ORIGINAL ARTICLE

Efficacy of Fiberoptic Laryngoscopy in the Diagnosis of Inhalation Injuries

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Background: A significant proportion of burn patients with inhalation injuries incur difficulties with airway protection, dysphagia, and aspiration. In assessing the need for intubation in burn patients, the efficacy of fiberoptic laryngoscopy was compared with clinical findings and the findings of diagnostic tests, such as arterial blood gas analysis, measurement of carboxyhemoglobin levels, pulmonary function tests, and radiography of the lateral aspect of the neck.

Objective: To determine if these patients were at risk for aspiration or dysphagia, barium-enhanced fluoroscopic swallowing studies were performed.

Design: Prospective study.

Settings: Burn intensive care unit in an academic tertiary referral center.

Main Outcome Measures: Need for endotracheal intubation and potential for aspiration.

Results: Six (55%) of 11 patients had clinical findings and symptoms that indicated, under traditional criteria, endotracheal intubation for airway protection. Visualization of the upper airway with fiberoptic laryngoscopy obviated the need for endotracheal intubation in all 11 patients. These patients also failed to evidence an increased risk of aspiration or other swallowing dysfunction.

Conclusions: In comparison with other diagnostic criteria, fiberoptic laryngoscopy allows differentiation of those patients with inhalation injuries who, while at risk for upper airway obstruction, do not require intubation. These patients may be safely observed in a monitored setting with serial fiberoptic examinations, thus avoiding the possible complications associated with intubation of an airway with a compromised mucosalized surface. In these patients, swallowing abnormalities do not manifest.

Arch Otolaryngol Head Neck Surg. 1998;124:1003-1007

INHALATION INJURY is defined as injury to the epithelial lining of the lower tracheobronchial tree and the lower airway. It is present in approximately one third of patients treated in burn centers.[1] Since the most immediate danger to patients with inhalation injuries is upper airway obstruction due to edema, early and even prophylactic endotracheal intubation based on clinical assessment is the standard conservative approach to treating these patients.[2] Signs of respiratory failure, unconsciousness, or the presence of major burns often make the diagnosis of severe inhalation injury obvious. Yet, patients without burns, stridor, hypoxemia, or major thermal injuries suspected of having an inhalation injury constitute a less defined subpopulation. Currently, diagnostic precision is difficult in identifying less severe injuries that do not require intubation. Unnecessary intubation places these patients at risk for damage to the larynx and subglottic regions; therefore, the patients with less severe inhalation injuries need to be identified to safely avoid intubation. Also, to our knowledge, there has never been a prospective analysis of the potential for patients with edema and a decreased range of motion of facial and cervical muscles to aspirate or to develop dysphagia after sustaining a less severe inhalation injury.

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RESULTS

Six (55%) of 11 patients had clinical findings and symptoms that suggested, without fiberoptic laryngoscopy, that they should be intubated for airway protection. In total, 8 patients (73%) presented with at least 4 signs and symptoms indicating a possible upper airway compromise. The history taken from the 11 patients revealed that 73% (8/11) were exposed to fire and smoke within an enclosed space such as a house or car. Clinical assessment showed the incidence of

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PATIENTS AND METHODS

From October 1996 to July 1997, 62 consecutive patients with suspected inhalation injuries were admitted to the Baltimore Regional Burn Center in Maryland. Inclusion criteria were exposure to fire and smoke within an enclosed space, singed facial hair, singed nasal vibrissae, facial burns, dysphonia or hoarseness, oral and/or nasal soot, cough, carbonaceous sputum, and swallowing difficulties. Exclusion criteria for this study were the presence of stridor (8 patients), altered mentation either previously existing or due to administered narcotics (19 patients), and burn injuries covering more than 15% of body surface area (13 patients) that mandated immediate protection of the airway by intubation. Noncompliance or leaving against medical advice (4 patients), facial palsy not permitting pulmonary function tests (1 patient), or intubation prior to admission to the burn unit (6 patients) also excluded patients from the study. Eleven patients (8 males, 3 females; mean ± SD age, 43 ± 16 years; age range, 12-88 years) participated in our study. Two patients were in their teens; 4 patients were in their third decade of life; 1 patient was in her fourth decade of life; 3 patients were in their fifth decade of life; and 1 patient was in the ninth decade of life. Of the 11 eligible patients, 2 had a history of mild asthma but denied the use of inhalers or other medication in the past. Eight patients were smokers. Three patients had no skin burns; the total body surface area burned in the remaining 8 patients ranged from 4% to 12%. No patient had sustained full-thickness facial burns.

On admission to the burn unit, each patient gave a history, with reference to the mechanism of injury, site of accident, loss of consciousness, and duration of smoke exposure. The location and percentage of total body surface area of all burns were recorded on standard Lund and Browder charts. An examination was performed to detect hoarseness or dysphonia as subjective changes of voice quality. Other recorded clinical parameters were the presence of cough, difficulties or pain with swallowing, singed facial or nasal hair, facial burns, loss of consciousness, carbonaceous sputum, and oral and/or nasal soot.

Blood samples were drawn to analyze arterial blood gases and to determine carboxyhemoglobin (COHb) levels. All patients underwent pulmonary function tests to obtain respiratory flow-volume loops. The flow-volume curves were considered to be abnormal and consistent with variable extrathoracic airway obstruction if both a flattened configuration of the inspiratory curve suggested diminished flow rates and a ratio of expiratory flow to inspiratory flow at 50% of the vital capacity (FEF_{50}/FIF_{50}) exceeding 1.0 was present. Other parameters were the mean forced expiratory volume in 1 second (FEV_1), and forced vital capacity (FVC). Radiographs of the lateral aspect of the neck were obtained and evaluated in view of possible soft tissue changes, especially since edema of the epiglottis similar to epiglottitis might be detected. Barium-enhanced video fluoroscopic swallowing studies were performed on patients with clinical symptoms consistent with possible dysphagia or aspiration on hospital day 2 to document and quantitate dysphagia or aspiration. Dysphagia was defined as the inability to accept and safely transport food and liquid from the mouth to the stomach. All 11 patients underwent laryngoscopy with a flexible fiberoptic laryngoscope (Olympus American Inc, Melville, NY). Local anesthesia in the nares consisted of the administration of 2% lidocaine spray or jelly. The attending physician, burn unit fellow, or otolaryngology senior resident performed all the fiberoptic examinations. The laryngeal examination results were recorded on videotape and were used for comparison if serial examinations were needed.

physical signs and symptoms to be highest for singed facial hair (91% [10/11]), dysphonia (82% [9/11]), and facial burns (73% [8/11]). Hoarseness was found in 55% (6/11) of the patients. Cough (55% [6/11]) and soot in the oral or nasal areas (45% [5/11])were also frequently seen (**Figure 1**).

Arterial blood gas analysis showed 2 patients to be hypoxemic on admission with a PaO_2 of 57 mm Hg and 59 mm Hg, respectively. These 2 patients had not received supplemental oxygen while being transported to the hospital. All other patients had significantly elevated levels of arterial partial oxygen pressures (183 ± 67 [mean ± SD] mm Hg). Carboxyhemoglobin levels were elevated in 4 patients (mean, 9.8%; range, 7.2%-14.9%).

Flow-volume curves showed significant abnormalities in 3 individuals. The FEF_{50}/FIF_{50} ratio exceeded 1.0 in 2 patients, indicating extrathoracic airway obstruction (FEF_{50}, 3.79 and 5.95; FIF_{50}, 3.18 and 4.38, respectively). One patient had a severe obstructive ventilation pattern with an FEV_1 that was 33.1% and an FVC that was 39% of their expected values. Sawtoothing, characterized by distinct regular oscillation of inspiratory or expiratory flow rates, was observed in 1 of the patients who also had an elevated FEF_{50}/FIF_{50} ratio. The remaining 8 patients showed no significant alteration of the FEV_1 (71.4 ± 23% [mean ± SD]) or FVC (75.5% ± 18%) from their predicted values.

Radiographs of the lateral aspect of the neck did not show soft tissue abnormalities in any of the patients. They were reviewed independently by a radiologist and members of the burn unit.

Findings of the fiberoptic laryngoscopy led to the division of patients into 2 groups. The first group consisted of 7 patients with minimal supraglottic mucosal edema, mild pooling of secretions, fully mobile true vocal folds, and visible ventricular folds. Inflammatory changes in these patients were not sufficiently severe to distort supraglottic structures or to compromise the airway lumen. Some of these patients were found to have soot present in the nares (**Figure 2**), oropharynx, nasopharynx, and even on the true vocal folds of the larynx (**Figure 3**). The second group consisted of 4 patients with moderate to severe supraglottic and/or glottic edema resulting in unequivocal distortion of upper airway structures. Edema was most pronounced in the area of the posterior glottis and interarytenoid space, thereby constricting the supraglottic or glottic aperture; however, the airway diameter was adequate to allow observation and did not require endotracheal intubation (**Figure 4**). Pooling of secretions in the piriform sinuses and posterior glottis was seen in 3 of the 4 patients. These patients were reexamined with the fiberoptic laryngoscope at 2-hour intervals to ensure that an adequate, stable airway was present. No patient required more than 2 serial fiberoptic examinations before a safe airway was seen.

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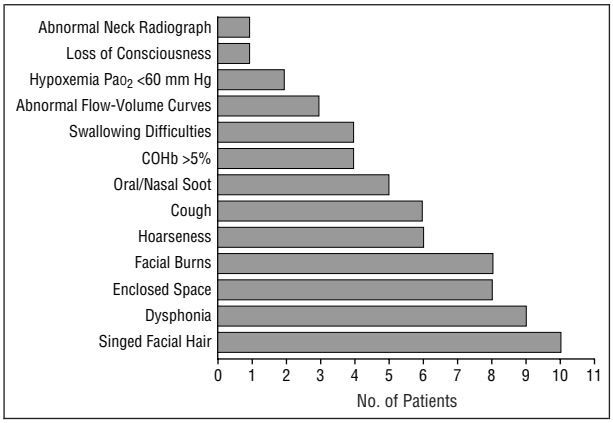


Figure 1. *Signs and symptoms of possible inhalation injury. The graph shows the incidence of clinical signs indicating an inhalation injury. Note that despite the occurrence of these symptoms, none of the 11 patients required intubation. COHb indicates carboxyhemoglobin.*

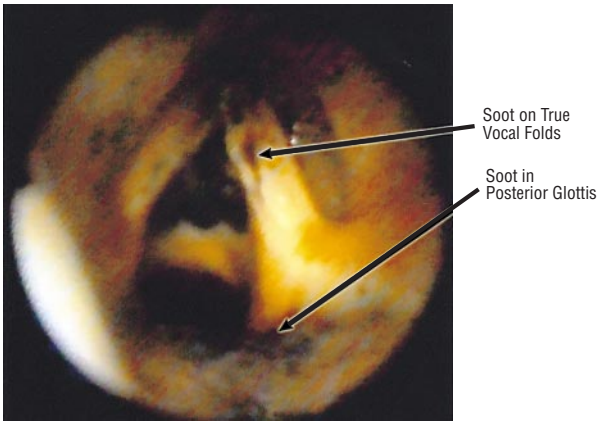


Figure 3. *Fiberoptic laryngoscopy revealed soot present in the larynx and normal laryngeal anatomy with little edema after inhalation of smoke in a house fire.*

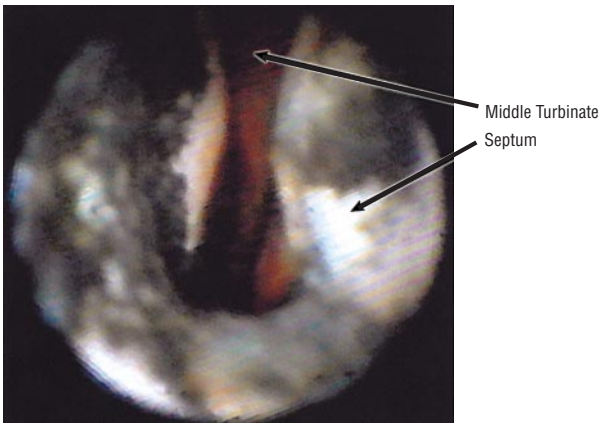


Figure 2. *View from the fiberoptic laryngoscope as it entered the nares of a patient with soot in the nostrils from inhaling smoke in an enclosed space.*

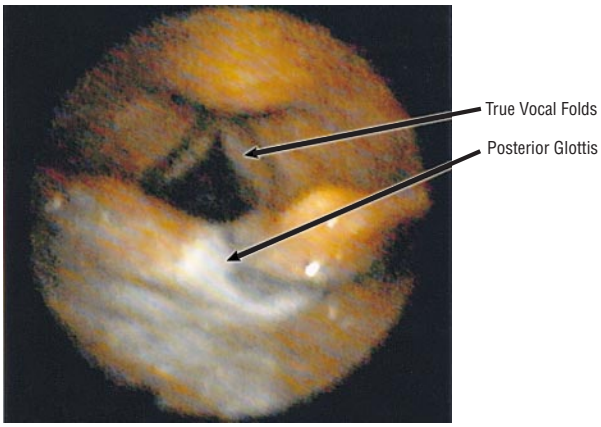


Figure 4. *View of larynx with edema and pooling of secretions in the posterior glottis. Serial fiberoptic laryngoscopies were performed in this patient.*

Patients complaining of swallowing problems underwent a barium-enhanced swallowing study. Four patients had mild pharyngeal pooling and delayed swallow responses. One patient had a moderately edematous epiglottis on fluoroscopic examination. However, aspiration or bolus stasis was not observed. In general, only mild swallowing dysfunction was seen, which could not be classified as significant dysphagia. No therapeutic interventions were indicated on the basis of these swallow studies.

COMMENT

Upper airway obstruction is a life-threatening complication of smoke-induced inhalation injury that may develop insidiously or progress rapidly, and therefore mandates prompt recognition and treatment, especially during the initial 24 hours after injury. Inhalation injuries are commonly divided into 2 categories: supraglottic and subglottic injuries. The mechanism of injury to the pulmonary parenchyma appears to be different from that of the supraglottis.[3] In the lung, toxic gases directly injure the alveoli, destroying the lung's surfactants, while impairing mucociliary function, which may lead to necrosis, ulceration, and sloughing of tissue. Edema and secretions frequently lead to bronchial obstruction, air trapping, and bronchopneumonia.[4] In the upper airway, particles such as soot, while not directly toxic, carry heat energy. These particles, in addition to absorbed chemicals, can cause intense mucosal burns, edema, and greatly increased mucus production in the upper airway. The physiological abnormalities of the supraglottis underline both the high vulnerability of the upper airway to thermal damage and the efficiency with which the glottis protects the lower airway. It is important to note that resuscitation of burn patients with intravenous fluid may further contribute to upper airway edema, mandating that the clinician be ever vigilant.[5]

The identification of patients in need of early endotracheal intubation can usually be made without difficulty in severe cases. However, in a retrospective study by Clark et al,[6] 51% of smoke-exposed patients did not require intubation. Unfortunately, there will be some patients with less severe inhalation injury who will progress to develop a critical upper airway. To address this possibility, at some burn intensive care units patients with multiple risk factors for inhalation injury are routinely intubated even though airway compromise is not present.[6] Prophylatic intubation of patients with suspected inhalation injury may place some at unnecessary risk for sequelae such as granuloma formation, paralysis of the

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vocal folds, bleeding, chondromalacia of the larynx, and tracheoesophageal fistula.[7,8] Also, the patient is unable to communicate and often must be heavily sedated. Colice et al[9] have proposed that inhalation airway injury and mechanical trauma from endotracheal intubation might have synergistic effects in producing tracheal stenosis. Historically, decisions about intubation have often been made by the attending burn surgeon, without visualization of the upper airway, making it unclear if intubation could have been avoided.[6] Most modern algorithms for airway management now use history, physical examination, bronchoscopy (with or without biopsies), and extent of burns to determine whether prophylactic intubation should be performed.[3] However, adding fiberoptic laryngoscopy may better define characteristics of patients with moderate inhalation injuries and may reduce unnecessary intubations.[10]

The role of flexible bronchoscopy has been clearly established as the most accurate way of diagnosing inhalation injuries, especially if biopsies of the lower airway are indicated based on endoscopic appearance.[11] However, approximately 25% to 50% of patients with positive findings on bronchoscopy will not develop significant respiratory complications.[12] Also, bronchoscopy may be uncomfortable for the patient and requires careful anesthesia of the larynx to avoid obstruction due to laryngospasm in a potentially inflamed airway. In patients in whom lower airway injury is unlikely, it may not be necessary to pass the endoscope below the true vocal folds. Some institutions may not have either the bronchoscope or the trained personnel available around the clock to perform bronchoscopy. Fiberoptic laryngoscopy is better tolerated by the patients, requires minimal medication, and is often more readily available.

Previous series have shown that fewer than 25% of patients with upper respiratory tract burns develop hoarseness.[13] Victims of inhalation injuries usually have no carbonaceous sputum at initial presentation, and half of them never produce any.[6] Worrisome findings, such as singed nasal vibrissae, predict inhalation injury in only 13% of patients, and 86% of patients with documented respiratory burns have no evidence of facial burns.[14] The absence of a skin burn should not be reassuring, since 12% of patients without a burn required intubation.[6] While there is a strong association between abnormal findings on oropharyngeal examinations in patients with abnormal bronchoscopic findings, the converse is not true.[15] This speaks to the importance of direct visualization of the upper airway. While a history of sustaining a burn or smoke inhalation in an enclosed space is important to note, it is not possible to predict the severity of an inhalation injury based on history alone.[6] In our study, 4 of 11 patients presented with all the common physical signs and symptoms that suggest the need for elective endotracheal intubation (singed facial hair, dysphonia/hoarseness, facial burns, cough, oral/nasal soot, and swallowing difficulties); 6 individuals had 6 signs and symptoms. In contrast to other authors,[16,17] we believe that the individual's clinical appearance (other than stridor, loss of consciousness, and altered mentation) contributes limited information to the assessment of the likelihood of a subsequent upper airway obstruction.

Chest radiography was not performed on admission in our patients, as reports have repeatedly shown that it is profoundly insensitive at predicting inhalation injuries.[12,18] Since supraglottic edema, especially of the epiglottis, may be detected by lateral view radiographs, these were obtained on admission to determine whether abnormalities or edema due to thermal damage could be diagnosed. In this series, no soft tissue could be detected on radiographs in any of the patients, including the 4 patients found to have significant supraglottic edema by direct visualization with fiberoptic laryngoscopy. In our series, lateral view radiographs of the neck do not appear to be a sensitive diagnostic tool in evaluating less severe inhalation damage.

Haponik et al[5] have shown that patients with suspected inhalation injury and normal admission flow-volume curves have a 94.1% posttest probability of not requiring intubation. Pulmonary function tests, while useful in assessing lower airway dysfunction, may reflect premorbid conditions and have low predictive value for determining the need for intubation.[15] Indeed, the positive predictive value of abnormalities such as sawtoothing or the FEF_{50}/FIF_{50} ratio for intubation is low at 32%. The effects of oral burns, anxiety, medication, and pain can further reduce the reliability of this strictly effort-dependent test in burn patients. Of note, 3 of our patients had produced significantly abnormal flow-volume curves, suggesting early intubation. This observation differs from that in the study by Haponik et al,[15] in which all patients who required intubation had reductions in their peak inspiratory flow rates. Also, 4 of 6 patients who required intubation had abnormal flow-volume curves that preceded abnormalities seen on fiberoptic examination. In our study, these patients with evidence of physiological pulmonary dysfunction were safely observed. Because pulmonary function tests have the ability to exclude lower airway injuries, we recommend their continued use. Alone, they appear to lack the diagnostic precision required for discriminating between upper airway obstruction necessitating intubation and inhalation injuries that may be observed.

A normal COHb level does not exclude the possibility that an inhalation injury has occurred.[19] An elevated COHb level indicates that inhalation of combustion products has occurred, and exposure to other toxic gases may be presumed. Levels above 5% to 10% are abnormal and may indicate a high probability of inhalation injury.[3] An important side effect of a high COHb level is that it renders pulse oximetry inaccurate, since the oximeter will "see" COHb as normal oxyhemoglobin.[20] Thus, a normal oximeter reading may be falsely reassuring. In our study, the COHb level had no correlation with upper airway problems. Arterial blood gas values may also be misleading; patients with "visible" burns usually arrive with unnecessarily high PaO_2 values, whereas others can often be markedly hypoxemic on admission. Like the measurement of COHb levels, the findings of arterial blood gas analysis can assist in the treatment of burn patients but have little predictive value in determining the degree of upper airway obstruction in less severe inhalation injuries.

The severity of the findings seen on fiberoptic laryngoscopy differed significantly from that predicted by

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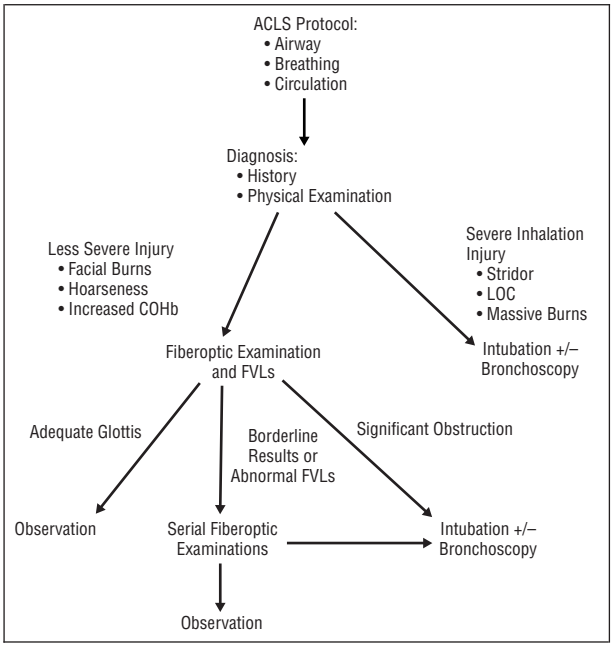


Figure 5. *Algorithm for airway management using fiberoptic laryngoscopy, flexible bronchoscopy, and flow-volume loops (FVLs) in patients with less severe inhalation injuries. ACLS indicates advanced cardiac life support; COHb, carboxyhemoglobin level; and LOC, loss of consciousness.*

clinical indexes in 4 patients in this study. The most common site of anatomical injury occurred at the arytenoid eminences and posterior glottis. Subtle impairment of vocal cord abduction due to interference with normal motion at the cricoarytenoid joint might account for the changes of flow rates and flow-volume patterns in patients with patent upper airways. However, direct visualization of the larynx was the best indicator of the extent of edema and inflammatory changes surrounding the glottic aperture. Our findings suggest that fiberoptic laryngoscopy should be included in the algorithm for airway management of cases in which less severe inhalation injuries are suspected (**Figure 5**). Connected to a video system, it can afford simultaneous observation by several members of the burn care team.

It is interesting that many of our patients (5/11) had soot demonstrated in the nares, oropharynx, and nasopharynx, and even in the larynx, on fiberoptic examination. Traditionally, soot in the upper airway raises concerns of airway obstruction, but from this small series it appears that soot may not be an accurate predictor of this, since all our patients were safely observed. Soot in the nares may be carried down into the larynx by mucociliary flow, without signifying an inhalation injury. Visibility of the entire upper airway by fiberoptic endoscopy allows this to be assessed.

The findings of barium swallow studies indicated that these patients with less severe inhalation injuries were not at risk for aspiration or other swallowing dysfunction. This conclusion was somewhat surprising, since some patients complained of dysphagia and had edema of the larynx. Although consisting of a small sample size, this study suggests that patients with less severe inhalation injuries do not require evaluation of their ability to handle oral intake. It would be interesting to evaluate patients who have sustained more severe inhalation injuries.

In conclusion, in this study, 6 patients may have been intubated based on pulmonary function test results and clinical parameters that are not sufficiently precise for documenting the degree of inhalation burns in the upper airway. In comparison with other diagnostic and clinical parameters, fiberoptic laryngoscopy provides significant advantages and predictive value of airway integrity. The patients in this series could be safely observed in a monitored setting with serial fiberoptic examinations. Increased use of fiberoptic visualization of the airway may allow for more efficient and accurate evaluation of inhalation injuries and avoidance of unnecessary prophylatic intubation in certain patient populations. Furthermore, in our study, aspiration and other swallowing abnormalities did not appear to complicate recovery.

Accepted for publication April 16, 1998.

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REFERENCES

1. Clark WR. Smoke inhalation: diagnosis and treatment. *World J Surg.* 1992;16:24-29.
2. Hantson P, Butera R, Clemessy JL, Michel A, Baud FJ. Early complications and value of initial clinical and paraclinical observations in victims of smoke inhalation without burns. *Chest.* 1997;111:671-675.
3. Emerson ET, Cruse CW. Inhalation injury and the burn patient. *J Respir Care Pract.* October-November 1996:41-46.
4. Pruitt BA, Cioffi WC, Shimazu T, Ikeuchi H, Mason AD. Evaluation and management of patients with inhalation injury. *J Trauma.* 1990;30(suppl):63-68.
5. Haponik EF, Meyers DA, Munster AM, et al. Acute upper airway injury in burn patients. *Am Rev Respir Dis.* 1987;135:360-366.
6. Clark WR, Bonaventura M, Myers W. Smoke inhalation and airway management at a regional burn unit: 1975-1983, I: diagnosis and consequences of smoke inhalation. *J Burn Care Rehabil.* 1989;10:52-62.
7. Reinhold H, Deloof T, Jortay A, Mathieu M, Vandesteene A. The risks of endotracheal intubation. *Acta Anaesth Belg.* 1978;29:69-84.
8. Peppard SB, Dickens JH. Laryngeal injury following short-term intubation. *Ann Otol Rhinol Laryngol.* 1983;92:327-330.
9. Colice GL, Munster AM, Haponik EF. Tracheal stenosis complicating cutaneous burns: an underestimated problem. *Am Rev Respir Dis.* 1986;134:1315-1319.
10. Talmi YP, Wolf M, Nusem-Horowitz S, Bar-Ziv J, Kronenberg J. Postintubation arytenoid subluxation. *Ann Otol Rhinol Laryngol.* 1996;105:384-390.
11. Masanes M-J, Legendre C, Lioret N, Maillard D, Saizy R, Lebeau B. Fiberoptic bronchoscopy for the early diagnosis of subglottal inhalation injury: comparative value in the assessment of prognosis. *J Trauma.* 1994;36:59-67.
12. Young CJ, Moss JM. Smoke inhalation: diagnosis and treatment. *J Clin Anesth.* 1989;1:377-386.
13. Moylan JA. Inhalation injury. *J Trauma.* 1981;21:720-721.
14. Moylan JA, Alexander LG. Diagnosis and treatment of inhalation injury. *World J Surg.* 1978;2:185-191.
15. Haponik EF, Munster AM, Wise RA, et al. Upper airway function in burn patients. *Am Rev Respir Dis.* 1984;129:251-257.
16. Brown DL, Archer SB, Greenhalgh DG, Washam MA, James LE, Warden GD. Inhalation injury severity scoring system: a quantitative method. *J Burn Care Rehabil.* 1996;17:552-557.
17. Clark CJ, Reid MM, Telfer ABM, Campell D. Respiratory injury in the burned patient: the role of flexible bronchoscopy. *Anaesthesia.* 1983;38:35-39.
18. Wittram C, Kenny JB. The admission chest radiograph after acute inhalation injury and burns. *Br J Radiol.* 1994;67:751-754.
19. Cohen MA, Guzzardi LJ. Inhalation of products of combustion. *Ann Emerg Med.* 1983;12:628-632.
20. Barker SJ, Tremper KK. The effect of carbon monoxide inhalation on pulse oximetry and transcutaneous PO_2. *Anesthesiology.* 1987;66:677-681.

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