MEASURING FORCE IN A LARYNGOSCOPE

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\textbf{ABSTRACT}

A laryngoscope is a surgical instrument used to facilitate endotracheal intubation task during general anaesthesia or mechanical ventilation. This task usually takes less than a minute, but requires very precise movements and force control ability; otherwise it may result in serious damages to the patient incisors, larynx, spinal column, changes in heart rate and/or blood-pressure.

This work presents a prototype of a device that can be easily adapt to a common laryngoscope, which allows the measurement of the force applied between the handler and the blade. The force measurements are acquired by a bluetooth\textsuperscript{\textregistered} data acquisition module and transmitted to a portable computer for data recording and analysis. Real-time force information is provided to laryngoscopists and alarm triggered as desired by according to the user settings. The software application – Laring Monitor - was built in Free Pascal and is able to be run in different operating systems (Windows, Linux and Mac X).

\textbf{KEY WORDS}

Laryngoscope, force sensors, endotracheal intubation

1. Introduction

Laryngoscopic interventions are part of daily clinical routine during anaesthesia. Laryngoscopy provide endolaringeal structure exposure of different sizes and kinds. A tooth broken are among the most numerous claims against intubators laryngoscopy providers \cite{1, 2}, however only 20\% of such cases are described as “difficult intubation” \cite{3}. Other reported laryngoscopy complications are ranging from mild mucosal edema, to intubation lesions and problems that may compromise the cardiovascular system \cite{4}. Palatopharyngeal wall perforation during intubation with a laryngoscope is also reported \cite{5}. The use of unnecessary force during the laryngoscopy intervention, the use of too large laryngoscope blade and the use of rigid stylet have been contributory factors to these complications \cite{4, 5}. In order to reduce risk of such injuries, several approaches have been described in clinical practice as the use of extension-extension position \cite{6} videolaryngoscopy \cite{7} or face-mask ventilation \cite{8}. Despite the presumed safety and efficacy of videolaryngoscopy, and disposable laryngoscopes, conventional techniques based Machintosh blades are still probably the most common.

The aim of the present study was to develop a laryngoscope device with automatic force measurement ability that can improve intubating performance and diminished the risk factors of upper-airway damage from non well training experts. In previous studies on forces associated with laryngoscopy interventions, a strain gauge sensor positioned between the handle and the blade of the laryngoscope was used by the Bucx et al. \cite{9}. In that work, the peak force applied on the maxillary incisors was shown to be 35N (SD 12) and mean force necessary was 20N (SD 6) while the force-time integral was 324N (SD 194) \cite{9}. In addition, the maximal values of the transverse forces oriented toward the intubator (Fmthmax) it was shown to between 0 and 10 N in 92\% of interventions \cite{10}. Moreover, there are evidences that show that proximal laryngoscope grips (close to the blade) generate lower forces than distal grips \cite{11}. Twisting forces on the distal flat segment of some laryngoscope may cause its failure \cite{12}.

Automatic measurement of the forces applied during laryngoscopy in manikin could improve trainee intubation skills curricula. This is important because inexperienced intubators tend to generate higher force during intubation than experienced intubators (anaesthetists and residents) \cite{10, 11}. The impulse (force * duration) has shown to be higher for the inexperienced groups largely because of the longer average duration of intubation \cite{13}. In addition, it was found that among experienced intubators, applied force correlated with patients’ weight and Mallampati class \cite{13}.

The force measuring device described in this paper intends to give a small contribution to minimize the above referred problems by presenting a device that is not part of the laryngoscope it-self, but can be put in the place quickly and easily and can be used whether in training or real intubation situations.

Next chapter presents the system description and device hardware and software, in chapter 3 are shown the preliminary results and discussed the results. Finally, in
the conclusions chapter final remarks and comments are presented.

2. System Description

A laryngoscope is a surgical instrument used to facilitate the intubation during general anaesthesia or mechanical ventilation. Figure 1 represents a picture of the laryngoscope used in this project (produced by Welch Allen). This instrument is usually made of two stainless steel parts: a handle (1) and an interchangeable blade (2). An optical fiber for lightning the intervention area (3) is normally included and eventually a camera viewer (not in this model). The handler incorporates the white bulb and the batteries.

![Figure 1 Laryngoscope (Welch Allen)](image)

Direct laryngoscopy is performed the technician by inserting the laryngoscope into the mouth of the patient lying down in the bed. The tongue should be moved out of the line of sight, and, the blade inserted anterior to the epiglottis followed by the application of a moment to the handle in order to open the airways path. This task requires a precise combination of upwards and inwards movements in order to be successfully performed. Usually, it is necessary less than a minute to place the laryngoscope in the target position and to proceed with the intubation. Unsuccessful laryngoscopy may result in serious damages to the patient incisive teeth, larynx, spinal column or changes in the heart rate and blood-pressure.

This laryngoscope was instrument with a thin layer of a piezoresistive resistive force sensor, FlexiForce® A201H (from Tekscan). This sensor is composed by two layers of polyester film, a conductive material layer, pressure-sensitive ink layer and finally a protection layer. A thin metal disk was glued over the sensor to better distribute the forces over the sensing area and to smooth eventual irregularities of the surface of the laryngoscope parts. In addition, the disk also avoids the sensor tips to be smashed by the laryngoscope parts when under force.

Figure 2 shows a detailed view of the sensor mounted in its place - the interface between the blade and the handle.

![Figure 2 Detailed view of the force sensor](image)

The blade can freely articulate around the rotation axis P, and thus transmit the force to the sensor, like in a first class lever type mechanical structure. The force applied to the handle $F_{handle}$ creates a moment $M$ forcing the blade to move downward exerting a force $F_{blade}$ in a way that opens the passage to the endotracheal tube to be inserted. Figure 3. The exact point of the application of the force $F_{blade}$ is not constant among individuals. Because of this, different blades lengths are normally available for the same handle to better match the individual physical characteristics.

The force applied to the handle $F_{handle}$ has to be kept the minimum possible that allows the intubation task to be performed successfully. As referred before, excessive force can cause problems to the patients.

When applying the force to the handle, the technicians may put the upper surface of the laryngoscope in contact with the upper jaw incisive teeth. Although this device cannot measure independently the moment and the teeth contact force, both contribute to the final reading, being this way accounted by the system. The lowest force that stills lead to a successfully intubation is therefore a measurement of the laryngoscopy performance.
2.1 Hardware Description

The resistance of the force sensor changes according to an exponential negative shape with the applied force, making thus more interesting to work in the lower part of the range in order to improve the sensitivity, Figure 4.

To convert the sensor output into voltage, it was built an electronic signal conditioning that includes a voltage divider circuit (with the sensor resistance in one branch), followed by a buffer to create a high impedance input. A voltage regulator is also included in the circuit to prevent battery discharger errors.

The output of the OP-AMP was connected to a BlueSentry-XPert Bluetooth™ sensor interface, which enables the data acquisition up to 3 ksamples/s with 16 bit resolution (0-5 V range) in a printed circuit board of 27x70 mm. This module can work in three different modes:

a) stand-by (to save the battery);
b) connected to a computer;
c) transmitting data.

2.2 Software

The data acquisition and presentation software – Laring Monitor - was developed using Lazarus Free Pascal software (http://www.lazarus.freepascal.org/). This software can run over the major operating systems (Windows, Linux and Mac OS) and also on a PDA WinCE.

The user can, through this application, set the module’s data acquisition rate, start/stop/standby modes, communication port and channels to be read, Figure 5.

The acquired data is converted in real time to force units and presented in the left part of the windows, bar graph. Disk logging is included in the software and can be defined in the right side of the windows. The options and communication settings can be adjusted to the desired values in the settings tab.

3. Results and Discussion

The laryngoscope together with the force sensing device was fixed to a rigid structure by the handle, and the blade loaded with known forces from 0 N up to 45 N in steps of 5 N. The forces were applied at the tip, at a distance of 100 mm from the rotation axis. The acquired data is presented in Figure 6.

The system characteristic is well approximated by a polynomial equation of the 3rd order. However, when measurements are taken with another blade (the blades are interchangeable), a deviation of the order of 9% was found. The change of the blade can be advisable to better match the individual anatomy or because of the cleaning procedure after use.

Positioning the sensor inside the laryngoscope is critical to the quality of the measurements, thus its mechanical design should provide a very well referenced point. Rigid force sensors based on strain gauge sensors may provide...
better repeatability, lower hysteresis and longer longevity than the A201 Flexiforce model used in this prototype. However, there is a tradeoff, and load cells present considerable larger dimensions, weight and complexity.

![Graph](image)

Figure 6 Characteristic of the device for loads place in the tip of the blade

### 4. Conclusion

Using evidences from the literature and experimental data, a learning system can be built around force laryngoscope procedure that can allow increase ability of experienced laryngoscopy providers and help trainee intubation skills. The device introduced in this paper can be used to measure and log the force between the blade and the handler of a laryngoscope. It is very easy to apply/remove and can give a precious information feedback to trainees to improve their skills. As this device is not part of the laryngoscope itself, it allows an easy integration in every laryngoscope without special changes. In addition, the capability of wireless Bluetooth transmission allows remote logging in a standard computer for later analysis. However, this device has a drawback, since the laryngoscope or the blade can be changed, precision and repeatability cannot be assured unless a careful placement of the sensor and system calibration is done. Thus measurements should be looked more as relative information that precise absolute measured data. It is expect to improve in the near future this limitation by creating a way to guaranty the precise position of the sensor and include in the software several types of laryngoscopes that can be freely selected by the user. Unfortunately, the BlueSentry-XPert data acquisition and transmitter module used in this prototype is no so small as it would be desirable. Thus, a homemade data acquisition pcb specific for this application is envisaged as a future upgrade.

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### References


