

BALLOON DILATION OF THE SUBGLOTTIS: A PILOT STUDY OF BALLOON SIZES & PRESSURES AT WHICH THE CRICOID WILL FRACTURE IN AN ANIMAL MODEL

Annette Ang, MD, Roheen Raithatha, MD, Vikash K. Modi, MD, Max M. April, MD, Robert F. Ward, MD
Weill Cornell Medical College, Department of Otorhinolaryngology, New York, New York

INTRODUCTION

The use of closed surgical approaches was the earliest documentation of interventional methods for the laryngotracheal stenosis. Traditionally, dilation was performed by passing a rigid instrument along the tracheal-long axis, thereby creating unnecessary injury to surrounding healthy mucosa and perhaps, even compounding the initial problem of stenosis. Most authors currently agree that radial pressure exerted by the balloon in opening an airway is far less damaging to the subglottic and tracheal wall mucosa. Although endoscopic balloon dilation is currently gaining acceptance as a primary or complementary treatment in the management of children with upper airway stenosis, there remains to be addressed the critical issue of the maximal pressure tolerable by the cricoid cartilage ring in a child. The cricoid cartilage is a complete ring and hence, it is logical to assume that there will be a pressure at which the ring will fracture.

MATERIALS AND METHODS



Figure 1. Laryngotracheal complex harvested from rabbit specimen.



Figure 2. Balloon dilatation of mounted specimen.

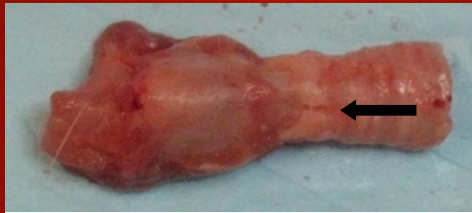


Figure 3. Gross fracture of anterior lamina of rabbit cricoid (arrow)

OBJECTIVES OF STUDY

1. To determine the maximum balloon size and pressure that will not result in a gross fracture of the cricoid.
2. To determine the minimum balloon size and pressure which will result in a gross fracture of the cricoid cartilage
3. To determine the patterns of fracture to the cricoid ring induced by balloon dilatation.

MATERIALS AND METHODS

The laryngotracheal complexes of 8 post-mortem New Zealand White rabbits (all males and 10-months-old) were harvested (Figure 1). The specimens were sized with a Size 4.0 endotracheal tube, equivalent to a diameter of 5.4 mm. This is comparable to an average 3- to 9-month-old infant.

An airway balloon catheter (Acclarent) was carefully maneuvered into each mounted laryngeal complex, such that the midpoint of the effective area of the balloon was positioned directly over the subglottis (Figure 2). The airway balloon was inflated under direct vision to a defined pressure, using an inline pressure gauge. Balloon dilation was performed, with incremental balloon sizes and pressures to determine the point of gross fracture of the cricoid ring (Figure 3).

RESULTS

There was no fracture of the cricoid at any pressure with a 6 mm balloon. This balloon is 0.6 mm larger than the measured subglottis. Any balloon size of 7.0 mm or larger created a gross fracture of the cricoid. These balloons were 1.6 mm or larger than the subglottis. The minimum pressure at which this occurred was 6 atm (Table 1). The cricoid fracture always occurred at the anterior lamina.

Rabbit	Size of airway by ETT sizing (5.4 mm)	Balloon Size (mm)	Balloon Pressure (atm)	Gross Cricoid Fracture
1	4	9	4	Yes
2	4	8	16	Yes
3	4	7	6	Yes
4	4	7	16	Yes
5	4	6	2	No
6	4	6	8	No
7	4	6	14	No
8 (Control)	4	N/A	N/A	No

Table 1. Balloon sizes and pressures applied in the rabbit airway model.

DISCUSSION

The New Zealand white rabbit has a history of being used as an animal model for airway studies since the caliber of the airway system closely resembles that of a newborn child (Figure 4). Recent reports of balloon dilations have utilized the balloon sizes of 5.0 mm to 8.0 mm, depending on the size of the airway. The pressures utilized have been reported in the literature to range from 2 to 6 atm. Most authors do concur that the balloon sizes utilized were guided by the degree of stenosis of the airways encountered at surgery. In our study, it should be noted that for a diameter of 5.4 mm, a size 7.0 mm balloon, at a relatively low pressure of 6.0 atm, was sufficient to cause a gross fracture.

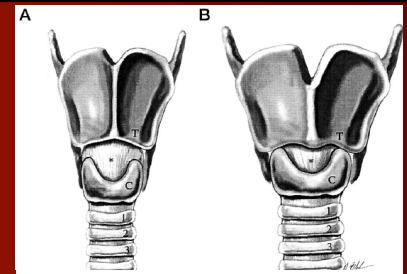


Figure 4. Comparison of rabbit laryngotracheal complex (A) to that of young child (B). The main difference is in the cricothyroid space between the two specimens.

Since this was a pilot study focused on the biomechanical effects of airway balloon pressure on the structure of the cricoid cartilage ring, there were limitations present. First, this study was conducted in an ex-vivo model of the rabbit larynx. Several variables with significant effect on airway dynamics have not been studied here – namely, the presence of support from soft tissue surrounding the laryngeal framework and oxygenation from a live circulation system. In addition, this experiment was performed in a non-diseased animal cricoid cartilage. The biomechanical characteristics of the cricoid cartilage in a child with subglottic stenosis may be different, depending on the thickness, character and age of the scar tissue. A further series of laboratory-based experiments are planned for further exploration of balloon dilation in the live rabbit model.

CONCLUSIONS

1. In this pilot study a fracture of the cricoid occurred when any balloon larger than 1.6 mm of the subglottis at pressures as low as 6 atm.
2. No fracture occurred at any pressure when a balloon 0.6 mm greater than the subglottis was used.
3. The cricoid fracture almost always occurred at the anterior lamina.