

# Measurement of Pressure between Upper Airway Tract and Laryngoscope Blade during Orotracheal Intubation with Film of Microcapsules

Shigehiro HASHIMOTO

Biomedical Engineering, Department of Mechanical Engineering, Kogakuin University,  
Tokyo, 163-8677, Japan

shashimoto@cc.kogakuin.ac.jp http://www.mech.kogakuin.ac.jp/labs/bio/

and

Tianyuan WANG

Department of Anaesthesiology, Third Teaching Hospital,  
Norman Bethune University of Medical Sciences, China

## ABSTRACT

The measurement system for the pressure between the blade of a laryngoscope and the upper airway tract during orotracheal intubation has been investigated with a film of microcapsules. Two types of the laryngoscope were used in the study: Wis-Foregger and Mac-Intosh. The film is attached on the surface of the blade of the laryngoscope. The measurement was applied to 20 cases of the orotracheal intubation. In the pressed part of the film, the microcapsules burst and release chemicals, which react with chemicals out of microcapsules and show a red color. The color density was photoelectrically measured, and converted to the pressure value in three regions on the blade; the epiglottis, the tongue, and the upper incisor. The results show that the pressures are  $1.2 \pm 0.6$  MPa on the epiglottis,  $0.8 \pm 0.4$  MPa on the tongue, and  $(11 \pm 3) \times 10$  MPa on the upper incisor, and that the pressures on the epiglottis are  $2.0 \pm 0.3$  MPa in bled cases, and  $0.8 \pm 0.4$  MPa in non-bled cases.

**Keywords:** Biomedical Engineering, Laryngoscope, Endotracheal Intubation, Pressure, Epiglottis, Tongue and Upper Incisor.

## 1. INTRODUCTION

During orotracheal intubation, a blade of a laryngoscope sometimes damages some parts of the upper airway tract: mucosae of epiglottis and upper incisors [1]. It happens because of the state of the subject and the skill of the operator. Few cases have been quantitatively reported on the pressure between the blade of laryngoscope and the upper airway tract during the orotracheal intubation. In the present study, the measurement system for the pressure between the blade of a laryngoscope and the upper airway tract during the orotracheal intubation has been investigated with a film of microcapsules.

## 2. METHODS

### Pressure Measurement Film

A pressure measurement film (Prescale, Fujifilm Corporation, Tokyo, Japan) is applied for the sensor of pressure. Several types of films are supplied according to the range of the pressure. Two types of the film are used in the present study: the ultralow pressure type (LLW, 0.5-2.5 MPa) and the high

pressure type (HS, 50-130 MPa). LLW is used for the lower surface, which pushes the epiglottis and the tongue. HS is used for the upper surface, which pushes the upper incisor.

Each film consists of two parts: A-film and C-film. The surface of the A-film is coated with microcapsules including achromatic dye. The C-film is coated with the dye, which develops a red color with the achromatic dye of the A-film. The microcapsules have distribution on their size. Variation of the size of microcapsules makes variation of strength, so that burst of the capsules occurs gradually (Fig. 1). When the applied pressure on the film becomes higher, the number of burst capsules increases. Thus, the color density on the film is proportional to the pressure. The film can record the highest pressure during the time course of measurement at a point, and distribution of pressure in the target area.

The films have been softly attached on the surface of the blade of the laryngoscope. Especially, the film has been divided into two parts at the curved area of the blade, to minimize the artifact of the pressure, which is applied to attach the film to the blade. The film attached on the blade is covered with the film of polyvinylidene chloride (0.01 mm thick) to protect from moisture in the oral cavity.

### Laryngoscope

Two types of the laryngoscope were used in the study: Wis-Foregger and Mac-Intosh (Fig. 2). Each shape of the blade is straight and curved, respectively. Each length of the blades is 162 mm and 132 mm, respectively.

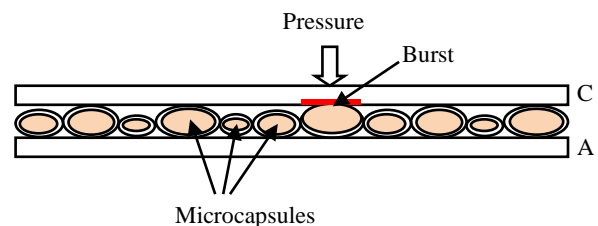


Fig. 1: Microcapsules on the film.

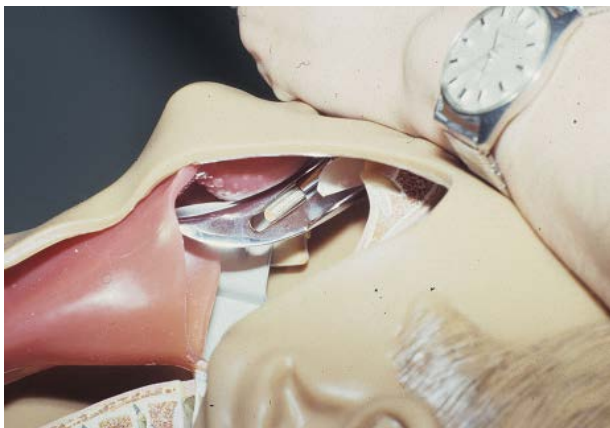
The measurement was performed in the orotracheal intubation of 20 cases: 10 cases for Wis-Foregger, 10 cases for Mac-Intosh (Fig. 3). The subjects are between 13 years old and 61 years old. Six of them are female and 14 of them are male. The height of them ranges between 1.39 m and 1.79 m. The body weight of them ranges between 43 kg and 67 kg.

Diazepam (0.02 mg per 1 kg of body weight) was given orally two hours before anaesthesia. Atropine sulfate (0.01 mg per 1 kg of body weight) and Meperidine (0.5 mg per 1 kg of body weight) were injected intramuscularly thirty minutes before anaesthesia. After oxygen inhalation for five minutes, anaesthesia was induced with intravenous injection of sodium pentothal (6 mg per 1 kg of body weight) and succinylcholine (1 mg per 1 kg of body weight).

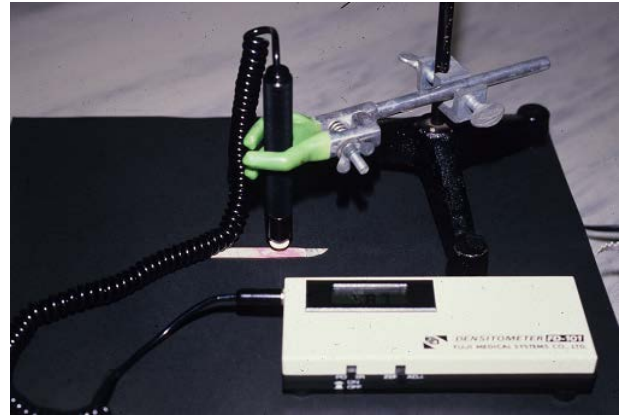
Immediately after induction, orotracheal intubation was performed with the laryngoscope, on which films are attached. The laryngoscope was pulled out paying attention to minimum touch with tissue of the oral cavity. The C-films were separated from the A-films soon, to minimize the excess development of the color.



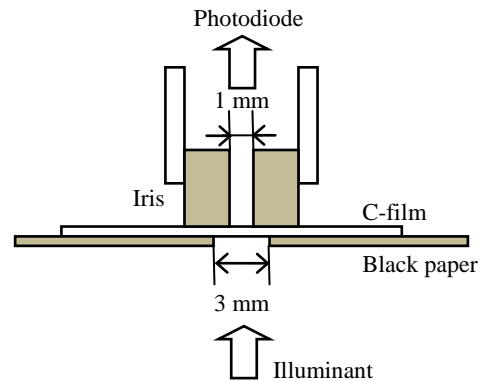
**Fig. 2:** Film of microcapsules attached on the blade of laryngoscope: Wis-Foregger (left) and Mac-Intosh (right).



**Fig. 3:** Orotracheal intubation demonstrated with manikin.



**Fig. 4:** Measurement system for the red color density at the C-film after Orotracheal intubation.



**Fig. 5:** Photoelectric measurement of red color density at C-film.

### Conversion to Pressure

After intubation, the red color density at the C-film was photoelectrically measured with the following system (Fig.4). The source of the light is limited through an aperture of 3 mm diameter. The intensity of the transmitted light limited through an aperture of 1 mm diameter was measured with the photometer (FD-101, Fujifilm Corporation, Tokyo, Japan) (Fig. 5).

### 3. RESULTS

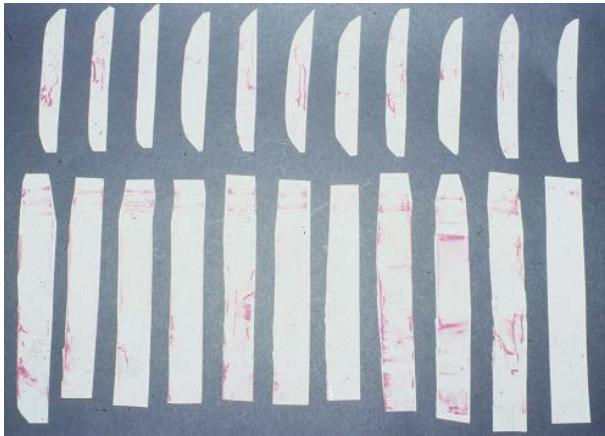
Figs. 6 and 7 show pieces of the C-film after the orotracheal intubation with the laryngoscope of Wis-Foregger and Mac-Intosh, respectively. "Control" shows the pieces, which were just attached on the blade of the laryngoscope without orotracheal intubation. Figs. 8 and 9 exemplify the pressure distribution in the three regions applied with the blade of the laryngoscope: the epiglottis, the tongue, and the upper incisor.

In the case of Fig. 8, the pressures are 0.31 MPa at the epiglottis, between 0.05 MPa and 0.36 MPa at the tongue, and 133 MPa at the upper incisor. In the case of Fig. 9, the pressures are 0.47 MPa at the tongue root, between 0.14 MPa and 0.16 MPa at the tongue, and 113 MPa at the upper incisor. In Figs. 8 and 9, the amplitude of the pressure is illustrated with the length of the arrows, which in the epiglottis and in the tongue regions is amplified by one hundred times more than

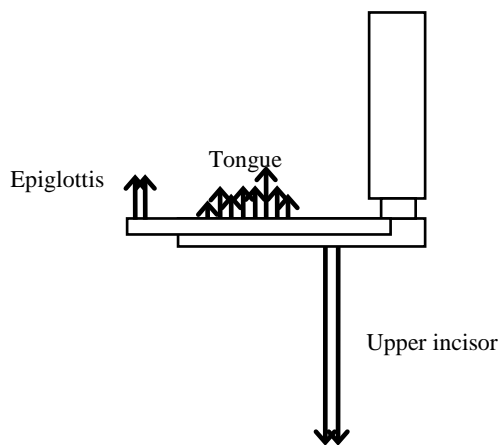
that in the incisor. The pressure has distribution not only along the longitudinal direction but also along the lateral direction, which is not displayed in the figure.



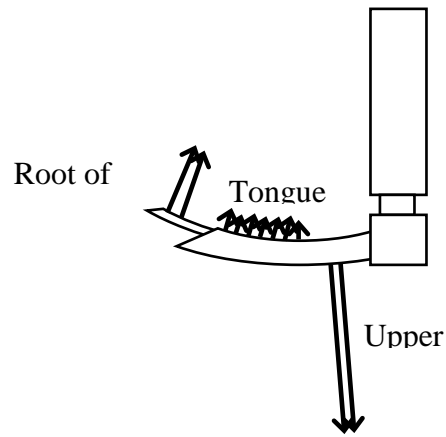
**Fig. 6:** C-films after laryngoscopy (Wis-Foregger) in 10 cases: control (left 3pieces), upper incisor (Left), epiglottis (Middle), tongue (right).



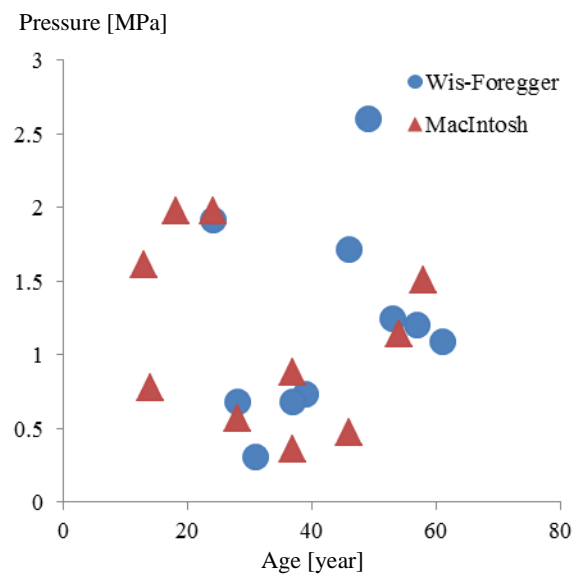
**Fig. 7:** C-films after laryngoscopy (Mac-Intosh) in 10 cases: control (right), upper incisor (top), epiglottis and tongue (bottom).



**Fig. 8:** A case of pressure distribution in the three regions applied with the blade of laryngoscope (Wis-Foregger).



**Fig. 9:** A case of pressure distribution in the three regions applied with the blade of laryngoscope (Mac-Intosh).



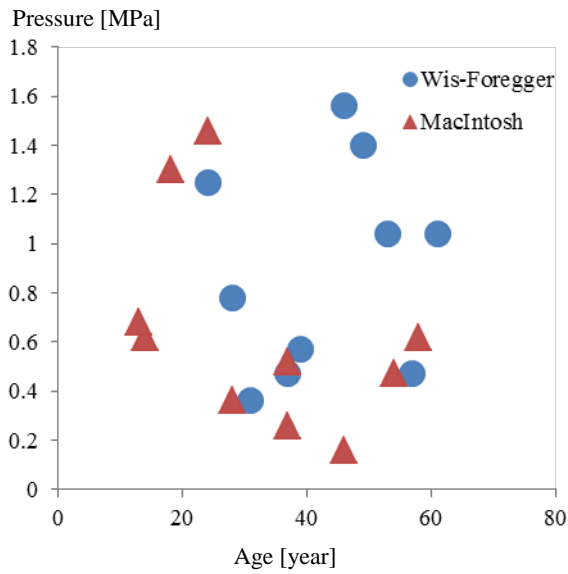
**Fig. 10:** Relation between the maximum pressure on epiglottis region and age of the subject.

In the following figure, the maximum values of the pressure are compared in the two regions: the epiglottis and the tongue. Figs. 10 and 11 show the maximum pressure in the region of the epiglottis and the tongue in relation to the age of the subject, respectively.

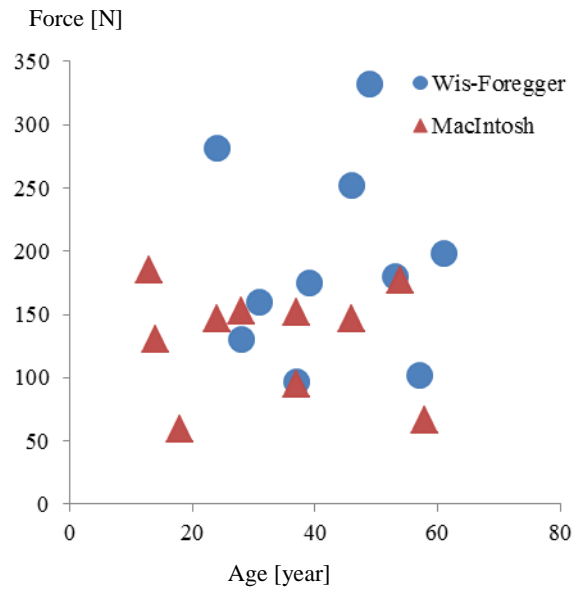
Figs. 12 and 13 show the pressure and the force on the upper incisor in relation to the age of the subject. The results show no significant tendency in relation to the age of the subject.

The results show that the pressure is  $1.2 \pm 0.7$  MPa with Wis-Foregger, where the pressure is  $0.8 \pm 0.4$  MPa with Mac-Intosh. The results show that the values of pressure with Wis-Foregger are not significantly different from those with Mac-Intosh.

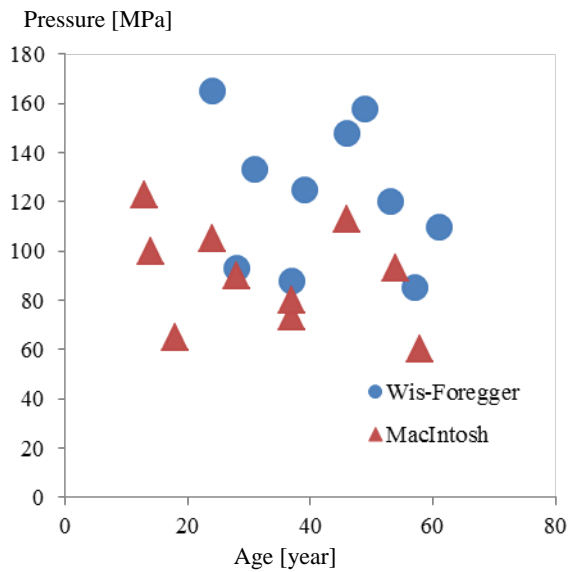
The measurement of 20 cases shows the following mean values. The pressures are  $1.2 \pm 0.6$  MPa on the epiglottis (Fig. 10),  $0.8 \pm 0.4$  MPa on the tongue (Fig. 11), and  $(1.1 \pm 0.3) \times 10^2$  MPa on the upper incisor (Fig. 12). The force on the upper incisor is  $(1.6 \pm 0.7) \times 10^2$  N (Fig. 13).



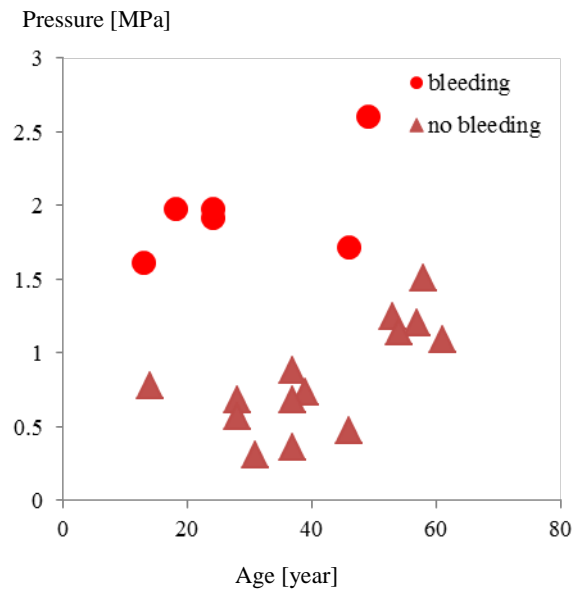
**Fig. 11:** Relation between the maximum pressure on tongue region and age of the subject.



**Fig. 13:** Relation between the force on upper incisor and age of the subject.



**Fig. 12:** Relation between the pressure on upper incisor and age of the subject.



**Fig. 14:** Relation between the maximum pressure on epiglottis region and age of the subject: bleeding case and non-bleeding case.

Small bleeding occurred at the epiglottis region at the mucosa of epiglottis in three cases with Wis-Foregger and the mucosa of tongue root in three cases with Mac-Intosh. The maximum pressure on the epiglottis region is  $2.0 \pm 0.3$  MPa in 6 bled cases, and  $0.8 \pm 0.4$  MPa in 14 non-bleed cases (Fig. 14). The values are statistically different at the significant level of 0.01.

#### 4. DISCUSSION

During orotracheal intubation, a blade of a laryngoscope sometimes damages some parts of the upper airway tract: the mucosa of the epiglottis and the upper incisors [1]. It happens because of the state of the subject and the skill of the operator.

Several devices have been designed to decrease the accidents. Some of them are as follows: covering the upper incisor with the polyethylene film [2], and the sliding blade with the force [3].

Few cases have been quantitatively reported on the pressure between the blade of laryngoscope and the upper airway tract during orotracheal intubation. For this kind of measurement, non-invasive methodology is necessary.

In the present study, the measurement system for the pressure between the blade of the laryngoscope and the upper airway tract during orotracheal intubation has been investigated with a film of microcapsules, and the pressure has been measured in 20 cases.

The micro capsule is available not only for the sensor of pressure on the surface but also for the sensor of shear stress in the flow. The suspension of the micro capsules was applied to simulate destruction of erythrocytes in the shear flow [4, 5].

Only the maximum value of the pressure is calculated in the region of the epiglottis and the tongue. The LLW film is colored with the very low pressure, which may be additionally applied on the blade of the laryngoscope with the upper airway tract during the taking off process of intubation.

To calculate the force, the pressure has to be integrated along the contact area. It is not easy to estimate the contact area precisely in the region of the epiglottis and the tongue. The pressure has also distribution on the blade in the contact area of the epiglottis and the tongue.

In the region of the upper incisor, on the other hand, the contact area can be easily measured, and almost even pressure is applied in the whole contact area. Thus, it is easy to estimate the force at the upper incisor with the area and with the mean pressure.

In the region of the epiglottis, the points of tissue, which the tip of the blade presses, are different with Wis-Foregger and Mac-Intosh. The results show that the pressure is  $1.2\pm 0.7$  MPa with Wis-Foregger, where the pressure is  $0.8\pm 0.4$  MPa with Mac-Intosh. There is no significant difference between these values at the significant level of 0.05.

Small bleeding occurred at the mucosa of the epiglottis in six cases. In the bleeding case, the maximum pressure between 1.6 and 2.6 MPa is applied on the epiglottis. The previous study shows that the strength of the soft palate of monkey is similar value.

The upper incisor was not damaged in the present study. The results show that the force between  $0.6\times 10^2$  N and  $3.3\times 10^2$  N was applied on the upper incisor. These values are smaller than the occlusal force.

The previous study shows that the periodontal membrane bears the force between 0.45 kN and 1.4 kN [6]. The strength depends on the dietary habit. The breaking load of compression on the root of the upper incisor was estimated 3.3 kN.

The pulling resistance of the upper incisor was estimated 0.24 kN. The force applied on the upper incisor during orotracheal intubation with a laryngoscope can be estimated smaller than these breaking loads.

## 5. CONCLUSION

The measurement system for the pressure between the blade of a laryngoscope and the upper airway tract during orotracheal intubation has been investigated with a film of microcapsules. The pressure applied on the upper airway tract was measured in 20 cases of orotracheal intubation with the laryngoscope. The results show that the pressures are  $1.2\pm 0.6$  MPa on the epiglottis,  $0.8\pm 0.4$  MPa on the tongue, and  $(11\pm 3)\times 10$  MPa on the upper incisor, and that the pressure on the epiglottis are  $2.0\pm 0.3$  MPa in the bled cases, and  $0.8\pm 0.4$  MPa in the non-bled cases.

## 6. ACKNOWLEDGMENT

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