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The Scales Tip Further in Favor of Steroids for Meningitis

ABSTRACT & COMMENTARY

Source: de Gans J, van de Beek D. Dexamethasone in adults with bacterial meningitis. *N Engl J Med* 2002;347:1549-1556.

THE ROLE OF CORTICOSTEROIDS IN MINIMIZING SEQUELAE OF acute bacterial meningitis has been debated strongly. The authors of this multinational European study sought to determine whether administration of steroids improved neurologic outcome in adults with suspected meningitis. Patients were eligible if they had undergone a lumbar puncture revealing cerebrospinal fluid (CSF) that was cloudy, showed bacteria, or had a leukocyte count greater than 1000/mm^3. Subjects were randomized to receive either placebo or dexamethasone 10 mg, administered 15-20 minutes prior to antibiotics and then every six hours for four days. All patients were treated empirically with amoxicillin, which is appropriate monotherapy in the Netherlands. The primary outcome was the Glasgow Outcome Scale score at eight weeks, in which a score of five was favorable and lower scores unfavorable.

In the study, 301 patients were randomized. Baseline characteristics were similar between treatment and placebo groups. Pneumococcus was isolated in 35% of patients, *Neisseria meningitidis* in 32%, and other bacteria in 10%; negative cultures were noted in 22%. The number of patients with unfavorable outcomes at eight weeks was significantly smaller in the dexamethasone group (15% vs. 25%, relative risk 0.59 [95% CI 0.37—0.94]). Mortality also was lower in the steroid-treated group (7% vs. 15%, relative risk 0.48 [95% CI 0.24 — 0.96]). A planned subgroup analysis showed that outcome and mortality improvements only were detectable among patients with pneumococcal meningitis. Treatment with dexamethasone did not result in an increased risk of gastrointestinal bleeding or other adverse events. The authors conclude that dexamethasone administered prior to antibiotic therapy improves the outcomes of adults with acute bacterial meningitis without increasing the risk of complications.

■ **COMMENTARY BY DAVID J. KARRAS, MD, FAAEM, FACEP**

Strong evidence favoring the benefit of corticosteroids in the treat-

INSIDE

ment of acute bacterial meningitis began emerging a decade ago. An early and highly influential study published in 1989 showed that dexamethasone, when administered just prior to antibiotics, greatly reduce the risk of neurological sequelae in an era when manyu infections were due to *Haemophilus influenzae* type B (HIB). [1] This led to recommendations that steroids be used empirically in children with acute meningitis. The data from studies of adults have been less compelling and opinions on the role of steroids for this group have been divided.

The microbiology of meningitis has changed in the last 10 years, with HIB infections now uncommon in children and accounting for a small number of infections in adult patients. Multiple studies showed steroids to be of marginal benefit in pneumococcal infections, now the most common cause of meningitis in all age groups except neonates. An expert review in the *New England Journal of Medicine* concluded that steroids should be limited to children not vaccinated against HIB and to adults with high CSF bacterial counts and increased intracranial pressure.[2] In patients not meeting these criteria, the risk of serious gastrointestinal bleeding was felt to be greater than the marginal benefit of steroids.

The present article is far stronger than most studies of dexamethasone in meningitis, most of which have very small sample sizes. In light of how equivocal the prior data have been, I would be inclined to use this study as my rationale for routinely administering steroids to adults with acute bacterial meningitis. ❖

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Clinical Clearance of the Spine in the Prehospital Setting

ABSTRACT & COMMENTARY

Source: Domeier RM, et al. Multicenter prospective validation of prehospital clinical spinal clearance criteria. *J Trauma Injury Infect Crit Care* 2002:53:744-750.

THIS STUDY PROSPECTIVELY EVALUATED A CLINICAL decision rule used to identify injured patients at low-risk for spinal injury in the prehospital setting. The presence or absence of five criteria were recorded during the field assessment: altered mental status, neurologic deficit, spinal tenderness, evidence of intoxication, or suspected extremity fracture. Patients lacking all five criteria were categorized as "low risk." All adult and pediatric blunt trauma patients who underwent spinal immobilization were eligible for enrollment. No attempts were made to alter immobilization practice. Outcome measures included the presence or absence of fracture and injury management.

Two hundred ninety-five patients with spinal injury were present in 8975 (3.3%) cases; 280 (94.9%) of these were identified by the decision rule [sensitivity 94.9%, specificity 35%, NPV 99.5%]. Thirteen of 15 missed injures were stable, requiring only simple immobilization and/or pain control. Two missed patients required surgical stabilization. The first, a patient with a C1-2 injury, was found to have three criteria during emergency department evaluation: evidence of intoxication,

altered mental status, and cervical pain. The second, a patient with a C6-7 subluxation, had a fracture dislocation of the hip, meeting criteria for a "suspected extremity fracture."

COMMENTARY BY MICHAEL A. GIBBS, MD, FACEP

The results of this study are in keeping with the findings of NEXUS, which employed similar criteria to effectively risk-stratify patients for spinal injury in the ED.[1] Substituting the "distracting injury" criteria used in NEXUS with "suspected extremity fracture" makes good sense, and is supported in a recent analysis of this specific variable.[2]

The fact that paramedics missed two significant injuries underscores the importance of adequate training, and reminds us that the prehospital environment can be a challenging place to assess patients. With adequate training, careful oversight, and attention to detail, there is no reason that paramedics should not be able to "clinically clear" the spine in the field. ❖

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Another Look at Deferred Care for Nonacute Conditions

ABSTRACT & COMMENTARY

Source: Washington DL, et al. Next-day care for emergency department users with nonacute conditions. *Ann Intern Med* 2002;137:707-714.

With emergency department (ED) overcrowding on the rise, the concept of deferring care for certain ED patients is being studied again. The authors of this randomized, controlled trial sought to determine if there were differences in health status and the use of health services during a one-week follow-up between patients who received usual ED care vs. those who were referred to next-day primary care.

The investigators incorporated previously developed deferred care criteria for three symptom complexes into chief compliant-specific data forms. These forms were used in the initial screening assessment of ED patients to identify nonacute conditions. The study took place between 7 a.m. and 3 p.m., on Mondays and Thursdays, in a level one ED that has 91,000 visits annually.

Of ambulatory adults requesting care, 1176 were screened, and 421 met deferred care criteria and were referred to a research assistant, who determined study eligibility. Patients were excluded for a number of reasons, including refusal to participate. In addition, patients were excluded who, in the nurse's judgment, required a more detailed evaluation. Of the 421 patients who met deferred care criteria, 299 met study eligibility requirements, and of those, 143 declined enrollment, leaving 156 patients for random assignment to either usual ED care (81) or deferred care (75) at a specific time the following day at the study site's primary care clinic.

By the end of the one-week follow-up period, 96% of the deferred care group and 95% of the usual care group had been evaluated at least once by a physician; 4% in each group had sought additional health services after their initial evaluation; and no patients were hospitalized or died. Using a previously validated tool, health status improved in both groups: 2.35 points (95% CI, 0.7-4.0) for the deferred group, and 4.20 points (95% CI, 2.2-6.2) for the usual care group, with a difference of 1.85 (95% CI, 0.69-4.39), which approached a predetermined point of clinical significance within the confidence interval. Both groups reported a reduction in number of days in bed or with disability, although the deferred care group reported less improvement in both measures and the 95% confidence intervals were sufficiently wide so that the possibility of one additional day in bed or with disability could not be excluded.

COMMENTARY BY STEPHANIE B. ABBUHL, MD, FACEP

This topic is not a new one to emergency physicians, who work daily amidst the crisis of ED overcrowding and who have been doing research in this area for more than 10 years. The concept of "deferring" care, which has superficial appeal, is a complex topic. Any potential program must have, at a minimum, a proven safety record in large populations, must be in compliance with the Emergency Medical Treatment and Labor Act (EMTALA), and must make sense globally for the efficiency of a health system. Unfortunately, various attempts to defer care have not held up under the scrutiny of critical review of methodology or have simply not been validated when studied in a different population.[1,2] For many emergency physicians, there also is an ethical issue of turning patients away who have sought emergency care.

This study suffers from many of the same methodologic problems that others have encountered. Selection bias is a major issue in this study, where 421 patients met deferred care criteria, but only 156 (37%) were randomized. It is concerning that 34% of the patients were not included because they declined enrollment, and one wonders if these patients were sicker than those who were studied. Patients who "required a more detailed evaluation" also were excluded, suggesting that a subjective nursing evaluation was part of the fundamental screening criteria. Another methodologic issue was the small sample size, and the "negative results" may represent an insufficiently powered study and must be interpreted with caution.

From a practical point of view, the infrastructure to support next-day care simply is not in place in many health systems. In fact, outpatient appointment availability may be suffering from as much overcrowding as EDs, but there are no systems in place to measure this. Finally, the question arises of the inherent inefficiency of a system that provides a sufficiently detailed screening examination to determine if a patient meets "deferred criteria," then not treating the patient. Treatment often is only a small part of the total time spent in the evaluation of the patient. ❖

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Pediatric Meningitis: Is It Bacterial or Not?

ABSTRACT & COMMENTARY

Source: Nigrovic LE, et al. Development and validation of a multivariable predictive model to distinguish bacterial from aseptic meningitis in children in the post-*Haemophilus influenzae* era. *Pediatrics* 2002;110:712-719.

IMMUNIZATION AGAINST *Haemophilus influenzae* AND, more recently, *Streptococcus pneumoniae*, has shifted etiologies to viral agents in pediatric meningitis. Clinicians need rapid, dependable means to differentiate viral from bacterial disease. To enhance diagnostic accuracy among ill children, Nigrovic and colleagues retrospectively analyzed 696 pediatric patients admitted with meningitis to Children's Hospital in Boston between 1992 and 2000. Ages ranged from 1 month to 19 years, with a median age of 5 months. Fever averaged 39.0°C for 2.1 days. Seizures were present in 7%. Final diagnoses included 125 (18%) with bacterial meningitis and 571 (82%) with presumed viral etiologies. All cases with bacterial meningitis had a cerebrospinal fluid (CSF) culture positive for a bacterial pathogen, or CSF pleocytosis of more than seven white blood cells (WBCs)/mm^3 together with a positive blood culture or CSF latex agglutination test positive for a bacterial pathogen. Aseptic meningitis was diagnosed by CSF pleocytosis with negative bacterial cultures and latex agglutination tests. Children were excluded if they had clinical sepsis; recent neurosurgical procedures; focal bacterial infections such as urinary tract infection or cellulitis; or were immunosuppressed.

Etiologies of bacterial meningitis in 125 children included the following pathogens: *Streptococcus pneumoniae* in 79 (63%); *Neisseria meningitidis* in 21 (17%); Group B Streptococcus in 13 (10%); non-typable *H. influenzae* in six (5%); enteric gram-negative rods in two (2%); and other streptococci in one (1%). Forty-two percent of patients studied had received antibiotics within 72 hours of lumbar puncture. Four children (3%) died.

The authors randomly selected 456 patients to perform logistic regression analysis of five objective, readily available predictors of bacterial meningitis: positive CSF Gram's stain, CSF protein greater than 80 mg/dL, peripheral absolute neutrophil count (ANC) greater than 10,000/mm^3, CSF ANC greater than 1000/mm^3, and occurrence of seizures. A Bacterial Meningitis Score (BMS) with a point value range of 0 to 6 was developed based on these five selected variables. Gram's stain had a weight of two points on the six-point scoring system, while the other four variables were one point each. Average CSF ANC was 2928 vs. 108/mm^3 for bacterial vs. aseptic meningitis. Average CSF protein was 230 vs. 57 mg/dL for bacterial vs. aseptic cases. The BMS then was validated by application to the other 240 randomized cases. Discrimination among variables between bacterial and viral meningitis was determined by receiver operating characteristic (ROC) curves to optimize sensitivity and specificity calculations.

In the validation cohort of 240 patients, a BMS of 0 accurately correlated with aseptic meningitis, with a negative predictive value of 100% for bacterial meningitis. A BMS of greater than 2 predicted bacterial meningitis with a sensitivity of 87% (95% CI: 72-96%) and a positive predictive value of 87% (same confidence intervals). When applied to the entire cohort of 696 patients, the BMS misclassified a mere 3.3% of cases. Of all patients with BMS greater than 2, only 21 were later

proven to have aseptic meningitis. Of all children with a BMS of 0, only 2/404 (0.5%) actually had bacterial meningitis. One was a pretreated 7-month-old with *S. pneumoniae* meningitis but only 11 cells in CSF and peripheral ANC of only 4500. The other was a 6-month-old with *N. meningitidis* with 10 cells in CSF and peripheral ANC of 8000. The authors conclude that the clinically and statistically derived, five-item BMS accurately distinguishes patients with bacterial and aseptic meningitis.

COMMENTARY BY MICHAEL FELZ, MD

A BMS score greater than 2 was correlated highly with bacterial etiologies, while scores of 0 identified aseptic meningitis with high specificity. The authors further mention that theirs is the first-ever validated, multivariate study on pediatric meningitis in the post-immunization era. I was impressed that the variables selected for use in the BMS are ones readily obtainable in the ED setting, where ill children with possible meningitis are first evaluated. The cohort of nearly 700 patients lends strength to the data analysis; most were infants, in whom clinical diagnosis is much more problematic. The shifting epidemiology of meningitis to viral etiologies still demands a high index of suspicion for bacterial pathogens, infrequent though they have become. This new tool, the BMS, is a promising weapon in the systematic investigation of the febrile, seriously ill child in the pediatric ED where time, and precision, are life-and-death priorities. I give this five-item BMS a "high-five." ❖

Special Feature

Nursemaid's Elbow

By Jacob W. Ufberg, MD

Radial head subluxation (RHS), also known as nursemaid's elbow or pulled elbow, is a common reason for pediatric emergency department (ED) visits. Most commonly occurring in children between the ages of 1 and 3 years, RHS has been reported in infants younger than 6 months,[1,2] and in older children in their pre-teens.[3] Most children present with the "classic" mechanism of longitudinal traction to the extended arm with the wrist in pronation, as may occur when lifting a child by the wrist to prevent a fall or while swinging a child by the arms. The anatomic mechanism of injury is generally a small tear in the attachment of the annular ligament to the periosteum of the radial neck, allowing the detached portion to become entrapped between the head of the radius and the capitellum of the distal humerus.

Presentation and Assessment

While most children will present with the classic history, as many as 33-49% of children may present without this classic history, with 22% of children in one series reporting a fall as the mechanism of injury.[2,4] Reports in children younger than 6 months indicate that RHS may occur with a caretaker rolling a child over in a bed or crib.[1] A child with RHS typically will present in the "nursemaid's position," with the arm held in pronation and slight flexion at the child's side.[4] The child generally refuses to use the arm, and commonly may point to either the elbow or the distal forearm when asked where the arm hurts.

Most children do not exhibit tenderness or swelling of the elbow on palpation. The entire arm should be carefully palpated, focusing on the clavicle, the elbow, and the distal radius, as these commonly are fractured in children. The physician may need to use the parent to help calm the anxious child, or may even stand at a distance and observe while the parent palpates the affected extremity to identify any sites of tenderness. The child may resist supination, or may have pain with supination.

Radiography generally is reserved for children in whom the diagnosis is unclear, or in whom attempts at reduction fail. Children who exhibit little or no tenderness on exam and hold the arm in the nursemaid's position do not require radiography prior to attempted reduction, whether or not the classic history has been described.[5] If performed, radiographs usually are normal, and positioning for films often reduces the subluxation.[2] Reports have identified displacement of the radiocapitellar line (a line drawn along the longitudinal axis of the radius which normally bisects the capitellum) in some children with RHS, however these radiographic changes resolved with reduction and were not found to alter treatment.[6,7]

Treatment

The reduction of RHS usually can be performed without the aid of sedation and/or analgesia. The parent should be informed that while the reduction may be painful for the child, the pain is transient and the child likely will regain use of the arm quickly. The two methods of reduction most commonly described are the supination method and the pronation method.

Supination Method. The child is seated on the parent's lap with the humerus held adducted to the child's side by the parent. The physician then holds the child's elbow with the thumb positioned over the child's radial head. The thumb may be used to apply pressure to the radial

head, but its main utility is to aid in the palpation of the "click" of reduction. The physician's other hand is used to grasp the child's wrist, and then to fully supinate the child's forearm in a steady fashion. Once supinated, the elbow can be fully flexed or extended. The flexion maneuver is more common, and may be slightly more successful than extension.[2]

Pronation Method. The child is positioned in the same manner as when using the supination method. However, the forearm is grasped and rapidly hyperpronated and fully flexed, once again using the thumb to help palpate the "click." This technique has been reported to be equally as effective as the supination technique in one recent trial,[8] and superior in another.[9]

After Reduction Attempt. If a click is heard or palpated, the child almost always will regain use of the arm within 30 minutes.[3] If no use of the arm occurs by 30 minutes, the physician should determine whether the child still holds the arm in the nursemaid's position, and if supination remains painful. This suggests the need for further reduction attempts. Most reduction attempts in which a click is not detected will be unsuccessful,[3] so repeated attempts should occur after 10 to 15 minutes of non-use. In Quan's study, 53 out of 54 attempts in which a click was felt or heard were successful, as opposed to only 4 out of 13 in which no click was obtained. Approximately 30% of patients required two or more reduction attempts.[3]

If multiple attempts are unsuccessful, and the child has not regained use of the arm, one of two approaches can be taken. Sacchetti recommends that radiographs be performed at this time, looking for occult fracture.[4] An alternate approach is to discharge the child with instructions to follow up in the ED in 24 hours, at which time radiographs may be performed if function has not returned spontaneously. Of 10 children in two case series released without return of function, six had spontaneous return of function in the intervening 24 hours before ED follow-up. The other four patients had return of function after repeated reduction attempts at the follow-up visit.[2,3] If reduction is successful, analgesia, ED follow-up, and referral are unnecessary. However, parents should be aware that approximately 24% of children with RHS will have recurrent episodes.[10]

The value of elbow immobilization in children with RHS that cannot be reduced on the initial visit is unclear. However, if a child has repeated subluxation immediately after successful reduction, immobilization and referral may be necessary.[7]

Conclusion

RHS is a common diagnosis among young children presenting to the ED. While the classic history of longitudinal traction on the arm often is present, the diagnosis rarely is in doubt based on the combination of history and clinical assessment. Multiple reduction techniques are effective for RHS, and most children regain use of the arm with one or two reduction attempts. Among children with RHS that cannot be reduced, the physician must weigh the apparent reliability of the parent(s), the level of parental anxiety, and the level of physician comfort with the diagnosis of RHS when considering whether to order radiographs or to discharge the child with follow-up in 24 hours. Emergency physicians should be able to document painless use of the affected arm at the initial or follow-up visit to make a definitive diagnosis of resolved RHS and to rule out other pathology such as occult fracture, tumor, or infection. ❖

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Physician CME questions

8. Which of the following was *not* one of the five criteria used in the study by Domeier et al for low-risk stratification of patients for spinal injury in the prehospital setting?

a. Intoxication
b. Altered mental status

c. Age greater than 70 years
d. Suspected extremity fracture
e. Spinal tenderness

9. Using five criteria to assign prehospital risk for spinal fracture, the study by Domeier et al found the criteria:
a. were highly specific.
b. had low negative predictive value.
c. were highly sensitive.
d. demonstrated high statistical accuracy.

10. The study by Washington et al on the issue of deferring care from the ED setting to next-day primary care providers:
a. suffered from the issue of selection bias.
b. conclusively demonstrated deferring care to be safe.
c. demonstrated deferred care to be safe with adults, but not with children.
d. demonstrated that deferring care was safest when suspected pharyngitis patients were excluded.

11. Nursemaid's elbow recurs in about what percentage of cases?
a. 24%
b. 33%
c. 50%
d. 66%
e. 75%

12. A child with nursemaid's elbow typically holds the affected arm in what position upon presentation to the ED?
a. Slight flexion and supination
b. Slight flexion and pronation
c. Full extension and supination
d. Full extension and pronation

13. A reasonable approach to reduction of nursemaid's elbow is:
a. hyperpronation and flexion.
b. supination and flexion.
c. longitudinal traction and flexion.
d. Both a and b
e. Both b and c

14. According to the recently published Bacterial Meningitis Score, the most accurate combination of predictors of a bacterial pathogen in ill children includes:
a. seizures, CSF neutrophil count greater than 1000, and positive CSF Gram's stain.
b. age younger than 6 months, nuchal rigidity, and hyponatremia less than 130 mg/dL.
c. headache, elevated peripheral WBC greater than 10,000, and high erythrocyte sedimentation rate greater than 40.
d. onset during enteroviral season, fever greater than 39°C, and CSF glucose less than 50.

15. In treating adults with acute bacterial meningitis, dexamethasone:
a. is effective when administered within six hours of antibiotic therapy.
b. improves neurologic outcome only in patients with pneumococcal infections.
c. increases the risk of adverse events.
d. only reduces mortality in patients with *Neisseria meningitidis.*

CME Objectives

To help physicians:

- Summarize the most recent significant emergency medicine-related studies;
- Discuss up-to-date information on all aspects of emergency medicine, including new drugs, techniques, equipment, trials, studies, books, teaching aids, and other information pertinent to emergency department care; and
- Evaluate the credibility of published data and recommendations.

V Tach on the Monitor

By Ken Grauer, MD

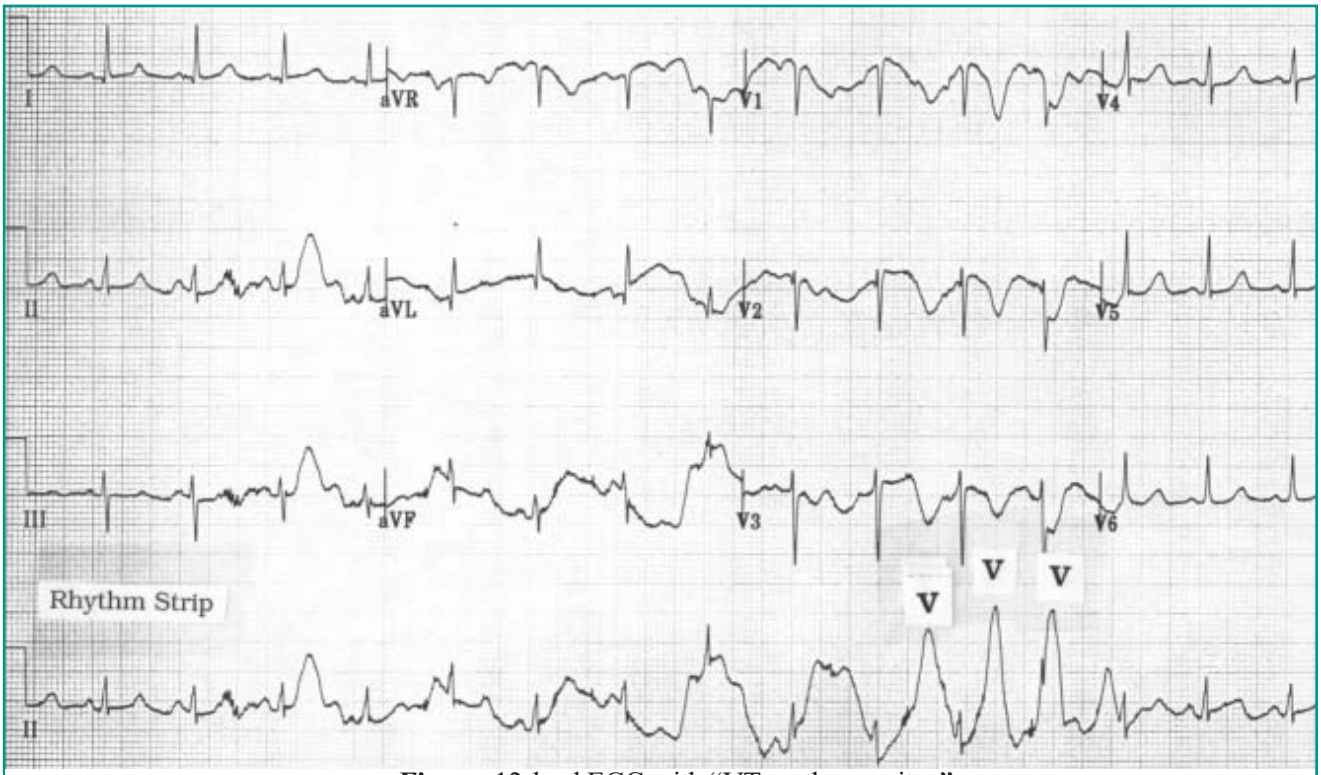

Figure. 12-lead ECG with "VT on the monitor."

Clinical Scenario: The tracing in the Figure said, "V Tach on the monitor" (salvo of beats marked "V" on the rhythm strip). The computerized interpretation also cautioned about "deep anterior T wave inversion suggestive of ischemia." Would you agree?

Interpretation: As always, the best way to approach the interpretation of any 12-lead tracing is to begin by assessing the rhythm on a single lead rhythm strip. A lead II rhythm strip is seen at the bottom of the 12-lead ECG shown in the Figure. This rhythm strip is marked by significant baseline wander with intermittent large erratic deflections (including three peaked upright deflections marked "V"). Despite the worrisome appearance of these three deflections, this is not ventricular tachycardia.

Artifact is a common phenomenon seen on the ECGs of acutely ill patients, in whom *many* potential sources of distortion-producing movement may exist (patient unable to remain still because of pain or dyspnea, performance of blood draws, or other invasive procedures on the patient).

Distinction between real ECG findings and artifactual distortion may be difficult unless one remains open to the latter as a possibility. Definitive diagnosis of an artifactual rhythm can best be made by the finding of an *undisturbed* underlying rhythm. This is seen in the lead II rhythm strip of this Figure, which begins and ends with several definite sinus beats. Despite baseline wander and the large *V-marked* deflections, the underlying sinus conducted QRS complex continues at a regular rate throughout the entire rhythm strip. A look at simultaneously recorded leads V_1, V_2, and V_3 reveals marked inconsistency in the shape of T wave inversion in these leads, raising the question of whether significant T wave inversion really is present at all. Only by repeating the ECG (and hopefully minimizing potential sources of artifact) will the issue of T wave inversion be resolved. ❖

In Future Issues: Wolff Parkinson White Syndrome

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Current Strategies for Airway Management in the Trauma Patient

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Peer Reviewer: **Perry W. Stafford, MD, FACS, FAAP, FCCM,** Chief of Trauma and Surgical Critical Care, Associate Professor of Pediatric Surgery, Department of Pediatric General and Thoracic Surgery, Children's Hospital of Philadelphia, PA.

In critical situations, the management of the airway is paramount. Virtually all algorithms begin with attention to and protection of the airway. In a patient with a traumatic injury, airway management assumes an essential role to stabilization and survival of the patient, but often presents unique challenges not inherent in other types of patients. The skill of the intubator is put to the ultimate test in the trauma patient, whose airway often is compromised by multiple complicating factors, including hemodynamic instability from multiorgan injury, cervical spine fractures, and direct trauma to the airway.

The process of airway management has evolved considerably to include sophisticated techniques and pharmacologic adjuncts. This two-part article will review the concepts of airway management in the trauma patient, the technique of rapid sequence intubation (RSI), and adjuncts to assist with the management of the difficult or failed airway.

—The Editor

The Trauma Airway

The airway in the trauma patient can present many challenges, even for the experienced clinician. These factors can occur individually or together to complicate the care of the trauma patient. *(See Table 1.)*

Preexisting Difficult Airway. As everyone who works in the field of emergency medicine knows, Murphy's Law virtually defines our existence—if something can go wrong, it will. Inevitably, a neckless, 375-pound man with advanced ankylosing spondylitis who is driving a compact car will have an unfortunate encounter with a tractor-trailer at 3 a.m. and be transported to your facility as a Level 1 trauma. As you prepare to perform the intubation, you realize that multiple previous airway manipulations have significantly altered the anatomy in the posterior pharynx.

Patients will bring to the trauma room preexisting anatomical variations that can complicate endotracheal intubation (ETI). In any patient who is not critical enough to require an immediate airway intervention, it is imperative to conduct as thorough an evaluation as possible before considering the use of a paralytic agent. The ultimate rule of airway management is to have a thoroughly prepared plan to deal with the patient's airway, and never paralyze a patient you suspect will be extremely difficult or impossible to intubate. Further, the ability

to adequately mask ventilate should be taken into consideration when deciding upon the type and method of airway intervention. Characteristics of patients who may be difficult to mask ventilate or intubate are discussed in detail in the "Difficult Airway" section.[1-5]

Trauma Immobilization. The physical process of trauma immobilization with a cervical collar and backboard significantly can limit access to the airway and the anterior neck. A properly placed collar inhibits opening of the mouth and, by intention, prevents repositioning of the head and neck. The collar further can obstruct visualization of the anterior neck and potentially lead one to miss laryngeal trauma or distortion of airway anatomy.

It is essential, therefore, to remove the cervical collar and utilize inline stabilization by a dedicated individual during attempts at intubation.

Cervical Spine Considerations. As in virtually all trauma cases, careful consideration must be given to potential injury to the cervical spine and spinal cord. This stated, however, airway management still remains at the top of the resuscitation algorithm. Failure to adequately control an airway due to theoretical concerns of cervical injury violates this standard. The emergency physician charged with the task of securing an airway must employ the best possible available techniques to maintain cervical stability and utilize refined intubation skills while not sacrificing the patient for protection of his spinal cord.

Table 1. Potential Complicating Factors in the Management of a Trauma Patient's Airway

- Pre-existing difficult airway (i.e., anterior larynx, short neck, poor jaw mobility, etc.)
- Physical constraints of trauma immobilization
- Potential or actual injuries to the cervical spine
- Mechanical distortion of the airway anatomy from direct trauma to oral, pharyngeal, or laryngeal structures
- Mechanical distortion of the airway from injuries to contiguous structures (lower neck, thorax, or trachea)
- Other non-airway factors, such as hypotension, brain injury, or pneumothorax, which compete with the urgency to control the airway

Mechanical Distortion of the Airway or of Contiguous Structures. Direct trauma to the face, larynx, or thorax can alter the normal anatomic relationships of the airway structures and can increase the difficulty of intubation.

Indications for Invasive Airway Intervention

The decision to intubate a patient in the emergency department (ED) can be the most significant and definitive step in the care of the trauma patient. The primary goals of intubation are to improve gas exchange, relieve respiratory distress by decreasing the work of breathing, and protect against aspiration. Secondary goals range from intentional hyperventilation to core rewarming.

Experienced clinicians will be familiar with the intubation criteria listed in Table 2.[6]

Respiratory Failure. Respiratory failure occurs when a patient is unable to oxygenate or ventilate adequately to meet his/her physiologic needs. The decision to intervene is based on abnormalities found on blood gas analysis and, often more importantly, the clinician's observation of the patient in respiratory distress.

Oxygenation failure often is defined as the inability to maintain a PaO_2 of 60 mmHg on an FiO_2 greater than 40%.

Ventilation Failure. The best indicator of hypoventilation is an abnormal pH. A pH less than 7.3 resulting from hypoventilation should prompt intervention. Intervention at a higher pH may be necessary if the patient appears fatigued or has significant comorbidity. Chronic compensated elevation in $PaCO_2$ does not require support. When making a decision based on abnormal blood gas analysis, carbon dioxide retention with a $PaCO_2$ greater than 55 (with previously normal $PaCO_2$) or rise in $PaCO_2$ by 10 acutely in chronic obstructive pulmonary disease (COPD) is an indication for intervention.

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Table 2. Indications for Intubation

- Oxygenation failure—PaO_2 < 60 on FiO_2 > 40%
- Ventilation failure—pCO_2 > 55 with previously normal pCO_2 or rise in pCO_2 by 10 acutely in COPD
- Need for intentional hyperventilation
- Profound shock—Reduces energy expenditure used during rapid breathing
- Intentional paralysis—To accomplish necessary procedures in a non-compliant patient
- To protect the patient from aspiration
- To alleviate mechanical obstruction
- To perform core rewarming

Table 3. Clues to Impending Respiratory Failure

- Hoarseness of the voice
- Stridor
- Poor handling of secretions
- Agitation
- Falling pulse oximetry
- Progressive rise in end tidal CO_2

Respiratory Muscle Fatigue. The increased work of breathing seen with decreases in lung compliance (e.g., pulmonary contusions, pulmonary edema, consolidation, pneumothorax, or atelectasis) and increases in airway resistance (e.g., bronchospasm or excessive airway secretions) can contribute to early fatigue of respiratory muscles. This can be seen clinically by agitation, diaphoresis, nasal flaring, the use of accessory muscles, and abdominal (seesaw motion) breathing. *(See Table 3.)*

Intentional Hyperventilation. Although this technique traditionally has been used to attenuate intracranial hypertension by inducing alkalosis to cause cerebral vasoconstriction, it recently has been shown to be appropriate in only limited situations.

Cardiovascular Support. Under normal physiologic conditions, energy expenditure for breathing is low. During states of physiologic stress, such as cardiogenic, hypovolemic, or septic shock, the oxygen demand of the pulmonary mechanism rises significantly. Early intervention with ETI in patients with significant hemodynamic compromise can improve oxygenation to the ischemic tissue and lessen myocardial workload.

Aspiration Protection. When a patient appears obtunded or lacks a gag reflex, ETI becomes vital to decrease the risk of aspiration and its attendant complications.

Mechanical Obstruction. Distortion of the airway can occur in a variety of traumatic injuries. In cases of impending airway obstruction or when obstruction already has occurred, the decision to intervene is a foregone conclusion.

With more subtle injury patterns, an airway may be intact at the time of initial examination, but the risk for potential obstruction can be very high. This situation is typified in the case of burns to the upper airway, where developing edema has the potential to completely obstruct the larynx and other posterior pharyngeal structures. Other examples include direct laryngeal trauma and penetrating wounds to the neck. Hematomas from injury to the carotid artery can expand and distort the airway beyond recognition.

Core Rewarming. A patient can develop substantial hypothermia as the result of a traumatic injury occurring during cold weather or secondary to submersion in cold water. As core temperature drops, many physiologic changes occur, resulting in coagulopathy, hypotension, and an overall decrease in survival. The principles of core rewarming place significant value on the delivery of heated, humidified oxygen to the lungs as a major method of adding heat to the body.[7] This is best accomplished via the use of an endotracheal (ET) tube. Humidified oxygen is heated to 45°C (113°F) and delivered continuously. A rise in core temperature of 1-2.5°C (1.8-4.3°F) per hour can be expected. Contrary to widely held belief, intubation of a hypothermic patient never has precipitated the onset of a lethal arrhythmia.

Rapid Sequence Intubation (RSI)

Historical Perspective and Overview. Prior to the emphasis on the development of controlled airway management strategies, airway management outside of the operating room (OR) was, to say the least, practiced with a particular lack of sophistication. Awake, non-pharmacologically assisted, oral intubation was common. Nasotracheal intubation also was utilized as a primary method of intubation or as a rescue technique. In the field, esophageal obturator airways were the standard modality.

If sedation became necessary, serial sedation frequently was utlilized. This method used incremental doses of an opiate such as morphine, along with a benzodiazepine like diazepam or lorazepam, to "soften the patient up a little." The drugs were given until the patient was sleepy enough to allow the introduction of a laryngoscope into the mouth. The problem resulted when the epiglottis or larynx was stimulated, causing rapid central nervous system (CNS) arousal and vomiting. This method is distinctly different from the delivery of rapid-push induction agents used in RSI.

Meanwhile, in the OR, anesthesiologists would take a carefully prepared patient, keep him or her from eating or drinking anything (NPO) for hours, evaluate the airway for a potentially difficult intubation, then deliver a cocktail of carefully measured drugs, which rapidly would induce unconsciousness and muscle relaxation. The completely defenseless patient could be intubated without resistance. If a difficulty arose, backup readily was available, and ultimately, the anesthesiologist had the option of canceling the case and trying another approach to intubation on another day.

In the ED, canceling the case is rarely, if ever, an option. Further, every ED/trauma patient seemingly just finished a dinner consisting of beer and a pizza with everything. He or she then often has the nerve to violate the law of inertia and go par-

tially through the windshield just before becoming entrapped in a car that flipped upside down in three feet of water. So much for NPO, a controlled environment, and an ASA class I (healthy) patient!

This type of setting demands a better approach to the patient in need of emergent definitive airway management.

When the technique of RSI was assimilated into emergency medicine practice from the OR, the word "induction" was replaced with "intubation," thereby focusing the procedure on the establishment of an airway rather than the induction of anesthesia for an operative case. The American College of Emergency Physicians endorses RSI as the standard of practice for airway management.[8] Nasotracheal intubation (NTI), which once was the primary method of intubation in the ED, largely has been replaced by RSI. A national survey of emergency medicine residencies showed an average of only 2.8 NTIs during a three-year period by emergency medicine residents.[9] RSI is considered routine in most EDs; it is utilized in up to 84% of all ED intubations, with success rates reported at 97%.[8,10-14]

The role of RSI in trauma has been evolving and it currently is considered the method of choice for emergent airway control in the traumatized patient unless specific contraindications are present.[1,4,15]

RSI Technique

RSI is a method of quickly obtaining optimal intubating conditions via the delivery of an induction agent (to induce unconsciousness) followed in rapid succession by a paralytic agent. The goal of RSI is to facilitate the passage of an ET tube into the trachea quickly and efficiently. RSI eliminates or reduces the need for ventilating the patient during the procedure unless oxygenation is impaired and the bag-valve mask must be used to maintain adequate saturation. This technique should minimize the chances of aspiration of stomach contents during the intubation.

Various methods of teaching RSI for the emergency clinician have been developed, but the use of the "Seven P's of RSI," as described by Walls and Murphy,[1] is the one that is the best developed. The algorithm described below is a modification of the above approach specifically adapted to the ED and includes eight P's—plan B, prepare, preoxygenate, pretreat, put down, paralyze, pass the tube, prove placement.

Plan B. The first P in this series refers to the predetermined plan for dealing with a difficult or failed orotracheal intubation. It can be very disconcerting (at the very least) to discover a heretofore unknown airway anomaly in what appears to be an easy intubation. A recent article published in the anaesthesia literature found an *unanticipated* failed intubation occurred in 0.4% of the cases (44 of 11,621 patients).[16] Published reports of the ED airway management experience at several teaching hospitals found that rate of difficult intubation was less than 5%.[11,12] A complicated situation rapidly can become a disaster if no pre-implemented plan exists to deal with an anomaly. To avoid potential disasters, it is recommended that all EDs have assembled an emergency airway cart for use in trauma patients.

Table 4. Contents of Ohio State University Airway Cart

A COMPLETE SET OF RSI DRUGS
- Induction/sedation agents: Etomidate, ketamine, midazolam, and fentanyl
- Paralytic agents: Succinylcholine, rocuronium, vecuronium
- Adjunctive medications: Atropine, lidocaine

ENDOTRACHEAL TUBES, VARIOUS SIZES AND TYPES (PEDIATRIC AND ADULT)
- Endotrol tubes
- Oropharyngeal and nasopharyngeal airways

ADDITIONAL LARYNGOSCOPE PARTS
- Miller and Macintosh blades
- Standard laryngoscope handle
- Short laryngoscope handle
- Pediatric laryngoscope handle
- Spare bulbs

AIRWAY ADJUNCTS
- Gum elastic bougie
- Laryngeal mask airways (LMAs) and intubating laryngeal mask airways (ILMAs)
- Combitubes
- A lighted wand stylet with multiple sizes of stylets
- Retrograde intubation sets

SURGICAL AIRWAY TOOLS
- Percutaneous and open cricothyrotomy kits
- Scalpels (#10, #11, #15 blades)
- Extra instruments

NEEDLES AND SYRINGES OF VARIOUS SIZES

It is present at all intubations. For a list of the items in the ultimate, complete, difficult airway cart, see Appendix 1 in *The Manual of Emergency Airway Management*.[17,18] The minimum required equipment utilized by the author as part of a difficult airway cart is listed in Table 4.

Prepare. Taking the time to organize and inventory the working environment directly prior to the actual intubation assures that everything needed to perform the task will be available and in good working order. Not only does this preparation provide peace of mind and decrease stress levels, it can be a time- and life-saving investment.

Preparation includes the following:

- Thoroughly evaluate the patient for a potentially difficult intubation and for difficulty with bag-valve mask ventilation;
- Remove the patient's dentures;
- Bring the difficult airway cart to the bedside;
- Have the chosen laryngoscope blades ready (two sizes of Macintosh blades, two Miller blades);
- Check the light on the laryngoscope blades;
- Verify the integrity of the balloon on the ET tube; and
- Have suction ready at the bedside. When preparing suc-

tion, it is useful to have two suction options available. A standard Yankaur tip works well for loose secretions but does not adequately aspirate such common items as steak, pizza, mushrooms, and other assorted food morsels often found in the posterior pharynx of ED patients. It may be useful to cut the tip off of the Yankaur suction with some trauma shears prior to intubating the patient.

• Verify the integrity of your IV access and start a second IV line. A disastrous situation can result when an induction agent is given, and the IV stops working before the paralytic agent can be pushed. Have your chosen means to secure the ET tube ready to implement.

• Have color-change capnography device at bedside.

Preoxygenate. As early as possible in the course of preparation for intubation, the patient should be placed on 100% FiO_2. Standard non-rebreather masks only deliver FiO_2 at approximately 70%, because they allow the entraining of room air. The goal is to "denitrogenate" the patient's functional residual capacity and replace it with oxygen. This step can afford the intubator some buffer time during the procedure. The healthy 70 kg adult can take as long as eight minutes to desaturate to 90%, whereas further desaturation from 90% to 0% can take only two minutes. This reflects the characteristic "slippery slope" found in the oxyhemoglobin saturation curve. Heavier patients and small children typically will desaturate faster.[19] The typical ED trauma patient requiring intubation may not have a normal cardiopulmonary function and, therefore, may fail to optimally oxygenate. Further, some pulmonary processes that impair oxygenation also will antagonize the effects of prolonged preoxygenation.

In an ideal setting, a patient should breathe 100% oxygen for five minutes prior to attempts at intubation. Most ED oxygen delivery devices (even non-rebreather masks) achieve only a 75% FiO_2; the use of a Capnoflo brand bag-valve mask delivers close to 100%. Patients who are stable enough should receive adequate preoxygenation. However, in the ED, some patients with impending apnea will not tolerate a five-minute period of preoxygenation. Instead, eight vital capacity breaths of 100% oxygen may serve the same nitrogen washout function and effectively retard apnea-induced hemoglobin desaturation.[20]

When studied, most ED oxygen delivery devices cannot deliver adequate oxygen flow to reach an FiO_2 even close to 100%. Non-rebreather masks only achieve a 75% FiO_2 because they allow the entraining of room air.

When put to the test, some commonly used resuscitation bag-valve mask systems achieved FiO_2s that never exceeded 40% (Code Blue™ and 1st Response™). By using a one-way exhalation valve that does not allow for the entrainment of room air, only the Capno-Flow™ and the Silicone Resuscitator™ brand bag-valve mask systems were able to deliver greater than 90% oxygen.[21]

Pretreat. The pretreatment phase of RSI involves the delivery of medications to modify the physiologic response during and after intubation. One mnemonic used to describe the types of medications frequently used in the pretreatment phase is "LOAD,"

Table 5. LOAD Mnemonic for Pretreatment Phase of RSI

L — LIDOCAINE (1.5 MG/KG IV *OR* NEBULIZED [SEE BELOW])

- The use of lidocaine in RSI has been advocated to blunt the intracranial pressure rise associated with RSI. The evidence supporting its effectiveness is not clear, and conflicting reports of the degree of effect exist.[22,23] A recent study implied that hemodynamic responses to laryngeal stimulation could be effectively blunted with the use of topical 4% lidocaine (sprayed directly on the larynx) and partially blunted with intravenous lidocaine.[24]
- Lidocaine also can be delivered topically to the posterior pharynx and upper airway by nebulization. Four cc of 4% lidocaine can be nebulized in a standard aerosol set with a facemask. This delivers 160 mg of lidocaine. Caution should be used so as not to exceed 5 mg/kg of lidocaine.

O — OPIATES (FENTANYL [SUBLIMAZE] 2-9 MCG/KG IV)

- Opiates can be used to attenuate the sympathetic responses to intubation. This can be important when treating a patient who might not tolerate hypertension or tachycardia associated with laryngeal stimulation. A recent study demonstrated that pretreatment with fentanyl (2 mcg/kg), immediately prior to the induction of anesthesia, significantly reduced the hemodynamic response to endotracheal intubation.[25]

A — ANTICHOLINERGIC AGENTS (CHOOSE ONE)

- Atropine: Children—0.01-0.02 mg/kg IV (min 0.1 mg); adults—0.5-1.0 mg IV *or*
- Glycopyrrolate (Robinul): Children—0.004 mg/kg IV; adults— 0.2-0.4 mg IV
  - Use in children to prevent potentially lethal bradycardia/asystole (seen with succinylcholine)
  - Use in adults and children as an antisialogogue when ketamine is used.

D — DEFASCICULATING AGENTS (CHOOSE ONE)

- Succinylcholine 0.15 mg/kg IV *or*
- Vecuronium 0.01mg/kg IV *or*
- Rocuronium 0.1 mg/kg IV

  - Defasciculation refers to decreasing/eliminating the muscle fasciculations (twitches) that occur in response to the initial depolarizing effect of succinylcholine. These muscle contractions can produce a rise in intracranial and intraocular pressure.
  - Use defasciculating doses of paralytic agents in patients with head injury or open-globe eye injuries.
  - Can use 1/10th the intubating dose of any available paralytic agent
  - Administer drug three minutes prior to intubation.

Detailed drug information and dosages derived from 2002 *Physician's Desk Reference* and the 2002 American Hospital Formulary Service Drug Information—American Society of Health-System Pharmacists.

Table 6a. Induction Agents for Use in RSI

ETOMIDATE (AMIATE)

Dosage: 0.3 mg/kg IV
Pregnancy Category: C
Preparation: 2 mg/mL
Description: Non-barbiturate, sedative hypnotic with anesthetic and amnestic properties (no analgesia)
Onset: < 60 seconds
Duration: 5-10 minutes
Reversal Agents: None
Indications: Need for rapid induction; excellent for older patients or those with tenuous cardiovascular status; hypotension
Contraindications: Allergy to etomidate; in Addison's Disease, must supplement corticosteroids
Major Side Effects: Apnea related to dose and rate of administration is rare and only minor respiratory depression is seen; pain on injection common; decreased ICP and cerebral perfusion pressure; spontaneous myoclonus (not seizure) is seen in up to 30% of patients; transient ACTH-resistant/hydrocortisone-responsive decrease in the production of cortisol; vomiting and hiccoughs are possible during and post-procedure

KETAMINE (KETALAR)

Dosage: 1-2mg/kg IV push
Pregnancy Category: Unknown
Preparations: 100, 50 & 10 mg/mL
Description: Dissociative anesthetic; PCP derivative. May act at multiple receptor sites including opioid and cholinergic; only single agent with anesthetic, amnestic, and analgesic properties.
Onset: IV: 30-60 seconds
Duration: IV: 10-15 minutes
Reversal Agents: None proven; naloxone & physostigmine may have some theoretical effect
Indications: The need for induction in a hypotensive patient; need for induction in a patient with bronchospasm
Contraindications: Elevated ICP; ischemic heart disease; age < 3 months
Major Side Effects: (Side effects rarely outweigh the potential benefits of ketamine as an induction agent in the hypotensive patient.) Transient 20-30% increase in BP; increase in heart rate; increase in ICP has been reported; nystagmus; nausea—vomiting is rare and usually occurs late after emergence; excess salivation can be controlled with atropine/glycopyrrolate; hallucinations on awakening (rare in children < 13 years of age). Hallucinations are much less frequent than previously reported in adults and virtually are eliminated by the addition of 2 mg of midazolam; transient apnea is very rare and seen only with rapid-push of high doses.

THIOPENTAL (PENTOTHAL)

Dosage: Adult— 3-5 mg/kg IV rapid push. Children—2-6 mg/kg IV rapid push. Decrease dose with hypotensive/elderly (1-2 mg/kg).
Pregnancy Category: C
Preparation: Multiple
Description: Barbiturate anesthetic agent with a rapid onset of action.
Onset: 30-60 seconds
Duration: 10-20 minutes
Reversal Agents: None proven
Indications: Induction of anesthesia in RSI; possibly useful in patients with head injury to lower ICP
Contraindications: Porphyria; status asthmaticus; significant cardiovascular problem producing hypotension; hypotension
Major Side Effects: Decreases BP—hypotension is common; barbiturates may potentiate/increase pain (antianalgesia); exacerbation of bronchospasm can occur in status asthmaticus; nausea/vomiting

PROPOFOL (DIPRIVAN)

Dosage: Adult and children: 2-2.5 mg/kg IV slowly over 30 sec in 2-3 divided
Pregnancy Category: B
Preparation: 10 mg/mL
Description: Non-barbiturate, sedative-hypnotic with anesthetic and amnestic properties.
Onset: < 60 seconds
Duration: 5-10 minutes
Reversal Agents: None
Indications: Induction of anesthesia in hemodynamically stable patients
Contraindications: Allergy to albumin or egg whites; hypotension; compromised cardiac function ; caution in elderly patients (exaggerated hypotension)
Major Side-Effects: Transient hypotension and apnea are related to dose and rate of administration; pain on injection (10%); decreased ICP and cerebral perfusion pressure

Detailed drug information and dosages derived from 2002 Physician's Desk Reference and the 2002 American Hospital Formulary Service Drug Information, American Society of Health-System Pharmacists.

described by Walls, et al, in the *Manual of Emergency Airway Management.*[26] *(See Table 5.)*

Put Down. The next step involves the induction of anesthesia with a rapid-acting induction agent. This step is performed virtually simultaneously with the next step, administration of a paralytic agent. Owing to the rapid onset of agents such as etomidate and ketamine, complete loss of consciousness can be achieved in 30-45 seconds. The onset of succinylcholine, the paralytic agent of choice, usually is less than 1 minute. When given in rapid succession, the onset of induction and paralysis can be almost simultaneous.

- Induction agents are given simultaneously to, or in rapid succession with, paralytic agents;
- Apply cricoid pressure (Sellick's maneuver). Do not release until placement is verified; and
- Do not ventilate until patient is intubated or reoxygenation is required.

Induction Agents — Etomidate (Amidate). If only one drug

Table 6b. Paralytic Agents for Use in RSI

SUCCINYLCHOLINE (ANECTINE/QUELICIN)

Dosage: Adult: 1.5 mg/kg IV rapid push
Pregnancy Category: C
Preparation: 20 mg/mL
Description: Depolarizing neuromuscular blocking agent
Onset: IV: 30-60 seconds
Duration: IV: 6-12 minutes
Reversal Agents: None
Indications: First-line paralytic agent in RSI
Contraindications: Burn or spinal cord injury patients > 48 h post injury; open-globe ocular injury; use can cause bradycardia unless pretreatment with anticholinergic; known hyperkalemia
Major Side-Effects: Muscular fasciculations; transient hyperkalemia; increased ICP and intraocular pressure

ROCURONIUM (ZEMURON)

Dosage: Adults and children: 0.6-1.2 mg/kg IV rapid push
Pregnancy Category: B
Preparations: 10 mg/mL
Description: Non-depolarizing neuromuscular blocking agent
Onset: 45-90 sec
Duration: 15-40 min.
Reversal Agents: Neostigmine
Indications: Good second-line agent for RSI; rapid onset but long duration of action
Contraindications: Hypersensitivity to rocuronium; hypersensitivity to bromides;
Major Side-Effects: Tachycardia; transient hypo/hypertension

Detailed drug information and dosages derived from 2002 *Physician's Desk Reference* and the 2002 American Hospital Formulary Service Drug Information, American Society of Health-System Pharmacists.

is available to utilize for RSI in ED patients, etomidate is the agent of choice. With its onset of action in one arm-to-brain circulation (30 seconds), a duration of action of only 3-10 minutes, and very little effect on cardiovascular hemodynamics, etomidate is ideally suited for sick, potentially hypotensive or grossly unstable patients. It has gained significant popularity for use in ED RSI.[27] *(See Table 6a.)*

Etomidate is a non-barbiturate sedative-hypnotic agent unrelated to other induction agents. This medication typically is delivered by a single dose of 0.3 mg/kg given by rapid IV push, often simultaneous with, or directly preceding, a paralytic agent. The reported incidence of etomidate-induced myoclonus (up to 30%) is of little significance since all movement will be obliterated with the coadministration of a rapid-acting paralytic drug. Benzodiazepines and opiates have been employed to attenuate etomidate-induced myoclonus. Studies in adults have found that the only consistent effects are achieved with fentanyl at doses of 500 mcg.[28] Transient adrenocortical dysfunction lasting 12 hours after a single bolus dose of 0.3 mg/kg of etomidate has been reported. This effect appears to have little clinical relevance since serum cortisol levels remain within normal parameters during the period of dysfunction.[29]

If etomidate is given without a paralytic agent, most patients will continue to breathe. Although sufficient intubating conditions often are produced with etomidate alone, myoclonus (especially involving the jaw) can interfere with the process, requiring rescue paralysis.

Ketamine (Ketalar). Ketamine, a dissociative anesthetic derived from PCP, is unique in that it is the only agent which provides analgesic, amnestic, and anesthetic (sedative-hypnotic) properties.

Despite an inherent myocardial depressant effect, ketamine stimulates the release of endogenous epinephrine, causing an increase in heart rate, blood pressure, myocardial oxygen consumption, and bronchodilation.

This agent is best suited for hypotensive patients, owing to the cardiovascular support provided by this drug. Current recommendations caution against the use of ketamine in patients with head injury. Although an increase in intracranial pressure is reported, this appears to result from an increase in cerebral blood flow. Increases in brain perfusion potentially can offset the increased ICP, calling into question the clinical relevance of this untoward effect.

The frequency of emergence hallucinations, reported with the use of ketamine in adults may be overstated. The addition of a benzodiazepine may control or minimize any effects that may occur. Further, in the ED patient who will remain ventilated, sedated, and paralyzed, emergence reactions have little significance.

Thiopental (Pentothal). Pentothal is a classic induction agent with very rapid onset and short duration of action. It can lower intracranial pressure. Since it can drop blood pressure significantly with one dose, it is not a good agent for unstable or hypotensive patients. This agent has amnestic and anesthetic properties with paradoxical antianalgesic effects sometimes observed.

Propofol (Diprivan). Propofol can produce potentially severe hypotension in cardiovascularly compromised or blood volume depleted patients. Availability of other choices makes propofol suboptimal for ED RSI in all but the most cardiovascularly stable patients.

Paralyze. This step involves the delivery of a rapid-acting paralytic agent given simultaneously, or in close succession with, an induction agent.

Paralytic agents induce profound muscle relaxation by inhibiting the action of acetylcholine (Ach) at the neuromuscular endplate. These drugs are either depolarizing or non-depolarizing, depending on their interaction with the Ach receptor. *(See Table 6b.)*

Depolarizing agents such as succinylcholine fit into the Ach receptor and act to initially cause depolarization of the motor endplate and induce contraction, manifesting clinically as fasciculations. Subsequently, the receptor is blocked by the succinylcholine, preventing Ach from binding and producing further contraction. The paralysis lasts until succinylcholine is degraded by acetylcholinesterase.

Non-depolarizing agents such as vecuronium and rocuroni-

um competitively inhibit the Ach receptor, occupying it and then exiting the site. These agents are removed from the neuromuscular junction and broken down in the liver. Their duration and onset of action generally are longer than succinylcholine.

Succinylcholine (Anectine/Quelicin). Succinylcholine is the first line agent for paralysis in RSI. No agent consistently has demonstrated comparable rapidity of onset and short duration of action. In otherwise normal individuals, the use of succinylcholine results in only minimal changes in serum potassium of 0.5-1 mEq/L.[19,30] The magnitude of this effect is enhanced in two groups of patients. The first group is those who have had massive tissue destruction such as severe burns, massive trauma, and rhabdomyolysis. Owing to the large surface area of damaged muscle that is capable of leaking potassium, severe, rapidly fatal hyperkalemia can develop. Mortality rates can reach 30%, even with treatment.[31]

The second group is comprised of patients who develop an up-regulation of acetylcholine receptors. When muscles lose their normal input from motor nerves, the acetylcholine receptors normally located in the motor endplates increase in density and spread over the surface of the muscle. Stimulation from succinylcholine causes an exaggerated release of potassium. Conditions which cause this effect include: CNS injury (CVA); spinal cord injury; neuromuscular diseases with muscle wasting (e.g., muscular dystrophy, etc.); disuse atrophy; and any other cause of chronic denervation. This problem is not seen if the injury is acute, but rather develops after 24-48 hours.

Recent literature suggests that the risk of adverse events when succinylcholine is used on known hyperkalemic patients (K > 5.5mEq/L) is lower than generally believed, with a maximum catastrophic event risk of 7.9%.[30] Although this clearly is not a trivial risk, succinylcholine may still be the drug of choice when neuromuscular paralysis is required and suitable alternatives are not available.

Succinylcholine can be stored unrefrigerated for up to three months with only minimal degradation (10% loss) of its paralytic properties.[18]

Rapacuronium (Rapalon). Rapacuronium is designed as a competitor to succinylcholine in RSI. To date, this agent has the shortest onset of action and duration of any non-depolarizing paralytic. Unfortunately, rapacuronium recently was removed from the market due to a few cases of fatal bronchospasm attributed to its use.

Rocuronium (Zemuron). Rocuronium is slightly slower than succinylcholine in onset of paralysis, but it is faster than most other non-depolarizing agents. A recent meta-analysis reported that although rocuronium was inferior to succinylcholine in providing excellent intubating conditions, it was comparable to succinylcholine in inducing clinically acceptable intubating conditions.[32] A recent report looked at rocuronium and found it to be an effective agent for RSI when succinylcholine was contraindicated.[33]

Pass the Tube. The goal of RSI is to get to this very point with the least possible difficulty. Here, the ET tube is passed through the cords via direct visualization. Prior to and during this process, cricoid pressure is maintained until the ET tube cuff is inflated where appropriate. A complete discussion of basic intubating techniques is beyond the scope of this text, so only a few tips will be presented. Many other techniques, tools, and tricks will be covered in the second part of this article.

One technique that has been described to facilitate direct visualization of a slightly anterior larynx is called "BURP" for "Backwards-Upwards-Rightwards-Pressure."[34,35] The assistant applies pressure to the thyroid cartilage, first backward, then upward, and finally rightward. The adult larynx should be displaced about 2 cm to the right. Meanwhile, the intubator should attempt direct visualization of the larynx. Alternatively, the intubator can place his or her hands over the assistant's hand and direct the pressure while attempting to visualize the glottis. When the cords are seen, pressure can be released by the intubator, and the assistant can continue to hold the optimal position.

A recent article described the use of a simple and effective technique called External Laryngeal Manipulation (ELM). ELM achieves the same backward, upward and rightward airway repositioning as does "BURP," however the pressure is applied by the intubator with his or her right hand.[36,37] One of the most common pitfalls is failure to adequately sweep the tongue out of the way. By inserting the blade as far to the right as possible, the intubator more effectively can force the tongue to the left.

The laryngoscope blade can be placed as deep as possible into the oropharynx, allowing it to enter the esophagus. When the blade slowly is withdrawn, the first anatomical structure to be encountered is the larynx, followed by the epiglottis.

Prove Placement. The final step is to verify the correct placement of the ET tube into the trachea. Inadvertent placement of the ET tube into the esophagus is OK. Failure to immediately recognize and remedy this error is not.

After the tube is passed and the cuff is inflated (where appropriate), the chest should be auscultated to listen for breath sounds. The stethoscope need only be placed in three locations to properly auscultate: the left axilla, the right axilla, and over the epigastrum. Absent breath sounds and/or sounds of gastric insufflation means that the wrong tube has been accessed. Unequal breath sounds can imply that the tube is in the right (or sometimes the left) mainstem bronchus.

In all ORs, the standard of care is to use the detection of a CO_2 waveform with formal capnography as confirmation of tracheal placement of an ET tube. The standard should be no less in the ED. Although quantitative capnography devices are beginning to appear in EDs, they are not yet commonplace. The use of inexpensive color-change CO_2 detectors represents a practical alternative. The detection of CO_2, indicated by a purple to yellow color change, is 100% specific for tracheal placement of the ET tube, whereas the failure to detect color change strongly suggests esophageal intubation.[38] In cardiac arrest, the lack of lung perfusion can lead to the absence of CO_2 and a lack of color change despite the correct placement of the ET tube in the trachea.

The esophageal intubation detector (EID) is a simple device that relies on negative pressure to detect misplacement of an ET

tube. This device is a small bulb that is squeezed to evacuate the air and then placed on the end of the ET tube. When the bulb is released, it tries to reexpand. If the ET tube is in the esophagus, the esophageal walls, which are not rigid, will collapse around the end of the ET tube and prevent air from being sucked up the tube and thereby prevent bulb reinflation. In the rigid trachea, however, air can be sucked into the ET tube and the bulb will reinflate in fewer than two seconds. In clinical application, this device generally has been effective in detecting most esophageal intubations when direct visualization was not possible or capnography was not available.[39-41] A recent report, however, documented cases in which the detector gave false positive results for tracheal intubation.[42]

A chest radiograph should be performed as soon as possible to confirm ET tube placement and document position.

Issues in the Pediatric Airway

A detailed discussion of all of the factors affecting the pediatric trauma airway is beyond the scope of this paper. Highlights of the anatomic and physiologic differences between the adult and pediatric patient as they pertain to airway management will be presented.[43,44]

Anatomic Differences

• Large tongue in children;

• Anterior position of tracheal opening: younger than 2 years of age—high anterior tracheal opening; 2-8 years—transition; older than 8 years—airway is like small adult;

• Large occiput causing neck flexion;

• Large tonsils and adenoids;

• Small cricothyroid membrane—cricothyroidotomy contraindicated;

• Acute angle between epiglottis and laryngeal opening—difficult nasal intubation;

• Narrowest part of the airway is below the vocal cords at the cricoid ring.

Physiologic Differences

• Shorter time to oxygen desaturation. As a result of increased basal metabolism and smaller functional residual capacity, pediatric patients can desaturate in 50% of the time that an adult patient does.

• Need for higher doses (2 mg/kg) of succinylcholine

• High tendency for vagal effects of succinylcholine—must use atropine to prevent bradycardia in patients younger than 10 years of age.

Implications for Airway Management. The above anatomic and physiologic differences have the following implications that warrant adjustment in standard intubating technique:

• Pay attention to adequate preoxygenation and expect rapid desaturation;

• Visualization of the anterior airway may be facilitated with a straight pediatric blade—if the airway is not easily visualized, try withdrawing a deeply placed blade slightly and watch the epiglottis fall into view;

• Do not hyperextend the neck. In a nontrauma patient, a towel roll can be placed behind the shoulders to raise the torso to match the position of the head;

• In-line spine immobilization during orotracheal intubation is recommended;

• Use uncuffed ET tubes until size 6.0 is required. Estimate ET tube size as (age in years + 16)/4;

• Pretreat patients with atropine (0.01 mg/kg with 0.1 mg minimum);

• Use 2 mg/kg succinylcholine;

• Do not perform surgical cricothyroidotomy in patients younger than 10 years of age;

• Use caution and expect difficulty with nasotracheal intubation;

• Do not push the ET tube too deep and intubate the right mainstem bronchus;

• Use Broselow tape to do dosages, diameters, and depths.

Implications for the Hypotensive Patient

In the injured patient who is hypotensive and requires definitive airway management, some modifications to the standard RSI protocol should be given consideration. Although almost all induction agents can produce hypotension and myocardial depression, the two agents etomidate and ketamine have the best hemodynamic profiles.[27,45] Etomidate has little effect on cardiac contractility and respiratory rate, making it an excellent choice for induction in the trauma patient. Although etomidate is very cardiostable, in hypotensive or volume depleted patients, doses should be reduced to one half the usual induction dose (from 0.3 mg/kg to 0.15 mg/kg).[46]

Ketamine releases endogenous catecholamines. In patients who are not catecholamine-depleted by prolonged maximal physiological stress, ketamine will accelerate heart rate and raise blood pressure. In patients with significant head injury, ketamine remains relatively contraindicated due to its possible adverse effects on intracranial pressure.[45,46]

Barbiturates (thiopental and methohexital), propofol, and large doses of midazolam should not be used in hypotensive patients due to their propensity to significantly lower blood pressure.

Fortunately, the most commonly employed paralytic agent, succinylcholine, does not produce hypotension. Bradycardia, which most often is seen in children who receive succinylcholine, can be abolished with small doses of atropine (0.02mg/kg). If succinylcholine must be redosed in adults, atropine (1-2 mg IV) should be given prior to the second dose to prevent enhanced vagal tone.

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CE/CME Objectives

Upon completing this program, the participants will be able to:

a.) Recognize indications for invasive airway intervention;

b.) Recognize a potentially difficult airway;

c.) Relate the technique of obtaining optimal intubation conditions via the delivery of induction and paralytic agents; and

d.) Identify both likely and rare complications that may occur during the process of intubation.

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1. Inline stabilization of the cervical spine is unacceptable during intubation attempts of a trauma patient.
   A. True
   B. False

2. Which of the following is an indication for intubation?
   A. Oxygenation failure
   B. PCO_2 greater than 60
   C. Profound shock
   D. Protection of patient from aspiration
   E. All of the above

3. Which of the following is *not* part of preparation for intubation?
   A. Thoroughly evaluating the patient
   B. Administering lidocaine
   C. Having laryngoscope blades ready
   D. Verifying the integrity of the balloon on the ET tube
   E. Having suction available

4. Which of the following patients will desaturate the fastest?
   A. Healthy, adult male
   B. Healthy, adult female
   C. Healthy 6-month-old female
   D. Healthy 12-year-old male

5. Which of the following medications is *not* part of the pretreatment phase of RSI?
   A. Atropine
   B. Lidocaine
   C. Succinylcholine 0.15 mg/kg
   D. Succinylcholine 1.5 mg/kg
   E. Vecuronium 0.01 mg/kg

6. Which of the following induction agents would be particularly beneficial in an asthmatic patient who requires intubation?
   A. Etomidate
   B. Thiopental
   C. Pentothal
   D. Propofol
   E. Ketamine

7. In a patient with Addison's Disease in whom etomidate is used as an induction agent, supplemental corticosteroids should be considered.
   A. True
   B. False

8. Which of the following is a contraindication to the use of propofol?
   A. Allergy to albumin
   B. Hypotension
   C. Compromised cardiac function
   D. Allergy to egg whites
   E. All of the above

9. Which of the following may be used to confirm ET tube position?
   A. Breath sounds
   B. Quantitative capnography devices
   C. Color change CO_2 detector

CE/CME Instructions

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D. Chest radiograph
E. All of the above

10. Pediatric patients have a shorter time to oxygen desaturation than do adult patients.
A. True
B. False

ANSWERS: 1-B; 2-E; 3-B; 4-C; 5-D; 6-E; 7-A; 8-E; 9-E; 10-A.