PRACTICAL SUMMARIES IN

ACUTE CARE

A Focused Topical Review of the Literature for the Acute Care Practitioner

Tackling The MRSA Epidemic: How Should You Change Your Practice?

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Introduction

Community-acquired methicillin-resistant *Staphylococcus aureus* (caMRSA) is a microbe that has become increasingly prevalent and clinically significant to acute care practitioners worldwide. The genetic mechanism that confers methicillin resistance is associated with virulence factors that affect the clinical presentation and treatment of infections caused by the bacterium. In light of the rapid penetration of caMRSA into the population, physicians are faced with management dilemmas requiring difficult decisions at the point of care.

This literature survey provides an overview of recent research and case series' describing the exponential increase in caMRSA infections and the most successful management strategies. One review article provides a description of the microbiology and clinical impact of the organism. Data on management of skin and soft tissue infections (SSTI), including the importance of drainage and debridement, are reviewed. The role of adjunctive antibiotic treatment is addressed, including the most successful and cost effective regimens. The pediatric experience with caMRSA at one children's hospital is described. The survey concludes with a provocative report of four cases of necrotizing pneumonia contracted by generally healthy adults following viral respiratory infections.

Clinical and Genetic Characteristics

Source: Zetola N et al. Community-acquired methicillin-resistant *Staphylococcus aureus:* An emerging threat, *Lancet Infect Dis* 2005;5:275-86.

Zetola and colleagues from Johns Hopkins University systematically reviewed the literature on clinical and genetic characteristics of caMRSA. They emphasized those factors conferring antibiotic resistance and virulence in the context of clinical presentation and management.

The mechanism of methicillin resistance is production of altered penicillin-binding protein (PBP) known as PBP2a. PBP2a decreases the affinity of the staphylococcus bacillus for beta-lactam antibiotics. A mobile genetic element, the staphylococcal cassette chromosome (SCC), carries the mecA gene, which encodes PBP2a. The acquisition of this SCC by methicillin-sensitive *S aureus* (MSSA) is the mechanism to which most authorities attribute the rise of caMRSA.

Multiple virulence factors may be produced by *S aureus* and are associated with specific clinical syndromes. The SCC has introduced new virulence factors along with methicillin resistance. The most well known is the Panton-Valentine leukocidin (PVL) gene, which confers tissue necrosis properties to the bacterium. Another

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described virulence factor is production of bacteriocins, naturally synthesized antibiotics toxic to microbes closely related to caMRSA. These confer a competitive advantage to the producing strain. Others potentiate adherence to epithelial cells, adherence to collagen, and increase tolerance to salt.

Furunculosis, causing severe necrosis and abscess formation, is the most common clinical manifestation of caMRSA. Impetigo, bullous impetigo, and scalded skin syndrome have been attributed to a clonal group of caMRSA that produces exfoliative toxins in addition to the PVL genes. Fulminant necrotizing pneumonia is strongly associated with caMRSA. Pulmonary abscess formation occurs along with septic shock; respiratory failure is common and mortality is high. Infection associated with influenza is recognized, though not unique to MRSA. Toxin-mediated syndromes cause a toxic shock syndrome-like illness.

The antibiotic management of suspected staphylococcal infections should be guided by the prevalence of MRSA in the community. In areas with documented caMRSA, vancomycin should be empirically administered to patients with life-threatening infections. Non-life threatening caMRSA infections remain susceptible to some non-beta-lactam antibiotics; clindamycin, co-trimoxazole, linezolid, and minocycline may be empirically prescribed for skin infections in adults. Clindamycin has the potential for inducible resistance.

Non-antibiotic management is particularly important in caMRSA. Adequate drainage is definitive management of abscessed skin infections. Intravenous immunoglobulin therapy may be an appropriate adjunct to patients with life-threatening toxin-mediated illness. Preventive measures should be instituted in high-risk populations (e.g.,intravenous drug users, nursing home residents, dialysis patients). Eradication of caMRSA colonization is controversial but may be attempted with topical mupirocin or systemic trimethoprim-sulfamethoxazole (TMP-SMX).

Commentary

Zetola and colleagues have made an important contribution to the literature with this review of caMRSA. The content was systematically and comprehensively culled from the relevant English and Spanish literature from 1966 forward. It offers clinicians a readable summary of the clinically relevant features of this emerging public health problem. Their description of the genetic basis of methicillin resistance in community-acquired disease and why this less resistant strain has more successfully propagated in the community than the more highly resistant nosocomial strain is particularly interesting. Strength of the paper is the review of the molecular basis of virulence factors. The authors separated virulence from antibiotic resistance but further explain how they relate through carriage on the SCC.

Two tables are well constructed. One relates virulence factors to clinical syndromes and characteristics. The second provides first- and second-line antibiotic recommendations for patients based on epidemiologic characteristics and severity of clinical presentation. High quality images show a characteristic presentation of furunculosis and a series of computed tomography images of necrotizing pneumonia.

The pathophysiologic framework of caMRSA is well constructed. Descriptions of the clinical syndromes may be applied to primary care or hospital-based emergency medicine practice. High-risk patient groups are identified. The antibiotic and non-antibiotic management strategies are sound.

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MRSA in an Outpatient Office

Source: Iyer S, Jones DH. Community-acquired methicillin-resistant *Staphylococcus aureus* skin infection: A retrospective analysis of clinical presentation and treatment of a local outbreak. *J Am Acad Dermatol* 2004;50:854-8.

Iyer and Jones described their clinical experience with caMRSA skin infections between December 2000 and March 2003. The case review is a retrospective analysis of all patients from their private Los Angeles office-based dermatology practice from whom cultures were positive for MRSA. Demographics, HIV status, infection type, antibiotic sensitivities, and response to treatment were described. The authors described changes in their antibiotic selections during the study period as the result of sensitivity data and clinical experience.

During the 28 months of the review, 39 patients (26.7%) were diagnosed with caMRSA infections, while 107 patients (73.3%) were diagnosed with MSSA infections. Of the 39 patients, 30 (97.4%) were male, 20 (51.3%) were HIV-positive, and 32 (69.6%) were diagnosed with cutaneous abscesses. Remaining diagnoses were folliculitis/furuncle, paronychia, impetigo, or cellulitis/wound infection. The caMRSA abscesses were characterized by significant inflammation and necrosis. Culture and sensitivity testing demonstrated susceptibility to gentamycin and vancomycin in all cases. Of the 39 caMRSA cultures, 38 (97.4%) were sensitive to TMP-SMX.

Iyer and Jones treated 30 of 32 abscesses with incision and drainage followed by antibiotics for 2 to 3 weeks. The other diagnoses were treated with antibiotics alone. Moxifloxacin was used empirically in 16 cases but successful in nine. The most successful antibiotic treatment regimens were linezolid (11 patients) and TMP-SMX combined with rifampin (6 patients). Success was 100%. Topical mupirocin alone successfully treated two cases of impetigo and one infected gluteal cleft.

The authors identified risk factors for caMRSA: use of contaminated instruments (e.g., hair clippers) and shared objects, systemic antibiotic use within 1 year, HIV disease, and recent hospitalization. Empiric antibiotic coverage shifted to linezolid after experiencing treatment failures with fluoroquinolones and TMP-SMX alone. Iyer and Jones concluded with these recommendations: nares treatment with topical mupirocin to eliminate carriage of caMRSA; systemic antibiotic coverage with TMP-SMX alone or in combination with rifampin, linezolid, or intravenous vancomycin.

Commentary

This retrospective chart review in one outpatient practice is of value to the practicing clinician because of its description and quantification of caMRSA infections. The culture and sensitivity data add to and generally reflect the experience of other researchers and clinicians encountering cutaneous caMRSA. The greatest strength of this paper was the authors' description of the real-world management challenges faced daily by clinicians when few evidence-based guidelines exist.

The paper has a number of weaknesses. The first is a low number of subjects (39) making extrapolations from the data and its subsets tentative. The authors noted success in 100% of patients treated with two antibiotic regimens. One was only initiated in 6 patients and the other in 11. Practice should not change on the basis of such numbers.

This chart review is purely descriptive. There was no protocol or control group. One can draw no conclusions about the effect of antibiotic treatment on patients with cutaneous abscesses because there was no control group treated with incision and drainage alone. The authors listed factors that they interpreted as risks or predispositions to caMRSA. Because no data were provided about the prevalence of these factors in patients with MSSA infections or in their general patient population, the reader cannot assess the correlation with MRSA. Strikingly, 97.4% of their caMRSA patients were male. With no information about the gender composition of their patient population, this statistic is meaningless. Finally, the authors did not address cost in their data or discussion. They reported and recommended empiric use of linezolid without noting its strikingly high price relative to alternatives.

In conclusion, this paper is an interesting description of one practice's experience with caMRSA. It adds to information about prevalence relative to MSSA and antibiotic resistance. Low numbers and absence of a clinical protocol limit further conclusions from the data.

MRSA Skin Infection

Source: Moran GJ et al. Methicillin-resistant *Staphylococcus aureus* in community-acquired skin infections. *Emerg Infect Dis* 2005;11(6):928-30.

Moran and colleagues trended the proportion of patients with purulent community-acquired SSTI culture positive for caMRSA from August 2001 through March 2004. The study location was a county-owned inner city emergency department in Los Angeles. Data from several antimicrobial clinical trials for SSTI were combined for this investigation. Of the 96 subjects, 24 (25%) were outpatients. The remaining patients were admitted to the hospital. Patients ranged in age from 20 to 60 years, and 77% were male.

From August 2001 through December 2002, 14 (29%) of 49 infections isolated caMRSA. From January 2003 through March 2004, 30 (64%) of 47 infections isolated the organism. No patient had traditionally recognized predisposing factors. Twenty percent of caMRSA patients had recently injected illegal drugs, and 20% were homeless; however, these factors were not statistically significantly different from those patients from whom other organisms were isolated. No studied epidemiologic characteristics differentiated patients with caMRSA from those with other causative pathogens. Antibiotic sensitivity data demonstrated 100% sensitivity to TMP-SMX, 98% sensitivity to clindamycin, 98% sensitivity to rifampin, and 82% sensitivity to tetracycline.

The authors concluded that the prevalence of purulent SSTI caused by caMRSA is increasing; the organism is now the most common cause at their institution. They noted a similar trend in Europe and other geographic regions of the United States. Important treatment implications are inferred. The authors stressed the importance of adequate drainage and debridement. In geographic areas with high prevalence of caMRSA, appropriate empiric antibiotic treatment includes clindamycin or the combination of TMP-SMX and rifampin.

Commentary

The data reported by Moran and colleagues suggest a steep upslope in the prevalence of skin abscesses caused by caMRSA.

Several caveats must be noted before extrapolating their conclusions to other settings. The first is that the number of subjects was small (96 patients enrolled over 32 months). This was a convenience sample of patients enrolled in four different antibiotic studies with differing eligibility criteria. One of the studies enrolled only uncomplicated infections treated as outpatients. Three other studies enrolled only complicated infections requiring admission. The first group is entirely contained within the first half of this study interval during which the percentage of caMRSA was significantly lower.

Analyzing the subgroups of outpatients vs inpatients during the first half of the study actually shows a higher proportion of caMRSA isolates in the outpatients, 8 (33.3%) of 24, vs 6 (24%) of 25 inpatients. This finding lends credibility to the authors' conclusion that the prevalence of caMRSA increased over time. One must use caution in extrapolating results from this study to other geographic areas and patient populations.

The authors noted that their results cannot be generalized to the entire group of SSTIs, only those with purulent material available for culture. It is not clear whether MRSA is increasingly the etiologic pathogen in patients with cellulitis without necrosis. It may well be that it is not; the authors noted the high proportion of caMRSA strains that carry the Panton-Valentine leukocidin factor associated with necrosis.

The antibiotic susceptibility data reported in this trial are consistent with other reports of caMRSA. Treatment recommendations correspond to the data. The importance of adequate surgical drainage and debridement is emphasized.

Community-Acquired MRSA

Source: Fridkin SK et al. Methicillin-resistant *Staphylococcus aureus* disease in three communities. *N Engl J Med* 2005:352:1436-44.

In this prospective population and sentinel surveillance study from three discreet geographic areas, Fridkin and colleagues documented the incidence of caMRSA, described epidemiological features, noted clinical characteristics, and reported antibiotic susceptibility data from 2001 and 2002. Population-based surveillance data were collected in Baltimore and Atlanta; hospital laboratory-based surveillance data were obtained from 12 hospitals in Minnesota. Medical records were reviewed, and subjects were interviewed to distinguish hospital-associated MRSA from caMRSA. The authors defined a community-associated infection as an MRSA isolate coming from a subject without established risk factors for MRSA; these included hospitalization, surgery, dialysis, or residence in a long-term care facility within one year of infection or the presence of a permanent indwelling catheter or percutaneous medical device.

Of 12,533 MRSA infections isolated from the three locations, 17% were classified as probable or confirmed caMRSA. Prevalences ranged from 8% in Baltimore to 20% in Atlanta. The relative risk was 1.51 for patients younger than 2 years relative to older patients. Racial disparity indicating a relative risk of 2.74 for black patients relative to white was found in Atlanta but not in Baltimore. Seventy-seven percent of infections were manifested by skin and soft-tissue disease; 6% of subjects had invasive disease defined as a positive culture from a

Table 1. Infections and Outcomes Associated with Community-Associated MRSA Disease, 2001-2002

VARIABLE	ATLANTA (N=1267)	BALTIMORE (N=115)	MINNESOTA (N=265)	TOTAL (N=1647)	*P* VALUE*
Invasive infections—no. (%)†					
- Bacteremia	30 (2)	7 (6)	6 (2)	43 (3)	0.66
- Meningitis	1 (<1)	1 (1)	0	2 (<1)	0.84
- Osteomyelitis	11 (1)	6 (5)	7 (3)	24 (1)	<0.01
- Bursitis	12 (1)	0	7 (3)	19 (1)	0.04
- Arthritis	13 (1)	0	2 (1)	15 (1)	0.52
Other infections— no. (%)†					
- Skin and soft tissue	973 (77)	95 (83)	198 (75)	1266 (77)	0.71
- Wound	136 (11)	8 (7)	13 (5)	157 (10)	<0.01
- Pneumonia	23 (2)	4 (3)	4 (2)	31 (2)	0.97
- Urinary tract	57 (4)	4 (3)	3 (1)	64 (4)	0.01
- Sinus	60 (5)	0	1 (<1)	61 (4)	<0.01
Underlying illness—no. (%)	594 (47)	70 (61)	80 (30)	744 (45)	0.08
Hospitalization — no. (%)	339 (27)	72 (63)	95 (36)	506 (31)	0.68
- MRSA disease primary reason— no./total no. (%)	251/339 (74)	41/72 (57)	79/95 (83)	371/506 (73)	0.62
- Intensive care unit stay—no./total no. (%)	26/339 (8)	7/72 (10)	4/95 (4)	37/506 (7)	0.14
- Discharged from hospital—no./total no. (%)	323/339 (95)	71/72 (99)	86/95 (91)	480/506 (95)	0.07
- Median stay—days	5	5	3	4	0.20

* *P* values were determined by means of the Cochran-Mantel-Haenszel summary statistic and indicate significant differences in infection rates among sites.
† Patients could have more than one infection.

Table 2. Number of Community-Associated MRSA Isolates That Were Susceptible to Selected Antimicrobial Agents, 2001-2002*

AGENT TESTED	ATLANTA	BALTIMORE	MINNESOTA	TOTAL	*P* VALUE†
		no. of susceptible isolates /total no. (percent)			
Ciprofloxacin	408/648 (63)	6/31 (19)	146/182 (80)	560/861 (65)	<0.001
Clindamycin	840/970 (87)	78/92 (85)	211/239 (88)	1129/1301 (87)	0.58
Erythromycin	98/907 (11)	11/94 (12)	110/235 (47)	219/1236 (18)	<0.001
Gentamicin	429/444 (97)	66/71 (93)	184/188 (98)	679/703 (97)	0.59
Rifampin	682/ 694 (98)	6/9 (67)	179 /184 (97)	867/887 (98)	0.21
Tetracycline	726/814 (89)	43/70 (61)	163/179 (91)	932/1063 (88)	0.44
Vancomycin‡	1016/1017 (100)	95/96 (99)	232/232 (100)	1343/1345 (100)	0.88
Linezolid	13/13 (100)	11/12 (92)	0	24/25 (96)	0.30
Trimethoprim-sulfamethoxazole	912/943 (97)	30/36 (83)	236/239 (99)	1178/1218 (97)	0.32

* Results were obtained at local facilities.
† *P* values were determined by means of the Cochran-Mantel-Haenszel summary statistic.
‡ Two isolates were nonsusceptible with the use of automated testing methods, but these results were not confined with the use of recommended methods.

Reprinted with permission: Fridkin et al. Methicillin-resistant *Staphylococcus aureus disease* in three communities. *NEJM* 2005:352(14);1436-1444.

Table 3. Effect of Initial Therapy on Selected Outcomes among 453 Patients with Confirmed Skin or Soft-Tissue Infections due to Community-Associated MRSA, 2001-2002*

INITIAL THERAPY	NO. OF PATIENTS	FOLLOW-UP VISIT TO HEALTH CARE PROVIDER		INCISION AND DRAINAGE ON FOLLOW-UP VISIT	NEW ANTIMICROBIAL AGENT PRESCRIBED ON FOLLOW-UP VISIT
		≥ 1 TIMES	≥ 2 TIMES		
Incision and drainage					
- Yes — no. (%)	196	54 (28)	30 (15)	19 (10)	45 (23)
- No — no. (%)	257	69 (27)	43 (17)	14 (5)	66 (26)
- Rate ratio (95% CI)	—	1.01 (0.80-1.29)	0.94 (0.70-1.27)	1.37 (1.00-1.87)	0.92 (0.71-1.18)
Inactive therapy					
- Yes — no. (%)	254	59 (23)	35 (14)	15 (6)	55 (22)
- No — no. (%)	199	64 (32)	38 (19)	18 (9)	56 (28)
- Rate ratio (95% CI)	—	0.81 (0.66-1.00)	0.83 (0.65-1.07)	0.80 (0.54-1.17)	0.85 (0.68-1.05)
Incision and drainage					
- Inactive therapy — no. (%)	108	20 (19)	11 (10)	8 (7)	16 (15)
- Active therapy — no. (%)	88	34 (39)	19 (22)	11 (12)	29 (33)
- Rate ratio (95% CI)	—	0.60 (0.41-0.87)	0.63 (0.39-1.02)	0.75 (0.43-1.28)	0.58 (0.39-0.88)
No incision and drainage					
- Inactive therapy— no. (%)	146	39 (27)	24 (16)	7 (5)	39 (27)
-Active therapy —no. (%)	111	30 (27)	19 (17)	7 (6)	27 (24)
- Rate ratio (95% CI)	—	0.99 (0.78-1.26)	0.98 (0.73-1.31)	0.87 (0.51-1.49)	1.05 (0.83-1.34)

* The outcomes were reported during the interview with each patient. Only patients who were interviewed were included in the analysis. Initial therapy was categorized as active if the patient received an antimicrobial agent with activity against *S aureus* and to which the MRSA was susceptible in vitro. Therapy was categorized as inactive if initial therapy included only antimicrobial agents to which the isolate had intermediate susceptibility on testing or was resistant in vivo. The rate ratio is the ratio of the rate of the outcome among the exposed group to the rate of the outcome among the group that was not exposed. CI denotes confidence interval.

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normally sterile site; infections included bacteremia, meningitis, osteomyelitis, bursitis, and arthritis. Pneumonia accounted for 2%. Antibiotic susceptibility data indicated greater than 95% sensitivity to gentamicin, rifampin, vancomycin, linezolid, and TMP-SMX. Seventy-three percent of patients received empiric antibiotic coverage to which the organism was not susceptible; however no adverse consequences were identified.

The authors concluded by exhorting clinicians to consider caMRSA as a potential pathogen, adequately drain and culture purulent material, and choose empirical antibiotics likely to cover caMRSA.

Commentary

This prospective surveillance study has a number of strengths that confer credibility to the results and conclusions: high numbers, rigorous methodology, and multiple data sources over three discrete geographic regions. The definitions of hospital associated and community-acquired infections are clear and specific. The article's Tables 1 and 2 collated the results such that they can be examined by region and in aggregate. (*Editor's note: These two tables and two others from the article are reprinted on pages 21,22, and 23.*) The spectrum of severity of caMRSA infection is similar across the three regions with similar distributions of SSTI, invasive infections, and pneumonia.

Conversely, antibiotic susceptibility shows regional differences with Baltimore demonstrating generally lower percentages to the various antibiotics than Atlanta or Minnesota. The latter result suggests that clinicians should understand the local experience with caMRSA with respect to prevalence and antibiotic susceptibility to guide empiric treatment.

The clinical characteristics of caMRSA infection are well defined. The authors were unable to identify adverse outcomes resulting from empiric treatment with antibiotics resistant to the infecting organism. They underscored the importance of surgical drainage of skin abscesses when feasible.

The authors identified limitations to their results. Importantly, data collection was limited to cases where a culture was obtained. Their report may have underestimated incidence and prevalence because cases where patients were treated empirically with no culture would not have been included. Because their methodology required patient interviews, only 41% of eligible patients were included in the outcome analysis.

Table 4. Frequency of Characteristics Potentially Related to Infection among 575 Patients with Confirmed Community- Associated MRSA Disease, 2001-2002*

POTENTIAL RISK FACTOR	NO. OF PATIENTS (%)
Any visit to a physician's office in past yr	357 (62)
Receipt of any antimicrobial agents in past yr	224 (39)
Chronic noninfectious skin disease	190 (33)
Stayed > 2 wk in non-health care high-risk setting in past 5 yr†	10 (2)
Health care-related employment in past 5 yr	69 (12)
- Health care provider or direct care	23 (4)
- Health care delivery support services	26 (5)
- Other type of health care	46 (8)
- Acute care or skilled-nursing facility	30 (5)
- Clinic or ambulatory care facility	12 (2)
Crowded household (>1 person/bedroom)‡	121 (51)
≥ 1 Household member ≤ 2 yr old	132 (23)
≥ 1 Household member > 60 yr old	109 (19)
≥ 1 Household member with established risk factor for MRSA infection	92 (16)
- Job in the health care setting	69 (12)
- Attendance at day care§	52 (9)
- History of MRSA infection	35 (6)
- Receipt of home care services	17 (3)
Self-reported annual income¶	
- < $20,000	144 (29)
- $20,000-$50,000	178 (36)
- > $50,000	173 (35)
Receipt of public assistance	92 (16)

* The categories are not mutually exclusive.
† A high-risk setting was defined as a department-of-corrections facility or military barracks.
‡ Data on crowding were available for 236 of the 575 interviewed patients.
§ Day-care attendance among household members was for amedian of 20 hours per week (range, 20 to 60).
¶ Data on income were available for 495 interviewed patients.

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TMP-SMX for MRSA

Source: Grim SA et al. Trimethoprim-sulfamethoxazole as a viable treatment option for infections caused by methicillin-resistant *Staphylococcus aureus*. *Pharmacotherapy* 2005;25:253-264.

Grim and colleagues performed a literature review of studies reporting the efficacy of TMP-SMX for MRSA infections. The authors were particularly focused on the question of whether this antibiotic combination may be generally recommended as a cost effective, well-tolerated oral agent for empiric treatment. They reviewed articles identified by a MEDLINE search of pertinent keywords from January 1966 through December 2003 and abstracts from infectious disease meetings.

Mechanisms of MRSA resistance to TMP-SMX are not completely understood but are thought to be chromosomally or plasmid mediated. They are probably distinct from multidrug resistance mechanisms, but several reports suggest a relationship. Resistance rates of MRSA to TMP-SMX vary considerably in different geographic regions ranging from 0 to 74% in the United States. Institutions with large numbers of HIV patients treated with TMP-SMX for pneumocystis prophylaxis have particularly high rates. Clonal outbreaks of resistant MRSA have been described, with the Brazilian clone conferring 100% resistance to TMP-SMX.

Grim and colleagues reported several small studies and case reports of patients with documented MRSA infections treated or prophylaxed with TMP-SMX. The data suggest efficacy; the only randomized, double-blind trial found a 100% cure rate in hospitalized intravenous drug users with MRSA but significant resistance in patients with MSSA.[1]

The authors concluded that the

available data supports the use of TMP-SMX for oral treatment of caMRSA but caution that vancomycin should be used for serious infections. Clinicians should be knowledgeable of local patterns of resistance and potential adverse drug effects and interactions before prescribing the combination drug. Finally, they highlighted the need for a randomized controlled trial comparing TMP-SMX to linezolid.

Commentary

The importance of this review is its focus on the value of TMP-SMX in the treatment of MRSA infections. The antibiotic combination is a potentially desirable agent for a number of reasons: low cost, oral and parenteral formulations, and an acceptable side-effect profile. The authors reviewed clinical, pharmacological, and microbiological data profiling the relationship between the antibiotic and MRSA.

The weakness of this review is the methodology. It is very poorly described, which leaves the reader unclear about inclusion and exclusion criteria for papers and abstracts reviewed. One cannot discern if the methodology was systematic or even the types of papers selected. The references suggest a range of source material including pharmaceutical package inserts, letters to the editor, and case reports.

The authors assembled the material in a readable fashion and were careful to focus on providing information of clinical relevance to practicing physicians. The most important portion of this review is the conclusion that the available data indicated that TMP-SMX is effective in the treatment of caMRSA infections. This is supported by many other recent and contemporaneous studies. Clinicians should understand that the drug is most useful for oral treatment of non-life-threatening infections managed in an outpatient setting. The end of the paper includes a brief but useful review of adverse reactions and drug interactions with appropriate cautions on patient selection. Finally, use of this common, cheap, and readily available drug may forestall development of resistance to linezolid and other newer antistaphylococcal antibiotics.

Pediatric Patients with MRSA

Source: Lee MC et al. Management and outcome of children with skin and soft tissue abscesses caused by community-acquired methicillin-resistant *Staphylococcus aureus*. *Pediatr Infect Dis J* 2004;23:123-7.

The goal of Lee and colleagues' prospective observational study was to identify the optimal management strategy for children with soft tissue abscesses caused by caMRSA. They specifically looked at the role of supplemental antibiotic therapy in patients primarily treated with incision and drainage. The patient population included children presenting to the emergency department or acute care clinic of a single institution, Children's Medical Center, Dallas, TX; eligible patients were treated for skin and soft-tissue abscesses that were culture positive for MRSA. Demographic and clinical data including management strategy were collected for the initial visit. Follow-up information was collected 1 to 6 days later and again about 1 week after the first follow-up contact.

Sixty-nine subjects were studied. All had antibiotics prescribed; 62 (90%) were treated with a drug to which the cultured pathogen was resistant, 5 (7%) were treated with an effective drug, and 2 were non-compliant. All of the isolates were susceptible to rifampin, TMP-SMX, gentamicin, and vancomycin; 88% were susceptible to clindamycin. Four (6%) patients initially treated with an ineffective antibiotic required hospital admission on the first follow-up visit. All hospitalizations were uncomplicated. The only identified predictor of hospitalization was the size of the initial lesion: an infected area greater than 5 cm in diameter was associated with a 33% chance of outpatient management failure. The susceptibility of the pathogen to the prescribed antibiotic was not associated with the success of outpatient treatment.

The authors concluded that children with skin abscesses less than 5 cm in diameter caused by caMRSA may be treated with incision and drainage without supplemental antibiotics.

Commentary

The importance of this study is its focus on identification of optimal management strategies for children with skin abscesses caused by caMRSA. There are advantages and disadvantages to the prospective observational methodology. An important advantage is identification of current common management practices; in this case, the authors identified 100% prescription of adjuvant antibiotic use in children with caMRSA abscesses. The main disadvantage is absence of the rigor of a clinical trial. In this study, management variation occurred with respect to use of incision and drainage, abscess packing, intravenous antibiotic administration on the first visit, and choice of antibiotic. Failure to control for these variables may affect interpretation of the data.

The authors were particularly interested in answering the question of the efficacy of antibiotics in abscesses caused by caMRSA.

Their conclusion that they are not necessary in lesions less than 5 cm in diameter is consistent with previous studies of patients with skin abscesses prior to the common occurrence of caMRSA. Likewise, a 2001 study of children with caMRSA concluded that recovery was not dependent upon treatment with effective antibiotics.[2]

The reader may use this study's conclusion as a general guideline when treating children with skin abscesses suspected to be caused by caMRSA. As always, the clinical judgment of the treating physician must be employed when making individual treatment decisions.

Oral Linezolid vs Intravenous Vancomycin

Source: Sharpe JN et al. Clinical and economic outcomes of oral linezolid versus intravenous vancomycin in the treatment of MRSA-complicated, lower-extremity skin and soft-tissue infections caused by methicillin-resistant *Staphylococcus aureus*. *Am J Surg* 2005;189:425-8.

In this open-label trial, Sharpe and colleagues compared the efficacy of oral linezolid therapy to intravenous vancomycin in patients with documented MRSA skin infections of the lower extremity requiring surgical intervention; the cost of therapy with each agent was concomitantly tracked. The study enrolled 117 patients, but 57 were excluded. The 60 remaining subjects were randomized to one of the two treatment arms. All were initially hospitalized for acute infection control but then completed treatment as outpatients. The authors rigorously defined clinical cure, clinical improvement, and clinical failure.

The results of the trial showed strikingly better clinical outcomes with oral linezolid: 97% of patients demonstrated clinical cure or improvement; the treatment failure rate was 3% with no amputations. The median length of inpatient therapy was 3 days followed by 7 days of outpatient treatment. Of subjects treated with intravenous vancomycin, 43% demonstrated clinical cure or improvement; 57% were treatment failures 7% of whom required amputation. The median length of inpatient therapy was 6 days followed by 4 days of outpatient intravenous treatment. The cost of inpatient linezolid therapy averaged $6438 less than vancomycin because of the lower length of stay. Outpatient costs were less with linezolid because it was administered orally and vancomycin required intravenous administration.

The authors concluded that oral linezolid offers definite economic advantage over intravenous vancomycin and may provide superior clinical results. They stated that vancomycin will remain first-line therapy for MRSA until a large, multicenter trial confirms their results.

Commentary

This study is an important contribution to the caMRSA literature for several reasons. The methodology was rigorous and definitions precise. The author's inclusion of economics in the outcome data is important; the decided cost advantage adds weight to the compelling clinical case for further study of oral linezolid for patients with complicated soft tissue caMRSA infections. These authors are the first to look at amputation as a discreet subset of treatment failure in patients with lower extremity infections treated with intravenous vancomycin. The 23% amputation rate for this treatment arm contrasted with 0% for the oral linezolid group is striking.

The study has several notable limitations. The first is the low number of subjects (60 patients). It is hazardous to extrapolate percentages obtained from such a limited data set to the whole population of complicated lower extremity caMRSA patients. It was a single site investigation and subject to the limitations of a narrow patient population. Finally, the authors only studied adult patients with lower extremity infections meeting their narrowly defined criteria.

The study's results are consistent with those of Weigelt and colleagues who conducted a large (1200 randomized patients) multicenter study of patients with complicated SSTIs randomized to treatment arms of vancomycin or linezolid.[3] They found that treatment with linezolid was well tolerated, produced superior outcomes in patients with caMRSA and equivalent outcomes in all patients with complicated SSTIs, and required an average of 5 fewer days of intravenous therapy than vancomycin.

Linezolid should be strongly considered for treatment of complicated SSTIs, particularly in patients with lower extremity infections believed secondary to caMRSA.

MRSA Pneumonia

Source: Francis JS et al. Severe community-onset pneumonia in healthy adults caused by methicillin-resistant *Staphylococcus aureus* carrying the Panton-Valentine leukocidin genes. *CID* 2005;40:100-107.

Outbreaks of caMRSA, increasingly recognized worldwide, have primarily manifested as SSTIs. A more ominous expression is described by Francis and colleagues in their report of four cases of necrotizing caMRSA pneumonia presenting to one of two Baltimore hospitals in a two-month period during the 2003-2004 winter. Bacterial isolates were typed by strain; the presence of staphylococcal cassette chromosome mec (SCCmec) type IV was identified by polymerase chain reaction (PCR). PVL virulence factor, associated with tissue necrosis, was detected by PCR.

All of the cases occurred in previously healthy adults. Patients 1, 3, and 4 were female; Patient 2 was male. Patients 1 and 3 tested positive for acute influenza A; the other two had influenza-like prodromes but were not tested for influenza. Two patients were initially treated with oral antibiotics as outpatients; they subsequently deteriorated and were admitted to the hospital. Clinical features common to all four patients included fever, shock, and cavitary lesions on chest imaging; all required intensive care. Three of the four had hemoptysis. Two patients had pneumothoraces requiring chest tubes, and one had an empyema. One patient required bilateral below-the-knee amputations for lower extremity necrosis. Patient 2 died on hospital day 2. The other three were hospitalized from 41 to 108 days. Patients 3 and 4 were discharged to rehabilitation facilities. Patient 1 was the only one discharged to home; she spent 4 weeks in the intensive care unit.

The microbiological analysis of the caMRSA cultured from all four subjects revealed PVL virulence factors and the SCCmec type IV element. All isolates were sensitive to clindamycin, TMP-SMX, and gentamicin.

The authors noted that post-influenza staphylococcal pneumonia is likely the result of influenza-mediated damage to the respiratory epithelium. PVL is associated with necrotizing staphylococcal pneumonia. Currently, the incidence of staphylococcal pneumonia in healthy adults is low. If the prevalence of caMRSA carrying the PVL gene continues to increase, the percentage of severe pneumonia cases may increase. Clinicians should keep caMRSA in their differential diagnosis when treating otherwise healthy adults with fulminant pneumonia, particularly during influenza outbreaks.

Commentary

Francis and colleagues have made an important contribution to the body of literature; their case series is a readable and comprehensive description of the clinical and molecular features of caMRSA necrotizing pneumonia. The article's Table 1 summarized salient clinical features of the four cases. The methods section depicts the methodology for patient selection, case definitions, identification and characterization of caMRSA, and molecular analysis of virulence factors and SCCmec typing. The descriptions are clear. The results are concise but complete.

The discussion makes several interesting points. The first is citation of literature documenting the increasing prevalence of caMRSA in the United States. The second is a review of case reports of necrotizing caMRSA pneumonia in previously healthy children and young adults. Those cases are consistent with the severity of this disease documented in this case series. The authors emphasized the association of severe necrotizing pneumonia with identification of the PVL virulence factor. They expressed concern that the rising incidence of caMRSA may herald an increase of necrotizing pneumonia in healthy patients. Finally, treatment recommendations for suspected caMRSA pneumonia were given based on common antibiotic susceptibility in vitro.

Conclusion/ Recommendations

The prevalence of caMRSA infections has rapidly escalated in many geographic regions in the United States and throughout the globe. Fridkin and colleagues demonstrated the importance of understanding the local experience with respect to prevalence and antibiotic susceptibility. SSTIs are the most common clinical expression of caMRSA, representing at least 75% of infections; the remainder comprise invasive diseases.

The data presented in this review support the following management guidelines in the opinion of this author at this time:

1. The primary treatment of uncomplicated skin abscesses less than 5 cm in diameter is incision and drainage. In the absence of surrounding cellulitis, systemic symptoms, or immunocompromising conditions, initial supplemental antibiotics are not indicated. Purulent material should be cultured so that the organism and sensitivities are identified if the infection does not resolve as expected. Close follow-up and monitoring are recommended. These recommendations apply to children and adults.

2. If empiric antibiotic treatment is necessary for outpatient treatment of skin infections, the clinician should understand local patterns of resistance to caMRSA. In most cases, TMP-SMX with or without rifampin is an excellent initial choice. Clindamycin or minocycline may be used in patients with contraindications to TMP-SMX. Oral linezolid is efficacious and well tolerated; however, the cost is prohibitive for routine use.

3. For complicated infections requiring surgery or inpatient treatment, linezolid is emerging as the

Table 5. MRSA Management Guidelines

THE PRIMARY TREATMENT OF UNCOMPLICATED SKIN ABSCESSES LESS THAN 5 CM IN DIAMETER IS INCISION AND DRAINAGE.
In the absence of surrounding cellulitis, systemic symptoms, or immunocompromising conditions, initial supplemental antibiotics are not indicated. Purulent material should be cultured so that the organism and sensitivities are identified if the infection does not resolve as expected. Close follow-up and monitoring are recommended. These recommendations apply to children and adults.
IF EMPIRIC ANTIBIOTIC TREATMENT IS NECESSARY FOR OUTPATIENT TREATMENT OF SKIN INFECTIONS, THE CLINICIAN SHOULD UNDERSTAND LOCAL PATTERNS OF RESISTANCE TO caMRSA.
In most cases, TMP-SMX with or without rifampin is an excellent initial choice. Clindamycin or minocycline may be used in patients with contraindications to TMP-SMX. Oral linezolid is efficacious and well tolerated; however, the cost is prohibitive for routine use.
FOR COMPLICATED INFECTIONS REQUIRING SURGERY OR INPATIENT TREATMENT, LINEZOLID IS EMERGING AS THE ANTIBIOTIC OF CHOICE.
In their small series, Sharpe and colleagues suggested that oral linezolid offers economically and clinically superior outcomes to intravenous vancomycin. Weigelt and colleagues validated their findings in a multicenter trial. Currently, the therapies are equivalent for empiric coverage of all complicated SSTIs. Linezolid is superior in those caused by caMRSA.
INTRAVENOUS VANCOMYCIN IS THE ANTIBIOTIC OF CHOICE FOR PATIENTS PRESENTING TO ACUTE CARE SETTINGS WITH LIFE-THREATENING caMRSA INFECTIONS.
Linezolid may be considered for patients with known resistance or contraindications to vancomycin.

antibiotic of choice. In their small series, Sharpe and colleagues suggested that oral linezolid offers economically and clinically superior outcomes to intravenous vancomycin. Weigelt and colleagues validated their findings in a multicenter trial. Currently, the therapies are equivalent for empiric coverage of all complicated SSTIs. Linezolid is superior in those caused by caMRSA.

4. Intravenous vancomycin is the antibiotic of choice for patients presenting to acute care settings with life-threatening caMRSA infections. Linezolid may be considered for patients with known resistance or contraindications to vancomycin.

Necrotizing pneumonia is a life-threatening manifestation of caMRSA. The presence of the PVL gene, conferring tissue necrosis properties, is probably responsible for the fulminant destruction of lung tissue.

Community-acquired MRSA should be considered in otherwise healthy patients presenting with life-threatening pneumonia, particularly in the post-influenza period. Intravenous vancomycin should be added to empiric antibiotic therapy for community-acquired pneumonia; standard antibiotic coverage will not provide adequate coverage for this pathogen.

Community-acquired MRSA is an emerging infection. The epidemiology and microbiological characteristics are dynamic. Acute care physicians and other practitioners are urged to follow the literature and local experience closely. Those communities with high prevalence of this microbe in SSTIs are at risk for increasing incidence of necrotizing pneumonia.

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Future Issues

- *What is the best diagnostic test for nephrolithiasis?*
- *Is an LP necessary in SAH with new generation scanners?*
- *Should narcotics be used in abdominal pain?*
- *Should RSI be used in the prehospital setting?*
- *Which antibiotic should be started in a child with meningitis?*
- *Evaluating PE with CT: A new paradigm*

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Upon completing this program, participants will be able to:

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- Discuss up-to-date information about new drugs, techniques, equipment, trials, studies, books, teaching aids, and other information pertinent to the stated topic;
- Evaluate the credibility of published data and recommendations about the stated topic.

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Physicians participate in this continuing medical education program by reading the articles, using the provided references for further research, and studying the CME questions. Participants should select what they believe to be the correct answers, then refer to the list of correct answers to test their knowledge. To clarify confusion surrounding any questions answered incorrectly, please consult the source material.

After completing this activity, participants must complete the evaluation form provided at the end of each semester (June and December) and return it in the reply envelope provided to receive a certificate of completion. When an evaluation form is received, a certificate will be mailed to the participant.

CME QUESTIONS

11. The clinical impact of the PVL gene on the SCC of caMRSA is:

a. increased bacterial adherence to epithelial cells.
b. increased bacterial adherence to collagen.
c. increased tolerance to salt environment.
d. conference of tissue necrosis properties.

12. The most important management principle for treatment of uncomplicated purulent soft-tissue caMRSA infections is:

a. early treatment with intravenous vancomycin.
b. adequate surgical drainage and debridement.
c. a 10-day course of TMP-SMX.
d. dermatology consultation.

13. According to the surveillance data collected and collated by Fridkin and colleagues, which of the following statements is correct?

a. caMRSA manifests widely differently in different geographic regions of the United States.
b. Children younger than 2 years are at lower risk for caMRSA infections than older children and adults.
c. Antibiotic susceptibility demonstrates regional differences such that understanding local patterns of resistance is important.

14. Which one of the following factors did Lee and colleagues identify as the best predictor of success or failure of outpatient management when treating children with skin lesions caused by caMRSA?

a. Diameter of the initial lesion
b. Susceptibility of caMRSA to the prescribed antibiotic
c. Reliability of the parent or caretaker
d. Initial incision and drainage performed by surgeon versus nonsurgeon

15. Which one of the following statements about caMRSA pneumonia is correct?

a. Non-immunocompromised patients are at minimal risk for the disease.
b. The post-influenza period renders patients particularly vulnerable.
c. Standard antibiotic recommendations for community-acquired pneumonia will cover caMRSA.
d. Complications are rare in generally healthy patients.

Answers: 11. d; 12. b; 13. c; 14. a; 15. b

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Managing the Airway of the Pediatric Trauma Patient: Meeting the Challenge

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Peer Reviewer: **Stephen Crabtree, DO, FACEP,** Northside Emergency Associates, Atlanta

Accidental injury is the number one cause of death and disability in all children between 1 and 18 years of age. In 2002, trauma accounted for 33-39% of mortality in children aged 1-14 years.[1]

Airway management is paramount in the management of the trauma patient and especially in the case of the pediatric trauma patient. A known pitfall in trauma management—under-resuscitation and subsequent hypoxia— is the most common cause of cardiac arrest in the child.[2-4] *Early identification and aggressive management of pediatric airway difficulties may affect the child's outcome.*

This article reviews the anatomic and physiologic differences between pediatric and adult airways and the critical aspects of management.

—The Editor

Introduction

Although children do have an increased susceptibility to respiratory compromise (*Table 1*), appropriate and timely airway management can profoundly influence mortality and morbidity and lead to a good outcome. Acute trauma may result in airway obstruction in the case of orofacial trauma or altered level of consciousness. Decreased oxygenation occurs in pulmonary injuries such as pneumothorax, hemothorax, chest wall injuries, pulmonary contusions, and aspiration. Ventilation can be compromised by airway obstruction, diaphragmatic injury, or central nervous system (CNS) depression. One of the main causes of early death in pediatric trauma is airway compromise often secondary to inadequate airway management.[2-4] Many trauma-associated deaths are preventable if appropriate, prompt care is provided at initial presentation.[5] Once respiratory arrest leads to pulseless cardiac arrest, survival as well as neurologic

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outcome is dismal.[2]

The pediatric airway presents a special challenge to many clinicians. Although airway management priorities in trauma are the same for children and adults, the pediatric airway has several unique features that emergency department (ED) physicians must understand to manage a pediatric trauma patient optimally.

This article does not extensively review basic airway management in trauma. Rather, the anatomic and physiologic differences between pediatric and adult airways as well as how and when these differences translate into differences in management are highlighted.

The Pediatric Airway: Anatomy

Overall, the pediatric airway is anatomically different than the adult airway. It has a different shape, is more pliable, and is smaller in diameter and length than the adult airway (*Figure 1*). These anatomic differences are most pronounced in infants and evolve with the child's growth. Generally, by the age of 8 years, the airway is considered to have the characteristics of the adult airway.[6]

Unique features in the child (*Table 2*) include a mouth that is smaller and oropharyngeal soft tissues, tongue, and tonsils that are proportionately larger than in the adult. The tongue is the main cause of airway obstruction in the child and may make visualization of the larynx difficult. In infants and children, the larynx is more cephalad and anterior than in adults.[7] The larynx or glottic opening of the trachea is at the level of C1 during infancy, transitioning to the level of C4-C5 in the adult.[8] Therefore, alignment of the oropharynx and larynx usually requires a straight laryngoscope blade. The thinner tip of the straight laryngoscope blade also helps elevate the floppy epiglottis out of the visual field. In children, the angle between the epiglottis and the larynx is more acute than in the adult, thus making blind nasotracheal intubation contraindicated in the young child; this angle is difficult to maneuver and blind manipulation can cause trauma and bleeding of the adenoids. The pediatric epiglottis is long, narrow, and floppy. A child's vocal cords have a slightly more anterocaudal angle than in an adult, therefore, if a child's head is not in the normal supine anatomical position, the vocal cords are more difficult to visualize during intubation. While an adult airway narrows after the cricoid cartilage, the narrowest portion of a pediatric airway is the cricoid cartilage. Historically, uncuffed endotracheal tubes (ETTs) have been recommended in children younger than 8 years because of concern about tissue necrosis from an improperly inflated balloon. New cuffed ETTs, which are safe in young children, have been developed, are widely available, and are becoming the preferred choice for intubation.[9] The rationale for using these cuffed ETTs is to increase effective ventilation by decreasing air-leak, a critical issue in children who require increased ventilatory pressures (e.g., children with acute respiratory distress syndrome).[2] A child's anatomically funnel-shaped larynx allows secretions to accumulate in the retropharyngeal area and increases the frequency of airway obstruction in children.[10]

In an infant, the relatively large occiput causes passive flexion of the cervical spine, as well as buckling of the pharyngeal airway.[2] To maintain cervical spine protection and an open airway, the patient must be kept in the 'sniffing position'. In this position, the external auditory meatus is aligned with the anterior border of the shoulder (*Figure 2*).

A pediatric trachea is smaller in diameter and length (5 cm long and grows to 7 cm by 18 months of age)[11] and is more pliable and compressible than the adult airway. Failure to appreciate this short length may result in right main stem bronchus intubation, inadequate ventilation, accidental tube dislodgement, and/or mechanical barotrauma.[11] The cricothyroid membrane is very small and difficult to palpate and to incise, therefore, cricothyroidotomy is contraindicated in children younger than 8 years.

Infants are obligate nasal breathers up to 6 months of age.[6] Infant nares are proportionately smaller than in adults and when occluded with mucous or secretions, they may cause significant airflow obstruction. This condition can be exacerbated by compressing the infant's nares with a face mask.[6]

The pediatric chest is more pliable than the adult chest. Even in the setting of significant blunt thoracic trauma, a child may have severe pulmonary contusions with no outward indication of severe trauma.[14] The high incidence of tension pneumothorax may be due to the increased pliability of the pediatric chest. The diaphragm and the abdominal wall musculature are relatively immature and weak despite being the major respiratory muscles in the child. Serious abdominal trauma or abdominal distention from bleeding or perforation can severely compromise a child's ventilatory status.

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Table 1. Reasons for Increased Pediatric Susceptibility to Respiratory Emergencies

PEDIATRIC CHARACTERISTIC	REASON FOR INCREASED SUSCEPTIBILITY TO RESPIRATORY EMERGENCIES
Higher metabolic requirements	Less tolerant of hypoxia and shock
Smaller airway diameter	Increased airflow resistance
Collapsible airways	Easily occluded
Compliant chest wall	May have significant lung injury and decreased air exchange despite relatively few external signs of trauma
Underdeveloped respiratory muscles	Diaphragm (the major muscle of respiration) fatigues relatively easy
Behavioral immaturity	Inability to verbalize respiratory distress or cooperate with intervention

Adapted from Mahadevan S, et al. *Principles of Emergency Medicine*. 1st. ed. Cambridge, UK; Cambridge University Press;2005.

Figure 1. Comparison of Pediatric and Adult Airway

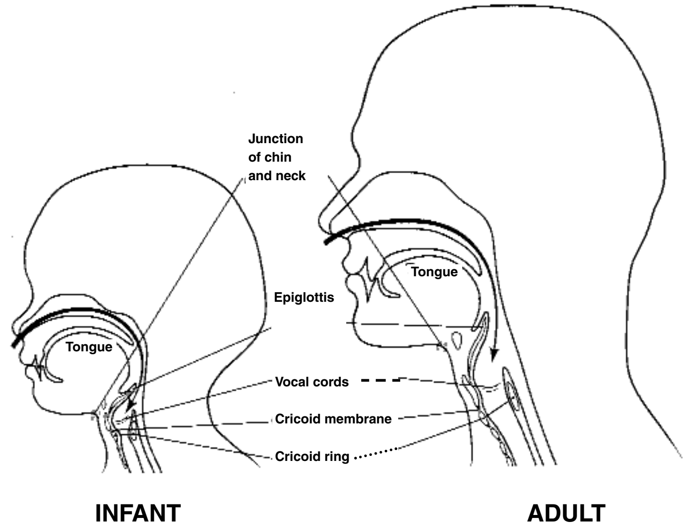

Figure 1. The anatomic differences particular to children are these: 1) Higher, more anterior position for the glottic opening. (Note the relationship of the vocal cords to the chin/neck junction.) 2) Relatively larger tongue in the infant, which lies between the mouth and glottic opening. 3) Relatively larger and more floppy epiglottis in the child. 4) Cricoid ring is the narrowest portion of the pediatric airway versus the vocal cords in the adult. 5) Position and size of the cricothyroid membrane in the infant. 6) Sharper, more difficult angle for blind nasotracheal intubation. 7) Larger relative size of the occiput in the infant.

Reprinted with permission from: Wall RM. *Manual of Emergency Airway Management.* Philadelphia:Lippincott Williams & Wilkins;2000:145.

The Pediatric Airway: Physiology

Children have great compensatory mechanisms, and their vital signs may remain normal even with a severe physiologic compromise. Likewise, changes in vital signs may be subtle and misleading and may result in inadequate assessment of respiratory status, leading to inadequate resuscitation and precipitous deterioration of the pediatric trauma patient.

The major cause of traumatic death in children is respiratory failure.[2-4] Given the increased metabolic rate of children, hypoxia is poorly tolerated. Normal cerebral blood flow increases proportionately to nearly twice that of adult levels by the age of 5 years, and then decreases,[2] a partial reason for children's severe susceptibility to cerebral hypoxia. Children and infants in particular have smaller lung volumes and higher oxygen demands than adults. Therefore, they consume their respiratory reserves more quickly than in adults.

Children also have increased oral secretions and vagal tone compared with adults. Historically, this has led to the dictum of pretreatment with atropine to avoid life-threatening bradycardia with laryngeal manipulation. Although a recent study documented that pretreatment with atropine may not prevent bradycardia in all cases, and thus may not be required for all pediatric patients,[8] it is still the standard of care.

Pediatric Airway Management Goals

The overall goals of airway management in the trauma patient are to: 1) provide a secure patent airway, 2) supply supplementary oxygen, 3) support ventilation, and 4) prevent aspiration. These goals are the same for the pediatric and the adult patient.

Assessment of the Pediatric Respiratory Status

Accurate assessment of the pediatric respiratory status is of the utmost importance. Failure to recognize and respond to pediatric respiratory distress can precipitously lead to cardiopulmonary arrest. Pediatric vital signs must be compared with age-related normal values. Pulse oximetry is a useful adjunct for monitoring a child's respiratory status.

Tachypnea is the initial compensatory mechanism for preserving minute volume.[2] Observation of a child's respiratory effort is the most accurate method to identify respiratory distress. Tidal volume assessed by chest rise or abdominal excursion can reveal the adequacy of the trauma patient's respirations. Respiratory noises (e.g., snoring or stridor indicating upper airway obstruction; wheezes indicating lower airway obstruction; and grunting, ominous for severe respiratory distress) are indications of work of breathing and airway obstruction.

The pediatric brain has high oxygen consumption, and hypoxia may result in an altered mental status. Thus, evaluation of overall general appearance (e.g., posture, level of alertness, or responsiveness) and other organ systems such as CNS (e.g., lethargy, agitation, or other altered mental status) and skin (e.g.,

Table 2. Unique Characteristics of Pediatric Airway Anatomy and Their Consequences on Airway Management

PEDIATRIC ANATOMIC FEATURE	AIRWAY MANAGEMENT SIGNIFICANCE
Large head, short neck	1. Neutral C-spine position/sniffing position difficult to achieve 2. Increased incidence of head trauma
Small mouth	1. Small mouth in conjunction with large soft tissue structures leaves less space for laryngoscope blade and subsequent airway visualization 2. Smaller straight laryngoscope blade can fit better into the child's mouth and lift soft tissues out of the way
Large tongue	1. Most common cause of airway obstruction
Large adenoids	1. Blind nasotracheal intubation contraindicated in children < 9 years secondary to large adenoids and potential to bleed 2. Oropharyngeal airway should not be inserted upside down and turned
Anterior and cephalad airway	1. Acute angle between epiglottis and anterior glottic opening makes nasotracheal intubation difficult 2. Alignment of different airway axes is often better accomplished with a straight blade than a curved blade
Long floppy epiglottis	1. Epiglottis can block visualization of the airway. A straight blade, with a narrower tip can be used to lift it out of the way.
Cricoid ring is narrowest part of the pediatric airway	1.Historically, uncuffed ETTs were recommended secondary to possible tissue necrosis from inflated balloon. 2. New data support the use of new cuffed ETTs, which decrease air leak and improve ventilation
Pediatric airway smaller, shorter, and delicate	1. Pediatric airway more prone to obstruction, compression 2. Right main stem intubation, and tube dislodgement are more common
Nares smaller; Infants up to 6 months of age are obligate nasal breathers	1. Small nares cause increased resistance to airflow especially when narrowed by secretions. 2. Compression of nares, can cause significant respiratory obstruction
Chest wall pliability	1. Children can have increased lung parenchymal damage with few outward signs.
Diaphragm is the main muscle of breathing	1. Abdominal trauma and distention can cause or contribute to severe respiratory compromise
Small cricothyroid membrane	1. Cricothyroidotomy contraindicated in children younger than 8 years

pallor, cyanosis, or delayed capillary refill) also will aid the recognition of respiratory distress and impending respiratory failure in a child.[2]

Management of the Pediatric Airway

Positioning. In a spontaneously breathing child, the airway should be optimized by placing the child's head in the sniffing position while maintaining neutral alignment of the cervical spine (*Figure 2*). Often a shoulder roll in an infant is recommended to help in obtaining a sniffing position. Due to the prominence of the tongue, the chin lift or jaw thrust maneuver combined with bimanual inline spinal immobilization may be necessary to maintain an unobstructed airway. The mouth and oropharynx should be cleared of secretions or debris, and supplemental oxygen should be administered. If the child's airway or ventilation is compromised, then mechanical methods may be necessary. Before attempts to mechanically establish an airway, the child should be pre-oxygenated.

Airway Adjuncts. Positioning alone may not be enough to keep the tongue from obstructing the airway. The nasal and oral airways are common airway adjuncts used in children.

Oral Airway. The oral airway is contraindicated for use in children who are conscious because it can trigger the gag reflex; but in an unconscious patient it may relieve upper airway obstruction. The appropriate oral airway will extend from the level of the incisors in the child's mouth to just anterior to the angle of the mandible. Placement of the oral airway by depressing the tongue with a tongue blade is recommended. The practice of inserting the oral airway backward and rotating it into position is not recommended for pediatric patients. Trauma with resultant hemorrhage into soft tissues may occur. Note that if the oral airway is too small, the tongue may be pushed into the pharynx causing increased airway obstruction. Proper positioning should result in improved and easier ventilation.

Ventilation and Breathing. If spontaneous ventilation and breathing are not adequate, children with trauma must have ventilatory assistance. Bag valve mask (BVM) ventilation can be successful; however, BVM ventilation may contribute to gastric distention with air and potential regurgitation and aspiration.[10]

Bag Valve Mask. Usual spontaneous tidal volumes vary from 5 to 8 mL/kg in infants and children.[2] Although most BVM devices are designed to limit the amount of pressure that can be exerted manually on the child's airway, the physician must minimize the potential for iatrogenic bronchoalveolar injury or development of a pneumothorax. Remember that self-inflating BVM devices will not deliver oxygen unless squeezed.[2] Putting this type of BVM device over the face of a spontaneously breathing child without squeezing the bag will result in a lack of oxygen delivery to the child.

If airway obstruction occurs and BVM ventilation cannot be achieved, the airway should be re-positioned. Jaw thrust or chin lift may be used, but chin tilt should be avoided in the setting of a suspected cervical spine injury. If repositioning does not succeed, an airway adjunct may be needed. Due to the relative size of an

Figure 2. Positioning of the Child for Ventilation

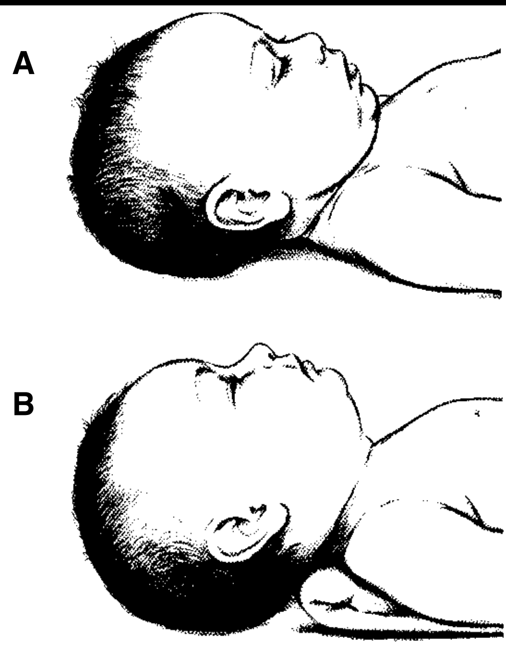

Figure 2. Positioning fo the Child for Ventilation.
A: Incorrect position with neck flexion. **B**: Correct position for infant. Note that the external ear canal is anterior to the shoulder.

Adapted with permission: Cote CJ, et al. *A Practice of Anesthesia for Infants and Children.* Philadelphia: WB Saunders;1993.

adult's hand to a child's neck, it is easy for a practitioner to accidentally apply additional pressure to the child's neck and cause further obstruction of the airway. The optimal placement of the hand is to apply the index finger to the mask, the middle finger to the mentum, and the ring and little finger to the bony angle of the mandible.[7]

Equipment. Equipment size changes with age. The ED physician caring for a child with trauma must have immediate access and knowledge of the appropriate sized equipment to use, as well as a systematic organization of this equipment. Length-based resuscitation methods provide accurately sized equipment and medication doses, and the most common form used is the Broselow tape. The Broselow tape should be measured with the red arrow at the patient's head and the color-coded section at the patient's heel. Color-coded carts and resuscitation supplies that correspond to the Broselow tape color-coded system have been shown to be more efficient than previous standard organization systems.[15]

A recent small study looked at common problems with the Broselow tape. The most common problem stemmed from holding the tape in the wrong direction: Specifically, the wrong end was put at the top of the patient's head. In several cases, clinicians had difficulty using the Broselow tape to determine the correct medication and equipment size to use. The older version of the Broselow tape had two white-colored sections, one of which was at the top and was not an actual dosing zone. The newest version has corrected this by making the zone closest to the head gray in color.[16]

ETT size can be estimated by comparing the diameter of the ETT to the size of the nail on the child's fifth finger, or calculated by the formulas:

Uncuffed ETT size: (Age in years)/4 +4

Cuffed ETT size: (Age in years)/4 +3

Most ETTs have a mark at the end of the tube that indicates the point of the tube that should be just past the vocal cords. The appropriate ETT depth of insertion in centimeters can be calculated by the formula: ETT depth cm = 3 × ETT size.

Laryngoscope Blades. Straight blades are easier to insert in the child's mouth, but the thinness of the straight blade can make moving and retracting a large tongue difficult. The curved laryngoscope blade is larger and bulkier than the straight blade, but it retracts the tongue more easily and may be useful in certain pediatric populations when the tongue is larger or bulkier than usual.

Endotracheal Intubation

Endotracheal intubation is performed to achieve definitive airway management. It is indicated in acute respiratory failure, as well as for airway protection, to decrease the work of breathing and for some therapeutic interventions (e.g., closed head injury with increased intracranial pressure). (*See Table 3.*) Almost half of endotracheal intubations in children are for trauma, with head injury being the single most common indication for intubation in children (25% of cases).[17-18]

Rapid sequence intubation (RSI) is the use of a systematic protocol involving sedatives and neuromuscular blocking agents to increase chances of a successful intubation, decrease risks of aspiration, and to avoid increases in intracranial pressure for head injured patients. Numerous studies have demonstrated that intubation without paralysis and with or without a sedative has a lower success rate in children and adults, as well as a higher complication rate than RSI.[17,19,20]

The ten steps of RSI include 1) a brief history, 2) preparation, 3) monitoring, 4) preoxygenation, 5) premedication, 6) assisted ventilation and cricoid pressure, 7) sedation, 8) paralysis, 9) intubation, and 10) confirmation of tube placement.[21] (*See Table 4.*)

Major differences between pediatric and adult RSI include the steps of preoxygenation and RSI pharmacy. Preoxygenation with the patient breathing 100% oxygen spontaneously for 5 minutes will 'washout' all the nitrogen in the lungs, providing the patient with an oxygen reserve. An adult patient can tolerate up to 5 minutes of apnea without developing hypoxia. A child has smaller lungs and higher metabolic needs than an adult; often times children can tolerate only 2-3 minutes of apnea before developing hypoxia.[18]

RSI pharmacy involves a choice of different pre-medications, sedative agents, and paralytic agents depending upon the clinical scenario. Important considerations are the presence of increased intracranial pressure and hypotension. Areas of controversy in pediatric RSI include the use of pre-medications, the use of etomidate as an RSI sedative, and the use of succinylcholine as a paralytic agent.

Premedications

RSI premedications include pharmacologic agents that are intended to blunt the cardiovascular stimulation of intubation; decrease intracranial pressure; decrease bradycardia, which can be caused by succinylcholine; decrease airway secretions; and prevent muscular fasciculations caused by depolarizing neuromuscular blocking agents. Succinylcholine has been demonstrated in studies to cause bradycardia, and atropine has been shown to effectively block it. However, it is unclear if the etiology of the bradycardia stems from the medication itself or from the vagal response to intubation.[21,22]

Lidocaine is used widely to mitigate increased intracranial pressure in head injured patients. However, its use is controversial with little or conflicting evidence as to its effects on intracranial pressure.[18,20,23] Although lidocaine also can cause complications of hypotension and dysrhythmia, it is customarily given as pretreatment for RSI in the setting of head injury.

Opiate analgesic agents (e.g., fentanyl) have been advocated to reduce adverse hemodynamic and intracranial pressure effects of intubation,[24] although the data for this use are scant. Opiates can cause hypotension in trauma patients. In addition, fentanyl, in particular, may be associated with chest wall rigidity, especially when given as a bolus.

Anticholinergics. Atropine (0.01-0.02 mg/kg IV min 0.1 mg; max 1 mg) has been recommended to prevent bradycardia resulting from vagal stimulation. Currently, it is recommended that atropine be used universally in children younger than 1 year to minimize the chance of bradycardia in response to laryngoscopy.[2] In children older than 1 year, atropine should be given only if succinylcholine also is being used. In adolescents and adults who receive a second dose of succinylcholine and in any patient with bradycardia, atropine should be given 1-2 minutes prior to intubation.[2] There is currently more discussion about the validity of the use of atropine.[25-27] However, there have been no definitive studies to support discontinuation of atropine with succinylcholine in children.

Defasciculating Agents. The use of one-tenth the dose of a nondepolarizing muscle relaxant 1-3 minutes before succinylcholine administration will decrease muscular fasciculations. This is not necessary in children 5 years or younger.[20] However, even in older patients administration of a defasciculation agent adds time and complexity to the RSI, and may not be clinically indicated in the management of an acute traumatic airway.[25]

Sedative Agents. Etomidate (0.2-0.3 mg/kg IV) is an imidazole hypnotic agent. It does not cause hypotension or increased intracranial pressure, making it the ideal hypnotic agent for the multitrauma patient with or without potential head trauma. Previously, the use of etomidate has been tempered because it causes adrenal suppression, even after a single dose. However, the clinical significance of this adrenal suppression is unknown.[28] In a recent study, it was found to be safe for pediatric patients with no clinically important adrenocorticoid suppression and a low incidence of clinically important hypotension.[29] Side effects include vomiting and myoclonic jerking, which are not usually clinically significant. The National Emergency Airway Registry (NEAR), a multicenter, prospective emergency medicine led registry, documented etomidate use in 42% of RSI procedures.[18] However, despite the growing amount of data to support the utility and safety of etomidate in children, it currently is not FDA approved in the pediatric population.

Table 3. Indications for Endotracheal Intubation

ACUTE RESPIRATORY FAILURE
PO_2 <60 or Low SaO_2
PCO_2 > 50
Apnea
Hypoventilation
AIRWAY PROTECTION
Neurologic dysfunction (seizure, coma)
Loss of protective airway reflexes
Copious secretions, blood
Upper airway obstruction, airway edema or trauma
DECREASED WORK OF BREATHING
Hemodynamic instability
Metabolic acidosis
SPECIAL SITUATIONS/THERAPEUTIC INTERVENTION
Management of ICP
Conduction of necessary diagnostic tests (e.g. CT head)

Paralytic Agents. Paralytic agents are a critical component of RSI. In one prospective study, intubation occurred successfully in 99% of adult patients with paralysis and in 82% without paralysis.[19] In children, intubation was successful 78% of the time with paralysis and only 44% of the time when only a sedative was used.[17] Although paralytic agents are essential to creating the optimal conditions for intubation, the potential complications of neuromuscular paralysis and inability to secure the airway must be seriously considered. Clinicians seem to use paralytic agents less frequently in children. In one study, paralytic agents were used for only 40% for pediatric intubations in children younger than 1 year.[18]

Paralytic agents are categorized into depolarizing and nondepolarizing agents. Depolarizing agents initially depolarize the motor endplate by acting at the acetylcholine receptor and induce contraction, manifested by fasciculations. Succinylcholine is the only depolarizing agent clinically available. The acetylcholine receptor is blocked, and binding is prevented until the succinylcholine is degraded by acetylcholinesterase. Nondepolarizing agents competitively inhibit the acetylcholine receptor. These agents are then degraded in the liver.

Succinylcholine (1.0-2 mg/kg IV) is the classic depolarizing agent. Its onset is rapid (30-60 seconds), and its duration is short (5-10 minutes). Succinylcholine may cause a rise in intracranial pressure or intraocular pressure, as well as an increase in airway secretions. These increased pressures caused by succinylcholine

Table 4. Rapid Sequence Intubation Modifications for Children

PHASE OF RSI	PEDIATRIC MODIFICATION
History and anatomic assessment (AMPLE)	
Preparation	Use length-based system for equipment organization, size determination, and medication dosages
Monitoring	Pediatric size EZ cap
Preoxygenation	1. 8 vital capacity breaths with high flow oxygen can be used if 5 minutes of preoxygenation not available. 2. Although adults may tolerate 4-5 minutes of apnea before hypoxia develops, children may tolerate only 2-3 minutes of apnea.
Premedication	1. Avoid bradycardia: - Atropine (0.01-0.02 mg/kg IV; min 0.1 mg; max 1 mg) 2. Avoid increased ICP: - Lidocaine
Assisted ventilation and cricoid pressure	
Sedation	1. Etomidate 0.3 mg/kg - Least cardiovascular effects 2. Ketamine 1-4 mg/kg - Contraindicated with increased ICP, but good to maintain blood pressure 3. Midazolam 0.05-0.1mg/kg* 4. Thiopental 0.5-4 mg/kg* * Can cause hypotension
Paralysis	1. Depolarizing neuromuscular blockage - Succinylcholine 1-2 mg/kg 2. Non-depolarizing neuromuscular blockade - Rocuronium 0.6 -1.2 mg/kg - Vecuronium 0.1-0.2 mg/kg
Intubation	
Confirmation of endotracheal tube placement	1. End-tidal CO_2, 2. O_2 saturation 3. EASY_CAP: - Purple: Unsuccessful - Tan: Questionable intubation - Yellow: Successful

are probably modest, and the clinical significance is controversial.[25,27] Complications of succinylcholine use include case reports of asystole, malignant hyperthermia, and hyperkalemia.[21,30]

Succinylcholine may induce an increase in serum potassium levels of approximately 0.5-1.0mEq/l.[30] This increase can be caused by two mechanisms. The first results from depolarization of the muscle and potassium leak. Although the significance of the increase in potassium level secondary to this mechanism may be less clinically important than previously documented, the effect is real.[31,33] The use of succinylcholine is contraindicated in patients who could have hyperkalemia (including patients with renal failure) or a significant burn or crush injury greater than 48 hours old. Succinylcholine also may cause hyperkalemia by receptor stimulation in patients with up-regulation of acetylcholine receptors and subsequent exaggerated release of potassium. This mechanism of hyperkalemia could occur in patients with spinal cord injury and neuromuscular diseases with wasting (e.g., muscular dystrophy).[31-39]

Rocuronium (0.6 to 1.2 mg/kg IV) is a nondepolarizing neuromuscular blocker. It has the shortest onset of all the nondepolarizing agents. The onset of rocuronium is almost comparable to succinylcholine (60-90 seconds) with a duration of action of 30-45 minutes. Meta-analysis showed that although rocuronium was inferior to succinylcholine in providing excellent intubating conditions, it was comparable to succinylcholine in inducing clinically acceptable intubating conditions.[34] A recent report looked at the use of rocuronium and found it to be safe compared with vecuronium and an effective agent for RSI when succinylcholine was contraindicated.[35,36]

Currently, there is controversy over whether to use succinylcholine, a depolarizing neuromuscular blocker, as the main paralytic agent in children.[25] However, despite the complications described in the literature, there is also a consensus that succinylcholine is the most reliable and rapid paralytic agent available for RSI. In patients in whom the use of succinylcholine may be unsafe (e.g., personal or familial history of malignant hypertension, skeletal muscle myopathies, extensive denervation of skeletal muscle or upper motor neuron injury), rocuronium is a documented safe alternative.

Cricoid Pressure

Cricoid pressure improves visualization of the vocal cords because the larynx will be displaced posteriorly; it also decreases the risk of aspiration. Cricoid pressure should be initiated as soon as sedation is started. Cricoid pressure prevents passive aspiration.[2, 37] If active vomiting occurs, cricoid pressure is to be lifted and the patient rolled to the side because esophageal perforation can occur.[38]

Intubation

Because the radius of the airway is inversely proportional to the resistance of flow, even a small amount of airway edema will result in a significantly increased resistance to flow causing increased work of breathing and possibly signs of respiratory distress in the pediatric patient. A child with any kind of upper res-

Table 5. Appropriate-Sized LMA Based Upon Patient Weight

WEIGHT (KG)	LMA SIZE
<5	1.0
5-10	1.5
10-20	2.0
20-35	2.5
35-55	3.0*
>55	4.0

* An ETT can be inserted into all LMAs, but removal of the LMA and extubation is tricky, often requiring destruction of the LMA. Separate intubating LMAs, designed for intubation through the LMA and subsequent removal of the LMA, exist for size 3.0 and above.

Adapted from Infosino A. Pediatric upper airway and congenital anomalies. *Anesthesiol Clin North Am* 2002;20(4):747-766.

piratory infection or repeated attempts at intubation may have an additional degree of restriction on the airway.

Any single intubation attempt should last no longer than 30 seconds to prevent profound hypoxemia.[2] Children, and especially infants, have smaller lung volumes and higher oxygen demands than adults, therefore, they consume their respiratory reserves more quickly than in adults.

Confirmation of Intubation

Disposable capnographic devices, (e.g., Easy-Cap) and end-tidal carbon dioxide monitors are mandatory adjuncts to evaluate endotracheal intubation. Visualization of the ETT being passed through the vocal cords, confirmation of proper placement by auscultation over the lung fields and the epigastric area, and vapor in the ETT are the initial nondefinitive confirmations of successful endotracheal intubation.; secondary confirmation is necessary.

Although Pediatric Advanced Life Support (PALS) guidelines do not recommend other confirmation devices in infants and children, devices such as the self-inflating rubber bulb have been found to be highly sensitive and specific for detection of esophageal intubation in adults. Two recent studies showed that the bulbs have high sensitivity and specificity in the pediatric patient population.[39,40]

Rescue Procedures

If RSI is started and the patient cannot be endotracheally intubated, the airway must be secured by other means. Most patients can be ventilated with BVM devices until the neuromuscular blockade has worn off. However, care must be taken not to inflate the stomach; a nasogastric tube should be placed to decompress the stomach.

Blind nasotracheal intubation should not be performed in children younger than 9 years.[20] It requires blind passage around a relatively acute angle in the naropharynx toward the anterosuperiorly located glottis, making intubation by this route difficult. The added potential for penetrating the cranial vault or damaging the more prominent nasopharyngeal adenoidal soft tissues, which results in hemorrhage, makes this procedure ill advised in a child. Additionally, it is a rare child who can cooperate with a nasotracheal intubation.

Awake intubations are performed on patients who potentially may be difficult to intubate and ventilate.[24] This procedure may be difficult in the pediatric patient due to behavioral and developmental inability to cooperate.

The laryngeal mask airway (LMA) can be an alternative means of securing the airway until a definitive airway can be obtained.[20,24,41-44] The LMA is a tube with a silicon cuffed mask-like portion on the distal end. It is inserted into the pharynx until resistance is encountered due to the hypopharynx. The mask is then inflated, sealing off the hypopharynx from the airway. The distal portion of the LMA is ideally situated above the airway, allowing ventilation and oxygenation to be performed. While the LMA does not optimally control the airway, it may be more protective than the BVM.[2,45] There is increasing literature, mostly in the form of case reports, documenting airway management success with LMA in children with abnormal anatomy in whom endotracheal intubation was difficult or impossible.[21] Intubation is possible through LMAs. Table 5 lists the LMA size based upon the child's weight.

Needle cricothyroidotomy with jet insufflation is an appropriate temporizing technique when airway access and control cannot be accomplished by BVM or orotracheal intubation in children younger than 8 years. The procedure consists of inserting a 12-14 gauge catheter through the cricothyroid membrane. The catheter is connected to a high pressure oxygen source (50 psi) and a one second burst of high pressure oxygen is given, followed by a 3-4 second period to allow for exhalation. Care must be taken to hold onto the catheter so that it stays in position. The catheter also may kink secondary to the high pressures; nonkinking catheters with metal spirals are availble. If the patient cannot spontaneously exhale, then jet insufflation is contraindicated. Chest movement should be used as a visible indicator of adequate ventilation. This procedure provides oxygenation but does not provide adequate ventilation, and progressive hypercarbia may occur. Complications include tension pneumothorax.

Emergency cricothyroidotomy is the airway of last resort in an adult with difficult airway. It is used often in patients with extensive facial and upper-airway injury. Cricothyroidotomy is difficult in children and contraindicated for an infant or small child. It only can be performed in an older child in whom the cricothyroid membrane is easily palpable, usually by the age of 8-10 years.[21] There are no data specifically on the complication rates in the pediatric population. But the overall complication rate of cricothyrotomy depends upon technique. In one recent small study, there were no reports of complications associated with the rapid four-step technique when performed in the ED; nonrapid four-step cricothyrotomies in the ED had an associated complication rate of 25%.[46]

Other alternative airways in children have similar indications and procedures as in adults. Retrograde intubation has been described in adults and is a rapid and safe technique; the only true contraindication is a patient who cannot be adequately oxygenated or ventilated.[24,47] The cricothyroid membrane is identified and pierced with an 18-gauge needle aimed cephalad. When air is aspirated, a guidewire is threaded through the needle until the proximal end emerges in the mouth.[21,24] The needle is removed, and a plastic sheath is passed over the wire until resistance is met. Then, the ETT is advanced over the wire, and the wire and sheath are removed from the mouth.[24] In children, a 20-gauge IV catheter with a 0.0021-inch J wire is adequate.[21] Retrograde intubation sets are available, however, an 18-gauge or larger needle and 80 cm J tipped guidewire can be used.[24] If using a central line kit, care must be taken that the J wire is of adequate length.

Lighted stylet, bullard larygoscope, ETT introducer, and fiber optic laryngoscope are all alternative airway techniques that may be used in a child with a difficult airway.[24]

Special Circumstances

Head Trauma. Closed head injury is the most common type of injury seen in pediatric trauma, and consummate airway management is necessary to optimize functional outcome.[5] The outcome of head trauma in children is better than in adults, but the outcome in children younger than 3 years is worse than that of a similar injury in an older child.[14] This difference is probably because young children are particularly susceptible to the effects of secondary brain injury that may be produced by hypovolemia and hypoxia. Maintaining oxygenation and preventing hypercarbia are critical in managing the pediatric head-injured trauma patient.

Cervical Spine Injury. Although the overall incidence of cervical spine injury is low, weak neck muscles, a higher fulcrum (C2-C3), and poor protective reflexes in children contribute to higher level cervical spine injuries than in adults.[20] In addition, cervical spine injuries may not appear on radiographs, therefore, there must be a high suspicion for cervical spine injuries in children with trauma.[5] Cervical spine immobilization may make airway management more difficult. The chin lift and jaw thrust maneuvers, as well as airway adjuncts, must be used in lieu of the head tilt. The larger occiput also may make immobilization of the child's head, neck, and spine in neutral position more difficult (*Figure 2*).

Laryngeal Injury. The difference in laryngeal anatomy in "position, consistency, size and shape" explains the types of injury that occur in children.[48] Laryngeal injuries are less common in children than in adults because of the relatively high location of the larynx in the neck, which allows the airway to be protected by the mandibular arch. A child also has a relatively short neck compared with that of an adult.[49] Up to 80-95% of serious laryngeal injuries in children occur in adolescents, secondary to blunt mechanisms typically resulting from accidents involving motorcycles, snowmobiles, water craft; and clothesline and direct blows during karate, snowboarding, and skating.[48,50] Because of the overall shape and smaller size, the pediatric patient will tolerate traumatic disruption less well than an adult.[48]

A high degree of suspicion is required to diagnose a laryngotracheal separation. Laryngotracheal separation commonly occurs within 2-3 cm of the carina.[49] In the ED, diagnostic assessment should include assessment of airway sounds (e.g., stridor, hoarseness, aphonia, cough, hemoptisis, respiratory distress), cyanosis, subcutaneous air, neck hematoma or tenderness, tracheal deviation, and cartilagenous stepoffs. If feasible, flexible fiberoptic endoscopy is preferred before oral tracheal intubation to avoid complete disruption of the larynx. However, if airway management is emergent—given that cricothyroidotomy is contraindicated in children younger than 10 years—and jet insufflation is fraught with complications, orotracheal intubation, if possible, is the preferred and relatively safe airway management procedure prior to definitive exploration and repair in the operating room.[51]

Tracheobronchial Injuries. Tracheobronchial injuries are also rare.[51] The low incidence is due to the elasticity of the mediastinum and tracheobronchial tree, which allows it to be compressed without causing injury.[51] In adults, bronchial injuries tend to occur in the right-sided main stem bronchus but this predominance is not seen in the pediatric population.[52,53] Therefore, these types of injuries are seen only with major accidents (e.g., falls from high levels or being thrown out of motor vehicles).[53] If tracheobronchial injuries are suspected, endoscopy is mandatory.[49,54]

Blunt Thoracic Injuries. Blunt thoracic injuries are the second leading cause of death from pediatric trauma.[12] Injuries to the vital thoracic structures—not including lung contusions—have a mortality rate of greater than 50%. Multiple studies have shown the most common injury with pediatric blunt chest trauma is a pulmonary contusion. Other common injuries included rib fractures, pneumothorax, and hemopneumothorax. In one study, 25% of the pneumothorax cases were tension pneumothorax.[13] The high incidence of tension pneumothorax may be due to the increased pliability of the pediatric chest.

Children with Special Health Care Needs. Children with apparent Down syndrome facies who undergo trauma should be managed carefully. Children with Down syndrome have a relatively complicated airway due to a large tongue and relative hypotonia. A curved blade may facilitate moving the tongue out of the way. The trachea is usually smaller than in other children of the same age, necessitating an ETT 1-2 sizes smaller than calculated.[55] Atlanto-axial instability also may be present, making them more prone to cervical spine injury.[15] Cervical spine immobilization is particularly important in these cases to prevent further injury.[20] In some cases, an LMA may be the best airway management technique. Children with congenital problems (e.g., Pierre Robin syndrome, tracheomalacia, or cleft palate) who are involved in trauma may have a predictably difficult airway. An LMA may be the best option in these cases because surgical airways are contraindicated in the young child.[21] As stated in the section on RSI, children with neuromuscular diseases should be intubated with a nondepolarizing neuromuscular blockade.

Nonaccidental Trauma. When managing the traumatic airway, the practitioner should always consider the mechanism of the trauma and the possibility of nonaccidental trauma.

Summary

Understanding the differences between the adult and pediatric airway and how these affect airway management in trauma is of critical importance in the timely and appropriate resuscitation of the pediatric trauma patient. This report highlights the specific anatomical and physiologic features unique in children and the implications for pediatric trauma management.

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CE/CME Instructions

Physicians and nurses participate in this continuing medical education/continuing education program by reading the article, using the provided references for further research, and studying the questions at the end of the article. Participants should select what they believe to be the correct answers, then refer to the list of correct answers to test their knowledge. To clarify confusion surrounding any questions answered incorrectly, please consult the source material. **After completing this activity, you <u>must</u> complete the evaluation form provided and return it in the reply envelope provided in order to receive a certificate of completion.** When your evaluation is received, a certificate will be mailed to you.

CE/CME Objectives

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

a.) discuss conditions that should increase suspicion for traumatic injuries;
b.) describe the various modalities used to identify different traumatic conditions;
c.) cite methods of quickly stabilizing and managing patients; and
d.) identify possible complications that may occur with traumatic injuries.

Physician CME Questions

1. At what age is a child's airway considered to be equivalent to an adult's airway?
   A. 5 years
   B. 8 years
   C. 12 years
   D. 16 years

2. Which one of the following paralytic agents is the first choice for pediatric rapid sequence intubation?
   A. Rocuronium
   B. Vecuronium
   C. Succinylcholine
   D. Isradipine

3. An 8-year-old male lost his grip while climbing over a fence and fell chest forward into the fence. He was brought to the emergency department by his mother. He has a puncture wound to his left chest made by the top of the fence. Initially, the patient was breathing comfortably with equal breath sounds. While awaiting chest x-ray, his breathing pattern changed. What would be the first mechanism of respiratory compensation in a pediatric patient in respiratory distress?
   A. Increased work of breathing
   B. Wheezing
   C. Tachypnea
   D. Head bobbing

4. You choose succinylcholine as your paralytic agent to intubate a 6-year-old child involved in a serious motor vehicle accident. Which one of the following medications is recommended before giving succinylcholine to this patient?
   A. Lidocaine
   B. Atropine
   C. Robinul
   D. Midazolam

5. An 8-year-old male with Down syndrome fell from the top of a play structure and hit his head on one of the platforms as he fell. Which

one of the following statements is true when considering intubation of a Down syndrome patient?
A. A straight blade may facilitate moving the tongue out of the way.
B. An ETT 1-2 sizes larger than calculated may be necessary for intubation.
C. These children are more prone to cervical spine injury.
D. An LMA is contraindicated in the Down syndrome population.

6. A 10-year-old female was brought in after falling in gymnastics class from the balance beam. The coach reported that she hit her head on the edge of the balance beam when she attempted to dismount. She arrived by ambulance wearing a cervical spine collar. When you initially examined her, she was responsive and cooperative to your questions with only complaints of pain on the neck. As you were finishing your primary survey, she became increasingly uncooperative and agitated. Which of the following is the *most* important initial step?
A. Re-assess her pupillary response
B. Re-assess her respiratory status
C. Prepare for intubation
D. Rush the patient for a CT scan

7. Which one of the following statements is true about the use of atropine in children?
A. Atropine is used in children younger than 1 year only if succinylcholine is the paralytic agent.
B. Atropine is not indicated for use in adolescents, except for bradycardia.
C. Atropine is given to prevent bradycardia resulting from vagal stimulation.
D. The correct dosing of atropine for a child is 0.1-0.2 mg/kg IV.
E. The maximum dose of atropine in the pediatric population is 2 mg.

8. A completely unresponsive 4-month-old child is brought into the emergency department by his parents. The parents reported he just suddenly "stopped breathing." You can see several bruises on his chest and head. You decide to intubate. Which one of the following procedures is appropriate for positioning this child for intubation?
A. Perform head tilt
B. Place a shoulder roll
C. Place the arms to the side
D. Extend the head back

9. When placing an oral airway in a child, which of the following statements is true?
A. For correct placement, insert the oral airway backward and rotate it into position.
B. Oral airways have no contraindications in the pediatric population.
C. Emesis may occur with oral airways in patients who are conscious.
D. For patients with relatively large tongues, use a smaller oral airway than recommended by age.

10. Which of the following statements regarding the preoxygenation phase of rapid sequence intubation of a child is true?
A. A child can tolerate up to 5 minutes of apnea before developing hypoxia.
B. Preoxygenation is the first step of rapid sequence intubation.
C. Five vital capacity breaths with high flow oxygen can be used if 5 minutes of preoxygenation is not available.
D. Any single intubation attempt should last no longer than 30 seconds.

Answers:
1. B
2. C
3. C
4. B
5. C
6. B
7. C
8. B
9. C
10. D

In Future Issues: **Ultrasound applications in the hypotensive patient**

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This issue of your newsletter marks the start of a new continuing medical education (CME) or continuing education (CE) semester and provides us with an opportunity to review the procedures.

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3. Cite methods of quickly stabilizing and managing patients; and
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Sincerely,

Brenda L. Mooney

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Vice-President/Group Publisher
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