Returning Adolescents to Driving after Sports-Related Concussions: What Influences Physician Decision-Making

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Objective To determine which data collected on an initial patient clinic visit for a sports-related concussion (SRC) might influence physicians to clear an adolescent to return to drive (RTD) after injury.

Study design Retrospective cohort study of 189 adolescents with a SRC referred to a hospital-based concussion clinic between June 1, 2015, and May 31, 2016. Subjects were ≥16 years with a valid driver's license (median age = 16, IQR [16, 17]). Concussion evaluations included Post-Concussion Symptom Scale, modified Balance Error Scoring System, and postinjury computerized neurocognitive testing (CNT). Clearance for RTD was the main outcome. Statistical comparisons were conducted with Mann–Whitney *U* and χ^2 tests and logistic regression.

Results In multivariable analysis, odds of being fully cleared to drive were 5.9-fold greater among patients who were administered CNT. Stated symptoms of "headache" and "sensitivity to light" were statistically significantly associated with RTD clearance. For a subset of 113 individuals undergoing CNT, each additional 10-millisecond decrease in simple reaction time was associated with 9% greater odds of being cleared to drive. Each additional 10-millisecond decrease in choice reaction time was associated with 4% greater odds of being cleared to drive.

Conclusions CNT and associated reaction time measures may facilitate a physician's objective decision-making. Making a RTD determination for adolescents recovering from an SRC should be a core component of a physician's assessment. *(J Pediatr 2017;■■:■■-■■).*

In the US, an estimated 27 million children aged 6-18 years participate in team sports annually, and as many as 60 million participate in some form of organized athletics.[1] Sports-related concussions (SRCs) are a type of mild traumatic brain injury (mTBI) occurring commonly in this group. An estimated 1.6-3.8 million SRCs occur annually in all age groups, and most of these occur in the pediatric population.[2-4]

Most clinicians are familiar with contemporary pediatric SRC standard of care: prompt recognition of the injury and withholding individuals initially from sport are imperative cornerstones of the treatment of SRCs.[5] Despite considerable debate over the specifics, the mainstay for subsequent management is physical and cognitive rest, followed by a gradual return to school and play as reported symptoms approach baseline.[4,6-15]

Many pediatricians, patients, and families remain unaware of the dangers of driving after an SRC.[16] Adolescents who suffer SRCs are often of the age when they are learning to drive, and driving is inherently a risky activity for novices.[17,18] Road fatalities are the leading cause of death for teens and young adults in the US and worldwide.[19,20] Driving is an activity that is made more difficult and potentially more dangerous after traumatic brain injury.[21-23] SRCs may affect many cognitive processes required for driving safely and may result in impaired driving.[21,24,25] SRCs may result in slower reaction time, visual impairment, and a decrease in concentration; the patient may experience headaches and dizziness, symptoms which may be distracting.[10,26-28]

There is an evolving recognition that pediatricians need to counsel their adolescent patients on the dangers of driving after an SRC.[29] For many adolescents, driving is an instrumental activity of daily living that may be hard to forego as the teen may need to drive school, after-school activities, and work.[30] Expert consensus endorses caution in determining fitness to drive after mTBI but offers little objective guidance to make this determination.[31,32] There is a gap in the medical literature on investigations of objective determinants of fitness to drive after mTBI.[33,34] The few studies performed have focused on adult populations.[23] There is a need for research-based evidence regarding the methods and tools used to determine whether adolescents with mTBI are fit to drive.[23]

We therefore undertook a retrospective chart review to determine which data obtained during a clinic visit might influence a physician's determination to withhold an adolescent post-SRC from driving. Our primary outcome measure was

BESS	Balance Error Scoring System
CNT	Computerized neurocognitive testing
EMR	Electronic medical records
mTBI	Minor traumatic brain injury
PCSS	Post-Concussion Symptom Scale
RTD	Return to drive
SRC	Sports-related concussion

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determining which specific independent measures are associated with a physician's decision to hold or clear a patient to return to drive (RTD) after an initial concussion consultation.

Methods

A retrospective chart review of all patients ages 16 and older who were seen from June 1, 2015, to May 31, 2016, at the principal author's home institution (a pediatric sports medicine clinic) for an initial diagnosis of concussion. Data were extracted from the EPIC (Verona, Wisconsin) electronic medical records (EMRs) system. All patients were diagnosed and treated by fellowship-trained, primary-care sports medicine physicians. Exclusion criteria included (1) concussion did not occur in sports, (2) physician did not document a driving recommendation, (3) patient did not possess a driver's license (did not drive), (4) ≥2 concussions in the study year, and (5) initial clinic visit >30 days after concussion.

The dependent measure of interest was physician-documented driving recommendations ("driving status"). Driving status at the initial visit was determined by the physician and was documented in the chart. Because of an internal hospital quality improvement project, all clinical assessments could be documented with the use of a driving status EMR template.[29] This facilitated a high rate of documentation, although there were individuals for whom there was no recorded driving status. The driving status for study participants was documented in the EMR using the following template: (1) patient not cleared to drive, (2) patient cleared to drive but not at night, (3) "other" (usually "free text" instructions from the treating physician), or (4) patient is fully cleared to drive. These 4 individual determinations were dichotomized into the following 2 categories: "cleared to drive" (#4), and "not cleared to drive" (#1-#3).

Independent measures were chosen for their plausible effect on driving fitness—including measures of symptom burden, postural stability, and reaction times—and because they are regularly used in the clinical assessment of pediatric SRCs and endorsed by expert consensus.[15,35] These included data extracted from the following tools: the Post-Concussion Symptom Scale (PCSS), CogState computerized neurocognitive testing (CNT) (Wausau, Wisconsin), and the modified Balance Error Scoring System (BESS).[35-37] The PCSS is a self-reported inventory used to rate the burden of 22 symptoms associated with concussion, via the use of a Likert scale of 0 (none) to 6 (severe).[38] The total PCSS score can therefore range from 0 to 132. The authors posited 8 PCSS symptoms might have a relation to driving fitness (headache, balance problems, drowsiness, dizziness, sensitivity to light, feeling slowed down, difficulty concentrating, vision problems). Individual scores for each of these symptoms, and total PCSS score, were collected on the first clinic visit. The PCSS was administered to all study participants.

The modified BESS test is a validated, commonly used measure of postural stability and vestibular function administered to concussed individuals.[37,39] Lower scores represent superior performance on the test. Normative data for a nonconcussed pediatric population have been published, with a median modified BESS score of 17 for ages 14-17 years.[40] The modified BESS was performed on all study participants.

CogState is a commonly used CNT in concussion assessment.[36] Simple and choice reaction time (milliseconds) measures are among the cognitive tasks that CogState CNT can assess. Both reaction time measures test general alertness and motor speed. "Simple reaction time" measures the time from stimulus to response; "choice reaction time" also measures time from stimulus to response but introduces an element of uncertainty by having 2 possible stimuli and 2 possible responses. These reaction time measures were documented at initial visit when CogState CNT was administered. Administration of the test was at the discretion of the treating physician.

Although most study participants took the CogState CNT, not all did. Data were analyzed as described in statistical methods for both the entire study sample (N = 183) and the subset that took CogState CNT (N = 113). Study approval for this retrospective review was obtained from the primary author's institutional research board.

Statistical Analyses

Statistical comparisons between patients who were cleared to drive on their initial visit vs those who were not cleared to drive were conducted with Mann–Whitney *U* tests for continuous variables and χ^2 tests for categorical variables. Multivariable logistic regression was used to determine which patient factors and symptoms were significantly associated with driving status after accounting for other important covariates. Variable selection for the multivariable model was based on backward stepwise selection. A subanalysis among patients who underwent CogState CNT on their initial clinic visit was performed similarly to assess the impact of simple reaction time and choice reaction time. Simple and choice reaction times were assessed in separate models due to strong collinearity between the 2 reaction time variables. Statistical significance was set at $P < .05$.

Results

A total of 189 individuals (106 male, 83 female) met study criteria. **Table I** shows a comparison of patient factors and symptoms by whether or not patients were cleared to drive on their initial visit. Patients who were cleared were significantly more likely to have a shorter duration of symptoms, lower PCSS scores, lower scores for each individual symptom, and CogState CNT administration. In multivariable analysis (**Table II**), CogState CNT administration, headache score, and sensitivity to light score remained statistically significantly associated with RTD status; BESS scores approached a trend toward significance. The effect size of CogState CNT administration was by far the largest: odds of being fully cleared to drive were nearly 6-fold greater among patients who underwent CogState CNT. In contrast, likelihood of being cleared to drive was

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