# A WIRELESS SENSOR NETWORK FOR ENDOTRACHEAL TUBE CUFF PRESSURE MONITORING

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***Abstract*— Endotracheal tubes (ETT) are kept in position using inflatable cuffs. The pressure of the cuff needs to be higher than a minimum value to hold the ETT in place. However, pressures exceeding 20mmHg produce damage of different degrees on the trachea. This paper shows an experimental network of wireless and low power nodes for monitoring the pressure of ETT cuffs (ETTC). All nodes communicate wirelessly through an RF link with a central station that displays values on a PC and generates alarms if values are beyond the limits prescribed by the physician. The system was tested to monitor the condition of several patient ETTC in a coronary intensive care unit of the "Hospital Privado del Sur", in Bahía Blanca, Argentina.**

***Keywords*— Endotracheal tube cuff pressure, sensor networks, low power electronics, health monitoring**

## I. INTRODUCTION

Endotracheal intubation is regularly used to establish an open airway in the trachea, which can be used to force ventilation and also as part of an anesthesia delivery system (Mansfield *et al.* 1993). The tube is inserted in the trachea and is kept in place through the use of an inflatable cuff (see Fig. 1). The cuff is inflated to a certain pressure externally in order to prevent gas leak and pulmonary aspiration. If the pressure of the cuff is excessive, then damage might occur on the mucous and submucous membrane by the restriction of the capilar blood flow. On the other hand, insufficient inflation of the cuff increments the risk of broncoaspiration (Escalante and Andrade, 2005).

Fig. 1. Endotracheal tube and inflatable cuff. A syringe is usually located at the end of the smaller tube to inflate the cuff. The pressure sensor is located at this point.

The pressure of the tracheal capilary perfusion has been estimated to require 22 mmHg and follows a proportional law with respect to the balloon pressure (Ganner, 2001). As reported in Escalante and Andrade (2005) the mucous membrane turns pale at 30 mmHg, white at 37 mmHg, and blood circulation stops at 45 mmHg. These numbers suggest that blood flow is initially affected by balloon pressure levels around 22 mmHg (Braz *et al.*, 1999) and that there exists complete blocking of tracheal capillaries at 37 mmHg. Pressures in excess of the perfusion pressure of mucosa and submucosa might lead to loss of mucosal ciliar (Klainer *et al.*, 1975), ulceration, bleeding, tracheal stenosis (Berlauk, 1986), and tracheoesophageal fistula (Staufer *et al.*, 1981).

In Herrera-Carranza (1997), the authors recommend the use of tubes of appropriate size, with a diameter greater than 30mm in adults; if this recommendation is followed, then a pressure of approximately 20mmHg in the cuff produces an effective seal. However, even if the initial ETTC pressure is low, a series of factors might increase it; for example, the use of nitrous oxide, a gaseous anesthetic commonly used in post anesthesia care units and intensive care units (Braz *et al.*, 1999) due to the diffusion of nitrous oxide into the cuff (Seegobin and van Hasselt, 1984). In addition, in this paper we present experimental evidence showing that in patients who are mechanically ventilated, the positive end-expiratory pressure (PEEP) set by the machine increases the ETTC pressure significantly.

The results reported in Escalante and Andrade (2005) and Curiel *et al.* (2001) strongly suggest that monitoring the pressure of the ETT cuffs (ETTC) reduce tracheal pain after intubation. In Escalante and Andrade (2005) two groups were analyzed. A first group was monitored three times a day, and the pressure was maintained at 20 mmHg. The second group was not monitored. Twenty four hours after extubation 30% of patients of the first group had moderate pain and 70% no pain at all, compared with 80% of moderate pain and 20% with no pain at all in the second group. The case reported in Curiel *et al.* (2001) showed that after 24 hours 10% of patients with ETTC pressures less than 42mmHg showed tracheal pain, in contrast with 53.3% of patients in the case where the ETTC pressures exceeded 42mmHg. The results reported in Guyton *et al.* (1997) suggest that patients with ETTC in excess of