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Inhalation injury in burn patients: Establishing the link between diagnosis and prognosis

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ABSTRACT

This study was to re-evaluate inhalation injury as a prognostic factor in burn patients and to determine the factors that should be considered when refining the definition of inhalation injury. A total of 192 burn patients (152 men, 40 women; mean age, 46.1 ± 13.8 years) who were suspected to have an inhalation injury and underwent bronchoscopy between January 2010 and June 2012 were included in this prospective observational study. All patients underwent bronchoscopy within 24 h of sustaining the burn. The bronchoscopic findings were classified as normal, mild, moderate, and severe. Mechanical ventilation was administered, when required. Age, percentage of TBSA burned, ABSI score, requirement of mechanical ventilation and PF ratio, but not inhalation injury, COHb level, and bronchoscopic grades, significantly differed between the survivors and non-survivors ($p < 0.05$). Mechanical ventilation (adjusted odds ratio [OR]: 9.787) and severe inhalation injury on bronchoscopy (adjusted OR: 45.357) were independent predictors of mortality on multivariate logistic regression analysis. Inhalation injury diagnosed through history does not predict mortality from burns. Other components such as severity of inhalation injury determined using bronchoscopy, and administration of mechanical ventilation might help predict the morbidity and mortality of burn patients with inhalation injury and all of the factors should be considered when the definition of inhalation injury is refined.

1. Introduction

Inhalation injury is generally defined as a direct thermal injury of the upper airway, chemical injury of the lower airway and/or an injury caused at the site of the fire by the inhalation of noxious gases [1,2]. The inhalation injury is a risk factor for increased morbidity and mortality in burn patients, and its incidence is approximately 10–20% among burn patients [2,3]. The mortality rate of burn patients is approximately 10–30%

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despite advances in burn management, and has been associated with age, burn area, and the presence of inhalation injury [4]. Inhalation injury interrupts the supply of oxygen to the body via massive swelling of the upper respiratory tract (which results from direct thermal damage), chemical irritation of the lower respiratory tract, and injuries resulting from noxious gases such as carbon monoxide and cyanide. Accurate diagnosis and prompt treatment of inhalation injury is essential for better prognosis, since inhalation injury is closely associated with the requirement of mechanical ventilation, secondary pneumonia, and acute respiratory distress syndrome. Inhalation injury is mainly diagnosed using a subjective history of smoke exposure in a closed space and delayed extrication [5]. Physical findings such as singed facial hair, carbonaceous deposits in the oropharynx or sputum, facial burn, and voice change also help to diagnose inhalation injury [2,5]. However, the diagnosis of inhalation injury through history is subjective and does not indicate the severity of the injury. These findings can be confirmed by diagnostic bronchoscopy within 24 h of the burn [6,7]. The lack of a uniform criteria for the diagnosis and definition of inhalation injury and the difficulty in determining its extent and severity are major obstacles in clinical trials [8]. Hence, the prognostic value of inhalation injury is in doubt. The purpose of this study is to re-evaluate inhalation injury as a prognostic factor in burn patients and to determine the factors that should be considered when refining the definition of inhalation injury.

2. Materials and methods

2.1. Patients

This prospective, observational study consisted of 192 burn patients who were suspected to have an inhalation injury on the basis of history (e.g., smoke exposure in a closed space) and physical findings (e.g., singed facial hair and carbonaceous deposits) and all of them were intubated at Hangang Sacred Heart Hospital, Hallym University, Seoul, Korea between January 2010 and June 2012. All patients were admitted to the burn intensive care unit (BICU) within 12 h of sustaining burns and underwent bronchoscopy within 24 h of the burn. Patients who underwent bronchoscopy after 24 h of the burn were excluded.

All patients received adequate fluid resuscitation based on the Parkland formula [9] (if $<$40% of the TBSA was burned) or the Warden formula [10] (if $\geq$40% of the TBSA was burned). The amount of fluid was titrated to maintain urine output at 1 mg/kg/h. The patients were intravenously injected with 0.5 mg atropine and 25–39 mg pethidine (for conscious patients) 30 min prior to the bronchoscopy. Bronchoscopy was performed through the endotracheal tube insertion of a flexible bronchoscope.

We looked for the following bronchoscopic findings: edema, blistering, hemorrhage, carbonaceous material, inflammation, and ulceration. We have devised our own bronchoscopic scoring system at our institute. This system assigns one point each to edema, blistering, and hemorrhage and two points each to carbonaceous deposits, inflammation, and ulceration. The points are then added to obtain a total score. Patients with scores of zero, one-to-three, four-to-six, and more than seven were graded with normal, mild, moderate, and severe inhalation injury, respectively.

2.2. Study design and variables

We recorded the following variables for each patient: age, gender, percentage of total body surface area (TBSA) burned, presence of full-thickness burns, and presence of inhalation injury. The abbreviated burn severity index (ABSI) score was calculated by assigning a numerical value to the variables age, gender, extent of burns, presence of full-thickness burns, and presence of inhalation injury depending on their severity, and then adding all five values [11]. The extent of burns was measured by an expert burns surgeon using a modified Lund and Browder chart [12].

Among patients who were suspected to have an inhalation injury on the basis of history and physical findings, patients who did not show any bronchoscopic findings (normal bronchoscopic finding) were included in the upper inhalation injury group and patients who showed any of the six bronchoscopic findings mentioned above were included in the lower inhalation injury group. We considered that patients (in the upper inhalation injury group) who showed normal bronchoscopic finding received thermal injuries just to the upper airway and patients (in the lower inhalation injury group) who showed any bronchoscopic findings received thermal injuries to the upper and lower airway.

Patients who underwent mechanical ventilation were included in the ventilation group. Mechanical ventilation was applied to patients with a sustained respiratory rate $>$30 breaths/min and a subjective sense of fatigue. The initial ventilator settings were as follows: ventilator rate, 12–18 breaths/min; tidal volume, 7–8 mL/kg; inspiration-to-expiration ratio, 1:3 to 1:2; positive-end expiratory pressure (PEEP), 8–10 mmHg; and lowest possible fraction of inspired oxygen (FiO_2) to keep oxygen saturation $>$90%. Carboxyhemoglobin (COHb) level and the arterial O_2 pressure (PaO_2)/FiO_2 (PF) ratio were measured using arterial blood gas analysis at admission immediately. Patients were also grouped according to their PF ratios: $>$300, 200–300 and $<$200.

This study was approved by the institutional review board of Hangang Sacred Heart Hospital, and informed consent was obtained from lineal family members of the patients.

2.3. Statistical analysis

Statistical analyses were conducted using SPSS 17.0 for Windows (SPSS Inc., Chicago, IL, USA). All continuous variables are expressed as means $\pm$ SD, and the frequencies of categorical variables are expressed as percentages. Continuous variables were analyzed with the independent t-test, when appropriate. Categorical variables were analyzed with the chi-square test. Multivariate logistic regression analysis was performed to evaluate risk factors for burns-related mortality. Kaplan–Meier survival analysis with the log rank test was performed to compare the effects of inhalation injury, mechanical ventilation and PF ratio. A probability value of $<$0.05 was considered statistically significant.