Predictive Utility of the Total Glasgow Coma Scale Versus the Motor Component of the Glasgow Coma Scale for Identification of Patients With Serious Traumatic Injuries

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Study objective: The motor component of the Glasgow Coma Scale (mGCS) has been proposed as an easier-to-use alternative to the total GCS (tGCS) for field assessment of trauma patients by emergency medical services. We perform a systematic review and meta-analysis to compare the predictive utility of the tGCS versus the mGCS or Simplified Motor Scale in field triage of trauma for identifying patients with adverse outcomes (inhospital mortality or severe brain injury) or who underwent procedures (neurosurgical intervention or emergency intubation) indicating need for high-level trauma care.

Methods: Ovid MEDLINE, Cumulative Index to Nursing and Allied Health Literature, PsycINFO, Health and Psychosocial Instruments, and the Cochrane databases were searched through June 2016 for English-language cohort studies. We included studies that compared the area under the receiver operating characteristic curve (AUROC) of the tGCS versus the mGCS or Simplified Motor Scale assessed in the field or shortly after arrival in the emergency department for predicting the outcomes described above. Meta-analyses were performed with a random-effects model, and subgroup and sensitivity analyses were conducted.

Results: We included 18 head-to-head studies of predictive utility (n=1,703,388). For inhospital mortality, the tGCS was associated with slightly greater discrimination than the mGCS (pooled mean difference in [AUROC] 0.015; 95% confidence interval [CI] 0.009 to 0.022; I^2=85%; 12 studies) or the Simplified Motor Scale (pooled mean difference in AUROC 0.030; 95% CI 0.024 to 0.036; I^2=0%; 5 studies). The tGCS was also associated with greater discrimination than the mGCS or Simplified Motor Scale for nonmortality outcomes (differences in AUROC from 0.03 to 0.05). Findings were robust in subgroup and sensitivity analyses.

Conclusion: The tGCS is associated with slightly greater discrimination than the mGCS or Simplified Motor Scale for identifying severe trauma. The small differences in discrimination are likely to be clinically unimportant and could be offset by factors such as convenience and ease of use. [Ann Emerg Med. 2017;70:143-157.]

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INTRODUCTION

Background

Unintentional injuries are the leading cause of death in the United States among people aged 1 to 44 years and the third leading cause among people aged 45 to 64 years.[1] In 2011, there were approximately 40,000,000 emergency department (ED) visits for injuries.[2] Approximately 18% of patients treated in the ED for an injury were transported by emergency medical services (EMS) personnel.[3]

Importance

Field triage by EMS personnel is a critical aspect of trauma systems because it helps to identify potentially seriously injured patients and inform transport decisions.[4-6] A key component of field triage for patients with trauma is level-of-consciousness assessment. The Glasgow Coma Scale (GCS)[7,8] is an instrument widely used for level-of-consciousness assessment by EMS personnel in the field and in other settings.[9] It consists of 3 items: eye (scored 1 to 4), verbal (scored 1 to 5), and motor (scored 1 to 6); scores are summed to obtain the total GCS (tGCS) score, ranging from 3 to 15 (lower scores indicating lower levels of

Editor's Capsule Summary

What is already known on this topic

The Glasgow Coma Scale (GCS) is widely used for field triage of injured patients to trauma centers.

What question this study addressed

Do 2 simplified versions of the GCS predict trauma outcomes as well as the full GCS?

What this study adds to our knowledge

In this meta-analysis of 18 studies, the slender predictive advantage observed for the full GCS over the 2 shorter scales was below reasonable thresholds for clinical importance.

How this is relevant to clinical practice

The full GCS can be effectively replaced by either of the 2 simplified versions studied.

consciousness). The 2011 field triage guidelines from the Centers for Disease Control and Prevention (CDC) National Expert Panel recommend transporting patients with tGCS scores of less than or equal to 13 to facilities providing the highest level of trauma care.[3]

In some circumstances (eg, intoxication, intubation, medication use, presence of other injuries influencing ability to respond), it may not be possible to accurately assess the verbal and eye components of the GCS, such that assessments are primarily based on the motor component of the GCS (mGCS). Scores of 5 or less on the mGCS are considered an indication of severe injury.[7,10-13] The mGCS has been proposed for assessment of trauma patients even when the tGCS can be obtained because it may be easier to use by EMS personnel in the field.[12] The Simplified Motor Scale is a streamlined version of the mGCS (scored 0 to 2, with a score of 0 corresponding to 1 to 4 on the mGCS, 1 corresponding to 5, and 2 corresponding to 6).[14]

During the development of the 2011 CDC field triage guideline,[3] the Expert Panel considered use of the mGCS as an alternative to the tGCS as a way to potentially simplify field triage, but did not adopt it part because of limited evidence in regard to predictive utility. However, more data are now available.

Goals of This Investigation

The purpose of this article is to systematically review the evidence on the predictive utility of the tGCS and mGCS in the field assessment of trauma for identifying patients with serious injuries to help inform clinical practice and guideline development for field triage of trauma by EMS personnel. It is based on a larger report commissioned by the Agency for Healthcare Research and Quality on use of the GCS in field triage.[15]

MATERIALS AND METHODS

Detailed methods and data for this review, additional outcomes, and additional key questions are available in the full report.[15] This article focuses on the comparative ability of the tGCS and the mGCS or Simplified Motor Scale to discriminate persons with serious from those with less serious traumatic injuries. The protocol for this review was developed with a standardized process,[16] with input from the National Highway Traffic Safety Administration, experts, and the public. The protocol was registered in the International Prospective Register of Systematic Reviews.[17]

Data Collection and Processing

A research librarian searched the Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, CINAHL, PsycINFO, Health and Psychosocial Instruments, and Ovid MEDLINE (January 1995 through June 2016) for relevant studies and systematic reviews (search strategy shown in Figure E1, available online at http://www.annemergmed.com). Searches were started from 1995 because the first studies to compare the predictive utility of the mGCS versus the tGCS were published in 1998 and 2003[12,13]; only 5 states had fully implemented trauma systems as of the early 1990s.[18] We also reviewed reference lists and searched clinicaltrials.gov. Inclusion was restricted to English-language articles. Studies published only as abstracts were excluded.

Selection of Participants

Two reviewers (R.C., A.T., N.C., or N.W.) independently evaluated each study on the basis of predefined criteria at the abstract and full-text review levels. We included prospective or retrospective cohort studies of children and adults with known or suspected trauma that compared discrimination of the tGCS versus the mGCS or Simplified Motor Scale administered soon after injury (in the field/out-of-hospital by EMS personnel or within 4 hours of arrival to the ED) for identifying persons with serious injuries. Presence of a serious injury was based on the following outcomes: inhospital mortality, receipt of neurosurgical interventions (defined as a surgical procedure of the brain, skull, or meninges, including craniotomy, ventriculostomy, shunts, or intracerebral pressure monitoring), meeting criteria for a severe traumatic brain injury (defined as imaging findings such as skull fracture with underlying brain injury, intracerebral contusion, cerebral contusion, or cerebral edema; or receipt of an acute intervention for brain injury), or receipt of emergency intubation. The measure of discrimination was the area under the receiver operating characteristic curve (AUROC). The AUROC value represents the probability that a patient who experiences an outcome will have a worse score on the scale than a person who does not experience it.[19,20]

Primary Data Analysis

One investigator (R.C., A.T., N.C., or N.W.) abstracted details about study characteristics and results. A second investigator checked the abstracted data for accuracy. Two investigators independently rated the quality of studies (good, fair, or poor), using prespecified criteria developed for evaluation of studies on prognosis[21] and diagnosis[22] (Figure E2, available online at http://www.annemergmed.com). Investigators did not review, assess, or screen articles that they authored. Discrepancies were resolved by consensus.

Meta-analyses were conducted to calculate pooled differences in the AUROC with the DerSimonian-Laird random-effects model with Stata/IC (version 13.1; StataCorp, College Station, TX). We also performed analyses with the profile likelihood method, an alternative random-effects model.[23] We defined a small difference in the AUROC a priori as a difference of less than 0.05, moderate as a difference of 0.05 to 0.10, and large as a difference of greater than 0.10. When a study reported only the point estimate of AUROC without providing a 95% confidence interval (CI) or a standard error, we imputed the standard error with the average standard error from other studies in the same meta-analysis. In all studies, the mGCS or Simplified Motor Scale scores were derived from the tGCS and applied to the same patient population. To account for this nonindependence, we assumed a correlation of 0.5 when comparing the tGCS with the mGCS or Simplified Motor Scale in the primary analysis. Two studies[24,25] reported data that allowed calculation of the correlations between the AUROCs for the tGCS and the mGCS or Simplified Motor Scale, which ranged from 0.5 to 0.9, depending on the outcome and comparison. Therefore, 0.5 is a conservative assumption for the correlation. Additional analyses were conducted assuming correlations of 0.3 and 0.8; results were similar and are not reported separately.

Stratified and sensitivity analyses were performed on the age group evaluated (children versus adults or mixed populations), assessment setting (out-of-hospital versus ED), study dates (all data collected after 2006 or some or all data collected before 2006), country (United States versus other), and risk of bias rating. Primary analyses were based on all studies, including those conducted with the National Trauma Data Bank. In 2012, 805 hospitals submitted data to the National Trauma Data Bank.[26] Because populations evaluated in studies reporting data from single trauma centers or systems could be included (in part or in full) in the National Trauma Data Bank, we performed a sensitivity analysis in which National Trauma Data Bank studies were excluded. For the primary analysis, we included multiple studies from the same trauma center or system unless there was clearly complete overlap in the populations assessed. In sensitivity analyses, we restricted analyses to one study from each trauma center that used field GCS scores; if multiple studies used field GCS scores, we used the study that evaluated more recent data.

For all comparisons and outcomes, we assessed the strength of evidence as high, moderate, low, or insufficient,

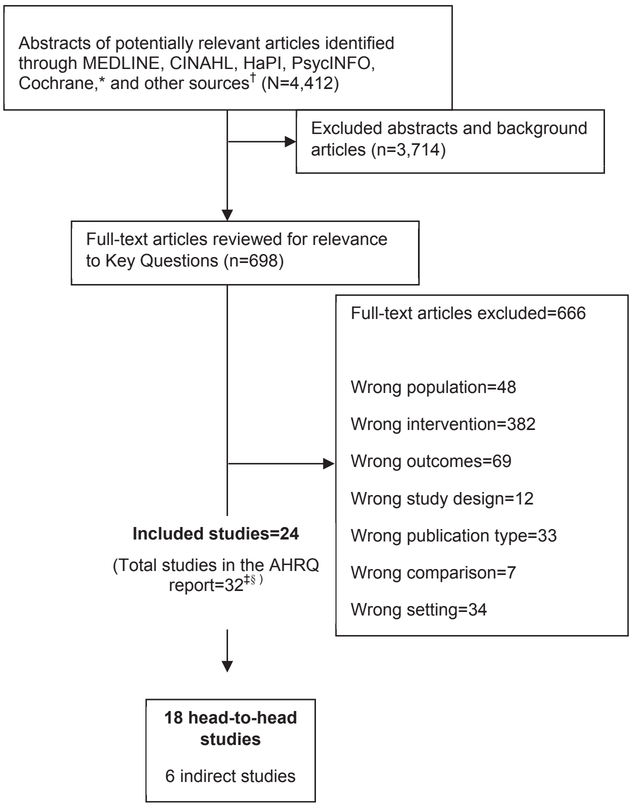

Figure 1. Outline of study selection and inclusion. *CINAHL*, Cumulative Index to Nursing and Allied Health Literature; *HaPI*, Health and Psychosocial Instruments. *Cochrane databases include the Cochrane Central Register of Controlled Trials and the Cochrane Database of Systematic Reviews. †Other sources include reference list, experts, etc. ‡Two studies were used both for key question 1 and key question 4. §Key questions 2, 3, and 4 that do not address predictive utility are addressed in the full Agency for Healthcare Research and Quality report.[15]

Table 1. Characteristics of head-to-head studies.

Author, Year	Settings Years of Study	Assessment Timing Measures or Scores Compared	N	Population Characteristics
Acker et al, 2014[28]	USA, Colorado, urban 2 Level I pediatric trauma centers, 2002 to 2011	ED A: tGCS B: mGCS	2,231	Age (mean), y: 6.9 (SD 5.8) Male patient: 65% Race: NR TBI: 100% ISS (median): 17 (IQR: 10–26)
Al-Salamah et al, 2004[29]	Canada, Ontario trauma registry, 72% urban, 28% suburban or rural, 1994 to 2002	Out-of-hospital A: tGCS score ≤13 B: mGCS score ≤5	795	Age (mean), y: 44 (SD 21) Male patient: 70% Race: NR TBI: NR ISS: NR
Beskind et al, 2014[11]	USA, Southern Arizona urban, university health network Level I trauma center, 2008 to 2010	Out-of-hospital A: tGCS B: mGCS	9,816	Age (median), y: 32 (IQR: 20–51) Male patient: 65.5% Race: NR TBI: NR ISS ≥16: 11.7%
Brown et al, 2014[30]	USA trauma registry,* 2007 to 2008	Out-of-hospital A: tGCS score ≤13 B: mGCS score ≤5	811,143	Age (median), y: 39 (IQR: 23–57) Male patient: 66% Race: NR TBI: NR ISS (median): 9 (IQR: 4–13)
Caterino and Raubenolt, 2012[31]	USA, Ohio urban, hospitals trauma and nontrauma centers, 2002 to 2007	Out-of-hospital A: tGCS ≤13 B: SMS ≤1	52,412	Age (mean), y: 53 Male patient: 55.9% White: 79.9% Black: 13.5% Hispanic: 1.5% Other race: 1.7% Race not documented: 3.4% TBI: 15.2% ISS (median): 9 ISS >15: 26.6%
Cicero and Cross, 2013[32]	USA trauma registry* 2007 to 2009	Out-of-hospital A: tGCS B: mGCS	104,035	Age (mean), y: 12.6 (SD 5.5) Male patient: 67% Nonwhite race: 38% TBI: NR ISS (mean): 9.9 (SD 10.3) Major injury (ISS >15): 15%
Corrigan et al, 2014[33]	USA trauma registry,* 2007 to 2010	Out-of-hospital A: tGCS B: mGCS	77,470	NR
Davis et al, 2006[34]	USA, California (San Diego) Urban, other data NR Date NR	Out-of-hospital and ED A: tGCS B: mGCS	12,882	NR
Eken et al, 2009[35]	Turkey, tertiary care ED of hospital Level IV trauma center, 2006	ED A: tGCS B: mGCS	185	Age (median), y: 59 (range 18–97) Male patient: 64% Race: NR TBI: NR ISS: NR
Gill et al, 2005[14]	USA, California (Loma Linda) urban, university Level I trauma center and children's hospital, 1990 to 2002	ED A: tGCS B: mGCS C: SMS	8,412	Age (median), y: 24 (IQR 15–38) Male patient: 71.5% Race: NR TBI: 17.1% ISS: NR
Gill et al, 2006[36]	USA, California (Loma Linda) urban, university Level I trauma center and children's hospital, 1990 to 2002	Out-of-hospital A: tGCS B: mGCS C: SMS	7,233	Age (median), y: 24 (IQR 16–38) Male patient: 70% Race: NR TBI: 17% ISS: NR

Table 1. Continued.

Author, Year	Settings Years of Study	Assessment Timing Measures or Scores Compared	N	Population Characteristics
Haukoos et al, 2007[37]	USA, Colorado urban, Denver Health Medical Center, Level I trauma center, 1995 to 2004	ED A: tGCS B: mGCS C: SMS	21,170	Age (median), y: 32 (IQR: 21–45) Male patient: 71% Race: NR TBI: 14% ISS score (median): 9 (IQR 2–14)
Healey et al, 2003[12]*	USA trauma registry,* 1994 to 2001	Out-of-hospital A: tGCS B: mGCS	202,255	NR
Holmes et al, 2005[38]	USA, California (Davis) Level I trauma center, 1998 to 2001	ED A: tGCS B: mGCS	2,043	≤2 y: 16% >2 y: 84% Male patient: NR Race: NR TBI: 5% ISS: NR
Kupas et al, 2016[39]	USA, Pennsylvania Level I, II, III, or IV trauma centers, 1999 to 2013	Out-of-hospital A: tGCS score ≤13 B: mGCS score ≤5	370,392	Age (median), y: 50 Male patient: 62% White: 79% Black: 14% Asian: 0.9% TBI: NR (88% blunt trauma) ISS >15: 29%
Ross et al, 1998[13]	USA, New Jersey Level I trauma center, 1994 to 1996	Out-of-hospital A: tGCS score ≤13 B: mGCS score ≤5	1,410	Age (mean), y: 37.1 (range 13–95) Male patient: 69% Race: NR TBI: NR ISS (mean): 14.4 ISS (median): 13
Thompson et al, 2011[25]	USA, Colorado urban, Denver Health Medical Center Level I trauma center, 1999 to 2008	Out-of-hospital A: tGCS ≤13 B: mGCS score ≤5 B: SMS ≤1	19,408	Age (median), y: 33 (IQR 22–48) Male patient: 71% Race: NR TBI: 18% ISS (median): 9 (IQR 4–17)
Van de Voordeet al, 2008[40]	Belgium pediatric trauma registry (PENTA) 2005	Out-of-hospital and ED A: tGCS score ≤13 B: mGCS score ≤5	96	Age (mean), y: 8.2 (SD 5.3) Male patient: 59% Race: NR TBI: NR ISS (median): 16

NR, Not reported; *TBI*, traumatic brain injury; *ISS*, Injury Severity Score; *IQR*, interquartile range; *PENTA*, Paediatric Network around Trauma registry.
*Patients from the National Trauma Data Bank data set.

using the approach described in the *Methods Guide for Medical Test Reviews*[16] and *Methods Guide for Effectiveness and Comparative Effectiveness Reviews*,[27] based on the overall risk of bias (graded low, moderate, or high); the consistency of results across studies (graded consistent, inconsistent, or unable to determine when only one study was available); the directness of the evidence linking the intervention and health outcomes (graded direct or indirect); the precision of the estimate of effect, based on the number and size of studies and CIs for the estimates (graded precise or imprecise); and reporting bias (suspected or undetected).

RESULTS

The search and selection of articles for the full report are summarized in the literature flow diagram (Figure 1). Database searches resulted in 4,412 potentially relevant citations; 698 articles were selected for full-text review and 18 head-to-head studies evaluated predictive utility.[11-14,25,28-40]

Twelve studies compared discrimination of the tGCS versus the mGCS, and 6 studies compared the tGCS versus the Simplified Motor Scale (Table 1).[11-14,25,28-40] All studies were retrospective analyses. Sample sizes ranged from 96 to 811,143. Fifteen studies were conducted in the United States, 2 studies in Europe, and 1 in Canada. Four studies restricted enrollment to children[28,32,38,40]; the other studies enrolled adults or mixed populations. Four studies used data collected in or after 2006. GCS scores were obtained during out-of-hospital assessment in 11 studies,[11-13,25,29-33,36,39] in the ED in 5 studies,[14,28,35,37,38] and in mixed (ED or out-of-hospital)

Table 2. Proportion of patients experiencing outcomes in head-to-head studies on predictive utility.

Study, Year	Inhospital Mortality, %	Neurosurgical Intervention, %	Severe Brain Injury, %	Intubation, %
Acker et al, 2014[28]	8.4	10.4*	NR	NR
Al-Salamah et al, 2004[29]	18	NR	NR	16†
Beskind et al, 2014[11]	2.9	3.8	NR	4.1‡
Brown et al, 2014[§, 30]	4.3	NR	NR	NR
Caterino and Raubenolt, 2012[31]	5.8	1.5	15‖	7.6‡
Cicero and Cross, 2013[§32]	3.8	NR	NR	NR
Corrigan et al, 2014[§33]	NR	NR	NR	NR
Davis et al, 2006[34]	NR	NR	NR	NR
Eken et al, 2009[35]	14	NR	NR	NR
Gill et al, 2005[14]	11	9.3	17‖	26†
Gill et al, 2006[36]	10	8.8	17‖	26†
Haukoos et al, 2007[37]	5.5	6.6	14‖	18‡
Healey et al, 2003[§12]	6	NR	NR	NR
Holmes et al, 2005[38]	NR	NR	6.3¶	NR
Kupas et al, 2016[39]	5.7	2.0*	NR	7.1‡
Ross et al, 1998[13]	6.6	NR	NR	3.5#
Thompson et al, 2011[25]	5.8	7.8	18‖	18‡
Van de Voorde et al, 2008[40]	11	NR	NR	NR

*Craniotomy only.
†Intubation in the ED.
‡Intubation in the out-of-hospital setting or ED.
§Studies from the National Trauma Data Bank database.
‖Skull fracture with underlying brain injury, intracranial hemorrhage, cerebral contusion, or nonspecific intracranial injury.
¶Traumatic brain injury on CT scan (intracranial hemorrhage, hematoma, contusion, or cerebral edema) or in need of acute intervention (neurosurgical procedure, antiepileptic medication for >7 days, neurologic deficit persisting until discharge, or ≥2 nights of hospitalization for treatment for blunt head injury).
#Intubation in the out-of-hospital setting.

settings in 2 studies.[34,40] Four studies focused on patients with traumatic brain injury,[28,33,34,40] and the remainder evaluated mixed trauma populations. No study reported the proportion of intoxicated patients. Thirteen[13,25,28-35,38-40] studies were rated moderate risk of bias and 5 studies low[11,12,14,36,37] risk of bias. Eight studies did not report attrition and 7 studies reported missing data in greater than 20% of patients. Four studies were based on analyses of the National Trauma Data Bank database[12,30,32,33] but evaluated different populations or outcomes.

The most commonly evaluated outcome was inhospital mortality; the proportion of patients with inhospital mortality ranged from 3% to 18%. Other outcomes reported in at least 5 studies were severe brain injury (5% to 39%), receipt of neurosurgical intervention (1.5% to 10%), and emergency intubation (4% to 26%). Studies used different definitions for these outcomes (Table 2).

Results from each study are summarized in Table 3.

The tGCS was slightly better than the mGCS or Simplified Motor Scale at discriminating individuals who experienced inhospital mortality from those who survived to hospital discharge (Table 4). Based on 12 studies, the pooled AUROC for the tGCS was 0.877 (95% CI 0.847 to 0.906) and for the mGCS was 0.855 (95% CI 0.822 to 0.888), with a pooled mean difference of 0.015 (95% CI 0.009 to 0.022; I^2=85%; Figure 2).[11,12,14,25,28,29,32,34-37,39] Based on 5 studies, the pooled AUROC for the tGCS was 0.884 (95% CI 0.852 to 0.916) and for the Simplified Motor Scale was 0.840 (95% CI 0.802 to 0.878), with a mean difference of 0.030 (95% CI 0.024 to 0.036; I^2=0%; Figure E3, available online at http://www.annemergmed.com).[14,25,31,36,37]

The tGCS was slightly better than the mGCS or Simplified Motor Scale at discriminating patients who went on to receive a neurosurgical intervention from those who did not. Based on 7 studies, the pooled AUROC for the tGCS was 0.786 (95% CI 0.729 to 0.842) and for the mGCS was 0.754 (95% CI 0.688 to 0.819), for a mean difference of 0.032 (95% CI 0.020 to 0.043; I^2=72%; Figure 3).[11,14,25,28,36,37,39] Based on 5 studies, the pooled AUROC for the tGCS was 0.809 (95% CI 0.766 to 0.853) and for the Simplified Motor Scale was 0.769 (95% CI 0.711 to 0.827), with a mean difference of 0.032 (95% CI 0.025 to 0.039; I^2=0%; Figure E4, available online at http://www.annemergmed.com).[14,25,31,36,37]

The tGCS was slightly better than the mGCS or Simplified Motor Scale at discriminating patients found to have a severe brain injury from those without severe brain injury. Based on 5 studies, the pooled AUROC for the tGCS was 0.791 (95% CI 0.734 to 0.827) and for the mGCS was 0.720 (95% CI 0.666 to 0.774), with a mean difference of 0.050 (95% CI 0.034 to 0.065; I^2=57%; Figure 4).[14,25,32,36-38] Based on 5 studies, the pooled

AUROC for the tGCS was 0.763 (95% CI 0.710 to 0.815) and for the Simplified Motor Scale was 0.713 (95% CI 0.654 to 0.771), with a mean difference of 0.048 (95% CI 0.038 to 0.059; I^2=72%; Figure E5, available online at http://www.annemergmed.com).[14,25,31,36,37]

The tGCS was slightly better than the mGCS or Simplified Motor Scale at discriminating patients who underwent emergency intubation from those who did not undergo intubation. Based on 6 studies, the pooled AUROC for the tGCS was 0.865 (95% CI 0.830 to 0.901) and for the mGCS was 0.822 (95% CI 0.775 to 0.870), with a mean difference of 0.034 (95% CI 0.020 to 0.048; I^2=88%; Figure 5).[11,14,25,36,37,39] Based on 5 studies, the pooled AUROC for the tGCS was 0.843 (95% CI 0.823 to 0.864) and for the Simplified Motor Scale was 0.783 (95% CI 0.747 to 0.819), with a mean difference of 0.040 (95% CI 0.030 to 0.050; I^2=55%; Figure E6, available online at http://www.annemergmed.com).[14,25,31,36,37]

Sensitivity Analyses

For all outcomes, estimates were similar when the profile likelihood method was used to pool data. Findings were also similar when studies were stratified according to whether they focused on children or evaluated adults or mixed populations, used out-of-hospital or ED GCS scores, and collected all data after 2006 or collected some or all data before 2006 (Table 4). Findings were also similar when analyses were restricted to low-risk-of-bias studies, studies of patients with traumatic brain injury, or studies conducted in the United States. Estimates were similar from National Trauma Data Bank and non–National Trauma Data Bank studies; excluding National Trauma Data Bank studies had little effect on estimates (Table 4). For outcomes for which multiple studies were available from a particular trauma center, restricting the analysis to the most recent study from each center that used out-of-hospital GCS scores also had little effect on estimates.

For some analyses, statistical heterogeneity was present. However, overall findings were consistent across studies and differences in AUROCs were generally similar. For example, for the tGCS versus the mGCS and inhospital mortality, statistical heterogeneity was high (I^2=85%), but differences in AUROC values favored the tGCS in all studies and ranged from 0.01 to 0.07. For tGCS versus mGCS and severe brain injury, the mean difference in AUROC was slightly higher in one study of children (0.121; 95% CI 0.068 to 0.174)[32,38] than in 4 studies of mixed populations of adults and children (0.046; 95% CI 0.038 to 0.054; I^2=0%),[14,25,36,37] but there was no statistically significant interaction with age group (P=.07). Differences in how severe brain injury was defined could explain some of the differences in estimates. The study in children used a composite outcome of head computed tomography (CT) imaging findings or need for intervention.[38] All of the studies of mixed populations of adults and children defined severe brain injury on the basis of CT imaging findings.

LIMITATIONS

Because of anticipated heterogeneity caused by differences in patient populations, outcomes, assessment settings, and other factors, we used the random-effects DerSimonian-Laird model to pool data. Statistical heterogeneity was moderate or high in some analyses. The DerSimonian-Laird estimator can result in CIs that are too narrow when statistical heterogeneity is present.[23] Therefore, we also performed analyses using an alternative random-effects model, the profile likelihood method, which may perform better under these conditions. Results were similar with the profile likelihood method. Statistical heterogeneity was high in some analyses, but tGCS was consistently associated with better discrimination, and the ranges for differences in AUROC values across studies were relatively narrow. Given the large study sample sizes, small differences in AUROC among studies were detected as statistical heterogeneity. Analyses based on the AUROC tend to favor measures based on scales with more input points, which "smooth" the curve and favor the tGCS (3-to-15 scale) over more abbreviated scale.

We had to impute standard errors for some studies included in pooled analyses. However, findings were similar when we used alternative imputation methods. Also, the tGCS and mGCS or Simplified Motor Scale was not performed independently in any study, so it is uncertain how findings on the other GCS components may have affected scoring of the mGCS. We assumed moderate correlation between tGCS and mGCS or Simplified Motor Scale scores, but findings were similar with alternative correlation assumptions.

Most studies of predictive utility had methodological limitations, including failure to report attrition, missing data, and unclear methods for measuring outcomes. However, restricting analyses to studies with low loss to follow-up or overall low risk of bias had little influence on findings. As detailed in the full report, data were limited on discrimination for other outcomes indicating need for high-level trauma care (eg, meeting criteria for trauma center need, having a high Injury Severity Score), although findings were consistent with the outcomes reported in this article.

Table 3. Summary of discrimination (AUROC) of head-to-head studies.

Author, Year, Country	Assessment Timing Measures or Scores Compared	N	Age, Years	Inhospital Mortality (95% CI)	Neurosurgical Intervention (95% CI)	Severe Brain Injury (95% CI)	Intubation (95% CI)
Acker et al, 2014,[28] USA	ED A: tGCS B: mGCS	2,231	≤18 Mean: 6.9	A: 0.949 (0.938 to 0.961) B. 0.941 (0.926 to 0.957) *P*=.06	A: 0.642 (0.603 to 0.681) B: 0.638 (0.601 to 0.675) *P*=.64* A: 0.808 (0.784 to 0.832) B: 0.774 (0.748 to 0.800) *P*<.001†	NR	NR
Al-Salamah et al, 2004,[29] Canada	Out-of-hospital A: tGCS score ≤13 B: mGCS score ≤5	795	≥16 Mean: 44	A: 0.82 B: 0.81 *P*=NR	NR	NR	NR
Beskind et al, 2014,[11] USA	Out-of-hospital A: tGCS B: mGCS	9,816	Mean: 32	A: 0.899 (0.874 to 0.923) B: 0.888 (0.864 to 0.913) Mean difference=0.010 (0.002 to 0.018)	A: 0.571 (0.533 to 0.609) B: 0.570 (0.531 to 0.608) Mean difference=0.002 (−0.013 to 0.016)	NR	A: 0.966 (0.955 to 0.976) B: 0.948 (0.933 to 0.963) Mean difference=0.018 (0.011 to 0.024)
Caterino and Raubenolt, 2012,[31] USA	Out-of-hospital A: tGCS ≤13 B: SMS ≤1	52,412	≥16 Mean: 53	A: 0.85 (0.84 to 0.86) B: 0.82 (0.81 to 0.83)	A: 0.75 (0.73 to 0.77) B: 0.70 (0.68 to 0.72)	A: 0.72 (0.71 to 0.72) B: 0.66 (0.65 to 0.66)	A: 0.86 (0.85 to 0.87) B: 0.83 (0.82 to 0.83)
Cicero and Cross, 2013,[‡32] USA	Out-of-hospital A: tGCS B: mGCS	104,035	<19 Mean: 12.6	A: 0.946 (0.941 to 0.951) B: 0.940 (0.935 to 0.945)	NR	NR	NR
Corrigan et al, 2014,[‡33] USA	Out-of-hospital A: tGCS B: mGCS	77,470	≥18	A: 0.886 (NR) B: 0.878 (NR)	NR	NR	NR
Davis et al, 2006,[34] USA	Out-of-hospital and ED A: tGCS B: mGCS	12,882	NR	A: 0.84 (NR) B: 0.83 (NR)	A: 0.80 (NR) B: 0.78 (NR)	NR	NR
Eken et al, 2009,[35] Turkey	ED A: tGCS B: mGCS	185	>17	A: 0.735 (0.655 to 0.797) B: 0.662 (0.589 to 0.730)	NR	NR	NR
Gill et al, 2005,[14] USA	ED A: tGCS B: mGCS C: SMS	8,412	Median 24	A: 0.906 (NR) B: 0.894 (NR) C: 0.878 (NR)	A: 0.874 (NR) B: 0.848 (NR) C: 0.851 (NR)	A: 0.826 (NR) B: 0.789 (NR) C: 0.791 (NR)	A: 0.865 (NR) B: 0.826 (NR) C: 0.826 (NR)
Gill et al, 2006,[36] USA	Out-of-hospital A: tGCS B: mGCS C: SMS	7,233	Median 24	A: 0.89 (0.88 to 0.90) B: 0.88 (0.87 to 0.89) C: 0.86 (0.86 to 0.89)	A: 0.86 (0.85 to 0.88) B: 0.84 (0.82 to 0.85) C: 0.83 (0.81 to 0.84)	A: 0.83 (0.82 to 0.84) B: 0.79 (0.78 to 0.81) C: 0.79 (0.77 to 0.80)	A: 0.83 (0.81 to 0.84) B: 0.79 (0.78 to 0.80) C: 0.79 (0.77 to 0.80)

Haukoos et al, 2007,[‡37] USA	ED A: tGCS B: mGCS C: SMS	21,170	Median 32	A: 0.92 (0.91 to 0.93) B: 0.90 (0.89 to 0.91) C: 0.89 (0.88 to 0.90)	A: 0.83 (0.82 to 0.84) B: 0.80 (0.79 to 0.81) C: 0.80 (0.79 to 0.81)	A: 0.76 (0.75 to 0.77) B: 0.71 (0.70 to 0.72) C: 0.71 (0.70 to 0.72)	A: 0.86 (0.85 to 0.87) B: 0.81 (0.80 to 0.82) C: 0.81 (0.80 to 0.82)
Healey et al, 2003,[12‡] USA	Out-of-hospital A: tGCS B: mGCS	202,255	NR	A: 0.891 (0.888 to 0.894) B: 0.873 (0.870 to 0.875) $P<.001$	NR	NR	NR
Holmes et al, 2005,[38] USA	ED A: tGCS B: mGCS	2,043	≤2	NR	NR	≤2 y: A: 0.72 (0.56 to 0.87) B: 0.60 (0.48 to 0.72) >2 y: A: 0.82 (0.76 to 0.87) B: 0.71 (0.65 to 0.77) AUROC (95% CI) for TBI in need of acute intervention ≤2 y: A: 0.97 (0.94 to 1.0) B: 0.76 (0.59 to 0.93) >2 y: A: 0.87 (0.83 to 0.92) B: 0.76 (0.71 to 0.81)	NR
Kupas et al, 2016,[39] USA	Out-of-hospital A: tGCS B: mGCS	370,392	≥18	A: 0.831 (0.828 to 0.834) B: 0.803 (0.800 to 0.806) Difference=0.028 (0.026 to 0.030)	A: 0.724 (0.718 to 0.730) B: 0.676 (0.670 to 0.682) Difference=0.048 (0.044 to 0.052)*	NR	A: 0.904 (0.902 to 0.907) B: 0.884 (0.882 to 0.887) Difference=0.020 (0.019 to 0.021)
Thompson et al, 2011,[25] USA	Out-of-hospital A: tGCS ≤13 B: mGCS score ≤5 B: SMS ≤1	19,408	All median: 33	A: 0.82 (0.74 to 0.90) B: 0.76 (0.70 to 0.83) C: 0.74 (0.70 to 0.77)	A: 0.70 (0.64 to 0.77) B: 0.66 (0.61 to 0.71) C: 0.66 (0.64 to 0.69)	A: 0.66 (0.60 to 0.71) B: 0.61 (0.57 to 0.65) C: 0.61 (0.58 to 0.64)	A: 0.70 (0.63 to 0.77) B: 0.65 (0.60 to 0.70) C: 0.65 (0.62 to 0.67)

*Craniotomy only.
†Intracranial pressure monitoring only.
‡Studies from the National Trauma Data Bank database.

Table 4. Pooled AUROC results of head-to-head studies.

Outcome and Analysis	tGCS vs mGCS, Difference in AUROC (95% CI)	Number of Studies	I^2, %	tGCS vs SMS, Difference in AUROC (95% CI)	Number of Studies	I^2, %
Inhospital mortality, overall	0.015 (0.009 to 0.022)	12	85	0.030 (0.024 to 0.036)	5	0
Adults or mixed	0.019 (0.012 to 0.025)	10	75	0.030 (0.024 to 0.036)	5	0
Children	0.006 (0.002 to 0.011)	2	0	—	—	—
Excluding NTDB studies	0.017 (0.008 to 0.025)	10	68	0.030 (0.024 to 0.036)	5	0
Excluding studies with potential overlap*	0.016 (0.008 to 0.024)	9	88	0.031 (0.023 to 0.039)	3	0
Out-of-hospital GCS score	0.016 (0.007 to 0.024)	7	91	0.031 (0.023 to 0.039)	3	0
ED GCS score	0.020 (0.006 to 0.034)	3	23	0.030 (0.020 to 0.039)	2	0
US setting	0.015 (0.008 to 0.022)	10	87	0.030 (0.024 to 0.036)	5	0
TBI patients	0.009 (−0.002 to 0.020)	3	0	—	—	—
Low-risk-of-bias studies	0.017 (0.015 to 0.020)	5	0	0.030 (0.022 to 0.037)	3	0
Enrollment before 2006	0.018 (0.011 to 0.024)	10	77	0.030 (0.024 to 0.036)	5	0
Enrollment after 2006	0.006 (0.001 to 0.011)	2	0	—	—	—
Neurosurgical intervention, overall	0.032 (0.020 to 0.043)	7	72	0.032 (0.025 to 0.039)	5	0
Adults or mixed	0.031 (0.018 to 0.044)	6	76	0.032 (0.025 to 0.039)	5	0
Children	0.034 (0.009 to 0.059)	1	—	—	—	—
Excluding studies with potential overlap*	0.032 (0.011 to 0.053)	4	79	0.038 (0.024 to 0.052)	3	19
Out-of-hospital GCS score	0.032 (0.011 to 0.053)	4	79	0.038 (0.024 to 0.052)	3	19
ED GCS score	0.029 (0.020 to 0.039)	2	0	0.029 (0.020 to 0.038)	2	0
US setting	0.032 (0.020 to 0.044)	7	72	0.032 (0.025 to 0.039)	5	0
TBI patients	0.017 (−0.022 to 0.056)	2	66	—	—	—
Low-risk-of-bias studies	0.026 (0.019 to 0.034)	4	0	0.029 (0.021 to 0.037)	3	0
Enrollment before 2006	0.033 (0.021 to 0.045)	6	74	0.032 (0.025 to 0.039)	5	0
Enrollment after 2006	0.019 (−0.009 to 0.047)	1	—	—	—	—
Severe brain injury, overall	0.050 (0.034 to 0.065)	5	57	0.048 (0.038 to 0.059)	5	72
Adults or mixed	0.046 (0.038 to 0.054)	4	0	0.048 (0.038 to 0.059)	5	72
Children	0.121 (0.068 to 0.174)	1	—	—	—	—
Excluding NTDB studies	0.050 (0.034 to 0.065)	5	57	0.048 (0.038 to 0.059)	5	72
Excluding studies with potential overlap*	0.065 (0.020 to 0.111)	3	76	0.051 (0.034 to 0.068)	3	74
Out-of-hospital GCS score	0.041 (0.028 to 0.053)	2	0	0.051 (0.034 to 0.068)	3	74
ED GCS score	0.060 (0.028 to 0.093)	3	73	0.044 (0.030 to 0.059)	2	51
US setting	0.050 (0.034 to 0.065)	5	57	0.048 (0.038 to 0.059)	5	72
TBI patients	—	—	—	—	—	—
Low-risk-of-bias studies	0.046 (0.038 to 0.053)	3	0	0.044 (0.035 to 0.053)	3	25
Enrollment before 2006	0.050 (0.034 to 0.065)	5	57	0.048 (0.038 to 0.059)	5	72
Enrollment after 2006	—	—	—	—	—	—
Emergency intubation, overall	0.034 (0.020 to 0.048)	6	88	0.040 (0.030 to 0.050)	5	55
Adults or mixed	0.034 (0.020 to 0.048)	6	88	0.040 (0.030 to 0.050)	5	55
Children	—	—	—	—	—	—
Excluding studies with potential overlap*	0.026 (0.015 to 0.037)	4	68	0.033 (0.025 to 0.040)	3	0
Out-of-hospital GCS score	0.026 (0.015 to 0.037)	4	68	0.033 (0.025 to 0.040)	3	0
ED GCS score	0.048 (0.039 to 0.057)	2	0	0.048 (0.039 to 0.057)	2	0
US setting	0.034 (0.020 to 0.048)	6	88	0.040 (0.030 to 0.050)	5	55
TBI patients	0.011 (−0.010 to 0.032)	1	—	—	—	—
Low-risk-of-bias studies	0.037 (0.022 to 0.052)	4	79	0.046 (0.038 to 0.054)	3	0
Enrollment before 2006	0.038 (0.020 to 0.055)	5	91	0.040 (0.030 to 0.050)	5	55
Enrollment after 2006	0.018 (0.005 to 0.031)	1	—	—	—	—

NTDB, National Trauma Data Bank.

*When multiple studies were published from the same trauma center, analysis was restricted to the most recent study using out-of-hospital GCS scores (excluded Gill 2005,[14] Haukoos 2007,[37] and Acker 2014[28]).

We restricted analyses to English-language studies. However, we identified no foreign-language study that appeared to meet inclusion criteria, and our focus was on studies applicable to US trauma settings. We were limited in our ability to assess publication bias, given the relatively small number of studies. We did not identify any ongoing studies in clinicaltrials.gov on predictive utility of the tGCS versus the mGCS or Simplified Motor Scale, although such studies are unlikely to be registered in this database.

Several studies were based on the large National Trauma Data Bank. We could not reliably determine the degree to which studies that analyzed data from single centers enrolled populations also analyzed in the National Trauma Data Bank studies. We performed sensitivity analyses in

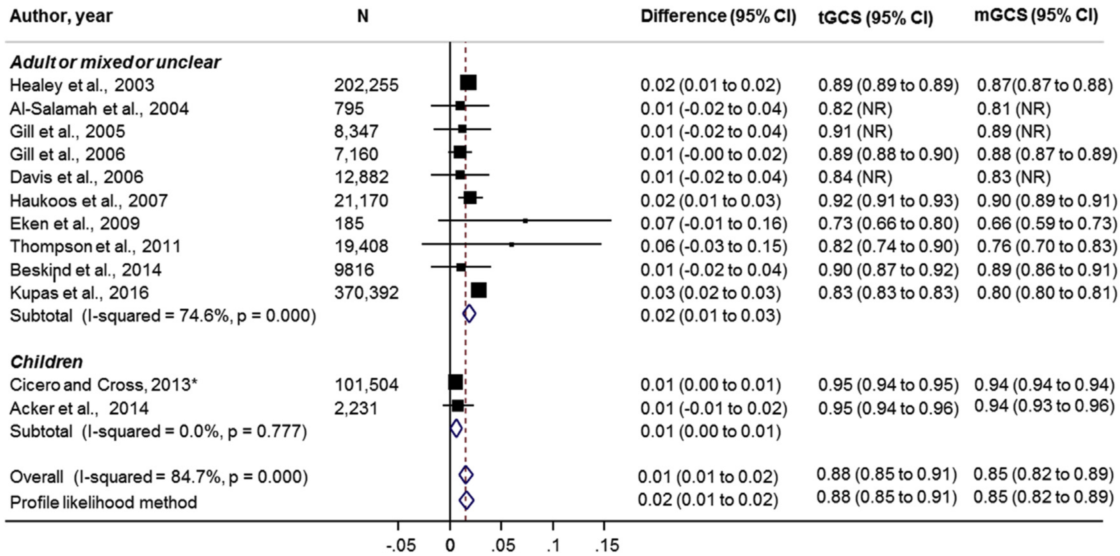

Figure 2. Pooled AUROC of inhospital mortality for the tGCS versus the motor component only. *NR*, Not reported. *Patients from the National Trauma Data Bank data set.

which National Trauma Data Bank studies were excluded, which had little effect on findings.

DISCUSSION

The findings of this review are summarized in Table 5. Based on head-to-head studies, the tGCS is associated with slightly better predictive utility than the mGCS, using the AUROC to compare the measures. The tGCS is better able than the mGCS to discriminate people with trauma who undergo neurosurgical intervention, meet criteria for severe brain injury, or undergo emergency intubation from people who do not experience these outcomes, although the differences in the AUROC on each of these outcomes was small (<0.05). The tGCS was also better than the mGCS at discriminating trauma patients who died during hospitalization from those who survived to hospital discharge, but the difference in the AUROC was even smaller (0.01) than for nonmortality outcomes. Findings for the tGCS versus the Simplified Motor Scale were similar to findings for the tGCS versus the mGCS for nonmortality outcomes, but the Simplified Motor Scale performed slightly worse than the mGCS for inhospital mortality (difference in AUROC 0.03). Similar results for the mGCS and the Simplified Motor Scale might be

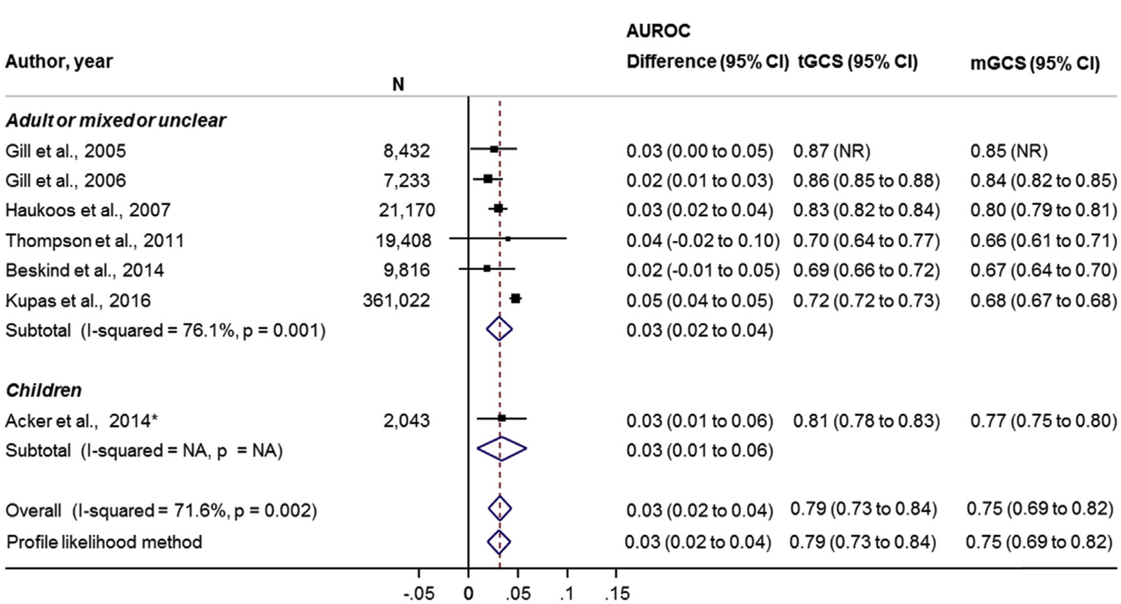

Figure 3. Pooled AUROC of neurologic intervention for the total GCS versus the motor component only. *NA*, Not applicable. *Intracranial pressure monitoring only.

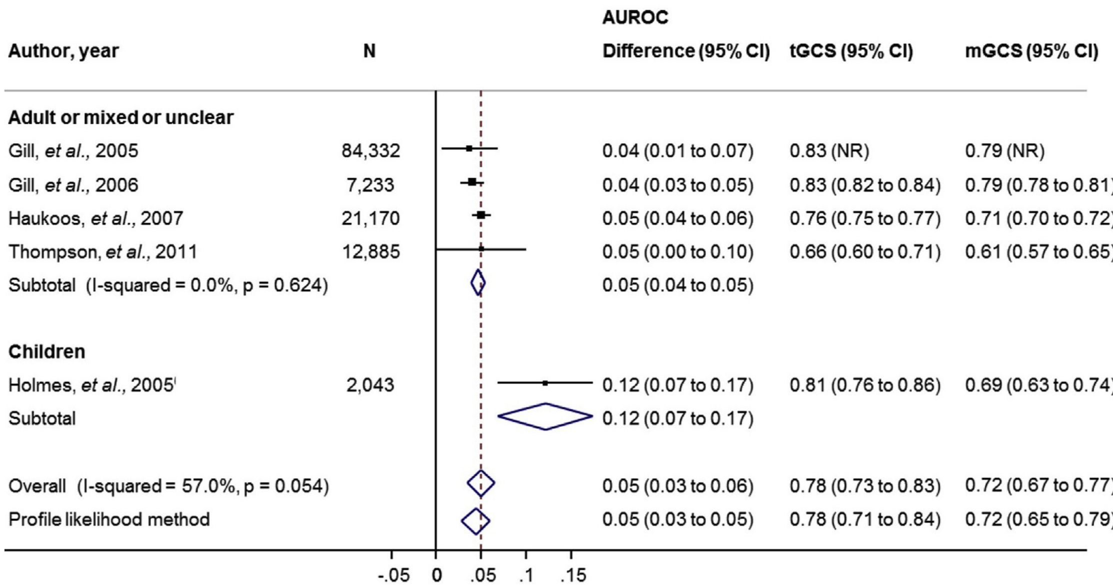

Figure 4. Pooled AUROC of severe brain injury for the total GCS versus the motor component only.

expected because the Simplified Motor Scale is based on the same information as the mGCS, with the only difference being that for the Simplified Motor Scale, data for patients with low scores on the mGCS (0 to 4) are collapsed into a single category. Therefore, any differences in predictive utility between the Simplified Motor Scale and mGCS are likely to be primarily related to ease of use. Findings were robust in sensitivity and subgroup analyses based on the age group analyzed (children versus adults or mixed), study year (before 2006 or after 2006), and risk-of-bias ratings. However, sensitivity and subgroup analyses were limited by small numbers of studies, particularly for nonmortality outcomes.

Our findings indicate that for every 100 trauma patients, the tGCS is able to correctly discriminate 1 to 5 more cases of severe trauma from nonsevere trauma than the mGCS or the Simplified Motor Scale. Although we classified such differences as "small," based on a priori thresholds, and unlikely to be clinically important, such thresholds are by nature somewhat arbitrary. The clinical importance of small differences in discrimination depend in part on the seriousness of the outcome evaluated, the degree to which triage and other treatment decisions are based on the GCS versus other factors, and the degree to which actions based on the GCS affect clinical outcomes. As detailed in the full report, no study compared the effects of using the tGCS

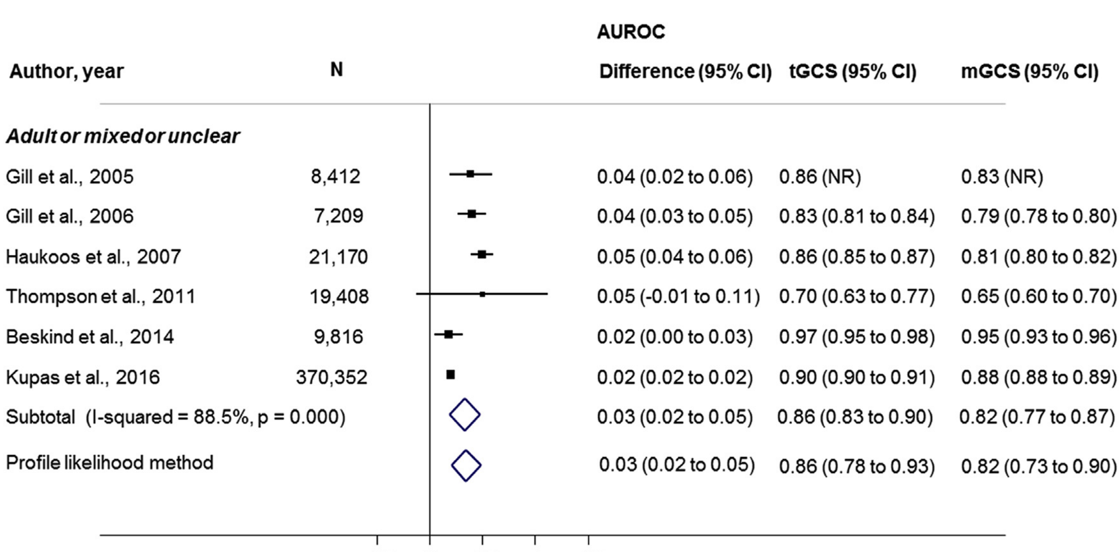

Figure 5. Pooled AUROC of emergency intubation for the total GCS versus the motor component only.

Table 5. Strength of evidence, discrimination for markers of serious traumatic injuries.

Comparison	Number of Studies (N)	Study Limitations	Directness	Consistency	Precision	Reporting Bias	Main Findings	Strength of Evidence Grade
Inhospital mortality								
tGCS vs mGCS	12 (756,145)	Moderate	Direct	Consistent*	Precise	Not detected	Difference in AUROC 0.015 (0.009–0.022)	Moderate
tGCS vs SMS	5 (110,435)	Moderate	Direct	Consistent	Precise	Not detected	Difference in AUROC 0.030 (0.024–0.036)	Moderate
Neurosurgical intervention								
tGCS vs mGCS	7 (429,124)	Moderate	Direct	Consistent	Precise	Not detected	Difference in AUROC 0.031 (0.018–0.044)	Moderate
tGCS vs SMS	5 (108,635)	Moderate	Direct	Consistent	Precise	Not detected	Difference in AUROC 0.032 (0.025–0.039)	Moderate
Severe brain injury								
tGCS vs mGCS	5 (134,186)	Moderate	Direct	Consistent*	Precise	Not detected	Difference in AUROC 0.050 (0.034–0.065)	Moderate
tGCS vs SMS	5 (100,223)	Moderate	Direct	Consistent*	Precise	Not detected	Difference in AUROC 0.048 (0.038–0.059)	Moderate
Emergency intubation								
tGCS vs mGCS	6 (436,391)	Moderate	Direct	Consistent*	Precise	Not detected	Difference in AUROC 0.034 (0.020–0.048)	Moderate
tGCS vs SMS	5 (108,635)	Moderate	Direct	Consistent*	Precise	Not detected	Difference in AUROC 0.040 (0.030–0.050)	Moderate

*I^2 was greater than 50% but the range in differences in AUROC across studies <0.05.

versus the mGCS or Simplified Motor Scale for field assessment of trauma on rates of over- or undertriage or clinical outcomes.[15] Factors that might offset slight differences in discrimination include ease of use and reliability. As noted in the full report, there were insufficient data to determine comparative interrater reliability of the tGCS, mGCS, and Simplified Motor Scale, although some evidence suggests that the mGCS is more likely to be scored accurately than the tGCS.[15]

As detailed in the full report,[15] data on other measures of predictive utility, such as diagnostic accuracy (sensitivity and specificity), were limited. Based on limited evidence, differences in diagnostic accuracy between the tGCS and the mGCS with standard cutoffs (≤13 for tGCS and ≤5 for mGCS) were small.[13,29,30,39,40] For inhospital mortality, 5 studies found a difference in sensitivity of 0% to 3% favoring tGCS and a difference in specificity of 0% to 5% favoring mGCS.[13,29,30,39,40] In the largest study, sensitivity was 70% for tGCS and 67% for mGCS, and specificity was 88% and 90%, respectively.[39] Interpretation of these findings depends on the relative importance of correctly identifying persons with severe trauma (sensitivity) versus correctly identifying persons without severe trauma (specificity). For other outcomes, data on sensitivity and specificity were available from only 2 or 3 studies. Discrimination is calculated from sensitivity and specificity over a range of test values, but decisions based on GCS scales are based on whether patients' scores are above or below a threshold score. Therefore, it would be helpful for future studies comparing GCS scales to routinely report diagnostic accuracy at standard cutoffs, in addition to measures of discrimination, to better understand comparative predictive utility.

Our findings on predictive utility of different GCS scales appear to have broad applicability to field triage in the United States because they are based on large studies conducted in US trauma settings in mixed populations of adults and children with various types of trauma. However, prospective studies that independently assess patients with the tGCS and the mGCS or Simplified Motor Scale would be useful for confirming the findings of the currently available retrospective studies. Ideally, head-to-head observational or randomized studies that assess one set of patients with the tGCS and another set with the Simplified Motor Scale or mGCS would be useful for understanding how differences in discrimination affect clinical outcomes, as well as risk of over- or undertriage. Studies are also needed to better understand the predictive utility in important subpopulations, including children, older patients, patients with specific types of trauma, and patients who have received field interventions before assessment. It would also be helpful for studies to routinely record and report the proportion of patients who are intoxicated or intubated, or in whom the nonmotor components of the GCS could not be adequately performed for other reasons. Studies that evaluate how the predictive utility of the tGCS compares with the mGCS or Simplified Motor Scale varies according to the level or type of training of assessing field personnel are also needed.

In conclusion, the tGCS is associated with slightly greater discrimination than the mGCS or Simplified Motor Scale for inhospital mortality, receipt of neurosurgical interventions, meeting criteria for severe brain injury, and emergency intubation, with differences in the AUROC ranging from 0.01 to 0.05. The small differences in discrimination are likely to be clinically unimportant and could be offset by factors such as convenience and ease of use.

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Search strategies.

Database: Ovid MEDLINE(R) and Ovid OLDMEDLINE(R)

Search Strategy:

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1 exp Glasgow Coma Scale/ (7598)
2 exp Trauma Severity Indices/ (26320)
3 ((glasgow adj3 coma*) or tgcs or mgcs or gcs).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (17103)
4 2 and 3 (8526)
5 1 or 4 (8526)
6 exp Craniocerebral Trauma/ (133918)
7 (tbi or ((head or brain* or cereb* or crani* or skull*) adj3 (injur* or traum* or wound* or damag*))).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (136121)
8 6 or 7 (196584)
9 exp Emergencies/ (35777)
10 exp Emergency Medical Services/ (105134)
11 (pre-hospital* or prehospital or paramedic* or emt or ems or emergency medical technician* or ambulance* or ((field* or onsite or on-site or scene* or accident*) adj5 triag*)).mp. (40109)
12 exp Emergency Treatment/ (100260)
13 exp emergency medicine/ (10629)
14 (pre-hospital* or prehospital or paramedic* or emt or ems or emergency medical technician* or ambulance* or ((field* or onsite or on-site or scene* or accident*) adj5 triag*)).mp. (40109)
15 exp accidents/ (152529)
16 (emergency or emergencies or triage or priorit*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (302727)
17 15 and 16 (13350)
18 9 or 10 or 12 or 13 or 14 or 17 (249494)
19 5 and 8 and 18 (990)
20 limit 19 to english language (889)
21 limit 19 to abstracts (928)
22 20 or 21 (973)

Database: Ovid MEDLINE(R)

Search Strategy:

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1 exp Glasgow Coma Scale/ (7453)
2 exp Trauma Severity Indices/ (26003)
3 ((glasgow adj3 coma*) or tgcs or mgcs or gcs).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (16669)
4 2 and 3 (8367)
5 1 or 4 (8367)
6 exp "wounds and injuries"/ (764490)
7 exp accidents/ (153435)
8 exp violence/ (73131)
9 (tbi or ((head or brain* or cereb* or crani* or skull*) adj3 (injur* or traum* or wound* or damag*))).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (133113)
10 ((case* or patient* or triag* or unconsciou* or consciou* or call* or "911" or emergenc*) adj5 (injur* or traum* or wound* or damag* or hurt*)).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (158827)
11 6 or 7 or 8 or 9 or 10 (1040851)
12 exp Emergencies/ (36151)
13 exp Emergency Medical Services/ (104345)
14 (pre-hospital* or prehospital or paramedic* or emt or ems or emergency medical technician* or ambulance* or ((field* or onsite or on-site or scene* or accident*) adj5 triag*)).mp. (39234)
15 exp Emergency Treatment/ (100137)
16 exp emergency medicine/ (10652)
17 (pre-hospital* or prehospital or paramedic* or emt or ems or emergency medical technician* or ambulance* or ((field* or onsite or on-site or scene* or accident*) adj5 triag*)).mp. (39234)
18 exp accidents/ (153435)

Figure E1. Search strategy criteria.

19 (emergency or emergencies or triage or priorit*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (297798)
20 18 and 19 (13245)
21 12 or 13 or 15 or 16 or 17 or 20 (248295)
22 5 and 11 and 21 (1587)
23 limit 22 to english language (1444)
24 limit 22 to abstracts (1483)
25 23 or 24 (1562)

Database: CINAHL

Search Strategy:

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1 (MH "Head Injuries+") (29202)
2 (tbi or ((head or brain* or cereb* or crani* or skull*) n3 (injur* or traum* or wound* or damag*))) (31690)
3 1 or 2 (38057)
4 (MH "Trauma Severity Indices+") (10932)
5 ((glasgow n3 coma*) or tgcs or mgcs or gcs) (6372)
6 4 or 5 (11,836)
7 (MH "Emergency Medical Services+") (69526)
8 (MH "Emergency Medical Technicians") or (MH "Emergency Medical Technician Attitudes") (8776)
9 (MH "Physicians, Emergency") or (MH "Emergency Nurse Practitioners") (2383)
10 (MH "Emergency Nursing") (11557)
11 pre-hospital* or prehospital or paramedic* or emt or ems or emergency medical technician* or ambulance* (27129)
12 (emergency or emergencies or accident*) n5 (triage or priorit* or classif* or identif*) (2730)
13 7 or 8 or 9 or 10 or 11 or 12 (90644)
14 3 and 6 and 13 (774)

Database: CINAHL

Search Strategy:

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1 (MH "trauma+") or (MH "wounds and injuries+") or (MH "emergency patients+") or (MH "accidents+") or (MH "violence+") (286638)
2 (tbi or ((head or brain* or cereb* or crani* or skull*) n3 (injur* or traum* or wound* or damag*))) (31922)
3 1 or 2 (293880)
4 (MH "Trauma Severity Indices+") (10983)
5 ((glasgow n3 coma*) or tgcs or mgcs or gcs) (6432)
6 4 or 5 (11915)
7 (MH "Emergency Medical Services+") (69734)
8 (MH "Emergency Medical Technicians") or (MH "Emergency Medical Technician Attitudes") (8800)
9 (MH "Physicians, Emergency") or (MH "Emergency Nurse Practitioners") (2395)
10 (MH "Emergency Nursing") (11562)
11 pre-hospital* or prehospital or paramedic* or emt or ems or emergency medical technician* or ambulance* (27291)
12 (emergency or emergencies or accident*) n5 (triage or priorit* or classif* or identif*) (2762)
13 7 or 8 or 9 or 10 or 11 or 12 (91020)
14 3 and 6 and 13 (2364)

Database: EBM Reviews - Cochrane Central Register of Controlled Trials

Search Strategy:

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1 (injur* or traum* or wound* or damag*).mp. [mp=title, original title, abstract, mesh headings, heading words, keyword] (47806)
2 ((glasgow adj3 coma*) or tgcs or mgcs or gcs).mp. (1148)
3 ((traum* or injur*) adj3 sever* adj5 (rated or rating* or scale*)).mp. [mp=title, original title, abstract, mesh headings, heading words, keyword] (123)
4 2 or 3 (1175)
5 (pre-hospital* or prehospital or paramedic* or emt or ems or emergency medical technician* or ambulance* or emergency or emergencies or accident* or triage or priorit* or classif* or identif*).mp. [mp=title, original title, abstract, mesh headings, heading words, keyword] (125583)
6 1 and 4 and 5 (217)

Database: EBM Reviews - Cochrane Database of Systematic Reviews

Search Strategy:

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1 (injur* or traum* or wound* or damag*).mp. [mp=title, abstract, full text, keywords, caption text] (4650)
2 ((glasgow adj3 coma*) or tgcs or mgcs or gcs).mp. (88)
3 ((traum* or injur*) adj3 sever* adj5 (rated or rating* or scale*)).mp. [mp=title, abstract, full text, keywords, caption text] (24)

Figure E1. Continued.

4 2 or 3 (97)
5 (pre-hospital* or prehospital or paramedic* or emt or ems or emergency medical technician* or ambulance* or emergency or emergencies or accident* or triage or priorit* or classif* or identif*).mp. [mp=title, abstract, full text, keywords, caption text] (8818)
6 1 and 4 and 5 (80)

Database: PsycINFO

Search Strategy:

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1 exp Traumatic Brain Injury/ (13891)
2 exp Head Injuries/ (5271)
3 exp trauma/ (59345)
4 exp accidents/ (11000)
5 exp violence/ (62018)
6 (tbi or ((head or brain* or cereb* or crani* or skull*) adj3 (injur* or traum* or wound* or damag*))).mp. (47797)
7 1 or 2 or 3 or 4 or 5 or 6 (155040)
8 ((glasgow adj3 coma*) or tgcs or mgcs or gcs).mp. (4566)
9 ((traum* or injur*) adj5 (critical* or sever* or threat*) adj7 (rat* or scale* or index* or classif* or identif*)).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures] (1171)
10 8 or 9 (5448)
11 exp Emergency Services/ (6316)
12 exp accidents/ (11000)
13 (pre-hospital* or prehospital or paramedic* or emt or ems or emergency medical technician* or ambulance* or ((field* or onsite or on-site or scene* or accident*) adj5 triag*)).mp. (2424)
14 (emergency or emergencies or triage or ((priorit* or early or earlie* or rapid* or quick* or swift*) adj5 (treat* or therap* or interven* or interven* or transport* or procedur*))).mp. (60383)
15 11 or 12 or 13 or 14 (72337)
16 7 and 10 and 15 (546)

Database: Health and Psychosocial Instruments

Search Strategy:

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1 (tbi or ((head or brain* or cereb* or crani* or skull*) adj3 (injur* or traum* or wound* or damag*))).mp. (1769)
2 ((glasgow adj3 coma*) or tgcs or mgcs or gcs).mp. (329)
3 ((traum* or injur*) adj3 sever* adj5 (rated or rating* or scale*)).mp. [mp=title, acronym, descriptors, measure descriptors, sample descriptors, abstract, source] (23)
4 2 or 3 (350)
5 (pre-hospital* or prehospital or paramedic* or emt or ems or emergency medical technician* or ambulance* or ((field* or onsite or on-site or scene* or accident*) adj5 triag*)).mp. (96)
6 (emergency or emergencies or accident* or triage or priorit*).mp. (1413)
7 5 or 6 (1486)
8 1 and 4 and 7 (8)
9 4 and 7 (23)

Database: Health and Psychosocial Instruments

Search Strategy:

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1 (injur* or traum* or wound* or damag*).mp. [mp=title, acronym, descriptors, measure descriptors, sample descriptors, abstract, source] (7032)
2 ((glasgow adj3 coma*) or tgcs or mgcs or gcs).mp. (330)
3 ((traum* or injur*) adj3 sever* adj5 (rated or rating* or scale*)).mp. [mp=title, acronym, descriptors, measure descriptors, sample descriptors, abstract, source] (23)
4 2 or 3 (351)
5 (pre-hospital* or prehospital or paramedic* or emt or ems or emergency medical technician* or ambulance* or emergency or emergencies or accident* or triage or priorit* or classif* or identif*).mp. [mp=title, acronym, descriptors, measure descriptors, sample descriptors, abstract, source] (6531)
6 1 and 4 and 5 (2)

Figure E1. Continued.

RISK OF BIAS CRITERIA

Risk Prediction Studies[1]

Criteria:

The study sample adequately represents the population of interest.

The study data available (ie, participants not lost to follow-up) adequately represent the study sample.

The prognostic factor is measured in a similar way for all participants.

The outcome of interest is measured in a similar way for all participants.

Important potential confounding factors are appropriately accounted for.

The observed effect of the prognostic factor on the outcome is very likely to be distorted by another factor related to prognostic factor and outcome.

Definitions of risk of bias based on above criteria:

Low: The least risk of bias, and results are generally considered more valid than those of studies with the same study design but more flaws. Low-risk-of-bias studies include clear descriptions of the population, setting, interventions, and comparison groups include clear reporting of missing data; apply appropriate means to prevent; and appropriately measure outcomes.

Moderate: Susceptible to some bias, although not enough to necessarily invalidate the results. These studies may not meet all the criteria for "low"-risk-of-bias rating, but do not have flaws likely to cause major bias. The study may also be missing information, making it difficult to assess limitations and potential problems.

High: Have significant flaws that may invalidate the results. They may have a serious or "fatal" flaw or set of flaws in design, analysis, or reporting; large amounts of missing information; or discrepancies in reporting. The results of these studies will be least likely to reflect flaws in the study design as the true difference between the compared interventions.

ASSESSMENT OF METHODOLOGICAL RISK OF BIAS OF INDIVIDUAL STUDIES

We assessed risk of bias of included studies, using predefined criteria. Our methods for assessing it are based on recommendations from the Agency for Healthcare Research and Quality.[27] For key question 1 (predictive utility), we applied the Quality in Prognostic Studies tool for prognostic studies.[21] The tool includes domains on study participation, study attrition, prognostic factor measurement, outcomes measurement, study confounding, and statistical analysis and reporting. For key question 4 (reliability and ease of use), we assessed risk of bias with criteria adapted from the Quality Assessment of Diagnostic Accuracy Studies.[22] This includes criteria about patient selection, whether raters were blinded to other ratings, how the scores from different assessments were compared, and the situation and timing of measurement. Two investigators independently assessed risk of bias for each study. Differences were resolved by discussion; we used a third rater to resolve discrepancies if needed. No study met inclusion criteria for key questions 2 or 3.

Studies rated low risk of bias have the least risk of bias, and their results are generally considered more valid than those of studies with the same study design but more flaws. For example, low-risk-of-bias studies on predictive utility select all or a random subset of patients who meet predefined criteria, report low attrition, perform the risk assessment scale for all patients, measure outcomes accurately, and, for all patients, assess and measure important confounders, use appropriate statistical methods, and avoid selective reporting of results.

Studies rated moderate risk of bias are susceptible to some bias, although not enough to necessarily invalidate the results. These studies may not meet all the criteria for a low-risk-of-bias rating, but do not have flaws likely to cause major bias. The studies may also be missing information, making it difficult to assess limitations and potential problems. The moderate-risk-of-bias category is broad, and studies with this rating vary in their strengths and weaknesses. The results of some of these studies are likely to be valid, whereas others may be only possibly valid.

Studies rated high risk of bias have significant flaws that may invalidate the results. They may have a serious or "fatal" flaw or set of flaws in design, analysis, or reporting; large amounts of missing information; or discrepancies in reporting. The results of these studies are at least as likely to reflect flaws in the study design as the true difference between the compared interventions. We did not exclude studies rated high risk of bias a priori, but performed sensitivity analyses in which such studies were excluded.

Figure E2. Quality assessment criteria.

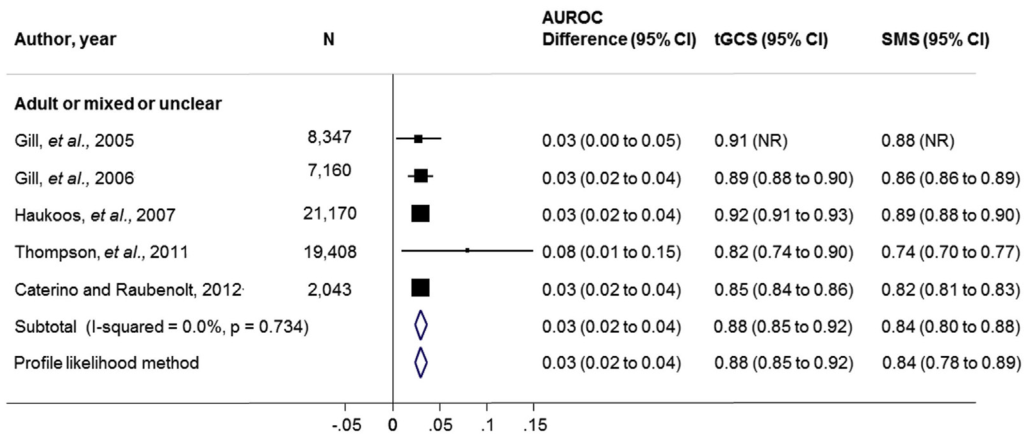

Figure E3. Pooled AUROC of inhospital mortality for the total GCS versus the Simplified Motor Scale. *SMS*, Simplified Motor Scale.

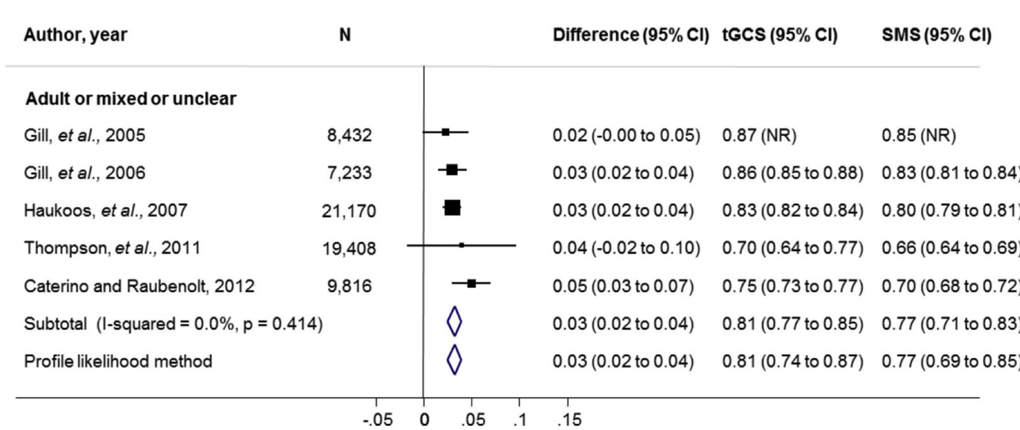

Figure E4. Pooled AUROC of neurologic intervention for the total GCS versus Simplified Motor Scale.

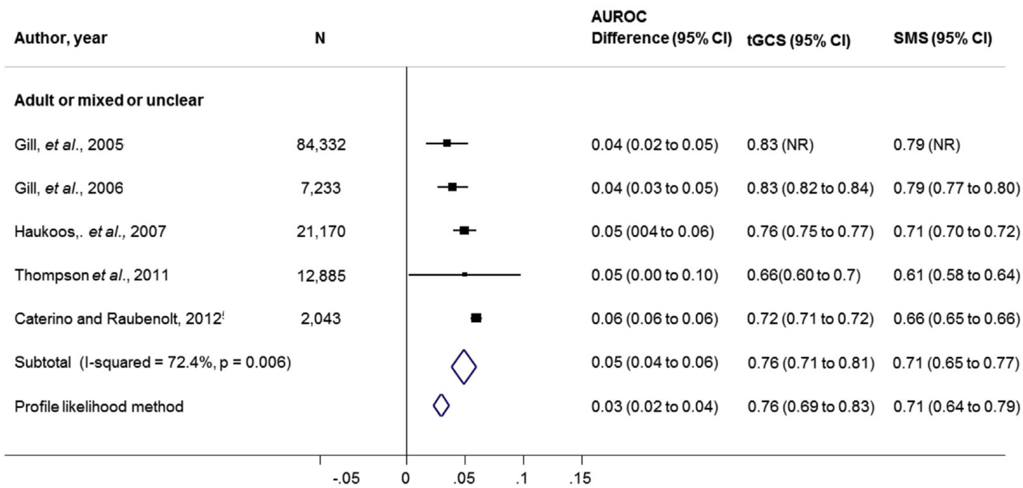

Figure E5. Pooled AUROC of severe brain injury for the total GCS versus the Simplified Motor Scale.

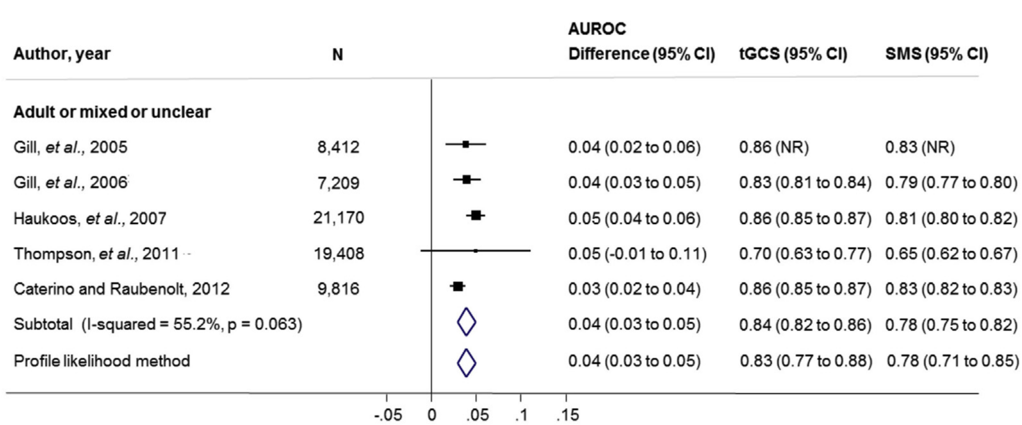

Figure E6. Pooled AUROC of intubation for the total GCS versus the Simplified Motor Scale.