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Pathological changes of the three clinical types of laryngeal burns based on a canine model

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ABSTRACT

Objective: The study was designed to examine pathological changes of inhalational laryngeal burns of three clinical types: congestive, oedematous and obstructive.

Methods: A total of 18 healthy, male, adult Beagle dogs were randomly assigned to inhale hot dry air at room temperature (group C), 80 °C (Group 1), 160 °C (Group 2) or 320 °C (Group 3) for 20 min to induce inhalation injury. Each larynx was evaluated and scored based on the 'clinical scoring and typing system of laryngeal burns at early stage'. Tissue samples of the epiglottis, laryngeal vestibule, vocal folds and infraglottic cavity of the larynx were observed microscopically and evaluated based on a 'pathological scoring system'.

Results: Pathological changes of the larynxes of groups 1 and 2 were primarily characterised by slight atrophy of the mucosa and mild oedema of the submucosal tissues. Group 3 larynxes showed two distinct pathological changes: oedematous and atrophic types. The larynxes of the atrophic type showed lower clinical scores (29.5 ± 0.7 vs. 44.3 ± 2.1) but higher pathological scores (18.6 ± 3.2 vs. 13.7 ± 1.8) than the larynxes of the oedematous type.

Conclusion: Severe laryngeal burns could manifest as severe laryngeal oedema or atrophic change. The laryngeal burns of the atrophic type might suggest an unsatisfactory prognosis, although it had less risk of laryngeal obstruction at an early stage.

1. Introduction

Inhalation injury remains one of the most serious complications of thermal accidents, and it is associated with significant morbidity and mortality. Inhalation injury affects the upper airway, major airway, terminal airway and parenchyma [1]. Due to the special location and structure of the larynx in the upper airway, laryngeal injuries represent a major part of the inhalation injury. For decades, most researchers have placed their emphasis on lower-airway injury related to the inhalation of products from incomplete combustion [1–4]. Much less research has been dedicated to understanding the response to upper-airway burns, especially laryngopharyngeal burns [5].

As an irregular tubular structure, the larynx is the narrowest part of the upper air tract. Stimulated by hot air, the laryngeal tissue might undergo oedematous change of various degrees in a very short time [6]. Mild laryngeal burns cause laryngeal congestion only, whereas moderate-to-severe thermal injury may cause respiratory obstruction that can be

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Table 1 – The clinical scoring system of laryngeal burns at early stage.

Items	Scores			
	0	2	4	6
Symptom	No discomfort	Pharyngalgia	Jam feeling, bucking	Choking
Tone	Normal	Abnormal	Hoarse	Laryngeal stridor
Mucosal colour	Pink	Congestive	Pink-white	Pale
Mucosal appearance	Smooth	Oedema	Small blisters only	Huge blister exceeding glottis
Secretion	Thin	Enhanced	Sticky but clean	Mixed with charcoal powder
Epiglottis	Normal	Move slower	Difficult in lifting	Rigid or ball-like
Angle between vocal cord	$>30^\circ$	20–30°	10–20°	$<10^\circ$ or hole like

If graded at "<12 h" after injury, an extra "1 score" should be given to each item.

life threatening [7]. The use of fibre-optic bronchoscopy for diagnosing diseases of the respiratory tract is well described and considered a valuable tool for evaluating laryngeal burns [4,8–10]. In 1999, based on the continuous laryngoscopic observations of patients with laryngeal burns in our department, a 'clinical scoring and typing system of laryngeal burns at early stage' was drafted, to classify the laryngeal burns into three types: congestive (slight), oedematous (moderate) and obstructive (severe) [11].

This scoring and typing system (Tables 1 and 2) could make it more efficient and less subjective in evaluating an early-stage patient of laryngeal burns and making medical decisions [12]. However, pathological examinations and analyses about those types of laryngeal burns have never been done hereto fore. Therefore, the current study was designed to investigate the histological morphology and pathological changes of the three clinical types of laryngeal burns, based on a well-established canine model of inhalational thermal injury [13].

2. Materials and methods

2.1. Materials

This study used 18 healthy, male, adult, Beagle dogs weighing approximately 10 kg. The animals were provided by the Animal Lab of Peking University First Hospital (Beijing, China). Dogs with trachyphonia or neck trauma were excluded.

Instruments included a custom-made electrical heating device (Fig. 1), an embedding machine (Sakura Medical, Japan), an ultrathin semiautomatic microtome (R-2, Sakura Medical, Japan), an automatic staining machine (DRS-2000, Sakura Medical Group, Japan), a timer, a divider, a measure gauge and an animal immobilisation device. The electrical heating device consisted of a ceramic tube ($4.5 \times 3.5 \times 30$ cm) surrounded with electrical thermal wire (300 W), interfaced to a digital temperature control device (220 V, 20 W, PD90-2, Zhejiang, China).

Table 2 – The clinical typing system of laryngeal burns at early stage.

Total score	Classification	Treatment
<7	Normal	Observe.
8–20	Congestive type	Observe, avoid local irritation.
21–30	Edematous type	Observe closely, prevent laryngeal occlusion.
31–49	Obstructive type	Perform preventive tracheotomy.

2.2. Animal grouping and preparations

All experiments were reviewed and approved by the Animal Ethics Committee of Peking University Health Science Centre and met China's regulations and rules on animal experiments. A total of 18 dogs were randomly divided into four groups: a control group (Group C), with three dogs (Dog A–C) and three experiment groups (groups 1, 2 and 3), with five dogs (Dog A–E) in each group. The dogs were anaesthetised with 3% pentobarbital sodium (25 mg kg^{-1}), at an average intravenous dose of 375 mg at 2 ml min^{-1} via the radial cutaneous vein of the forelimb. A piece of fentanyl transdermal patch (size: 2.60 cm^2; content of fentanyl: 1.0 mg $patch^{-1}$; release rate of fentanyl: 6 $\mu g\ h^{-1}$; and time for analgesia: 72 h) was pasted at the dog's nape for analgesia after skin preparation. The dogs were immobilised in the supine position.

2.3. Experimental procedures

The room temperature was maintained at 26 ± 2 °C; the air humidity was kept at $40 \pm 2\%$. Two rubber stoppers were used to close the nostrils, and the tongue was extended to avoid glossoptosis. A ceramic tube was placed in the mouth between the jaws and parallel with the airway, at a distance of 10 cm from the epiglottis. The inflexible appended thermal probe of the temperature control device was fixed in the oral cavity, 5 cm away from the epiglottis, without tissue contact (Fig. 1). The time for heated air inhalation was 20 min.

The temperature of the heated air was controlled at room temperature (26 °C), 80 °C, 160 °C and 320 °C by the temperature control device for the groups C, 1, 2 and 3, respectively. Heated air was inhaled into the dogs' airway by their spontaneous inspiratory efforts. The temperature of the heated air varied within a range of $\pm$ 5 °C.

2.4. Data collection and sample observation

The dogs were allowed to wake up after injury induction, and the recovery times from anaesthesia were recorded. After revival, their basic living conditions (eating and drinking and body movements) were evaluated by two breeders together. Their respiratory rate and breathing sounds were checked at an interval of 4 h. At 24 h after injury, after anaesthesia, all the