
Original Contributions

THE ASSOCIATION BETWEEN FIELD GLASGOW COMA SCALE SCORE AND OUTCOME IN PATIENTS UNDERGOING PARAMEDIC RAPID SEQUENCE INTUBATION

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□ **Abstract**—Early intubation is standard for treating severe traumatic brain injury (TBI). Aeromedical crews and select paramedic agencies use rapid sequence intubation (RSI) to facilitate intubation after TBI, with Glasgow Coma Scale (GCS) score commonly used as a screening tool. To explore the association between paramedic GCS and outcome in patients with TBI undergoing prehospital RSI, paramedics prospectively enrolled adult major trauma victims with GCS 3–8 and clinical suspicion for head trauma to undergo succinylcholine-assisted intubation as part of the San Diego Paramedic RSI Trial. The following data were abstracted from paramedic debriefing interviews and the county trauma registry: demographics, mechanism, vital signs including GCS score, clinical evidence of aspiration before RSI, arrival laboratory values, hospital course, and outcome. Paramedic GCS calculations were confirmed during debriefing interviews. Patients were stratified by GCS score, with chi-square and receiver-operator-curve (ROC) analysis used to explore the relationship between GCS and hypoxia, head injury severity, aspiration, intensive care unit (ICU) length of stay, and outcome. Cohort analysis was used to explore potential reasons for early extubation and discharge from the ICU in some patients. A total of 412 patients were included in this analysis. A total of 81 patients (20%) were extubated and discharged from

the ICU in 48 h or less; these patients had higher pre-RSI oxygen saturation (SaO₂) values and higher arrival serum ethanol levels. Paramedic and physician GCS calculations had high agreement (kappa = 0.995). A statistically significant relationship was observed between GCS score and Head Abbreviated Injury Score (AIS), survival, and pre-RSI SaO₂ values. However, ROC analysis revealed a limited ability of GCS to predict the presence of severe TBI, injury severity, desaturation, aspiration, ICU length of stay, or ultimate survival. In conclusion, paramedics seem to accurately calculate GCS values before prehospital RSI. Although a relationship between paramedic GCS and outcome exists, the ability to predict the severity of injury, airway-related complications, ICU length of stay, and overall survival is limited using this single variable. Other factors should be considered to screen TBI patients for prehospital RSI. © 2005 Elsevier Inc.

□ **Keywords**—Glasgow Coma Scale; paramedic; prehospital; EMS; Rapid Sequence Intubation; traumatic brain injury; head trauma

INTRODUCTION

Secondary brain injury plays an important role in the outcome of patients with severe traumatic brain injury (TBI) (1–5). Early intubation of patients with traumatic

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coma has become standard of care to reverse hypoxia and prevent aspiration due to a loss of airway reflexes (6–8). This includes the use of neuromuscular blockade to facilitate laryngoscopy in some prehospital systems (9–14). Concerns over paramedic use of these agents include the consequences of failed intubation attempts as well as unnecessary exposure of patients to a potentially dangerous procedure (15,16).

The selection of appropriate patients who will benefit from field rapid sequence intubation (RSI) has not been adequately defined. Most algorithms define a Glasgow Coma Scale (GCS) score of 8 or less as the primary indication for intubation (6). It is not clear, however, that this represents the optimal strategy for screening patients to undergo invasive prehospital airway management. Field GCS may not accurately predict head-injury severity due to paramedic inexperience with this assessment and the potential for rapid improvement in the immediate post-injury period (17,18). In addition, aspiration may not be preventable in these patients but may instead occur immediately after the injury, before the arrival of prehospital personnel (19,20). Furthermore, the requirement for neuromuscular blocking agents to facilitate intubation suggests the presence of protective airway reflexes that may obviate the need for active airway management. Finally, although head injury is associated with hypoxia and respiratory dysfunction, the predictive value of GCS in identifying patients who might benefit from aggressive airway management strategies is unknown (21–25).

The San Diego Paramedic RSI Trial was performed to investigate the impact of paramedic RSI on outcome in patients with severe TBI, with patients enrolled based on GCS and clinical suspicion of TBI. The overall success with this procedure and its impact on outcome have been explored in separate analyses (26,27). Here we explore the predictive value of GCS with regard to head injury severity and the need for emergent intubation using data collected during the trial.

METHODS

The San Diego Paramedic RSI Trial was a prospective, descriptive study designed to assess the impact of paramedic RSI on outcome in patients with severe TBI (26). Approval was granted by the Investigational Review Board from our institution and the State Emergency Medical Services (EMS) Authority. This analysis used data collected as part of the larger trial.

San Diego County paramedics attended an 8-h training course before participation in the trial. This included home-study materials, a pre-test, formal lectures, review of the study protocol, mega-code scenarios, and a post-

test. In addition, a 30-min instructional video was used specifically to teach GCS scoring, with a didactic component as well as sample cases for practice assigning GCS values.

The trial enrolled adult major trauma victims with severe TBI as defined by: 1) apparent age 18 years or older, 2) major trauma victim as per county protocols, 3) transport time of 10 min or greater to the trauma resuscitation suite, 4) suspected head injury by mechanism or physical examination, 5) GCS score 3–8, and 6) inability to intubate without RSI. Subjects were excluded for failure to achieve intravenous access or if cardiopulmonary resuscitation (CPR) was required before RSI. Details regarding the trial protocol have been presented elsewhere (26,27).

Field worksheets served as both a protocol guide and data collection tool. One of the principal investigators performed a debriefing immediately after delivery of each patient. The specific findings on neurologic examination were reviewed at that time to confirm proper GCS scoring. In addition, San Diego County prehospital and trauma databases were used for clinical and outcome data. All data were entered into an Excel (Microsoft Corporation, Redmond, WA) spreadsheet, including: patient demographics, mechanism of injury, field GCS score, vital signs, pre- and post-intubation SaO₂ values, clinical evidence of aspiration, hospital arrival arterial blood gas (ABG) values, Abbreviated Injury Scores (AIS) for each body system, Injury Severity Score (ISS), and final discharge diagnoses. Clinical evidence of aspiration was defined as either direct visualization of blood or vomitus beyond the vocal cords during laryngoscopy or the presence of rhonchi on pulmonary examination in a patient with oropharyngeal blood or vomitus.

Data for all trial patients were reported descriptively. The primary goal of this analysis was to explore the relationship between paramedic GCS score calculations and head-injury severity, the presence of factors related to the need for intubation such as hypoxia and aspiration, and eventual outcome. Paramedic GCS score determinations were compared to those of the principal investigators, which were based on reported neurological examination findings during the debriefing interview.

The association between paramedic GCS score calculations and the need for early intubation was explored using chi-square test for trend. Patients were stratified by GCS score and the incidence determined for each of the following: moderate to severe head injury (Head/Neck AIS of ≥ 3), mortality, early extubation and ICU discharge (48 h or less), pre-intubation aspiration, pre-intubation hypoxia, and desaturation during the RSI procedure. Desaturation was defined by a decrease in SaO₂ below 90% after administration of RSI medications or

continued decrease if pre-RSI SaO₂ was already below 90%.

The ability of paramedic GCS calculations to predict various clinical factors was explored using receiver-operator curve (ROC) analysis, modeling GCS score against desaturation during RSI, pre-intubation aspiration as determined by paramedics, moderate-to-severe TBI (Head AIS 3+), severe traumatic injury (Injury Severity Score [ISS] > 30), overall survival, ICU stay > 48 h for survivors, and a composite endpoint of death or ICU stay > 48 h. Area-under-the-curve (AUC) was used to quantify predictive ability for each ROC analysis. Logistic regression was used to explore the relationship between GCS score, serum ethanol, and either survival or the presence of severe TBI (Head AIS 4+).

Patients with early extubation and ICU discharge (ICU length of stay 48 h or less) were compared to other patients with regard to demographics, mechanism of injury, prehospital factors, and hospital data. Statistical calculations were performed using StatsDirect™ (StatsDirect Software Inc., Ashwell, UK). Statistical significance was attributed to a *p* value less than 0.05.

RESULTS

A total of 426 patients were enrolled in the trial over 3 1/2 years. Of these, 12 patients were ultimately determined not to have sustained traumatic injuries, including 10 patients with hemorrhagic cerebrovascular accidents, 1 with a myocardial infarction and malignant dysrhythmia while driving, and 1 with an arterial gas embolism while SCUBA diving; complete data from two other patients taken to non-trauma centers were unavailable for review. Descriptive data for the remaining 412 patients are displayed in Table 1. Of note, paramedics cited the presence of intact airway reflexes (clenched jaw or presence of gag reflex so as to prevent laryngoscopy) as the primary indication for RSI in 91% of patients. A total of 111 patients (26.9%) had a Head/Neck AIS score of less than 3, with 53 (12.9%) having a score of 0 or 1. Of the 285 survivors, 81 (28.4%) were discharged from the hospital in 48 h or less. Over half of all patients experienced a desaturation during the RSI procedure, whereas less than a quarter of patients were hypoxic before RSI. The incidence of hypoxia before RSI was significantly greater than after RSI (23.9% vs. 5.9%, respectively, OR 4.97, 95% confidence interval [CI] 3.07–8.07, *p* < 0.001).

Table 1. Data for All Trial Patients Included in this Analysis (n = 412)

Parameter	Mean or % (95% CI)
Demographics	
Age (years)	38.5 (36.7, 40.3)
Gender (% male)	80 (76, 84)
Mechanism of injury (%)	
Assault	7 (4, 9)
Bicycle accident	6 (4, 9)
Fall	25 (21, 30)
Gunshot wound	6 (4, 8)
Found down	3 (2, 6)
Motorcycle accident	6 (4, 9)
Motor vehicle accident	35 (31, 40)
Pedestrian versus automobile	9 (7, 13)
Other	3 (2, 5)
Prehospital factors	
Initial SBP (mm Hg)	126 (122, 130)
Pre-RSI SaO ₂ (%)	90.8 (89.5, 92.1)
Post-RSI SaO ₂ (%)	96.3 (95.3, 97.3)
GCS score	4.9 (4.7, 5.0)
RSI factors	
Successful ET tube (%)	85 (81, 88)
Successful combitube (%)	14 (11, 18)
RSI performed en route (%)	35 (30, 40)
Transported by aeromedical (%)	24 (20, 28)
Abbreviated injury scores	
Head/neck	3.4 (3.3, 3.6)
Face	0.5 (0.4, 0.6)
Chest	1.2 (1.0, 1.4)
Abdomen	0.7 (0.5, 0.8)
Extremities	0.9 (0.8, 1.0)
Skin	0.9 (0.8, 0.9)
ISS	25.5 (23.9, 27.0)
Hospital data	
Length of stay (days)	11.0 (9.5, 12.5)
ICU stay (days)	6.5 (5.6, 7.4)
Mortality (%)	31 (27, 36)

CI = confidence intervals; SBP = systolic blood pressure; RSI = rapid sequence intubation; SaO₂ = oxygen saturation; GCS = Glasgow Coma Scale; ET = endotracheal; ISS = injury severity score; ICU = intensive care unit.

Principal investigator GCS calculations agreed with paramedic assessments in the field in all but two patients ($\kappa = 0.995$); for these two, the physician and paramedic GCS calculations differed by a single point. A statistically significant relationship was observed between paramedic GCS score and Head AIS, mortality, and pre-intubation hypoxia, but not early ICU discharge, pre-intubation aspiration, or desaturation (Figure 1). Logistic regression revealed a statistically significant association between GCS and Head/Neck AIS, ISS, and overall mortality (Table 2). The ability of GCS score to predict various clinical variables based on ROC analysis was generally poor. These included desaturation during RSI, pre-intubation aspiration, moderate to severe TBI (Head AIS 3+), severe traumatic injury (ISS > 30), overall survival, ICU stay > 48 h for survivors, and a composite endpoint of death or ICU stay > 48 h (Figure 2).

Survivors extubated and discharged from the ICU in 48 h or less were younger, more likely to be male, had a higher incidence of assault and a lower incidence of gunshot wounds and pedestrian vs. auto, required fewer endotracheal (ET) intubation attempts, had a lower incidence of desaturations and clinical aspiration, had higher pre- and post-RSI SaO₂ values, and lower ISS and H/N AIS scores (Table 2). They also had higher serum ethanol levels on arrival, which might explain the misinterpretation that significant TBI requiring intubation was present. The addition of serum ethanol to a logistic regression model resulted in modest improvement in the ability of GCS score to predict either survival (OR 1.32, 95% CI 1.09–1.61, $p = 0.005$; adjusted OR 1.37, 95% CI 1.11–1.69, $p = 0.004$) or the presence of severe TBI (OR 0.80, 95% CI 0.68–0.95, $p = 0.009$; adjusted OR 0.79, 95% CI 0.66–0.94, $p = 0.007$).

DISCUSSION

A complex relationship exists between level of consciousness, head-injury severity, aspiration risk, and hypoxia (1,2,19,28). Although it is clear that severe TBI is associated with an increased risk of both aspiration and respiratory dysfunction, both of which can lead to hypoxia and secondary brain injury, it is less clear that early intubation is an effective means to address these factors (21–25). The aspiration that accompanies severe TBI may actually occur in the first moments after injury, and the presence of airway reflexes that necessitate RSI may obviate the need for active airway management (19,20). In addition, hypoxia may be reversible with non-invasive airway maneuvers. Finally, the benefits of oxygenation and airway protection associated with intubation may come at the price of a rise in intracranial pressure with

Table 2. Comparison between Survivors Discharged from the ICU in 48 Hours or Less and Other Patients with Regard to Various Demographic and Clinical Factors

	Early ICU discharge (n = 81)	Other patients (n = 331)	Odds ratio or difference in means (95% CI)
Demographics			
Age (years)	32.0	40.0	-8.0 (-12.4, -3.6)***
Male (%)	89	79	2.1 (1.0, 4.5)*
Mechanism (%)			
Assault	18	4	5.2 (2.3, 11.5)***
Bicycle accident	6	6	1.1 (0.4, 3.0)
Fall	26	25	1.1 (0.6, 1.9)
Found down	6	3	2.4 (0.8, 7.3)
Gunshot wound	0	7	0.0 (0.0, 0.7)*
Motor vehicle accident	35	44	0.7 (0.4, 1.2)
Pedestrian versus auto	4	11	0.3 (0.1, 1.0)*
Other	5	2	3.4 (0.9, 13.0)
Prehospital factors			
ET attempts (#)	1.4	1.7	-0.3 (-0.5, -0.1)**
Desaturation (%)	35	58	0.39 (0.16, 0.96)*
ET successful (%)	89	84	1.54 (0.72, 3.26)
Aspiration (%)	18	31	0.47 (0.25, 0.87)*
Clinical data			
SBP initial (mm Hg)	134	125	9 (-1, 19)
SBP arrival (mm Hg)	141	138	3 (-16, 12)
GCS	5.1	4.8	0.3 (-0.1, 0.8)
Sat pre (%)	94.0	90.0	4.0 (0.8, 7.2)*
Sat post (%)	98.8	95.7	3.1 (0.5, 5.7)*
Arrival lab values			
pH	7.38	7.33	0.05 (0.01, 0.08)**
pO ₂ (mm Hg)	351	296	-55 (-99, -12)*
pCO ₂ (mm Hg)	33.6	37.4	-3.8 (-7.2, -0.4)*
Base excess	-3.5	-5.1	1.6 (-3.2, 0.1)
Serum EtOH (mg/dL)	190	87	103 (56, 149)***
Inpatient factors			
H/N AIS	2.4	3.7	-1.3 (-0.8, -1.6)***
ISS	11.0	29.5	-18.5 (-16.3, -20.8)***
Days in ICU	1.2	7.9	-6.7 (-8.8, -4.6)***
Days in hospital	3.5	12.6	-9.1 (-13.0, -5.8)

* $p < 0.05$;

** $p < 0.01$;

*** $p < 0.001$.

ICU = intensive care unit; CI = confidence intervals; ET = endotracheal; SBP = systolic blood pressure; GCS = Glasgow Coma Scale; EtOH = ethanol; H/N AIS = Head/Neck Abbreviated Injury Score; ISS = injury severity score;

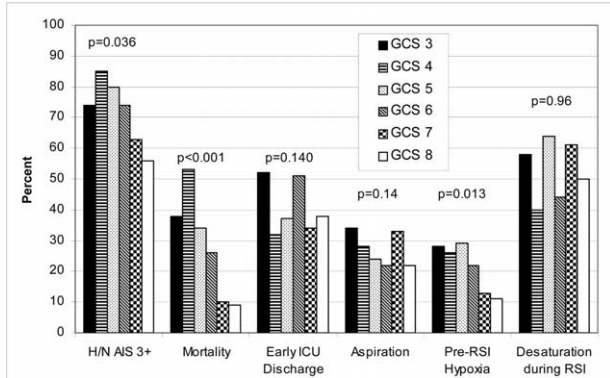


Figure 1. Relationship between GCS score and the incidence of various clinical factors, including: significant head injury (H/N AIS 3 or greater), mortality, short ICU stay (48 h or less), clinical aspiration, pre-RSI hypoxia (SaO₂ < 90%), or desaturation during the RSI procedure. Chi-square test for trend was used to determine whether a statistically significant progression was observed with increasing GCS score (p values shown).

airway manipulation and the adverse effects of positive-pressure ventilation (29–40). The use of neuromuscular blocking agents introduces additional risks associated with paralysis and apnea (15,41).

The GCS score is the most widely used measure of level of consciousness in the assessment of TBI patients, and although it was originally intended to be calculated after the initial resuscitation to give prognostic information, it has since been applied to the prehospital arena and Emergency Department to define the need for emergent intubation (6,17,18,42–52). Here we explore the predictive value of GCS score with regard to head injury severity and the need for intubation in a population of patients undergoing paramedic RSI. The protocol employed during the San Diego Paramedic RSI Trial relied on the presence of a GCS score of 8 or less as the major determinant for inclusion. Paramedic GCS score calculations seemed to be accurate, as they agreed with principal investigator calculations in virtually all cases. Although a relationship between paramedic GCS score and both head injury severity and eventual outcome was observed, the ability of GCS to accurately predict the presence of severe TBI or ultimate survival was relatively poor, with AUC values only slightly better than a value of 0.50, representing the complete lack of discriminatory ability. It is intriguing that a GCS score of 3 was associated with better outcomes and less severe injuries than a GCS of 4 or 5. This has been noted previously and likely reflects the poor prognosis associated with decorticate or decerebrate posturing (17,18,43,49–53). The use of GCS score alone in our study did not predict clinical aspiration at the time of intubation, desaturations, or the duration of ICU stay.

It is notable that a relatively high percentage of patients who did not have significant TBI were enrolled. Over a quarter of patients had a Head/Neck AIS score of 2 or less, indicating transient or no loss of consciousness with a negative head computed tomography (CT) scan. The presence of alcohol may have played a role in their inclusions, representing a significant problem in the pre-hospital triage and treatment of patients with potential TBI.

The duration of intubation in the ICU was used as a surrogate to define the need for intubation. No association was observed between GCS score and length of ICU stay in survivors. In contrast, less severe head injuries and the absence of pre-RSI hypoxia were both associated with short ICU stays. Again, this suggests that GCS score alone is not a reliable predictor of the need for intubation. Pre-RSI hypoxia was present in about a quarter of patients despite the administration of oxygen via non-rebreather mask, whereas post-RSI hypoxia was quite rare. Although this suggests the efficacy of RSI in reversing hypoxia, it is notable that

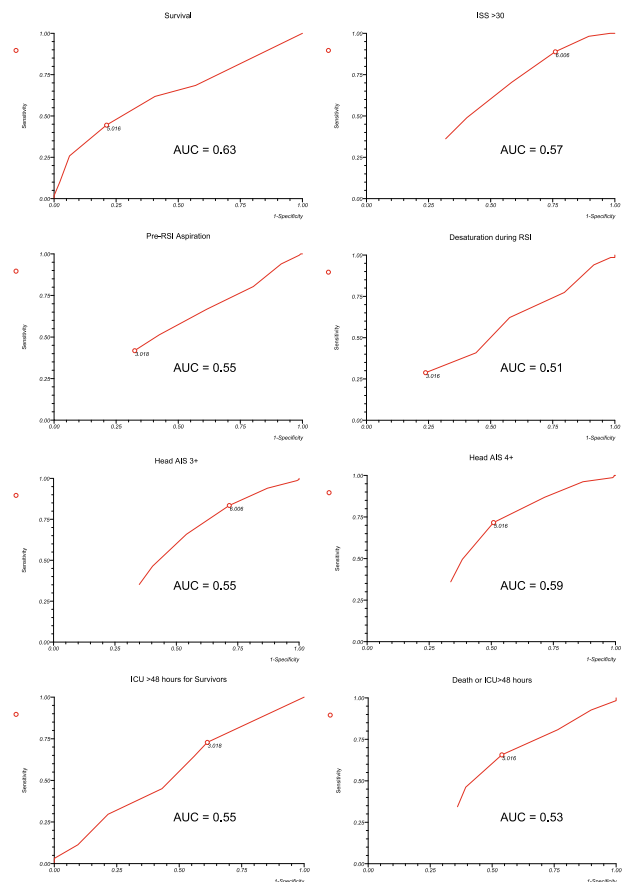


Figure 2. ROC analyses demonstrating the ability of Glasgow Coma Scale (GCS) score to predict various clinical parameters. Optimized discriminatory GCS and area under the curve (AUC) values are indicated.

over half of all patients experienced oxygen desaturation during the RSI procedure (54). The relative impact of hypoxia before and during the procedure is difficult to determine (55,56). Pre-RSI hypoxia was associated with lower GCS scores, possibly due to an increase in the incidence of aspiration or the presence of associated injuries. Future algorithms to define the need for early intubation should consider the inclusion of pre-RSI SaO₂.

As multiple investigators produce data challenging the efficacy of early intubation with severe TBI, it becomes increasingly important to refine our selection criteria (26,57–60). This is especially true given the potential adverse effects of invasive airway management, especially with use of RSI medications, and our growing recognition of the detrimental effects of positive-pressure ventilation (32–40). The goals of intubation—to reverse hypoxia and prevent aspiration—must be kept in mind, and consideration should be given to the use of oxygen saturation or as assessment of airway protective reflexes when deciding who should undergo intubation.

Several limitations to this analysis must be considered. The intent of the San Diego Paramedic RSI Trial was to determine the impact of the use of paramedic neuromuscular blocking agents on outcome in severe TBI and not to explore the predictive ability of GCS. In addition, we relied heavily on self-reported data by paramedics, including the presence of clinical aspiration and the GCS scores themselves. Higher GCS scores were not included, making it impossible to compare patients with a GCS score of 8 or less to those above this threshold. The main outcomes measures regarding the indications and justification for intubation are ill defined, with the significance of our definitions for clinical aspiration and a short ICU stay unclear.

CONCLUSIONS

Paramedic GCS score calculations seemed to be accurate and were associated with Head AIS and overall mortality. However, paramedic GCS scores were not able to accurately predict the presence of moderate to severe TBI, severe traumatic injury, overall survival, pre-intubation aspiration, desaturation, or the duration of ICU stay. Furthermore, a substantial percentage of patients enrolled under trial protocols did not have significant TBI. Future studies should explore the integration of factors such as hypoxia and the presence of airway protective reflexes into the decision to perform early intubation with head injury.

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REFERENCES

1. Chesnut RM, Marshall LF, Klauber MR, et al. The role of secondary brain injury in determining outcome from severe head injury. *J Trauma* 1993;34:216–22.
2. Chesnut RM, Marshall SB, Piek J, Blunt BA, Klauber MR, Marshall LF. Early and late systemic hypotension as a frequent and fundamental source of cerebral ischemia following severe brain injury in the Traumatic Coma Data Bank. *Acta Neurochir Suppl (Wien)* 1993;59:121–5.
3. Kokoska ER, Smith GS, Pittman T, Weber TR. Early hypotension worsens neurological outcome in pediatric patients with moderately severe head trauma. *J Pediatr Surg* 1998;33:333–8.
4. Pigula FA, Wald SL, Shackford SR, Vane DW. The effect of hypotension and hypoxia on children with severe head injuries. *J Pediatr Surg* 1993;28:310–4; discussion 315–6.
5. Stocchetti N, Furlan A, Volta F. Hypoxemia and arterial hypotension at the accident scene in head injury. *J Trauma* 1996;40:764–7.
6. Wall RL. Rapid-sequence intubation in head trauma. *Ann Emerg Med* 1993;22:1008–13.
7. Hatley T, Ma OJ, Weaver N, Strong D. Flight paramedic scope of practice: current level and breadth. *J Emerg Med* 1998;16:731–5.
8. Smith JP, Bodai BI. The urban paramedic's scope of practice. *JAMA* 1985;253:544–8.
9. Wayne MA, Friedland E. Prehospital use of succinylcholine: a 20-year review. *Prehosp Emerg Care* 1999;3:107–9.
10. Pace SA, Fuller FP. Out-of-hospital succinylcholine-assisted endotracheal intubation by paramedics. *Ann Emerg Med* 2000;35:568–72.
11. Hedges JR, Dronen SC, Feero S, Hawkins S, Syverud SA, Shultz B. Succinylcholine-assisted intubations in prehospital care. *Ann Emerg Med* 1988;17:469–72.
12. Doran JV, Tortella BJ, Drivet WJ, Lavery RF. Factors influencing successful intubation in the prehospital setting. *Prehosp Disaster Med* 1995;10:259–64.
13. Sing RF, Reilly PM, Rotondo MF, Lynch MJ, McCans JP, Schwab CW. Out-of-hospital rapid-sequence induction for intubation of the pediatric patient [see comments]. *Acad Emerg Med* 1996;3:41–5.
14. Sing RF, Rotondo MF, Zonies DH, et al. Rapid sequence induction for intubation by an aeromedical transport team: a critical analysis. *Am J Emerg Med* 1998;16:598–602.
15. Wang HE, Yealy DM. Out-of-hospital rapid sequence intubation: is this really the “success” we envisioned? *Ann Emerg Med* 2002;40:168–71.
16. Spaite DW, Criss EA. Out-of-hospital rapid sequence intubation: are we helping or hurting our patients? *Ann Emerg Med* 2004;42:729–30.
17. Moskopp D, Stahle C, Wassmann H. Problems of the Glasgow Coma Scale with early intubated patients. *Neurosurg Rev* 1995;18:253–7.
18. Bazarian JJ, Eirich MA, Salhanick SD. The relationship between

- pre-hospital and emergency department Glasgow coma scale scores. *Brain Inj* 2003;17:553–60.
19. Atkinson JLD. The neglected prehospital phase of head injury: apnea and catecholamine surge. *Mayo Clin Proc* 2000;75:37–47.
 20. Vilke GM, Vadeboncoeur TF, Davis DP, Poste JC, Ochs M, Hoyt DB. The predictive value of paramedic assessment of aspiration in patients undergoing prehospital rapid sequence intubation [abstract]. *Prehosp Emerg Care* 2004;8:88–9.
 21. Maciver IN, Frew IJC, Matheson JG. The role of respiratory insufficiency in the mortality of severe head injuries. *Lancet* 1958; 1:390–3.
 22. Graham DI, Adams JH. Ischaemic brain damage in fatal head injuries. *Lancet* 1971;1:265–6.
 23. Graham DI, Adams JH, Doyle D. Ischaemic brain damage in fatal non-missile head injuries. *J Neurol Sci* 1978;39:213–34.
 24. Graham DI, Ford I, Adams JH. Ischaemic brain damage is still common in fatal non-missile head injury. *J Neurol Neurosurg Psychiatry* 1989;52:346–50.
 25. Clifton GL, McCormick WF, Grossman RG. Neuropathology of early and late deaths after head injury. *Neurosurgery* 1981;8: 309–14.
 26. Davis DP, Hoyt DB, Ochs M, et al. The effect of paramedic rapid sequence intubation on outcome in patients with severe traumatic brain injury. *J Trauma* 2003;54:444–53.
 27. Ochs M, Davis D, Hoyt D, Bailey D, Marshall L, Rosen P. Paramedic-performed rapid sequence intubation of patients with severe head injuries. *Ann Emerg Med* 2002;40:159–67.
 28. Chesnut RM. Secondary brain insults after head injury: clinical perspectives. *New Horizons* 1995;3:366–75.
 29. Modica PA, Tempelhoff R. Intracranial pressure during induction of anaesthesia and tracheal intubation with etomidate-induced EEG burst suppression. *Can J Anaesth* 1992;39:236–41.
 30. Cotrell JE, Hartung J, Giffin JP. Intracranial and haemodynamic changes after succinylcholine administration in cats. *Anesth Analg* 1983;62:1006–9.
 31. Millar C, Bissonnette B. Awake intubation increases intracranial pressure without affecting cerebral blood flow velocity in infants. *Can J Anaesth* 1994;41:281–7.
 32. Tremblay L, Valenza F, Ribeiro SP, Li J, Slutsky AS. Injurious ventilatory strategies increase cytokines and c-fos m-RNA expression in an isolated rat lung model. *J Clin Invest* 1997;99:944–52.
 33. Tremblay LN, Miatto D, Hamid Q, Govindarajan A, Slutsky AS. Injurious ventilation induces widespread pulmonary epithelial expression of tumor necrosis factor- α and interleukin-6 messenger RNA. *Crit Care Med* 2002;30:1693–1700.
 34. Slutsky AS, Ranieri VM. Mechanical ventilation: lessons from the ARDSNet trial. *Respir Res* 2000;1:73–7.
 35. Zhang H, Downey GP, Suter PM, Slutsky AS, Ranieri VM. Conventional mechanical ventilation is associated with bronchoalveolar lavage-induced activation of polymorphonuclear leukocytes. *Anesthesiology* 2002;97:1426–33.
 36. Uhlig S. Ventilation-induced lung injury and mechanotransduction: stretching it too far? *Am J Physiol Lung Cell Mol Physiol* 2002;282:L892–6.
 37. Imai Y, Parodo J, Kajikawa O, et al. Injurious mechanical ventilation and end-organ epithelial cell apoptosis and organ dysfunction in an experimental model of acute respiratory distress syndrome. *JAMA* 2003;289:2104–12.
 38. Wilson MR, Choudhury S, Goddard ME, O'Dea KP, Nicholson AG, Takata M. High tidal volume upregulates intrapulmonary cytokines in an in vivo mouse model of ventilator-induced lung injury. *J Appl Physiol* 2003;95:1385–93.
 39. Chiumello D, Pristine G, Slutsky AS. Mechanical ventilation affects local and systemic cytokines in an animal model of acute respiratory distress syndrome. *Am J Respir Care Med* 1999;160:109–16.
 40. Network TARDS. Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome. *N Engl J Med* 2000;342:1301–8.
 41. Davis DP, Stern J, Ochs M, Sise MJ, Hoyt DB. A follow-up analysis of factors associated with head-injury mortality following paramedic rapid sequence intubation. *J Trauma*; in press.
 42. Teasdale G, Jennett B. Assessment of coma and impaired consciousness: a practical scale. *Lancet* 1974;2:81–2.
 43. Marion DW, Carlier PM. Problems with initial Glasgow Coma Scale assessment caused by prehospital treatment of patients with head injuries: results of a national survey. *J Trauma* 1994;36: 89–95.
 44. Arbabi S, Jurkovich GJ, Wahl WL, et al. A comparison of prehospital and hospital data in trauma patients. *J Trauma* 2004;56:1029–32.
 45. Norwood SH, McAuley CE, Berne JD, Vallina VL, Creath RG, McLarty J. A prehospital Glasgow Coma Scale score \leq 14 accurately predicts the need for full trauma team activation and patient hospitalization after motor vehicle collisions. *J Trauma* 2002;53:503–7.
 46. Udekwu P, Kromhout-Schiro S, Vaslef S, Baker C, Oller D. Glasgow Coma Scale score, mortality, and functional outcome in head-injured patients. *J Trauma* 2004;56:1084–9.
 47. Lieberman JD, Pasquale MD, Garcia R, et al. Use of admission Glasgow Coma score, pupil size, and pupil reactivity to determine outcome for trauma patients. *J Trauma* 2003;55:437–42.
 48. Pal J, Brown R, Fleischer D. The value of the Glasgow Coma Scale and Injury Severity Score: predicting outcome in multiple trauma patients with head injury. *J Trauma* 1989;29:746–8.
 49. Amin AP, Kulkarni HR. Improvement in the information content of the Glasgow Coma Scale for the prediction of full cognitive recovery after head injury using fuzzy logic. *Surgery* 2000;127: 245–53.
 50. Healey C, Osler TM, Rogers FB, et al. Improving the Glasgow Coma Scale score: motor score alone is a better predictor. *J Trauma* 2003;54:671–8; discussion 678–80.
 51. Rutledge R, Lentz CW, Fakhry S, Hunt J. Appropriate use of the Glasgow Coma Scale in intubated patients: a linear regression prediction of the Glasgow verbal score from the Glasgow eye and motor scores. *J Trauma* 1996;41:514–22.
 52. Teoh LS, Gowardman JR, Larsen PD, Green R, Galletly DC. Glasgow Coma Scale: variation in mortality among permutations of specific total scores. *Intensive Care Med* 2000;26:157–61.
 53. Gill MR, Reiley DG, Green SM. Interrater reliability of Glasgow Coma Scale scores in the emergency department. *Ann Emerg Med* 2004;43:215–23.
 54. Dunford JV, Davis DP, Ochs M, Doney M, Hoyt DB. Incidence of transient hypoxia and pulse rate reactivity during paramedic rapid sequence intubation. *Ann Emerg Med* 2003;42:721–8.
 55. Manley G, Knudson MM, Morabito D, Damron S, Erickson V, Pitts L. Hypotension, hypoxia, and head injury: frequency, duration, and consequences. *Arch Surg* 2001;136:1118–23.
 56. Davis DP, Dunford JV, Poste JC, et al. The impact of hypoxia and hyperventilation on outcome after paramedic rapid sequence intubation of severely head-injured patients. *J Trauma* 2004;57:1–8.
 57. Eckstein M, Chan L, Schneir A, Palmer R. Effect of prehospital advanced life support on outcomes of major trauma patients. *J Trauma* 2000;48:643–8.
 58. Murray JA, Demetriades D, Berne TV, et al. Prehospital intubation in patients with severe head injury. *J Trauma* 2000;49:1065–70.
 59. Gausche M, Lewis RJ, Stratton SJ, et al. Effect of out-of-hospital pediatric endotracheal intubation on survival and neurological outcome: a controlled clinical trial [see comments]. *JAMA* 2000;283: 783–90.
 60. Wang H, Cassidy L, Peitzman A, Adelson PD, Yealy D. Association of out-of-hospital endotracheal intubation with adverse outcome after traumatic brain injury. *Prehosp Emerg Care* 2004; 8:84.