). METHODS: This was an observational study of children 6 to 18 years of age who presented to an ED with blunt head injury (case-patients) or minor extremity injury (controls). SAC and graded-symptom-checklist scores were compared. American Academy of Neurology concussion grades, presence of loss of consciousness and posttraumatic amnesia were also compared with SAC and graded-symptom-checklist scores among case-patients. RESULTS: Three hundred forty-eight children were enrolled. SAC scores trended lower (greater cognitive deficits) for case-patients compared with controls but did not reach significance. Graded-symptom-checklist scores were significantly higher among case-patients. Presence of altered mental status magnified this effect. There was no correlation between SAC scores and other indicators of mTBI. There was a positive correlation between graded-symptom-checklist scores and posttraumatic amnesia and American Academy of Neurology concussion grade. CONCLUSIONS: The graded symptom checklist reliably identified mTBI symptoms for all children aged 6 years and older. SAC scores tended to be lower for case-patients compared with controls but did not reach significance. Patients with altered mental status at the time of injury manifest an increased number and severity of symptoms. Additional research into strategies to identify cognitive deficits related to mTBI and classify mTBI severity in children is needed. Pediatrics 2010;126:688–695

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KEY WORDS brain concussion, closed head injury, traumatic brain injury

Blunt head trauma is common

METHODS among children and accounts for nearly 600,000 emergency department (ED) visits annually. Most of these patients suffer mild traumatic brain injuries (mTBIs), also known as concussions. Although most children will recover from mTBI, they may initially display subtle symptoms and cognitive changes not identified by informal orientation questions. Concussion-grading scales (e.g., American Academy of Neurology [AAN]) are not designed to detect these subtle changes; they ignore many common mTBI symptoms and

Participants We conducted an observational cohort study in the ED of a regional pediatric trauma center with an annual volume of 47,000 visits. We prospectively enrolled patients aged 6 to 18 years. Child-dren were enrolled as case-patients if they had suffered blunt head trauma in the previous 24 hours and had an initial GCS of 13. We categorized case-patients as those with and without unambiguous evidence of altered mental status (AMS), which we defined as (1) any history of LOC, (2) any history of posttraumatic amnesia, or (3) a GCS of focus almost exclusively on posttrauma. Children were included as concussive amnesia and loss of consciousness (LOC). Their relationship (contusions, sprains, to cognitive deficits is unclear. To nondisplaced fracture, no concussion-grading scale concomitant head has been prospectively evaluated. Coma Scale (GCS), a widely used measure of TBI, provides

Patients were excluded for any of the following: open head injury, intoxication, no assessment of symptoms or cognition, use of narcotics for pain controlative deficits.

of the SAC, Identifying effects of mTBI soon after nonaccidental trauma, ad-hoc injury has at least 2 benefits. Patients neurosurgical service educated on expected postconcussive PATIENTS AND controls if they had suffered tremity trauma strains, minor tures) without injury. The Glasgow injury. The Glasgow
injuries, or the symptoms report fewer symptoms than those who do not receive this ed-
ucation.7 The symptoms of mTBI are nonspecific and mimic other common pediatric diseases
such as attention-deficit/hyperactivity disorder, depres- sion, and learning disabilities.8 Providing
the primary care physician with objective evidence of mTBI sequelae should help minimize
prescribing unnecessary medication and allow for more appropriate referral. As the number
of children admitted for mTBI declines,9 the responsibility of manag- ing mTBI sequelae will
increasingly fall to primary care providers. An instru-
tion is critical for improving the care of patients with mTBI. Currently, there is no validated
screen- ing instrument for identifying cogni- tive deficits attributable to mTBI in pe- diatric
patients that could readily be applied in the ED or office. The Stan- dardized Assessment
Concussion (SAC) is a brief sideline screening tool that requires no formal neuropsycho-
logical training.10 It focuses on the cog- nitive domains and symptoms most commonly associated with
mTBI.11 It has been shown to be effective in de- tecting cognitive deficits in older teen-
agers and young adults suffering sports-related concussion; it has not been well studied in younger
child- ren.10,12–14 One adult ED study demon- strated the sensitivity of the SAC to the acute
cognitive changes associated with mTBI.15 Recently, the authors of the SAC highlighted the
utility of sys- tematic evaluation of mTBI by using a concussion-symptom inventory for ini-
tial diagnosis of and monitoring recov- ery from mTBI.16 Our primary goal was to identify a
more informative, quickly adminis- tered evidence-based tool that could be adapted for use in
the pediatric ED. Our secondary goal was to inves- tigate what, if any, relationship ex- isted
between the AAN concussion grade, the GCS, and the SAC. The pri-
mary outcome was
comparison of SAC scores and symptom severity in head-injured case-patients ver-
presence of preexisting central ner- vous system abnormalities. Non- English-speaking patients
were ex- cluded, because the SAC has only been validated in an English-speaking popu-
lation. English-speaking children of Spanish-speaking parents were in- cluded; consent was obtained
from the parents in Spanish. Patients were en- sus non–head-injured controls. The
compa-
graded-symptom-
traditional indi-
severity, such as LOC,
concussion
among case-
hypothesized that chil-

(J.A.G.) or research assistants during son of SAC and
peak hours between noon and mid- checklist scores to
night 10 hours/day, 7 days/week, ex- cators of mTBI
cluding some holidays, from July 1, posttraumatic amnesia,
2007, to June 30, 2008. The study was grades, and GCS
approved by the Colorado Multiple In- patients. We
stitutional Review Board.
ment easily applied in a busy practice setting that identifies and quantifies and cognitive deficits and and mTBI symptoms than children with administration and scoring objectively demonstrates their resolution.

The accompanying the SAC. Three re-

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rated parental responses only to ques- tions relating to posttraumatic amne- sia and LOC. We did not attempt to quantify the duration of posttraumatic amnesia, because some children were discharged before complete resolu- tion of their amnesia. We recorded the presence or absence of amnesia at any time after injury and evaluated it as a dichotomous variable. All subjects were evaluated by using the SAC ver- sion A. GCS scores and AAN concussion grades were assigned to case-patients only. Assignment of concussion grades relied on the subject’s and/ or wit- ness’s recollection of the duration of symptoms for grades 1 and 2 (15 or 15 minutes, respectively). Any child with LOC was assigned a concussion grade of 3 (most severe). If there was no witness to the head injury or the witness did not know if the subject suf- fered a LOC, no grade was assigned. GCS scores were assigned following the traditional adult classification system.19

Data Collection and Processing Responses to the SAC and graded symptom checklist were elicited by the research assistants or principal investigator. Before data analysis, the principal investigator reviewed each subject entry for missing or dis- crepent data. Any discrepancies prompted a review of the medical record and comparison with the data-collection form, and final deter- mination was made by the principal investigator.

Data Analysis We chose a difference between case- patients and controls of 15% (3 points) on the SAC to be clinically rele- vant. This difference was based on pre- vious research results,10,12,13,17 which have shown that nearly 90% of sub- jects will score 2 or more points below preinjury baseline after mTBI and that decrements generally range between search assistants who enrolled sub-

2 and 4 points. Sample-

size calcula- jects participated in a tutorial led by

each age group, the principal investigator, who de-

tions showed that for

controls were tailed SAC administration and assign-

required to detect such a

difference ment of concussion grades.

with 80% power, assuming a com-

The SAC assesses 4 cognitive domains: orientation to time; immediate mem- ory; concentration; and delayed recall. The SAC also incorporates a graded symptom checklist on which the sever- ity of symptoms considered to be rep- resentative of mTBI is documented. The SAC and graded symptom checklist are scored separately. Administration takes 5 minutes. Responses to each item on the SAC are dichotomous: 1 point for each correct answer, 0 points for each incorrect answer. Lower scores on the SAC (possible range: 0–30 points) indicate greater cogni- tive deficit. The graded symptom checklist measures patient-reported severity of 15 symptoms on a 3-point scale. Higher checklist scores (possi- ble range: 0 – 45 points) indicate an in- creased number and/or severity of symptoms. Version A of the SAC, includ- ing the graded symptom checklist, is included in the Appendix.

mon SD of 3.4 (based on research re- suits10,12) using a 2-sided 2-group t test. Two-group
t tests were used to compare the primary outcome measures between case-patients and controls. Spearman correlation coefficients were calculated to compare SAC and graded-symptom-checklist scores to AAN concussion grade, LOC, and posttraumatic amnesia in head-injured patients. The average graded-symptom-checklist score was calculated for grade 1, 2, and 3 concussions on the AAN scale. Logistic regression was used to examine the association between AMS (witnessed LOC, post-traumatic amnesia, or a GCS of 13 or 14) and graded-symptom-checklist scores, for which the median value of graded-symptom-checklist scores for case-patients with AMS (12 points) was used to categorize the outcome variable. The model was adjusted for age. The association between graded-symptom-checklist scores as a continuous outcome and AMS was also examined. We did not record educational regression and level; our study population all had less software (SAS than a high-school education. Instead, was used for all subjects were stratified into 4 age categories to ensure comparison of case-patients with controls of similar development level: 6 to 8, 9–11, 12–14, and 445 patients 15–18 years. This process is consistent enrollment with that of previous studies in which declined participation the SAC in younger children was evaluated exclusion criteria.17,18 We adapted the questions of patients (165 the graded symptom checklist so that controls) were the language was age-appropriate. For was no difference example, rather than asking whether between case-patient the subject had nausea, we asked if he

We modified the SAC in the following

adjusted for age. SAS 9.2 Institute Inc, Cary, NC) analyses. categories to

RESULTS opmental

During the study period, were approached for Forty-one patients

tiation, and 66 patients met criteria. The remaining 348

case-patients and 183 enrolled (Table 1). There

tence in age or gender

patients and controls.
Falls accounted or she “felt like throwing up.” These children younger changes were standardized and asked related injuries in the same manner for all subjects. No aged 12 changes were made to the cognitive mean time since components of the SAC. We incorpo-injury for the controls, case-patients

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TABLE 1 Patient Demographics

<table>
<thead>
<tr>
<th>Age Group, y</th>
<th>Mean Age SD, y (n)</th>
<th>% Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls</td>
<td>Case-Patients</td>
<td>Controls</td>
</tr>
<tr>
<td>No AMS</td>
<td>AMS</td>
<td>No AMS</td>
</tr>
<tr>
<td>6–8</td>
<td>7.5</td>
<td>7.6</td>
</tr>
<tr>
<td>0.7</td>
<td>(32)</td>
<td>59</td>
</tr>
<tr>
<td>(0.7)</td>
<td>(18)</td>
<td>61</td>
</tr>
</tbody>
</table>

FIGURE 1 SAC scores according to age group. Shown are means and 95% CIs. a P .001.
without AMS, and case-patients with AMS was 5.3, 3.8, and 4.4 hours, respectively, and not significantly different.

Primary Outcomes

Total SAC scores trended lower among case-patients aged 9 years and older but were not significant (Fig 1). The 12- to 14-year age group showed the only significant difference in SAC scores (P .001). When only those patients with unambiguous evidence of AMS were compared with the control group, only the 12- to 14-year age group demonstrated a significant difference similar to that of the entire case-patient group (data not shown). Graded-symptom-checklist scores for case-patients were substantially higher than those of controls. These differences were statistically significant for all ages (P .0001) (Fig 2).

FIGURE 2 Graded-symptom-checklist scores according to age group. Shown are means and 95% CIs.
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Secondary Outcomes Spearman correlation coefficients and P values that compared SAC and graded-symptom-checklist scores to traditional indicators of mTBI severity (AAN concussion grade, LOC, posttraumatic amnesia) and time since injury were calculated. We found significant positive correlations of graded-symptom-checklist scores with post-traumatic amnesia (P .0001), AAN grade (P .03), and time since injury (P .003). That is, higher graded-symptom-checklist scores correlated with the presence of posttraumatic amnesia, higher AAN grade, and longer time since injury. No significant correlation existed between the SAC and traditional indicators of mTBI severity. No correlation analysis was performed for the GCS scores, because 96% of the case-patients had a GCS of 15. LOC did not correlate with either SAC scores or graded-symptom-checklist scores.

Posthoc Analysis To further investigate the correlation between AMS and symptoms, we calculated odds ratios for symptom scores on the basis of the presence or absence of AMS. Subjects with unambiguous evidence of AMS were 2.8 times more likely (95% confidence interval: 1.4–5.5) to have a graded-symptom-checklist score of 12 and had a mean graded-symptom-checklist score 5 points greater than those without AMS, when adjusting for age.

SAC score
22
20
Age group
Checklist score
Given the lack of prospective data for AAN concussion grade, we conducted further comparisons against the graded symptom checklist. We calculated Spearman correlation coefficients for each of the 15 individual symptoms in the checklist. Three symptoms showed a correlation (P < .05): dizziness, photophobia, and memory disturbance. The mean graded-symptom-checklist score was 9.2 (95% CI: 7.7–10.7) for case-patients with an AAN grade 1 concussion, 15.4 (95% CI: 11.5–19.3) for AAN grade 2 concussion, and 11.3 (95% CI: 9.1–13.5) for AAN grade 3 concussion. The difference between grade 1 and 2 injuries was significant, but the difference between grade 1 and 3 injuries was not.

DISCUSSION We found no difference in SAC scores between case-patients and controls. With the exception of the youngest age group, there was a trend toward lower scores among case-patients, and the difference in the 12- to 14-year-old group did reach significance. When we compared only those patients with unambiguous evidence of AMS to controls, we were still unable to detect a difference in SAC scores. Although the SAC scores of those in the 12- to 14-year-old age group did differ significantly, this finding is likely attributable to chance, given that the 15- to 18-year-old group did not demonstrate a statistically significant difference.

Previous research has consistently demonstrated the validity and reliability of the SAC in this age group.10,13,14,20 Because we defined a case-patient as any child with blunt head trauma regardless of symptoms, we may have included subjects without actual underlying concussive brain injury, and the subsequent differences may not have been large enough to reach significance. However, this is unlikely to fully account for our findings, because differences did not reach significance in the subset of case-patients with unambiguous evidence of AMS. Another possible explanation relates to the fact that our study was powered on the basis of previous studies of baseline and postinjury scores of the same individuals, whereas in our study we compared scores among different individuals. More variability would be expected between individuals; thus, we may have included too few subjects to reach significance. The graded-symptom-checklist scores differed considerably between case-patients and controls in all age groups. This difference was even more appreciable when we compared subjects with unambiguous evidence of AMS to those without AMS. There was a strong correlation between the presence of posttraumatic amnesia and greater symptom severity. Subjects with any posttraumatic amnesia (but not LOC) had a greater number and/or more severe symptom complex compared with children without posttraumatic amnesia. Furthermore, the mean graded-symptom-checklist score for case-patients with an AAN grade 3 concussion (any LOC) was actually lower than that found for case-patients with a grade 2 concussion, which suggests that LOC does not necessarily indicate a greater injury. This result is in line with earlier literature that revealed that posttraumatic amnesia is a reliable indicator of mTBI severity and is predictive of somatic, cognitive, and emotional symptoms.21–23 Because the disposition of patients was left to the discretion of treating physicians, we could not quantify the total duration of posttraumatic amnesia and evaluate the impact of its duration on this effect. It should be noted that the results of a recently published large multicenter study of children with TBI revealed that LOC is a risk factor for more severe TBI.24 Our results showed a correlation between AAN concussion grade and graded-symptom-checklist composite scores. However, only 3 symptoms (dizziness, photophobia, and memory disturbance) showed a
correlation when considered individually. A few other symptoms approached significance. Given that not all subjects will suffer all 15 symptoms, it is likely that our sample size was too small to accurately detect all significant correlations. Nearly all of our case-patients (96%) had a GCS of 15 at the time of evaluation despite having significantly more symptoms than controls. This finding highlights the important observation that a normal level of alertness and interaction with the environment does not exclude mTBI. A GCS of 15 should not reassure providers that no brain injury occurred, and it should not be construed to obviate the need for more detailed evaluation. The GCS is not a useful tool for classifying mTBI severity. The positive association between time since injury and graded-symptom checklist scores is interesting. Results of previous sport-related concussion research with the SAC revealed the greatest symptoms shortly after injury. We expected decreasing symptoms over time rather than the increasing symptoms noted. There are 2 possible explanations for the unexpected finding. We studied a pediatric ED population that largely depends on adults to seek care on their behalf. There may have been a delay in seeking care among some subjects until the parents became concerned about the severity of symptoms or that symptoms were not clearing as quickly as expected. Second, the checklist elicits all symptoms present since the injury, not simply those present at the time of injury.

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ED evaluation. Therefore, it is an
that the graded additive rather than cross-sectional
the SAC sys- measure.
the symptoms of The results of this study must be inter- preted in light of some limitations.
Un- like studies using the SAC on the side- line immediately after a concussion, we evaluated
patients up to 24 hours after injury, which allowed time for cognitive disturbances to resolve.
Case-patients were compared with controls rather than their own prein- jury baseline, which
introduced a greater degree of score variability. As mentioned above, we also included as case-
patients any patient who suffered blunt head trauma regardless of
mTBI in a school-aged pediatric popu- lation. Posttraumatic amnesia was found to predict
greater symptom se- verity. Future efforts should focus on creating a rapid, easily administered
tool for detecting the cognitive effects of mTBI in children that accounts for developmental
differences and pro- vides an assessment of the likelihood for developing postconcussive syn-
drome. Such a tool should be amena- ble to monitoring recovery after the acute event
and easily administered in busy practice environments. whether there was clear evidence of
underlying concussive injury. The sub-
group of case-patients who did not
thank James demonstrate unambiguous mental
McCrea, PhD status changes may have contained
and review of some patients who suffered head inju-
the manuscript.

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ries but not brain injuries and, there- fore, performed similarly to controls on the SAC. It would be ideal to compare SAC scores to those of another cognitive test previously validated in a pediatric mTBI population as a reference standard. However, no test that could be quickly administered in an ED setting exists. Fi- nally, subjects were not followed longitudi- nally, and we cannot draw any conclu- sions regarding the predictive value of these instruments.

CONCLUSIONS Current methods of identifying the ef- fects of mTBI on the pediatric brain are suboptimal. The GCS has no role in as- sessing the severity of mTBI. Our re- sults suggest that the AAN concussion- grading scale may not accurately reflect the severity of injury and should be used with caution, especially when making decisions about returning ath- letes to competition.

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I STANDARDIZED ASSESSMENT OF CONCUSSION - ER VERSION

I am going to ask you some questions

. RIENTATION RETROGRADE AMNESIA? U NO EI YES

What Month is it? 0 1 What's the Date today? 0 1 What's the Day of Week? 0 1 What Year is it? 0 1 What Time is it right now? (within 1 hr.) 0 1

Award 1 point for each correct answer.

I ORIENTATION TOTAL SCORE I) | CI

COORDINATION - examples: I am going to test your memory.

I will read you a TANDEM WALKI FINGER-NOSE-FINGER

list of words and when I am done, repeat back as many words as you can remember, in any order.

LIST I TRIAL 1 I TRIAL 2 I TRIAL 3 FINGER I 0 1 0 1 0 1 PENNY I 0 1 I O 1 I O 1 BLANKET I 0 1 O 1 O 1 BLANKET I O 1 I O 1 I O 1 LEMON I 0 1 I O 1 I O 1 INSECT I O 1 I O 1 I O 1 TOTAL I

Trials 2 & 3: I am going to repeat that list again. Repeat back as many words as you can remember in any order, even if you said the word before.

Complete all 3 trials regardless of score on trial 1 & 2. 1 pt. for each correct response. Total score equals sum across all 3 trials. Do not inform the subject that delayed recall will be te

Do not inform the subject that delayed recall will be te IMMEDIATE MEMORY TOTAL SCORE *

Tell me if you are currently experiencing or have experienced any of the following symptoms since you were in'ured. If so, rate the symptom as mild, moderate, or severe. Circle response for each item.

SYMPTOM SEVERITY

NONE MILD MODERATE SEVERE

Headache O 1 2 3 Nausea O 1 2 3 Vomiting O 1 2 3 Dizziness O 1 2 3 Poor balance 0 1 2 3 Blurred/Dbl vision 0 1 2 3 Sensitivity to light 0 1 2 3 2 Sensitivity to noise 0 1 2 3 Ringing in ears 0 1 2 3 Poor concentration 0 1 2 3 Memory problems 0 1 2 3 Not feeling "sharp" 0 1 2 3 Fatigue/sluggish 0 1 2 3 7 Sadness/depression 0 1 2 3 Irritability 0 1 2 3

Poor recall of events before injury Length:

NORMAL I ABNORM

ABNO

AL

STRENGTH -

Right Upper Extremity E] | [:1 Right Lower Extremity U | EI Left Upper Extremity I I | Left Lower Extremity III I I]

SENSATION examples: I I I

I III

V NCENTRATIO

Digits Backward: I am going to read you a string of numbers and when I am done, you repeat them back to me backwards, in reverse order of how I read them to you. For example, if I say 7-1-9, you would say 9-1-7.
If correct, go to next string length. If incorrect, read trial 2. 1 pt. possible for each string length. Stop after incorrect on both trials.

Months in Reverse Order: Now tell me the months of the year in reverse order. Start with the last month and go backward. So you'll say December, November...Go ahead. 1 pt. for entire sequence correct.

Do you remember that list of words I read a few times earlier? Tell me as many words from the list as you can remember in any order. Circle each word correctly recalled. Total score equals number of words recalled.

FINGER PENNY BLANKET LEMON INSECT IDELAYED RECALL TOTAL SCORE * I N

Symptom Index & Neurologic Screening are imponant for examination, but pg incorporated into SAC Total Score.

ORIENTATION I I 5 IMMEDIATE MEMORY I I 15
CONCENTRATION I / 5 DELAYED RECALL I / 5

SAC Tom SCORE -> I /so

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