Role of fiberoptic bronchoscopy in management of smoke inhalation lung injury

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Abstract Background: Smoke-inhalation injury (SII) is an unfavorable prognostic sign and a major cause of mortality in burn patients. Subsequently, it is important to diagnose early, determine accurately the injuries severity and to intervene early in these patients.

Objective: The objective of the present study is to evaluate the role of fiberoptic bronchoscopy (FOB) in management of SII as early diagnostic and prognostic tool.

Patients and methods: 57 patients suspected clinically to have SII were evaluated by submitting them to FOB. The following data were collected: total number of ventilator days, duration of intensive care unit (ICU) stay, pneumonia development, and patient outcome.

Results: 39 patients of 57 studied patients (68.4%) were proved bronchoscopically to have SII. Significant correlations were noted between bronchoscopic scoring and development of pneumonia ($R^2 = 0.344$; $P < 0.001$), total number of ventilator days ($R^2 = 0.479$; $P < 0.0001$) and ICU-stay ($R^2 = 0.211$; $P = 0.01$). Receiver operating characteristic curve analysis showed that an admission grade $P_3$ of bronchoscopic grading of SII predicted pneumonia development with a sensitivity of 77%, specificity of 92%, positive predictive value (PPV) of 85%, and negative predictive value (NPV) of 88%.

Conclusion: FOB may have a great value in evaluation, predicting prognosis and management of smoke inhalation lung injury. FOB obtained within few hours of admission was predictive of the total number of ventilator days and ICU-stay days and the development of pneumonia in patients with SII.

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Introduction

Inhalation injury is defined as an injury to the epithelial lining of tracheobronchial tree and lower airways [1]. Smoke inhalation injury is a major cause of morbidity and mortality in burn patients as it can trigger respiratory failure,
pneumonia, septicemia and ARDS [2]. It is, along with age and total burn surface area (TBSA), one of the three most significant predictors of death after thermal injury. The incidence of SII in burn patients who require hospitalization ranges from 20% to 30% [3–6]. This incidence increases with the size of TBSA up to that patients with >80% TBSA have a 75–93% incidence of SII [7].

The reported mortality in this population is around 30%. The incidence of respiratory failure is significant after inhalational injuries, with subsequent hypoxemia, pneumonia, respiratory failure, prolonged ventilatory support and extended hospitalization [3–6].

Enclosed-space fires, loss of consciousness, facial burns and large TBSA (>40%) should raise the suspicion of SII [8]. Ideally, all victims suspected of having SII should undergo fiberoptic bronchoscopy in order to evaluate the possibility of SII [9]. It is important that SII be diagnosed early, thus predicting the risk of pneumonia development, the duration of mechanical ventilation that may be required and facilitating an appropriate treatment strategy [10].

FOB is the gold standard for the diagnosis and evaluation of the severity of airway inhalation injury. In addition, fiberoptic bronchoscopy is often used for airway hygiene, removing particulate matter, mucus plugging obstructing bronchi, and the large quantity of inflammatory secretion that forms because of cellular necrosis [11]. Furthermore, fiberoptic bronchoscopy can predict the evolution of patients from a respiratory standpoint and can early detect the development of pneumonia [7]. Bronchoscopic grading through the abbreviated injury score (AIS), can classify thermal injury to the airway into 5 grades: 0 (no injury), 1: (mild injury), 2: (moderate injury), 3: (severe injury), or 4: (massive injury), with progressive decrease in PaO2/FiO2 as the grading is increased [12]. Higher AIS at admission in patients with extensive burns, correlated with a longer duration of mechanical ventilation, a trend toward a greater frequency of tracheostomy, and a longer ICU stay [13]. Classically, imaging tests such as chest X-rays and CT scans have little or no value in the diagnosis of SII [9,11].

Aim of the present study

The aim of the present study is to evaluate the role of FOB as a diagnostic, prognostic and therapeutic tool in the management of suspected smoke inhalation lung injury.

Patients and methods

The present prospective study was performed in Al-Babtin Centre for Burns and Plastic Surgery, Ministry of Health, state of Kuwait in the period from September 2012 to January 2014.

Patient selection

57 patients were enrolled in this study. These patients experienced smoke inhalation ranging from 10 to 120 min and suspected clinically to have SII.

Inclusion criteria were as follows:

- Patients aged more than 6 years of age.
- Any burned patient arriving incubated on MV or requiring MV within 48 h of admission AND clinically suspected to have SII (SII was suspected on the basis of smoke exposure within a confined space or soot at the nares, pharynx, larynx, facial burns).
- History of loss of consciousness.
- Large TBSA ≥40%.

Approval of our institutional Ethics Committees for the study protocol and written informed consent were obtained from each patient’s family before inclusion in the study.

Measurements

The clinical data recorded included age, sex, TBSA, associated injuries, chest radiograph, inhalation injury grade by bronchoscopy, initial arterial blood gas analysis, initial plasma carboxyhemoglobin (CO-Hb) level drawn to document the severity and duration of smoke inhalation, total number of ventilator days, duration of intensive care unit (ICU) stay, pneumonia development, and patient outcome. The study defined pneumonia as consolidation on the chest radiograph film, body temperature of >38 °C or <36 °C, white blood cell count of >12,000 cells/mm³ or <4,000 cells/mm³, and positive culture of sputum or endotracheal aspirates except for normal respiratory/oral flora. Extubation criteria were adequate when consciousness and capacity to maintain adequate arterial oxygen partial pressure/inspired oxygen fraction ratio (PaO2/FiO2 = P/F ratio) > 200 provided by using simple oxygen devices (FIO2 < 0.4 and with low levels of positive end-expiratory pressure (PEEP) of < 5 cm H2O).

Bronchoscopy

Bronchoscopy was performed according to a standardized protocol within 24 h of admission in all clinically suspected SII patients (57 patients). An Olympus BF260 videobronchoscope (Olympus Medical Systems Corporation; Tokyo, Japan) was used to perform all airway evaluations. Follow-up airway inspection was conducted according to the patients’ condition.

39 patients (68.4%) were proved bronchoscopically to have SII. The mean age of the patients with SII was 41 ± 32 (range, 9–73 years), 30 patients (76.9%) were males and 9 patients were females (23.1%).

The degree of bronchial mucosal status was evaluated by using a standardized bronchoscopic scoring system based on the abbreviated injury score (AIS) criteria, as previously published [14]. This scoring was graded into five categories (0: no injury; 1: mild; 2: moderate; 3: severe; and 4: massive injury) (Table 1).

Statistical analysis

SPSS software was used for statistical analysis. Data were tabulated and presented as mean ± SD. Pearson correlation analysis was used and P < 0.05 was considered as statistically significant.

Results

39 patients were proved bronchoscopically to have SII. The mean age of the patients with SII (39 patients) was 41 ± 32
that a bronchoscopic score of ≥3 had a sensitivity of 77%, specificity of 92%, PPV of 85%, and NPV of 88% for predicting pneumonia development. Seven patients had a bronchoscopic scoring of ≥3, and in three of these patients, pneumonia developed, with a mean hospital stay of 17 ± 1 days.

**Discussion**

The need to predict accurately the severity of SII is important. Accurate determination of the severity of SII would substantially contribute to effective treatment. The factors, which most significantly affect the prognosis of patients with burns, are: total body surface area burn, the age of the patient, and the presence of inhalational injury.

The reported incidence of inhalational injury burn complications occurs in 7–20% of patients requiring hospitalization [15]. Inhalational injury from burns can increase mortality by 20% and the occurrence of pneumonia by up to 40% [15]. Clinically significant inhalational injuries often do not manifest for three to four days after the exposure [16]. Complications of inhalational injury are not uncommon in patients with burns, coma, or other severe unexplained clinical symptoms [3,17,18]. There are many cases that are easily missed due to inhalation injury that can occur irrespective of burn injuries severity.

The severity of SII in the early phase immediately after the incident has rarely been investigated [13,19–23]. Some studies [20,21] suggested FOB for the diagnosis of SII. One study reported that bronchoscopy findings are correlated with SII severity, and thus bronchoscopy can be used to detect upper airways, and contribute to effective treatment. The factors, which most significantly affect the prognosis of patients with burns, are: total body surface area burn, the age of the patient, and the presence of inhalational injury.

We assessed bronchoscopic findings at admission and found that it were of early predictive value as regard the

<table>
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<th>Table 1</th>
<th>Abbreviated injury score (AIS) for bronchoscopic gradation of inhalation injury.</th>
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<tr>
<td>Grade</td>
<td>Findings</td>
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<tr>
<td>Grade 0: (no injury)</td>
<td>Absence of carbonaceous deposits, erythema, edema, bronchorrhea, or obstruction</td>
</tr>
<tr>
<td>Grade 1: (mild injury)</td>
<td>Minor or patchy areas of erythema, carbonaceous deposits in proximal or distal bronchi (any or combination)</td>
</tr>
<tr>
<td>Grade 2: (moderate injury)</td>
<td>Moderate degree of erythema, carbonaceous deposits, bronchorrhea, with or without compromise of the bronchi (any or combination)</td>
</tr>
<tr>
<td>Grade 3: (severe injury)</td>
<td>Severe inflammation with friability, copious carbonaceous deposits, bronchorrhea, bronchial obstruction (any or combination)</td>
</tr>
<tr>
<td>Grade 4: (massive injury)</td>
<td>Evidence of mucosal sloughing, necrosis, endoluminal obliteration (any or combination)</td>
</tr>
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</table>

(range, 9–73 years), 30 of the patients were males (76.9%), and 9 patients were females (23.1%). All the studied patients required mechanical ventilation either due to respiratory failure or prophylactic ventilation due to wide TBSA (>40%). 17 of the studied patients needed surgical intervention.

Mortality was 9 patients (23%). The causes of death in these patients were smoke inhalation (n = 2), pneumonia (n = 2), and sepsis (n = 5). The initial carboxyhemoglobin level was 19 ± 14% (range, 5–40%). 32 patients (82%) needed repeated FOB examination and repeated bronchoalveolar lavage (BAL) to remove secretions, slough and carbonaceous material till the airways became clear. After lavage, there was progressive improvement of all bronchoscopic findings. 30 patients survived and 9 patients died with mortality rate 23%. The cause of death in these patients was smoke inhalation (n = 2), pneumonia (n = 2) and sepsis (n = 5) (Table 2). Death in the 5 patients with sepsis was the result of wound sepsis.

The mean hospital stay of all patients was 16 ± 18 days, and of the dead patients was 25 ± 8 days. There was a significant correlation between bronchoscopic scoring and clinical factors in the form of development of pneumonia and total number of ventilator days and ICU stay days (Table 3).

The bronchoscopic scoring of early-discharge patients, whose hospital stays were <5 days, was mainly grade 1 and 2. Receiver operating characteristic curve analysis also showed

<table>
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<th>Table 2</th>
<th>Patients with SII; demographics and characteristics.</th>
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<tbody>
<tr>
<td>Characteristics</td>
<td>Subjects (n = 39)</td>
</tr>
<tr>
<td>Age, mean (SD), years</td>
<td>41 (32)</td>
</tr>
<tr>
<td>Sex, n (%)</td>
<td>30 (76.9)</td>
</tr>
<tr>
<td>Male</td>
<td>9 (23.1)</td>
</tr>
<tr>
<td>Female</td>
<td>13% (17)</td>
</tr>
<tr>
<td>Initial COHb, mean (SD)%</td>
<td>20 (17)</td>
</tr>
<tr>
<td>Balance, first 24 h</td>
<td>21.9 (12.3)</td>
</tr>
<tr>
<td>Bronchoscopic grading of SII ≥3</td>
<td>7 (39.17%)</td>
</tr>
<tr>
<td>COHb, carboxyhemoglobin; SD, standard deviation; SII, smoke inhalation injury; TBSA, total burn surface area.</td>
<td></td>
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<tr>
<th>Table 3</th>
<th>Correlation between bronchoscopic grading and clinical indices.</th>
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<tbody>
<tr>
<td>Bronchoscopic scoring</td>
<td>R² Regression coefficient P</td>
</tr>
<tr>
<td>P/F ratio</td>
<td>0.039 501.12 0.03</td>
</tr>
<tr>
<td>Infusion volume, 24 h</td>
<td>0.091 877 0.07</td>
</tr>
<tr>
<td>Balance, first 24 h</td>
<td>0.044 799 0.13</td>
</tr>
<tr>
<td>%TBSA</td>
<td>0.411 –4.33 0.17</td>
</tr>
<tr>
<td>Development of pneumonia</td>
<td>0.344 0.19 &lt;0.001</td>
</tr>
<tr>
<td>Ventilation days</td>
<td>0.479 4.01 &lt;0.001</td>
</tr>
<tr>
<td>ICU-stay days</td>
<td>0.211 2.81 0.01</td>
</tr>
<tr>
<td>Hospital days</td>
<td>0.101 4.11 0.07</td>
</tr>
<tr>
<td>Outcome</td>
<td>0.0911 –0.09 0.21</td>
</tr>
</tbody>
</table>

P/F ratio, PaO₂/FiO₂; ICU, intensive care unit; %TBSA, %total burn surface area.
development of pneumonia, the total number of ventilator days, and ICU-stay. The AIS criteria constitute a standardized bronchoscopic scoring system for the degree of inhalation injury.

Serial repetition of fiberoptic bronchoscopy after the diagnosis remains controversial among experts. In the literature, there are no prospective or intervention studies specifically examining this issue. In the USA, a study of 624 patients with SII receiving different treatment regimens showed no conclusive (statistically significant) results regarding the aggressive use of fiberoptic bronchoscopy, although there seemed to be a slight trend toward shorter hospital stays in those who underwent more than one procedure during their hospital stays [24].

Albright [13] reported that the method of assessing SII severity involves analyzing bronchoalveolar lavage fluid for leukocyte differentiation and the concentrations of specific cytokines, chemokines, and growth factors. This study assessing bronchoalveolar lavage fluid showed that a greater severity of inhalation injury is associated with a greater degree of alveolar neutrophilia, prolonged ventilator requirements, longer stay in both the intensive care unit and the hospital, and enhanced pulmonary inflammatory mediator production. Other studies of SII using FOB examination include the study of Bahaa El-Din et al. [25] who reported usefulness of FOB to confirm the diagnosis, manage and predict evolution of pneumonia in SII patients.

Several limitations to our study include the following. First, our study had a relatively small sample size, which did not permit us to detect small differences in total ventilator days; thus, we should examine more cases in the future. Second, we were unable to link the development of pneumonia to other origins e.g. aspiration of oral, pharyngeal, or gastroduodenal contents which may lead to the development of pneumonia. Third, we did not study any inflammatory markers in BAL and its relation to SII severity. Fourth, the study could not assess the therapeutic role of FOB and therapeutic value of its several repetitions in order to clear airways from secretions, slough and carbonaceous materials.

Conclusions

The use of FOB has great value in the early diagnosis and predicting prognosis of SII. AIS assessed by FOB was predictive of the total number of ventilator days and ICU-stay and the incidence, etiology, morbidity, and mortality, Crit. Care Med. 40 (4) (2012) 1113–1121.

Conflict of interest

None declared.

References


Inhalation lung injury


