burns 39 (2013) 1212–1220

Available online at www.sciencedirect.com

SciVerse ScienceDirect

journal homepage: www.elsevier.com/locate/burns

# Circulational heat dissipation of upper airway: Canine model of inhalational thermal injury

Zhao Ran [a], Di La-na [a], Wen Chun-Quan [a], Ning Fang-gang [a], Zhang Guo-an [a,1,*]

[a] Burn Department, Beijing Jishuitan Hospital, No. 31, Xinjiekou East Street, Xicheng District, Beijing 100035, PR China

ARTICLE INFO

*Article history:*
Accepted 4 January 2013

*Keywords:*
Canine model
Blood circulation
Circulational heat dissipation
Inhalation injury
Inhalational thermal injury
Contribution

ABSTRACT

*Background:* The upper airway has powerful heat-absorbing ability, in which the blood circulation may play an important role.

*Objective:* This study aimed to explore the circulational heat-dissipating ability, and to investigate the contribution of blood circulation to the heat-absorbing ability of upper airway.

*Methods:* 18 adult, male Beagle dogs were divided into three groups to inhale thermal dry air of 70–80 °C, 150–160 °C or 310–320 °C for 20 min. Blood temperatures and blood flow rates of bilateral common jugular veins (CJVs) were measured. Dogs' breathing rates and air temperatures in middle trachea were also measured. According to the formula "$Q = c{\cdot}m{\cdot}\Delta T$", T", the heat dissipated by blood ($Q_{\text{-}blood}$) and the heat release by air ($Q_{\text{-}air}$) were calculated out. The contribution of circulational heat dissipation to the heat-absorbing ability of upper airway was defined as "$C_{\text{-}blood}$".

*Results:* The blood temperature rise of CJV was 2.24 ± 0.60 °C. The blood flow rate of CJV was 44.5 ± 5.9 ml/min. The air temperature in middle trachea was 63.5 ± 18.9 °C. The mean breathing rate was 51.8 ± 7.5/min. The calculated "$Q_{\text{-}blood}$" and "$Q_{\text{-}air}$" were 13197.3 ± 4408.6 J and 33540.2 ± 24578.7 J, and the "$C_{\text{-}blood}$" was 55.2 ± 25.0% (21.7–88.8%).

*Conclusion:* Circulational heat dissipation plays an important role in the heat-absorbing process of upper airway when inhaled air is less than 160 °C. However, for air higher than 160 °C, some other mechanism might be dominant in the upper airway's heat-absorbing ability.



## 1. Introduction

Burns is the leading cause of traumatic death, and inhalation injury is a major contributor to the morbidity and mortality associated with serious burns [1]. The mechanism for inhalation injury can be attributed to a combination of heat, hypoxemia and chemical effects of the toxic inhalants [2]. Recently, most research regarding inhalation injury put emphasis on the smoke-related injury, covering pathophysiological changes [3,4] and inflammatory reactions [5] of lower airway, ventilation strategies [6] and responses to medical interventions [7,8]. However, studies about inhalational thermal injury of upper airway are limited.

Multiple studies reported the heat-absorbing and gas-humidifying potentials of the upper airway, including the nose, larynx and cervical trachea, where over 90% of the heat is released from the heated air [9,10]. According to Rong et al. [11], from mouth to middle trachea, the temperature of heated air dropped markedly from 80–320 °C to 37.9–89.1 °C, suggesting the powerful heat-absorbing ability of posterior oral cavity, pharynx, larynx and upper trachea.

* Corresponding author. Tel.: +86 010 58516361; fax: +86 010 58516719.
E-mail address: jstburn@yahoo.cn (Z. Guo-an).

[1] Vice Chairman of China Burn Association.

0305-4179/$36.00 
http://dx.doi.org/10.1016/j.burns.2013.01.007

There were several possible explanations for the upper airway's heat-absorbing ability: mucosal fluid evaporation, circulational heat dissipation, breath holding and air's vortex motion [10–14]. Since the blood flow of airway mucosa is abundant [15], which was found to increase markedly with thermal dry air inhalation [16], it is reasonable to hypothesize that the blood circulation plays an important role in upper airway's heat-absorbing ability. Thus, we designed the present study, aimed to explore the circulational heat-dissipating function of upper airway, and further to investigate how much percentage of heat released by heated air could be dissipated by blood circulation. Because when exposed to hyperthermia, dogs' breathing patterns could be too complicated (through either nose or mouth or both [17]) to control, we designed to choose the upper airway from posterior oral cavity to upper trachea as our study objects.

## 2. Materials and methods

### 2.1. *Materials*

An custom-made electrical air-heating device (Fig. 1) comprised of a ceramic tube (4.0 cm × 3.5 cm × 30 cm) wined by electrothermic wire (300 W) and a temperature control device (China, Zhejiang, PD90-2, 220 V, 20 W) connecting a thermal probe. Though this device, air flow could be heated to and maintained around the target level with a fluctuation range of less than 10 °C. In this study, we set the target temperature at 73 °C, 153 °C and 311 °C to maintain the air at 70–80 °C, 150–160 °C, and 310–320 °C, respectively. Other materials included four digital thermometers with needle-like thermal probes (YUHUA, H6801), disposable plastic tubes (diameter = 0.2 cm, length = 3.0 cm, cut from a transfusion tube), waterproof plastic films, a tracheostomy tube (Mallinckrodt, F13, ID = 0.3 cm), a ultrasound flowmeter (Transonic, T402-PB), a timer (CHUNHU, MS0047), and necessary experimental instruments.

### 2.2. *Laboratory animals and groups*

This study was reviewed and approved by the animal ethics committee of Peking University Health Science Center. All experiments were performed in accordance with institutional animal care research protocols. 18 healthy, male, adult, Beagle dogs weighing 10.7 ± 0.4 kg, supplied by the Laboratory Animal Center of the Military Academy of Medical Science of the Chinese People's Liberation Army, were randomly allocated into three groups, six in each, to inhale air of 70–80 °C (group I), 150–160 °C (group II) and 310–320 °C (group III).

### 2.3. *Experimental procedure*

#### 2.3.1. *Animal preparation*

After overnight fasting, dogs were anaesthetized with 3% pentobarbital sodium (25 mg/kg), and an average intravenous dose of 350 mg at 2 ml/min was provided via the radial cutaneous vein of forelimb to control the breathing rate at 9–12/min. They were immobilized at supine position. Ringers lactate solution and 5% glucose were infused at a ratio of 1:1 through the dorsal vein of the foot (1 ml/kg/h). Hair around thyroid cartilage was removed in an area of 30 cm × 30 cm. After the tracheotomy was performed, and a small tracheostomy tube with a flexible thermal probe in it was inserted into the main trachea (Fig. 1). The inserted length was 10–13 cm.

#### 2.3.2. *Implantation of thermal probes and measurement of blood flow rate*

The probe's needle-like top was inserted into a plastic tube at middle after 10 min's immersion in povidone–iodine, and waterproof plastic film was pasted around the insertion point. For one dog, three probe-tube combination devices like this were prepared.

After common disinfection and draping, we cut the skin open to expose and free the left common jugular vein (CJV) for 10 cm from jugular venous angle. During temporal blood interception, the plastic tube was inserted into CJV to replace a length of it. In this way, temperature of the venous blood flowing through the tube was measured (Fig. 2). Same steps were performed to the right CJV and right femoral vein (FV). Then probes of ultrasonic blood flowmeter were fixed around the bilateral CJVs and right FV (close to the tube-inserting point), to measure the blood flow rates in real time.

#### 2.3.3. *Dry heated air inhalation procedure*

Room temperature was 26 ± 2 °C, and air humidity was 40 ± 2%. Two rubber toppers were used to close the nostrils,

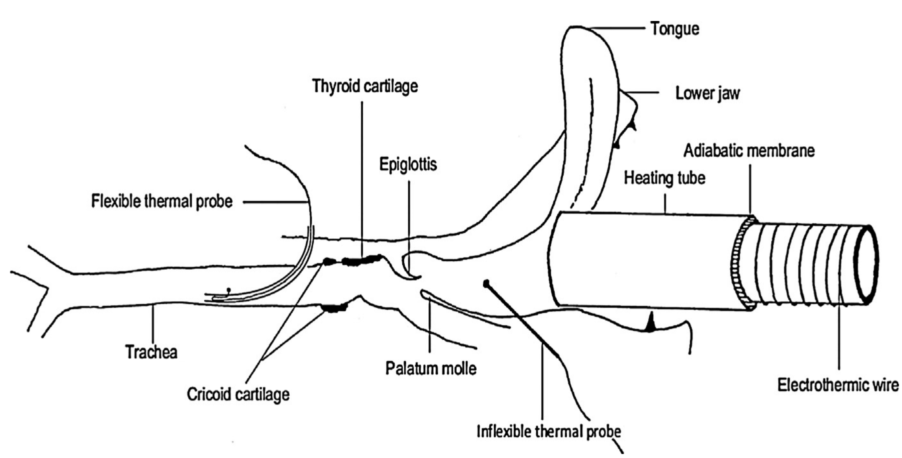


**Fig. 1 – Experimental device.**