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Diagnostic Strategies Based upon Outcome Data in Pulmonary Embolism

ABSTRACT & COMMENTARY

Source: Musset D, et al. Diagnostic strategy for patients with suspected pulmonary embolism: A prospective multicentre outcome study. *Lancet* 2002;360:1914-1920.

THIS PROSPECTIVE, MULTICENTER, OUTCOME STUDY WAS designed to evaluate a diagnostic strategy based on clinical pretest probability, spiral computed tomography (CT), and venous compression ultrasonography (US) of the legs in patients with suspected pulmonary embolism (PE). The main objective was to assess the safety of withholding anticoagulant treatment in patients with low or intermediate clinical probability of PE and negative findings on spiral CT and venous US.

After reasonable exclusions, 1041 consecutive inpatients and outpatients with clinically suspected PE were entered during a 19-month period in 14 centers in France. All patients were assessed for a pretest likelihood of PE (high, intermediate, or low) and then underwent spiral CT and bilateral US of the legs within 24 hours. Patients with negative spiral CT and US who were clinically assessed as having a low or intermediate clinical probability were left untreated. Patients shown to have either deep-vein thrombosis (DVT) on US, or PE on spiral CT, received anticoagulant therapy. Patients with a high pretest probability of PE, but negative spiral CT and US, underwent ventilation perfusion (VQ) lung scanning, pulmonary angiography, or both.

If either the US or the spiral CT was nondiagnostic and the other study normal, or if only isolated subsegmental emboli were seen on the spiral CT, the patient was classified as inconclusive and underwent VQ scanning, pulmonary angiography or both. All patients were followed for three months, with telephone interviews at one and two months and a clinic visit at three months.

Follow-up was completed for 98.8% of the study population. PE was diagnosed in 360 (34.6%) patients. Of patients with PE, 55 (15 %) had positive US despite negative spiral CT. Of 601 patients with negative spiral CT and US, 525 were classified as having low or intermediate pretest probability and 507 of them were not treated. Of these patients, nine (1.8%, 95% CI 0.8-3.3%) experienced DVT or PE during the three-month follow up: three patients had DVT, one PE, and five more deaths were judged as possibly related to PE. The remaining 76 patients were classified as having high pretest probability of PE, and VQ scanning or angiography was positive in four (5.3%, 95%CI 1.5-13.1%). The diagnostic strategy proved inconclusive in 95 patients (9.1%). In this group, PE was confirmed in eight patients (9.6%) by VQ or angiography.

COMMENTARY BY STEPHANIE B. ABBUHL, MD, FACEP

This is the first large outcome study to look at the strategy of clinical probability of PE, spiral CT, and US to diagnose PE and is a major contribution to the evolving literature in this area. The authors conclude that withholding anticoagulant therapy is safe in patients with a low or intermediate pretest probability, and a negative spiral CT and US. In this group, the rate of PE/DVT at follow-up was 1.8%, a rate similar to other major trials that have looked at outcomes using various diagnostic strategies. It is important to note that the safety of this strategy was most convincing in outpatients, in whom the follow-up PE/DVT rate was only 0.8% (95% CI 0.2-2.3), as compared to inpatients, with a rate of 4.8% and a wide 95% CI (1.8-10.1). While the safety of excluding PE by negative spiral CT and US in hospitalized patients is not confirmed by this study and will require further investigation, in the ED, this strategy now has persuasive outcome data to support it.

In patients with the diagnosis of PE, 15% had a positive US despite a negative spiral CT, emphasizing the need to combine US with spiral CT to safely rule out PE. This is analogous to previously studied strategies where nondiagnostic VQ scans have been combined with US to safely withhold anticoagulation. Of note, a significant limitation was that only single-detector-row spiral CT was used in this study. Newer generation multi-detector CT scanners will need to be studied to evaluate their impact on similar outcome studies.

One of the major limitations to the study was the rate of inconclusive results (9.1%) necessitating VQ or angiography. Only 12 patients (3.3% of all patients with detectable thrombi) had isolated subsegmental filling defects and negative US, three of whom had PE confirmed, the others had a normal VQ or angiogram, were not anticoagulated, and had no events at follow-up. Thus, this study does not resolve the ongoing controversy surrounding isolated subsegmental filling defects.

Also of interest is the fact that the US was done only once and not serially, as has been done in other outcome studies. One wonders if any of the deaths in the patients who were not anticoagulated could have been prevented with a second US done within one week from the initial exam.

Since d-dimers were not included in the strategy, this study provides no information about how to incorporate d-dimers into this approach. Finally, it is important to remember that CT involves contrast injection and radiation and many patients will need other strategies because of renal insufficiency, contrast allergy or pregnancy. ❖

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West Nile Virus: Sound the Alarm from Coast to Coast

ABSTRACT & COMMENTARY

Source: Centers for Disease Control and Prevention. Provisional surveillance summary of the West Nile virus epidemic-United States, January-November 2002. *MMWR Morb Mortal Wkly Rep* 2002;51:1129-1133.

West nile virus (WNV) erupted unexpectedly in the United States in 1999 with an outbreak among residents of New York City. Intense and systematic clinical, epidemiologic, and public health investigation followed, and publication of the analysis of 59 hospitalized patients provided guidance for recognition of additional cases. In conjunction with the Centers for Disease Control and Prevention (CDC), the ArboNet surveillance network of state and local public health departments was established to monitor WNV activity reported in humans, animals, and mosquitoes during the ensuing three years.

The facts from this database are alarming. From a single epicenter of human cases in 1999, WNV all-source activity has now expanded south- and westward in dramatic fashion to involve 44 states plus Washington, DC, by the conclusion of 2002. In striking contrast to the 149 cases of human WNV infection in 10 states reported for the three-year period of 1999-2001, the reported number of cases for 2002 alone totaled 3389, among whom 2354 (69%) suffered from the most invasive manifestation, West Nile meningoencephalitis (WNME). Of these, 199 (9%) died. Taken together, these data sound a sobering note for our nation: since 1999, a total of 3955 cases of West Nile infection (either febrile illness (WNF) alone or WNME) have been documented across 37 states, with 254 deaths. This represents the largest arboviral meningoencephalitis epidemic ever observed in the western hemisphere, eclipsing the 1975 outbreak of a related flavivirus, St. Louis encephalitis, which swept through the midwestern United States. Furthermore, this is the largest WNME epidemic ever reported worldwide.

COMMENTARY BY MICHAEL FELZ, MD

Since the last review of WNV in this publication (*Emerg Med Alert* 2002;9:25-26), this emerging mosquito-borne epidemic has expanded dramatically. *(See table.)* The explosive quantity, severity, and geographic range of human infection in America are worrisome indeed. Equally disturbing is ArboNet surveillance data demonstrating that WNV has now been detected in a total of 44 states among 111 species of birds (chiefly crows, blue jays, and raptors), nine mammalian species (primarily humans and horses, but also dogs, cats, squirrels, rabbits, skunks, chipmunks, and bats), and 36 species of mosquitoes (mainly Culex, but also Aedes and Anopheles).

Table. Human WNV Infections by Year and Extent

YEAR	# CASES	EXTENT
1999	62	1 state
2000	21	3 states
2001	66	10 states
2002	3389	37 states

Source: Centers for Disease Control and Prevention. On line at WWW.cdc.gov/ncidod/dvbid/westnile/qa/cases.htm. (Accessed 2/11/2003.)

From the standpoint of the emergency department (ED) physician, WNV must now be centered prominently in the differential diagnosis of patients presenting with ever, headache, vomiting, mental status change, stiff neck, proximal muscle weakness or flaccid paralysis, and cerebrospinal fluid (CSF) revealing lymphocytes with elevated protein and negative bacterial pathogens. Empiric treatment for bacterial meningitis and/or herpes simplex virus encephalitis is appropriate until results of testing for WNV-IgM in serum and CSF are clarified. Ventilatory support may be required, especially for those older than age 65, in whom respiratory failure and death from WNME are at least six-fold higher than in younger patients.

To further unsettle our troubled nation, 2002 marked a number of firsts for WNV infection. The first cases of transfusion-related WNV infection were reported and confirmed in six instances; 27 other cases are under investigation by the CDC. The first cases of organ-donor transmission were reported among four recipients of separate organs from a 20-year-old woman who had received numerous blood products prior to her death (heart, liver, and both kidneys were donated). Three of these recipients developed WNME, two were intubated, and one died. The first case of maternal transmission to a breast-fed infant occurred in a mother who developed WNME after transfusion for postpartum hemorrhage; WNV IgM was detected in maternal serum and CSF, breast milk, and infant serum. The first report of in utero WNV infection occurred in a 20-year-old woman with fever, leg weakness, hyporeflexia, lymphocytosis in CSF, and WNV-IgM in serum and CSF at 27 weeks gestation. Upon delivery at 38 weeks, her infant had chorioretinitis, severe white matter and cortical destruction on magnetic resonance imaging, and WNV-IgM in cord blood and CSF. Placenta was positive for WNV by PCR. And finally, two microbiologists were documented in

2002 with the first incidence of laboratory-acquired WNV infection. Each had a finger puncture wound while dissecting brain tissue from WNV-infected wildlife. Seroconversion to positive WNV-IgM occurred in each researcher.

So what is the ED physician to do? Be vigilant for encephalitis and aseptic meningitis patients, or apparent Guillain-Barré patients with atypical features such as fever and CSF pleocytosis. Each could represent a case of WNME, especially in areas recently discovered to have dead crows, jays, hawks, and eagles, and sick horses. Advise 20-30% DEET repellant and long sleeves to reduce mosquito exposure. Hope that health departments and the CDC develop improved mosquito control measures or an effective vaccine. Be ready for an epidemic of WNV of ominous proportions among humans, birds, and horses, from coast to coast, this summer. It may not be a pleasant picnic any more, any place. ❖

Coronary Angiography and Cocaine-Associated Chest Pain

ABSTRACT & COMMENTARY

Source: Kontos MC, et al. Coronary angiographic findings in patients with cocaine-associated chest pain. *J Emerg Med* 2003;24:9-13.

Whether coronary angiography is indicated in patients with cocaine-associated myocardial infarction (MI), let alone chest pain, is not clear. This paper from the Medical College of Virginia examined the issue, using primarily prospective observational data on consecutive patients admitted for evaluation of chest pain associated with historical or laboratory evidence of cocaine use. Patients were included if they underwent coronary angiography within five weeks of emergency department (ED) evaluation. The institution employs a tiered structure of triage and disposition for chest pain patients. Based upon risk stratification, the history and physical are supplemented with electrocardiography, serum markers, and nuclear imaging, as well as close follow-up of those discharged from the ED with a negative initial work-up for cardiac ischemia.1

Reasonable criteria were used for biomarker or electrocardiographic evidence of MI. For the purposes of this study, "significant" coronary artery disease (CAD) by angiography was defined as ≥ 50% stenosis of at least one vessel. Of 734 patients who were evaluated for symptoms consistent with myocardial ischemia after cocaine use, 90 underwent coronary angiography within five weeks. Mean patient age was 42, and roughly two-thirds were male. Approximately one-third had evidence of prior coronary artery disease, and MI was evident by either CPK-MB and/or cardiac troponin I (TnI) in 31 patients (34%). Criteria for angiography are listed in the Table.

Significant CAD was found in 45 patients (50%); most of who had single-vessel disease. Of the 31 patients with MI by CPK-MB or TnI, 24 (77%) had significant disease on angiography. Patients without evidence of myonecrosis (the remaining 59 patients)—but with significant CAD on angiography—were more likely ($p < 0.01$) to have prior MI, prior revascularization, a history of CAD, or an increased cholesterol. The authors conclude that the majority of patients with cocaine-associated MI have significant CAD. Similar patients without myonecrosis have a low incidence of CAD; therefore, coronary angiography is not the best first test for evaluation for ischemia in this group.

COMMENTARY BY RICHARD A. HARRIGAN, MD, FAAEM

The authors readily acknowledge that this prospective observational study is limited due to its single location, and the likelihood that not all patients with cocaine-associated chest pain were captured. Another point of importance, however, is that only 90 of 734 (13%) underwent coronary angiography within five weeks. Keeping that in mind, the conclusion that "the majority of patients with cocaine-associated MI have significant CAD" is true—for those who end up on the angiography table (i.e., for those in their cohort). As in any observational study, the diagnostic evaluation was left up to the treating (in this case, critical care unit attending) physician. It would be interesting to know how many of the original 734 patients who did not undergo coronary angiography "ruled-in" by cardiac enzymes. The reader must be careful—the temptation to generalize this data to our population (ED patients with evidence of myonecrosis by serum enzymes) from the study population (ED patients with evidence of myonecrosis by serum enzymes—who

Table. Indications for Coronary Angiography (n=90)

• Elevated serum markers	31 (34%)
• Reversible perfusion defect on stress test	15 (17%)
• Positive rest myocardial perfusion imaging	12 (13%)
• Ischemic changes on ECG	6 (7%)
• Congestive heart failure/reduced ejection fraction	8 (9%)
• Known prior coronary artery disease	8 (9%)
• High risk chest pain characteristics/recurrent pain	10 (11%)

ultimately underwent coronary angiography within five weeks) is flawed. This study does remind us, however, that cocaine-associated chest pain can be "serious" chest pain—with underlying CAD. ❖

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Special Feature

The Electrocardiogram in Wolff-Parkinson-White Syndrome

Part II: The Arrhythmias

By William J. Brady, MD

Wolff-Parkinson-White syndrome (WPW) is a well-described form of ventricular pre-excitation. In 1930, Wolff, Parkinson, and White described the "combination of bundle branch block, abnormally short PR interval, and paroxysms of tachycardia occurring in young, healthy patients with normal hearts."[1] This syndrome involves an accessory conduction pathway, termed the bundle of Kent. The bundle of Kent bypasses the atrioventricular (AV) node, creating a direct electrical connection between the atria and ventricles. The importance of recognizing this syndrome is that WPW patients are prone to develop a variety of tachyarrhythmias which may lead to unpleasant, disabling symptoms and, in the extreme, sudden cardiac death. The vast majority of patients with ventricular pre-excitation remain asymptomatic; in those patients who develop symptoms related to pre-excitation, tachyarrhythmias are responsible. Reentrant tachyarrhythmias (paroxysmal supraventricular tachycardia or PSVT) account for most presentations (70%) followed by atrial fibrillation (25%) and less frequently by atrial flutter (< 5%); fortunately, ventricular fibrillation is a highly unusual complication of the previously diagnosed and properly managed patient. *(See Figure 1.)* The physiology of ventricular pre-excitation and related findings on the non-arrhythmic ECG were discussed in Part I of this article (*Emerg Med Alert* 2003;9:68-70).

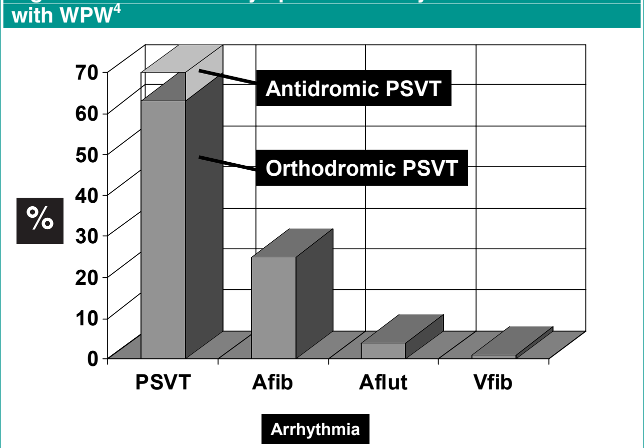
The most frequently encountered arrhythmia seen in WPW is PSVT, also referred to as AV reciprocating tachycardia. In this instance, activation of the ventricle occurs through either the normal conduction system or the accessory pathway with return of the impulse to the atrium by the other pathway. The particular path chosen by the individual arrhythmia determines not only the nomenclature used to describe the rhythm disturbance but also the electrocardiographic findings and level of clinical concern. Regarding terminology, such PSVT is referred to as either orthodromic (antegrade conduction via the AV node) or antidromic (retrograde conduction via the AV node).

The orthodromic AV reciprocating tachycardia is a re-entrant tachycardia in which the atrial stimulus is conducted to the ventricles through the AV node with a return of the impulse to the atria through the AP. *(See Figure 2A.)* Such tachycardia represents approximately 90% of PSVT cases seen in the WPW patient. The electrocardiographic characteristics of this tachycardia include a regular, narrow QRS complex without a delta wave, in that the ventricles are being activated through the normal conduction pathway. *(See Figure 2A.)* In a relative sense, the AV node is able to control the ventricular rate, which ranges from 160-220 bpm in the adult and 160-260 bpm in the child.

In approximately 10% of PSVT patients with WPW, an antidromic (retrograde) reciprocating tachycardia is observed. In this instance, the re-entrant circuit conducts in the opposite direction, with anterograde conduction down the AP and retrograde return of the impulse to the atria via the AV node. *(See Figure 2B.)* With this pathway, the QRS complexes appear wide (a pronounced delta wave). The ECG demonstrates a very rapid, regular, wide-complex tachycardia; this arrhythmia is nearly indistinguishable from ventricular tachycardia. *(See Figure 2B.)*

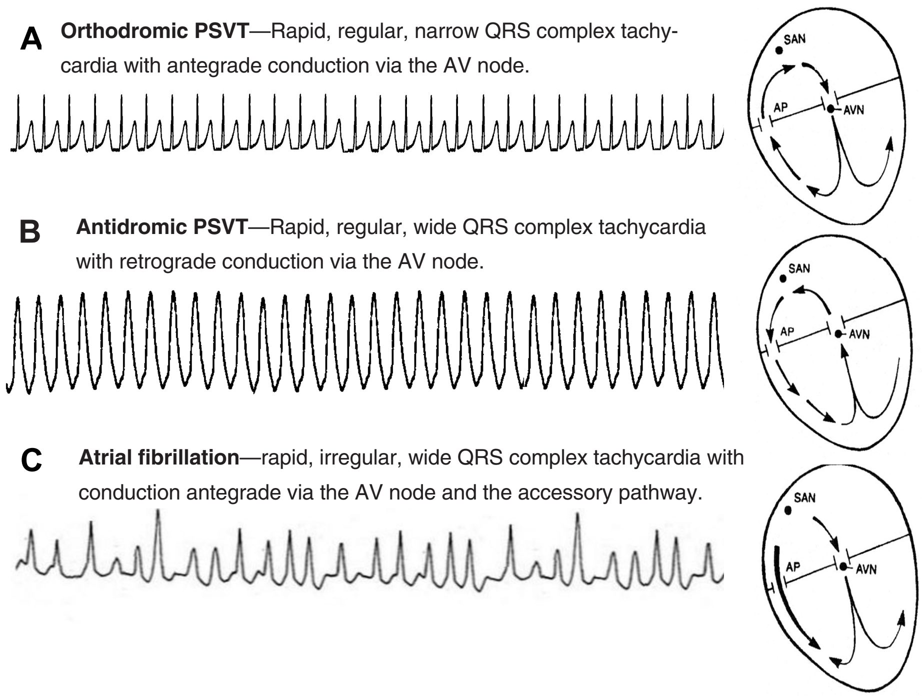
Atrial fibrillation occurs in up to 20% of patients with symptomatic arrhythmia and WPW.[2] In patients with normal conducting systems, the AV node acts to slow conduction and prevents the transmission of the rapid atrial beats to the ventricles—essentially, the AV node "protects" the ventricles from excessive rates. Accessory

Figure 1. Incidence of Symptomatic Arrhythmia in Patients with WPW[4]



pathways, however, lack the feature of slow, decremental conduction—thus the pathway can conduct atrial beats at a rate that can approach or exceed 300 bpm, subjecting the ventricle to very rapid rates. *(See Figure 2C.)* With ventricular responses at or above 300 beats per minute, the risk of ventricular fibrillation is greatly increased—due not only to the poor coronary and systemic perfusion which results from such excessive ventricular rates but also to the arrival of a subsequent depolarization while the heart is repolarizing from the previous cycle—in essence, the R-on-T phenomenon.[3] The features suggestive of atrial fibrillation with preexcitation are the irregularity of the rhythm, the rapid ventricular response (much too rapid for conduction down the AV node) and the wide, bizarre QRS complex, signifying conduction down the aberrant pathway. Ventricular fibrillation in the setting of pre-excitation presents in similar fashion to the non-WPW scenario.

Figures 2 A-C. Arrhythmias in Patients with WPW



A **Orthodromic PSVT**—Rapid, regular, narrow QRS complex tachycardia with antegrade conduction via the AV node.

B **Antidromic PSVT**—Rapid, regular, wide QRS complex tachycardia with retrograde conduction via the AV node.

C **Atrial fibrillation**—rapid, irregular, wide QRS complex tachycardia with conduction antegrade via the AV node and the accessory pathway.

When the patient presents with arrhythmia, the diagnosis of WPW may not be known nor apparent due to the arrhythmia. The rhythm scenarios and/or features should suggest, not confirm, the diagnosis of WPW:

• Rapid, regular, narrow QRS complex tachycardia with ventricular rate greater than 220 bpm for adults, greater than 240-260 bpm for children;

• Rapid, irregular, widened QRS complex tachycardia with ventricular rate greater than 180 bpm, beat-to-beat variation in QRS complex morphologies, and/or bizarre QRS complex morphologies; and

• In the setting of any tachyarrhythmia, excessively high ventricular rates and/or widened QRS complex. ❖

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23. West Nile meningoencephalitis is best recognized by the combination of:

a. fever, confusion, weakness, and lymphocytes and protein in CSF.
b. fever, diplopia, seizures, and abnormal EEG.
c. fever, chills, arthralgias, and normal CSF.
d. fever, headache, hyperreflexia, and hypodensities on CT scanning.

24. Given the results of the prospective outcome study for patients with suspected PE, which of the following statements is false?
   a. It is reasonable to withhold anticoagulation from outpatients with a low pretest probability of PE and a negative spiral CT.
   b. It is reasonable to withhold anticoagulation from outpatients with an intermediate pretest probability, a negative spiral CT, and negative bilateral US of the legs
   c. Patients with a high pretest probability of PE, a negative spiral CT, and negative bilateral US of the legs, require further evaluation with VQ scanning, angiography or both.
   d. Patients with inconclusive results on spiral CT, US, or both require further evaluation with VQ scanning, angiography or both.

25. In the WPW patient with palpitations who presents to the ED, the presence of a rapid, regular, wide QRS tachycardia most likely suggests that conduction is occurring as such:
   a. Antegrade via the AV node and retrograde via the accessory pathway.
   b. Antegrade via the AV node and antegrade via the accessory pathway.
   c. Retrograde via the accessory pathway and antegrade via the AV node.
   d. Retrograde via the AV node and antegrade via the accessory pathway.

26. Which rhythm disturbance is rarely seen with WPW?
   a. Paroxysmal supraventricular tachycardia
   b. Normal sinus rhythm
   c. Atrial fibrillation
   d. Ventricular fibrillation

27. In patients with cocaine-associated chest pain and coronary artery disease by cardiac catheterization, most had
   a. single vessel disease.
   b. double vessel disease.
   c. triple vessel disease.
   d. left main coronary artery disease.

Answer key:

23. a	25. d	27. a
24. a	26. d	

CME Instructions

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- 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.

ECG Review

An Athletic ECG

By Ken Grauer, MD

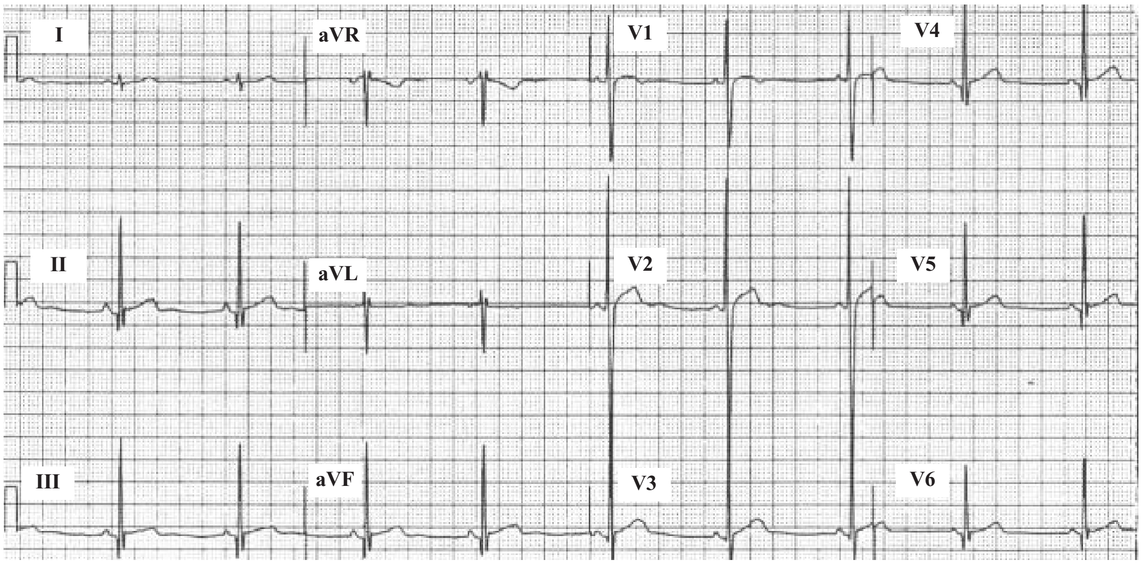

Figure: 12-lead ECG obtained from a 21-year-old athlete.

Clinical Scenario: The 12-lead ECG shown in the Figure was obtained from a 21-year-old, endurance-sport, male athlete. What important cardiac abnormality might be present? What else might this ECG be reflective of?

Interpretation: The ECG in the Figure is not a normal tracing. There is sinus bradycardia and arrhythmia, normal intervals (PR, QRS, and QT), and a vertical—though still normal—mean QRS axis of approximately +90°. The findings of concern are several: 1) moderately deep (though narrow) Q waves in multiple leads (II, III, aVF, V_3-V_6); 2) markedly increased QRS amplitude (deep S waves in leads V_1-V_2, and early transition with tall R waves in leads V_2-V_4); and 3) the suggestion of prominent septal forces (tall R wave = S in lead V_1, early transition, and the inferolateral Q waves just noted). In addition, there are some ST-T wave changes consistent with an early repolarization pattern (slight J point ST segment elevation in the inferolateral leads, and ST segment coving in leads V_1-V_4).

ECG abnormalities commonly are seen in otherwise healthy young adults. This especially is true in athletes. A recent study by Pelliccia and colleagues is particularly insightful with regard to the clinical relevance of ECG abnormalities in young adult athletes (Pelliccia A, et al. *Circulation* 2000;102:278-284). Among a series of more than 1000 consecutive young Italian men and women participating in 38 different sporting activities, 60% had a normal or near normal tracing (early repolarization, 1° AV block and incomplete right bundle-branch block were all considered near normal and acceptable normal variants in these otherwise healthy young adult athletes). Forty percent of the overall group had at least mild-to-moderate ECG abnormalities, of which approximately one-third had distinctly abnormal tracings. Marked abnormalities were significantly more common in male athletes, athletes younger than 20 years of age, and in those participating in endurance sports (rowing, cycling, cross-country skiing, or long-distance running). Surprisingly, despite even striking ECG abnormalities, structural abnormality (beyond modest physiologic increase in selected cardiac dimensions on echocardiography) was uncommon. The "good" news derived from this study is that the ECG finding of a normal ECG in a young competitive athlete is highly predictive of a normal heart. The problematic result is that as many as 15% of young adult athletes may have a markedly abnormal ECG, such as the one shown in the Figure. While echocardiography is appropriate (to rule out hypertrophic cardiomyopathy) in individuals such as the 21-year-old athlete in this case, the overwhelming majority of young competitive athletes with distinctly "abnormal" ECGs will end up having a structurally normal heart. ❖

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Current Strategies for Airway Management in the Trauma Patient

Part II: Managing Difficult and Failed Airways

Authors: **Colin G. Kaide, MD, FACEP, FAAEM,** Assistant Professor of Emergency Medicine, Department of Emergency Medicine, The Ohio State University, Columbus; **Jason C. Hollingsworth, MD,** Emergency Medical Staff Physician, Community Hospital of Indianapolis, Indianapolis, IN.

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.

This article, the second of two parts, deals with the potentially disastrous situation in which either the patient's airway presents a substantial challenge or standard intubation methods have failed. There are few more anxiety-provoking events in a practitioner's clinical practice. The article begins with some algorithms to guide a general approach to difficult airways, followed by a discussion of airway adjuncts and alternatives. The practitioner reading this article is strongly encouraged to read the Manual of Emergency Airway Management *by Walls, et al., for an excellent and complete discussion of all aspects of airway management.*[1]

— The Editor

Introduction

In general, 1-3% of patients will be difficult to intubate with direct laryngeal visualization. Further, anesthesia literature shows a 0.1-0.4% incidence of intubation failure in patients who were judged apriori as likely to be intubated successfully. Because emergency department (ED) patients generally are sicker and undergo much more cursory and rapid preintubation evaluations, unexpected difficulties are more likely to be encountered. With this understood, the incidence of rescue cricothyrotomy is only 1%, according to early data from the National Emergency Airway Registry.[2]

Orotracheal intubation employing rapid sequence intubation (RSI) (and in-line cervical stabilization as indicated) is central to airway management. It is the default method of airway control in the trauma and non-trauma patient when both intubation and the use of the bag-valve mask (BVM) are predicted to be successful.

Because the skill set and knowledge base of the individual physician is the best predictor of intubation success, all physicians who are entrusted with the responsibility of airway management should be adequately trained in the assessment and care of the potentially difficult airway. In addition, training in the use of alternative intubation techniques and devices should be mandatory. The importance of developing a "Plan B" for dealing with the difficult or failed airway cannot be underestimated.

Predicting the Difficult Airway

Central to this discussion of the difficult airway are the answers to the following three questions:

• Can this patient be ventilated with a BVM?;

• Will attempts at intubation likely be successful?; and

• Can a cricothyrotomy be performed on this patient if it becomes necessary?

The answers to these questions are based on examination of the airway and neck anatomy as described below. Difficulties with any of these three components can lead to problems in managing the airway.

Predictors of Difficulty with Mask Ventilation. A recent study identified five variables that independently predicted difficult mask ventilation:[3]

- Presence of a beard;
- Body mass index greater than 26 kg/m^2;
- History of regular snoring;
- Edentulousness; and
- Age older than 55.

The presence of any two of these attributes was 72% sensitive and 73% specific for difficult mask ventilation.

Predictors of Difficult Intubation. A thorough evaluation of the patient prior to attempts at laryngoscopy can help to predict a difficult intubation. Walls et al use the "LEMON Law" as a tool to remember what to check to identify a difficult airway during an evaluation.[1] *(See Table 1.)*

Mallampati Classification. The Mallampati classification was developed to correlate a simple visual inspection of the patient's pharynx with the ability to obtain direct visualization of the larynx. Airways are designated as Class I, II, III, or IV. *(See Figure 1.)* Mallampati classes roughly correlate with the Cormack and Lehane direct laryngoscopic views, graded as 1, 2, 3, and 4.[4,5] Predicted difficulty in obtaining visualization of the cords increases from easy to very difficult as the Mallampati class rises.

Approach to the Difficult Airway

Orotracheal intubation employing RSI is central to airway management. It is the default method of airway control in the trauma and non-trauma patient when both intubation and the use of the BVM are predicted to be successful. When intubation is predicted to be difficult, the use of RSI should not be reflexive, but rather undertaken only when an adequate back-up plan is readily available.

The following approach to the difficult airway assumes that the patient is awake and has been examined, so that the potential difficulty of intubation and mask ventilation may be judged.

BVM Prediction: Difficult. In any circumstance in which a patient appears to be difficult to oxygenate with a mask, the decision to use paralytic agents must be considered carefully. If RSI is to be used, the ability to provide a surgical airway must be assured.

After unsuccessful intubation, any patient whose O_2 saturation can't be maintained over 90% with the use of a BVM will need a surgical airway.

Intubation Prediction—Easy; BVM Prediction—Easy. In this circumstance, the initial approach to intubation should be with RSI, utilizing inline stabilization of the cervical spine as indicated by the patient's injury patterns.

Intubation Prediction—Difficult; BVM Prediction—Easy. This situation potentially can become the "can't intubate, can oxygenate" scenario. As long as the patient can be adequately oxygenated and ventilated by the BVM and, despite a difficult airway, successful intubation is predicted, an attempt at RSI still is indicated. It is prudent, however, to have a back-up plan readily available.

Intubation Prediction—Difficult; BVM Prediction—Difficult. This represents the potentially disastrous situation of "can't intubate, can't oxygenate." Under these circumstances, other options that do not utilize paralytic agents are indicated. These include awake oral intubation and nasotracheal intubation. If the cords can be visualized during the course of an awake intubation attempt using topical anesthetics, it is reasonable either to proceed with the intubation if possible or to revert to the use of RSI.

The Failed Airway

There are many definitions of a failed airway. The one that is favored in the National Airway Course occurs when either of two scenarios develops:[6]

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Table 1. The LEMON Law

L: LOOK EXTERNALLY

- Short, muscular neck
- Protruding upper incisors
- Receding mandible
- Full dentition
- High-arched palate
- Severe facial trauma

E: EVALUATE THE 3-3-2 RULE

Describes the ideal external dimensions of the airway:

3 — The opening of the jaw should be large enough to accommodate three fingers (3-4 cm).

3 — The distance from the mentum to the hyoid bone should be at least three fingerbreadths.

2 — The distance from the floor of the mouth to the thyroid cartilage should be at least two fingerbreadths.

M: MALLAMPATI CLASSIFICATION *(SEE FIGURE 1)*

O: OBSTRUCTION

- Blood in the upper airway
- Expanding hematoma
- Swelling of intraoral structures
- Foreign body
- Abscess
- Laryngeal edema

N: NECK MOBILITY

- Inability to flex or extend the neck (due to cervical collar, arthritis, etc.)
- Cervical spine injury

Table 2. RSI in the Head-Injured Patient

- Pre-oxygenate with 100% oxygen and hyperventilate
- Lidocaine 1.5 mg/kg
- Esmolol (2 mg/kg) or fentanyl (3 mcg/kg)
- Cricoid pressure
- Etomidate (0.3 mg/kg) or thiopental (3-5 mg)
- Succinylcholine (1.0-1.5 mg/kg)
- Laryngoscopy and orotracheal intubation

1) Orotracheal intubation with direct laryngoscopy is unsuccessful after three attempts by an experienced physician. This is the "can't intubate, can oxygenate" scenario.

2) A single failed attempt at orotracheal intubation with the inability to maintain $SpO_2 > 90\%$ using a BVM. This is the "can't intubate, can't oxygenate" scenario.

If the "can't intubate, can't oxygenate" scenario arises, a surgical airway is clearly indicated. If other devices such as an intubating laryngeal mask airway (ILMA) or a Combitube are available, they can be used as temporizing measures in preparation for a more definitive airway. Since these adjuncts do not place a cuffed endotracheal tube (ETT) into the trachea, they do not substitute for definitive management.

Airway Management in the Trauma Patient

There are a few aspects of airway management that are unique to the trauma patient and require special preparations and precautions.

Closed Head Injury. In the closed head injured (CHI) patient, changes in hemodynamics, oxygenation, and ventilation should be minimized in an attempt to maintain adequate cerebral perfusion pressure. Historically, blind nasotracheal intubation was the method of choice for securing the airway in the head-injured patient. In more recent studies, however, orotracheal intubation has been shown to be more rapid and associated with fewer complications.[7] Since laryngoscopy causes a marked increase in intracranial pressure (ICP), several measures must be taken in an effort to blunt this response. Modifications in the standard RSI protocol should be performed as follows. *(See Table 2.)*

The patient should be hyperventilated in an effort to decrease ICP with a goal $PaCO_2$ of 30-35 mmHg. Administer lidocaine (1.5 mg/kg) 3-5 minutes prior to intubation, as it has been suggested that this can blunt the increase in ICP secondary to laryngeal stimulation.[8,9] Beta-blockers (e.g., esmolol) and opiates (e.g., fentanyl) may be given 2-3 minutes prior to intubation to attenuate the sympathetic response in the normotensive patient.[10] Etomidate or thiopental are effective induction agents that have not been shown to increase ICP.

Maxillofacial Trauma. Facial trauma can distort normal anatomy significantly. Injuries can range in severity from soot in the airway from a house fire to a gunshot wound entering in the submental area and exiting through the upper cranium. Any such scenario mandates special attention to the type and extent of injury and the current state of respiratory compromise.

In cases in which airway obstruction is either present or imminent, immediate, decisive action is required. Alternatively, some patients may present with some minor respiratory difficulty, but pose a significant risk for rapid deterioration (e.g., severe oral burns, gunshot wounds near the carotid, and intraoral lacerations with hemorrhage). In these patients, a few moments should be taken to plan a strategy to intervene effectively and safely without causing more harm in the process. Expectant management or waiting too long to decide may force the physician to perform a crash cricothyrotomy or an emergent tracheostomy. The latter procedure often is not in the ready repertoire of most emergency physicians.

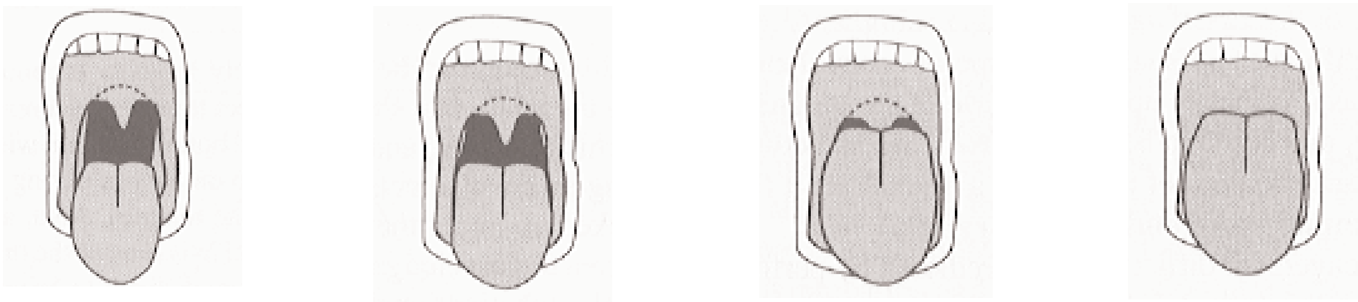
One of the most feared scenarios in airway management is the patient with maxillofacial trauma and an unsecured airway. As in the management of all difficult airways, proper preparation significantly will increase the chances of successfully securing the airway. The patient should be prepped immediately for a surgical airway in the event of a failed intubation.

There is an associated cervical spine (c-spine) injury in up to 5% of patients with maxillofacial trauma and neurologic injury in up to 36%.[11,12] The risk of c-spine injury in patients with maxillofacial trauma, however, is not any higher than the risk associated with other blunt trauma patients with a significant mechanism of injury.[13]

Of the three major types of facial fractures described by Le Fort, the Le Fort III fracture frequently involves airway compromise secondary to soft tissue obstruction. *(See Figure 2.)*

If there is no concern for c-spine injury, the patient may be

Figure 1. Mallampati Classification



MALLAMPATI CLASS I	MALLAMPATI CLASS II	MALLAMPATI CLASS III	MALLAMPATI CLASS IV
• No difficulty • Soft palate, uvula, fauces, pillars visible	• No difficulty • Soft palate, uvula, fauces visible	• Moderate difficulty • Soft palate, base of uvula visible	• Major difficulty • Hard palate only visible

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placed in an upright or lateral position to allow blood and secretions to drain.[14] In preparing the patient for intubation, it is imperative to check the oropharyngeal anatomy. The patient's mouth should be opened to assure adequate jaw mobility. This is particularly important in the setting of mandibular fractures due to the high incidence of temporomandibular joint dysfunction. Never attempt nasotracheal intubation in the setting of maxillofacial trauma. RSI is the initial method of choice if the patient passes the LEMON law. If RSI is not possible or is contraindicated, then a surgical airway is indicated.

Direct Airway Trauma. When discussing airway management in the setting of airway trauma, there are two subcategories—direct and penetrating trauma—that require quite different considerations and approaches.

Patients with penetrating trauma usually have more clinical clues to airway involvement than patients with blunt trauma. Important signs or symptoms of airway involvement include dyspnea, cyanosis, subcutaneous emphysema, hoarseness, and air bubbling through the wound site. Penetrating trauma to the neck carries with it a high degree of morbidity and mortality. The overall mortality is as high as 11%,[15] with up to 40% requiring emergent intubation.[10,16] Tracheobronchial injury occurs in approximately 10-20% of patients with penetrating trauma to the neck.[17-20]

There are three anatomic zones of the neck. *(See Figure 3.)* Zone I is located between the clavicles and cricoid cartilage. This area is injured least frequently, but is the most likely to require emergent airway management due to the close proximity to major pulmonary and vascular structures.[10] Zone II is located between the cricoid cartilage and the angle of the mandible. This is the most common area of injury but carries the lowest mortality. Finally, Zone III is located between the angle of the mandible and the base of the skull. This zone is the one most commonly associated with vascular and pharyngeal injuries, but is least likely to require emergent airway management.[10]

There are several important indications for intubation in the setting of penetrating trauma to the neck. They include acute respiratory distress, airway compromise from blood or secretions, extensive subcutaneous emphysema, tracheal shift, and altered mental status.[21] Any gunshot wound to the anterior neck also is an indication for early intubation to prevent obstruction from an expanding hematoma.[22] Finally, a stab wound to the anterior neck is an indication for early intubation only if there is evidence of vascular or direct airway trauma.[23] Although the risk of c-spine injury in the setting of penetrating trauma is less than with blunt trauma, full c-spine immobilization still is recommended.[13]

Orotracheal intubation with RSI is the technique of choice in securing the airway in the patient with penetrating trauma to the neck.[22] Occasionally, administration of paralytics may turn a non-obstructed airway into an obstructed one due to relaxation of an injured airway segment. For this reason, it may be reasonable to do an "awake look" under sedation and topical anesthesia or an awake intubation. Ketamine has been suggested as a good induction agent to use in this setting without an associated paralytic.[24]

In the setting of severely distorted anatomy or excessive secretions, fiberoptic bronchoscopic intubation may be helpful to assess the degree of tissue injury.[17] Occasionally, the entrance wound provides a direct communication between the anterior neck and the trachea. In this case, it may be easier to intubate directly through the wound. Keep in mind, however, that this is only a temporizing measure and ultimately must be converted to a more secure airway. If a surgical airway is required in the presence of an anterior neck hematoma, a tracheostomy should be performed rather than a cricothyroidotomy.

Blunt trauma to the neck frequently is more complicated. Unlike penetrating trauma, blunt trauma carries with it a very high incidence of associated c-spine injuries. Specifically, up to 50% of blunt airway trauma patients have concurrent c-spine injuries.[25] Therefore, strict c-spine immobilization precautions need to be maintained while securing the airway. There also is a high incidence of esophageal injuries in patients with laryngotracheal fractures. For this reason, bronchoscopy and

Figure 2. Le Fort Fractures

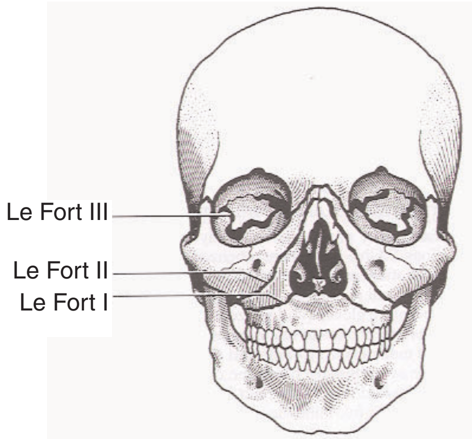

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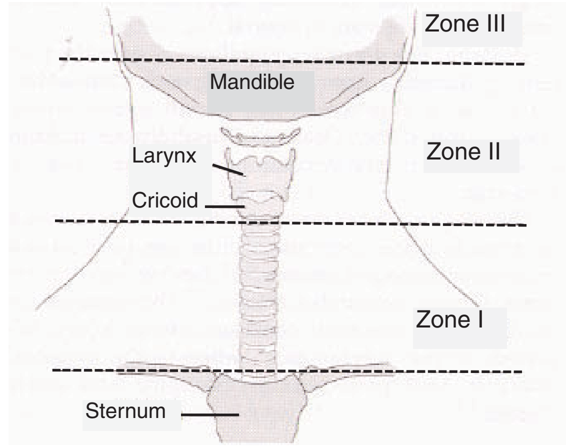
Figure 3. Zones of the Neck



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esophagoscopy are recommended in any patient with a high clinical suspicion for laryngotracheal injury.[14]

In terms of securing the airway, there are essentially three initial methods of choice—RSI, awake intubation, and awake fiberoptic intubation. The exception occurs in a laryngeal fracture, in which emergent tracheostomy is the best first maneuver. The American Society of Anesthesiology recommends awake intubation in all patients with possible airway anatomy disruption.[25] The concern is that the passage of the ETT may dislodge the severed ends of the larynx, turning a non-obstructed airway into an obstructed one.[10,14]

Cervical Spine Injury. All trauma patients who come in on a backboard in c-spine precautions should be assumed to have a c-spine injury until proven otherwise. Because airway comes before c-spine, airway management will be performed in the setting of a presumed c-spine injury, so appropriate precautions need to be taken when securing the airway. Keep in mind that 3-6% of initial survivors from major trauma have clinically significant c-spine injuries.[26]

In uncomplicated trauma, a c-spine may be clinically "cleared" and considered to have low probability of injury if the following five criteria are met: The absence of midline c-spine tenderness; normal alertness; and the absence of intoxication, painful distracting injury, and focal neurologic deficit.[27] Patients able to meet these criteria would seem unlikely to require airway support. Multitrauma scenarios in which airway management becomes mandatory often are significantly more complex, and by definition cannot employ the above criteria.

In gunshot wounds to the head (not involving the neck), the distinct absence of concomitant cervical trauma has been documented in multiple reports.[28-30] In this scenario, in the absence of other coexisting cervical injury (i.e., falls from significant height, etc.), the c-spine may be considered as low priority.

Historically, attempts to preserve the integrity of the cervical cord led to use of nasotracheal intubation (NTI) as the preferred route of airway access. It was felt that laryngoscopy with oral endotracheal intubation caused too much movement of the c-spine. More recent literature, however, indicates that oral intubation with manual in-line axial head and neck stabilization (MIAS) is as safe or safer than NTI in this setting.[31-34]

The two initial methods of choice for securing the airway are oral intubation with RSI or awake fiberoptic intubation. When performing RSI, the anterior portion of the collar should be removed to allow for MIAS and cricoid pressure.[31] MIAS has been shown to immobilize the c-spine better in the setting of endotracheal intubation than the cervical collar alone.[35] The Bullard laryngoscope, a fiberoptic rigid laryngoscope, has been advocated by many to be the intubating method of choice in trauma patients with potential c-spine injuries, since the Bullard does not require alignment of the oral, pharyngeal, and tracheal axes to view the larynx.[36-38] The specifics of the Bullard will be discussed below.

Thoracic Trauma. Thoracic trauma may present difficulties when it causes a distortion of the trachea from its normal midline position. This can occur with a tension pneumothorax or with a large intrathoracic hematoma. Occasionally, a large pneumothorax can cause significant subcutaneous emphysema tracking into the neck, which can interfere with the ability to identify the trachea and/or cricothyroid membrane.

Pneumothorax, hemothorax, or significant trauma to the lung (pulmonary contusion) can inhibit the practitioner's ability to adequately preoxygenate the patient prior to the intubation. If the patient's airway can wait, it may be very reasonable to reverse a collapsed lung or evacuate a hemothorax first so as to maximize the preoxygenation phase of the intubation.

Burns. The key principle in the treatment of burn patients with airway involvement is aggressive airway management. Because upper airway edema is progressive during the 24-36 hours following the burn, it is advisable to secure an airway sooner rather than later. Some strong indications for intubation include: stridor or hoarseness; known inhalation of toxic fumes; carbonaceous material in the oropharynx or nares; or increased work of breathing.

Table 3. Awake Intubation

IV SEDATION SUGGESTIONS
• Midazolam: Use doses sufficient to induce some relaxation and amnesia.
• Fentanyl: Titrate with midazolam to reduce awareness and discomfort.
• Ketamine: Administer as for conscious sedation (0.5-2 mg/kg titrated to effect).
TOPICAL ANESTHESIA
• Lidocaine nebulized (4 cc of 4% lidocaine nebulized)
• Cetacaine spray
• Lidocaine spray

Smoke inhalation in burn patients accounts for nearly half of all deaths related to fire.[39] Further, the possibility of carbon monoxide poisoning should be given consideration. Since a pulse oximeter is unable to differentiate between oxyhemoglobin and carboxyhemoglobin, a blood gas sample needs to be analyzed for carboxyhemoglobin.

Standard oral endotracheal intubation with RSI is the initial method of choice to secure the airway when no obvious obstruction is visualized. If in doubt, "an awake look" should be performed under sedation and topical anesthetics. If no problems are seen, one can proceed with RSI. Because of the incidence of upper airway edema, however, there should be low threshold for proceeding to fiberoptic intubation or cricothyrotomy.

Alternative Intubation Techniques and Airway Adjuncts

As previously discussed, the primary intubation technique in the trauma patient is oral endotracheal with RSI. In some circumstances, however, this is either not possible or contraindicated (e.g., closed tracheal disruption, known allergy to RSI medications, or predicted difficult intubation). It also is important to have back-up methods of securing the airway. There are many alternative intubation techniques and airway adjuncts. Only those that have been shown to be safe and effective in trauma patients will be discussed.

Awake Intubation. An awake intubation is performed on patients who potentially may be difficult to intubate. Unlike the serial sedation of the past (used to "soften the patient up"), this procedure utilizes sedation in combination with topical anesthetics to facilitate laryngoscopy while intentionally maintaining the patient's airway reflexes and spontaneous respiration. Topical anesthetics can be administered by nebulization or by direct application to the pharynx. *(See Table 3.)*

This technique can be implemented to obtain a close look at the glottis to assure the ability to visualize the cords (an "awake look"). When the cords are visualized, an attempt to pass the tube can be made or the blade can be withdrawn and formal RSI then can be used.

A few minutes before the intubation, nebulized lidocaine may be delivered to the patient to provide pharyngeal/laryngeal anesthesia. This can be supplemented further by cetacaine or topical lidocaine sprayed directly into the posterior pharynx. The patient then can receive the sedative of choice titrated to effect, much like in a conscious-sedation procedure.

Nasotracheal Intubation. NTI was once the technique of choice in establishing an airway in a trauma patient. Today, however, it rarely is indicated in the acute management of trauma patients secondary to the increased time requirement, lower success rate, and increased risk of severe bleeding when compared to oral endotracheal intubation.[40] In fact, it is indicated only if clear contraindication exists to RSI and other airway modalities are not available. Absolute contraindications include coagulopathy, mid-face fractures, or basilar skull fractures.[41]

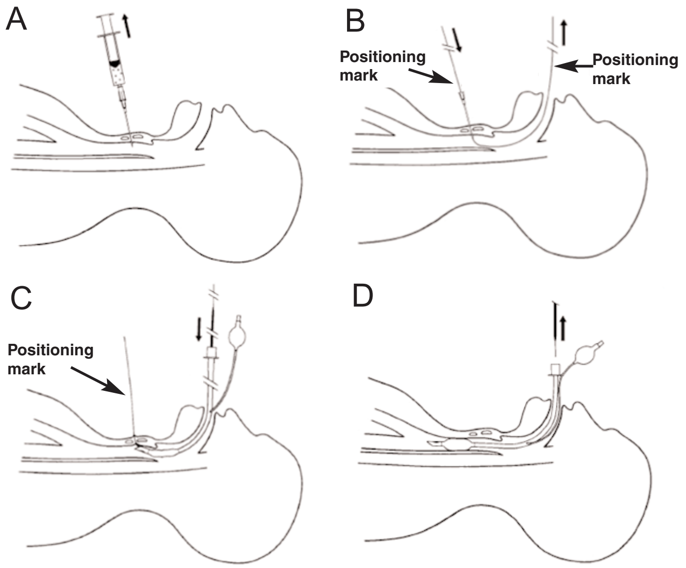
Retrograde Intubation. This is an excellent technique to utilize in the setting of maxillofacial trauma, particularly with significant upper airway bleeding or limited jaw opening, as well as with unstable c-spine injuries. It has a unique niche in the management of the trauma airway and has been demonstrated to be a safe and rapid technique in trauma patients.[42] The only true contraindication is an apneic patient who cannot be adequately oxygenated or ventilated.

The cricothyroid membrane first is identified and the inferior aspect of the membrane is punctured with a needle-directed cephalad. When air is aspirated, a guidewire is inserted and advanced retrograde until the proximal end is controlled through the mouth. The needle is removed, leaving only the guidewire in place. A plastic sheath is passed antegrade over the wire until resistance is met at the anterior laryngeal wall. The ETT then is passed antegrade over the sheath through the vocal cords and up against the cricothyroid membrane. The wire and sheath are removed simultaneously through the mouth.

The Cook retrograde intubation set, which contains a sheath, is the set-up of choice; however, an 18-gauge needle, an 80-cm J-tipped guidewire, and hemostats can be used. Triple-lumen central line placement kits contain the needles, syringes, and guidewire needed to perform the procedure. Swan-Ganz sheath introducer kits, however, contain a guidewire that often is too short. *(See Figure 4 A-D.)*

Lighted Stylet. This technique involves the blind placement of an ETT containing a battery-operated, lighted stylet that transilluminates the anterior soft tissues of the neck. The technique takes advantage of the anterior location of the trachea in relation to the esophagus. The ETT is bent at a 90° angle just proximal to the cuff, so that it resembles a hockey stick. The lightwand is turned on and the ETT lightwand unit (ETT-LW) is advanced blindly into the posterior oropharynx. The device is rocked back and forth in the midline in an imaginary arc. When the ETT-LW has entered the glottic opening, a well-circumscribed glow can be seen in the anterior neck, slightly below the laryngeal prominence.[43] A faint glow above the laryngeal prominence indicates that the tip is in the vallecula; a dim light located on the side of the neck indicates that the tip is in the piriform sinus, and a very dim light in the anterior neck indicates that the tip is in the esophagus. Once tracheal intubation is confirmed as described above, the stylet is retracted approximately 10 cm and the ETT-

Figure 4 A-D. Retrograde Intubation



The cricothyroid membrane is identified and the inferior aspect punctured with the needle directed cephalad. The guidewire is inserted and advanced until controlled in the mouth. The ETT is then placed.

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LW is advanced until the glow begins to disappear at the sternal notch, indicating that the tip of the ETT is approximately 5 cm above the carina.[44] The locking clamp then is released and the lightwand removed while stabilizing the ETT.

Clinical scenarios where the lightwand is useful include patients with difficult airways in whom direct laryngoscopy has failed, and in patients with copious upper airway bleeding or secretions. Patients with anterior neck soft-tissue trauma or morbidly obese patients are relative contraindications due to inadequate transillumination of the anterior neck. Prior to the invention of the trachlight with a brighter light source, its use was limited in the ED by the need to dim overhead lights. Dimming the ambient lights no longer is recommended.

Bullard Laryngoscope. The Bullard laryngoscope is an indirect fiberoptic, rigid laryngoscope. The blade is wider and longer than conventional laryngoscopes and the end of the blade is able to retract the epiglottis. The independently styletted ETT is side-loaded onto the laryngoscope. Because the Bullard utilizes indirect laryngoscopy, the oral, pharyngeal, and tracheal axes do not need to be aligned to visualize the larynx. This translates into less c-spine movement. For this reason, many consider it to be superior to conventional laryngoscopy in patients with potential c-spine injury.[36,45] In a study conducted by Watts et al comparing Bullard and Macintosh laryngoscopes, the degree of c-spine extension was significantly less with the Bullard.[38]

The Bullard laryngoscope is an excellent tool for endotracheal intubation in the c-spine injured patient; however, it is not without its disadvantages. Because the blade is larger than conventional laryngoscopes, manipulation is more cumbersome and this can translate into a longer intubation time.[38]

Endotracheal Tube Introducer. The ETT introducer is a 60 cm, semirigid rod, approximately 5 mm in diameter. It is elastic and flexible, with the distal 2 cm angled upward 36°. This type of device was first described in 1949 and also is known as a gum elastic bougie or an Eschmann tracheal tube introducer.[46,47] A less expensive plastic version called the Flex-Guide ET Tube Introducer (GreenField Medical Sourcing, Inc., Northborough, MA) also is available.[47]

These devices, which have become very popular in Europe for difficult intubations, are designed to enter the trachea blindly and allow an ETT to be guided into position. In studies with patients with simulated c-spine injuries and a Mallampati score of 3 or less, successful first attempt intubations are reported at 96-100%, compared to significantly lower rates with a traditional stylet.[48,49]

While the jaw and tongue are lifted by a laryngoscope, the device is placed blindly into the pharynx with the introducer aligned in the midline and the angled tip pointed upward. The angle of the tip facilitates placement under the epiglottis and through the cords. When tracheal placement is achieved, the tip of the introducer is advanced over the tracheal rings, creating a "washboard" sensation. When it is fully inserted, the tip should impact on the carina and provide resistance to further insertion. When in place, the introducer can be withdrawn until a black mark on the device is aligned with the lip. At this depth (37 cm) the device is in far enough to be located beyond the cords. An ETT then can be placed over the introducer and guided into the trachea, with subsequent removal of the device through the ETT. This device may have significant utility in trauma patients for whom limited neck mobility may be tolerated.

Laryngeal Mask Airway and the Intubating Laryngeal Mask Airway. The laryngeal mask airway (LMA) is an ETT with an attached silicone rubber collar that covers the supraglottic area, thereby enclosing the larynx. The device originally was invented by Brain in the early 1980s and subsequently has undergone several modifications.[50] Today, two forms are in widespread use: the classic LMA and the intubating LMA (ILMA). Both are relatively easy to use and serve as quick rescue devices for patients who can't be intubated by conventional means.

The classic LMA comes in sizes for adolescents, and for small, average-size, and large adults. There also are four weight-based sizes (1-2.5) designed for children. Before inserting the LMA, apply water-soluble lubricant to the sides of the collar. When inserting the LMA, place the tip of the cuff against the patient's hard palate and advance it along the natural curve of the hypopharynx until resistance is met. The collar then is inflated with the size-appropriate amount of air.

In the ILMA there are two important modifications to the classic design, which allow for the placement of an ETT. First, there is a single stiff bar vertically oriented across the mask aperture that lifts the epiglottis away from the path of the ETT. Second, there is a ramp within the barrel-mask junction

Table 4. Predictors of a Difficult Cricothyrotomy

- Lack of operator skill and familiarity with the various techniques for cricothyrotomy
- Anatomical distortion of the anterior neck (e.g., trauma, infection, cancer, etc.) obscuring identification of the cricothyroid membrane
- Coagulopathy or excessive bleeding potential
- A small patient (usually younger than 12 years) in whom the cricothyroid membrane is too small to identify accurately
- Subcutaneous emphysema dissecting into the anterior neck, obscuring the anatomy

designed to direct the ETT into the trachea. The ILMA also is equipped with a steel handle that facilitates its insertion, manipulation, and removal to minimize c-spine movement.[51] Success rates of intubation with the ILMA were comparable to those achieved with a fiberoptic scope in patients with anticipated difficult intubation.[52] The ILMA only comes in adult sizes equivalent to sizes 3, 4, and 5 found in the classic LMA.[53-55]

The ILMA is inserted in the same manner as the classic LMA but with the assistance of the metal handle. Once in place with the collar inflated, the ETT (up to size 8.0) is placed into the metal tube of the ILMA and advanced into the trachea. The ILMA then can be either left in place or withdrawn over the ETT.

The primary advantage of the LMA is that it is quick and easy to use with minimal training. Keep in mind, however, that the LMA is not a substitute for a cuffed ETT. It is only a bridge until the placement of a more definitive airway. The LMA does not prevent aspiration, and it is unable to overcome obstruction at the level of the larynx.

Esophageal-Tracheal Combitube. The Combitube is a dual lumen tube with a cuffed esophageal lumen and a cuffed tracheal lumen. The esophageal lumen is open to the upper airway and is closed at the distal end. The tracheal lumen is open only at the distal end. A large, proximal balloon seals the oropharyngeal airway when inflated. A small, distal balloon seals the esophagus or trachea, depending on the position of the Combitube.

The Combitube is inserted blindly along the posterior oropharynx until the printed rings are aligned with the teeth. The proximal balloon is inflated, followed by the distal balloon. Ventilation should be started through the longer esophageal lumen. This will result in tracheal ventilation 90% of the time. Check tube placement by auscultating over the stomach and both axilla. If no breath sounds are present, the tube is in the trachea and the shorter tracheal tube should be used for ventilation.

Like the LMA, the Combitube is a rescue airway device and does not take the place of a cuffed ETT. It also is very easy to place, but does not protect the airway against aspiration. Its role in trauma patients has been defined as a rescue device in patients who cannot be expeditiously intubated by conventional means.[56]

Flexible Fiberoptic Bronchoscope. Although the fiberoptic bronchoscope provides excellent visualization of the upper airway anatomy during intubation, it rarely is used by emergency physicians in the management of the trauma airway. Bronchoscopy requires a level of skill that most emergency physicians do not attain in their limited experience with this instrument. In most cases, the use of bronchoscopy is reserved for our ear-nose-throat and anesthesiology colleagues. Nonetheless, there are certain well-defined indications for fiberoptic bronchoscopy in airway management. Examples include the awake patient with a known difficult airway, the patient with an unstable cervical spine injury, the patient with upper airway burns, and finally the patient with an expanding neck hematoma.

Because intubation over a fiberoptic bronchoscope requires more time and technical skill than conventional laryngoscopy, it is not recommended in the setting of penetrating neck trauma.[16] An explanation of the procedural details is beyond the scope of this text.

Surgical Airway

With all of the advances in adjunctive airway techniques, cricothyrotomy is performed infrequently. The National Emergency Airway Registry reported a 1% ED cricothyrotomy rate in more than 6000 ED intubations.[57] Due to the infrequent need for surgical airways, physicians may lack the experience and skill needed to practice this technique safely and efficiently.[58,59] For this reason, it is essential for the emergency physician to be familiar with the anatomy of the neck and the steps required to perform the procedure.

There are several indications for cricothyrotomy, the most common of which is the inability to intubate the trachea in a patient who cannot be oxygenated or ventilated. Another signifigant indication includes trauma to the face severe enough to significantly distort airway anatomy.

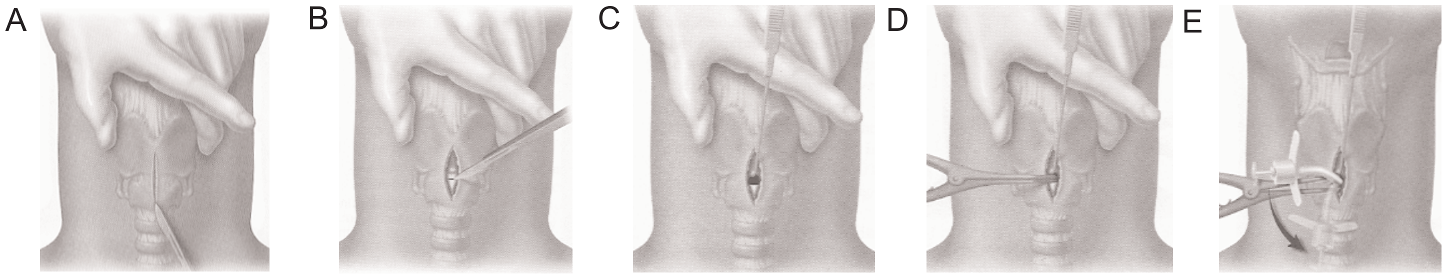
Cricothyrotomy is contraindicated in cases of laryngeal fracture and in the setting of complete laryngotracheal separation, as the skin may be the only tissue holding the proximal trachea in the neck.[60-62] Owing to the small size of the cricothyroid membrane, the procedure also is contraindicated in children younger than 10-12 years of age, in whom needle cricothyrotomy is the preferred technique. *(See Table 4.)*

There are three main techniques that currently are practiced: the standard method; the rapid four-step technique; and the wire-guided technique.

The first step in any cricothrotomy technique is to correctly identify the landmarks. The thyroid cartilage generally is the most prominent structure in the anterior neck (Adam's apple). The cricoid cartilage lies inferior to the thryoid cartilage, separated by the cricothryoid membrane.

After the anatomy is identified, a 3-4 cm vertical skin incision should be made over the cricothyroid space while holding the thyroid cartilage with the non-dominant hand. A tracheal hook is introduced into the cricothyroid space and traction is applied in a cephalad direction. A transverse incision is made in the cricothyroid membrane and the tract is dilated with a dilator or scalpel handle. A Shiley cuffed tracheostomy tube then is inserted in a posterior and caudal direction. The balloon can be inflated and the introducer removed. A 6.0 ETT can be used if a

Figure 5 A-E. Cricothyrotomy Technique



5A. Identify landmarks.

5B. After the anatomy is identified, a 3-4 cm vertical incision is made.

5C. A tracheal hook is introduced and traction is applied in a cephalad direction.

5D. The tract is dilated.

5E. A tube is inserted.

Used with permission from: Walls R, Luten R, Murphy M, et al, eds. *Manual of Emergency Airway Management*. Philadelphia: Lippincott, Williams & Wilkins; 2000:91-96.

Shiley is not available. *(See Figure 5 A-E.)*

Brofeld designed the rapid four-step technique in an effort to simplify the procedure and decrease the time involved.[63] In this technique, the cricothyroid membrane is identified by palpation. A horizontal stab incision then is made through both the skin and cricothyroid membrane with a No. 20 scalpel blade. The larynx is stabilized with a tracheal hook pulling caudal traction on the inferior aspect of the cricoid cartilage.

A Shiley tracheal tube is introduced into the trachea as described above. This technique has been shown to be much faster than the standard method in a cadaver study;[64] however, there are some concerns regarding an increased risk of laryngeal injury.[65] Davis et al showed no increased risk of laryngeal injury when compared to the standard method when using a "Bair claw," as opposed to a tracheal hook, to retract the cricoid membrane.[66]

The wire-guided technique utilizes an approach similar to the Seldinger technique used to obtain central venous access. In this technique, the neck structures are identified and a vertical skin incision is made over the cricothyroid membrane. An 18-gauge needle attached to a syringe is directed inferiorly through the cricothyroid membrane. Aspiration of air confirms placement of the needle in the trachea. The syringe is removed and the guidewire is inserted through the needle. The needle then is removed and the Shiley ETT with dilator is inserted over the wire. Finally, the wire and dilator are removed, leaving the airway in place in the trachea. Although not significantly different in terms of efficiency or rate of complications, it was shown to be preferred over the standard technique.[66]

Conclusion

In this day and age, airway management by the emergency physician has risen to a degree of sophistication well beyond that practiced by any other specialty except anesthesia. It is the responsibility of any physician who practices emergency medicine to obtain and maintain the requisite skills necessary to practice airway management at this level.

At the core of airway management in all patients is a good understanding of when and how to intervene and provide definitive airway control. Although the setting and injury patterns can be dramatic, management of the trauma airway involves the same basic skills required for any other difficult airway. The well-prepared physician should possess sound, basic intubation skills and be intimately familiar with the various induction and paralytic agents. He or she should have a working knowledge of some of the common airway adjuncts and the requisite skills to create a surgical airway. Finally, the physician should be aware of, and have a plan to deal with, the potential pitfalls and disasters that can occur while taking control of a patient's vital functions.

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CME Objectives

Upon completing this program, the participants will be able to:
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2.) understand specific airway techniques that may be used in patients with a difficult airway; and
3.) comprehend the advantages and disadvantages of the surgical airway.

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1. Which of the following variables independently predicts difficult mask ventilation?
   A. Presence of a beard
   B. Body-mass index greater than 26kg/m^2
   C. History of regular snoring
   D. Edentulousness
   E. All of the above

2. A patient's airway is assessed and the prediction is easy intubation and easy bag-valve-mask ventilation. What should be the initial approach to the airway?
   A. Cricothyrotomy
   B. Intubation with RSI
   C. Tracheostomy
   D. Definitive airway mangement with LMA
   E. Awake oral intubation

3. Which of the following Mallampati classifications would be predicted to be the most difficult intubation?
   A. Class I
   B. Class II
   C. Class III
   D. Class IV

4. Which anatomic zone of the neck is the area between the clavicles and the cricoid cartilage?
   A. Zone I

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B. Zone II
C. Zone III
D. Zone IV
E. Zone V

5. Which of the following factors decrease an individual's probability of having a cervical spine injury?
   A. Absence of midline cervical spine tenderness
   B. Normal alertness
   C. Absence of intoxication
   D. No painful distracting injuries
   E. All of the above

6. A 27-year-old presents with a closed head injury. Which of the following agents should *not* be part of an RSI for this patient?
   A. Atropine
   B. Lidocaine
   C. Etomidate
   D. Succinylcholine
   E. Esmolol

7. Which of the following may be signs of airway involvement in a patient with penetrating trauma to the neck?
   A. Dyspnea
   B. Cyanosis
   C. Subcutaneous emphysema
   D. Hoarseness
   E. All of the above

8. Which of the following injuries carries the highest risk of associated cervical spine injuries?
   A. Blunt trauma to the neck
   B. Penetrating neck trauma
   C. Gunshot wound to the head
   D. Gunshot wound to the orbit
   E. Knife wound to the neck

9. Which of the following is true regarding the Bullard laryngoscope?
   A. It is a flexible laryngoscope.
   B. The blade is shorter and narrower than the conventional laryngoscope.
   C. Use results in less c-spine movement than conventional laryngoscopy.
   D. Manipulation of the blade is easier than traditional larygoscopes.
   E. The oral, pharyngeal, and tracheal axes need to be aligned to visualize the larynx.

10. Which of the following is *not* true regarding the LMA?
   A. It is relatively easy to use.
   B. It may serve as a rescue device in a patient that cannot be intubated by conventional means.
   C. The LMA is a definitive airway.
   D. The LMA does not prevent aspiration.
   E. The LMA does not overcome obstruction at the level of the larynx

Answer Key:

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

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yes ☐ no ☐ 3. Are you able to comprehend the advantages and disadvantages of the surgical airway?

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