Demonstrating Coniotomy with Reusable Phantom Larynx

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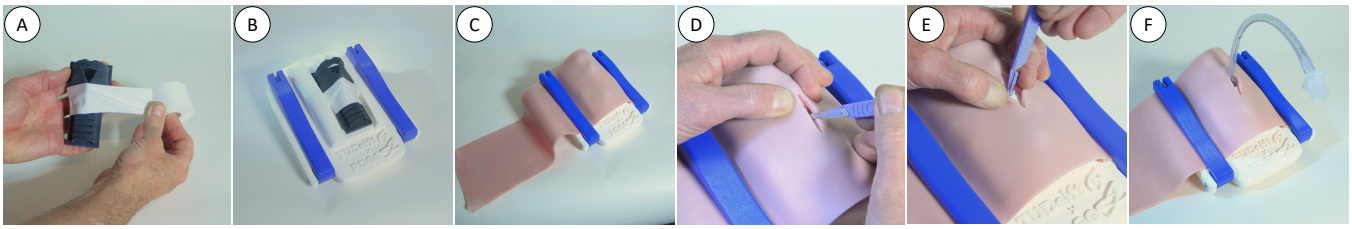

Figure 1: The coniotomy procedure: (A) the larynx is covered with a few layers of tape, (B) the larynx is slided into the housing structure, (C) the larynx is covered by artificial skin that has to be clamped by the device, (D) the exact position of the vertical cut has to be determined and a cut has to be performed, (E) after the vertical cut, the ligaments have to be cut horizontally for a few centimetres to facilitate the insertion of the tube, (F) the tube can be inserted deep enough to ventilate the patient.

Abstract

In emergencies of suffocating patients, doctors typically perform an incision made through the skin and cricothyroid membrane to clear the patient's airway. This type of procedure is called coniotomy. To master this procedure, doctors must undergo simulated practical training, sometimes under high stress. Current practical sessions often include models to simulate coniotomy that consists of the skin and the larynges with attached tracheae from butchered pigs, which are not always available, are expensive, and might be unsustainable to use. In this work, we present a reusable phantom larynx setup to facilitate a coniotomy procedure that is easier and cheaper. Our proposed setup comprises a 3D-printed polyurethane larynx with silicon rubber to simulate skin and accommodate multiple incisions. With this setup, we aim to provide visitors with an interactive and safe experience by performing the coniotomy procedure using a scalpel on the right spot and placing the ventilating tube.

CCS Concepts

• **General and reference** → Experimentation; • **Applied computing** → **Education**; **Life and medical sciences**.

Keywords

phantom, coniotomy, coniotomy training, larynx

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1 Introduction

Surgical education heavily relies on the acquisition and transfer of *procedural knowledge* [8]. To become a skilled surgeon requires time-consuming, expensive, and periodic training. Therefore, researchers have introduced quick and less expensive methods for replicating surgical procedures [7], e.g., by using virtual simulators and physical models [6]. While models and practical setups are introduced in neurosurgery [1, 5, 7], no existing phantom currently supports a coniotomy procedure. This procedure requires an incision through the skin above the larynx and the placement of the ventilating tube to provide an alternative airway for the patient. Especially in cases of blockage of the upper airways, medical professionals need to be able to execute a coniotomy (or cricothyrotomy) to save the life of the patient [9]. In this work, we present an easy-to-produce and anatomically accurate setup to accommodate coniotomy procedures. This comprises a polyurethane 3D-printed larynx with silicon rubber to simulate skin [3] and accommodate multiple incisions. With this setup, we aim to provide visitors with an interactive and safe experience by performing the coniotomy procedure using a scalpel on the right spot and placing the ventilating tube.

In case the upper airways of a patient are blocked, it is essential for the medical professional to be able to execute a coniotomy (or cricothyrotomy) in order to save the life of the patient. Not many doctors have the chance to practice this procedure very often. Sometimes, prepared pig throats are used as training models; sometimes, simple printed parts are covered with chamois leather skin. Our goal was to develop a cheap, easy-to-produce, and anatomic-correct phantom that is clean and reusable.

2 Related work

Coniotomy (also known as cricothyrotomy) is a surgical procedure used in situations with blocked airways, for example, facial trauma.

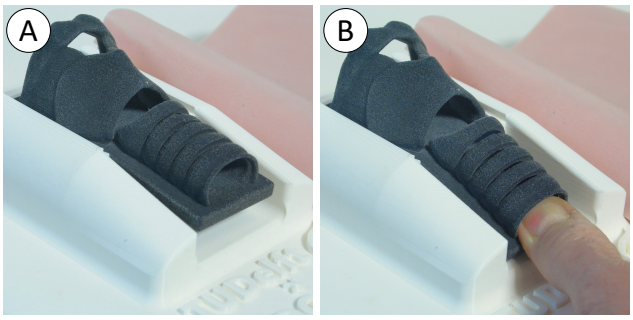

Figure 2: The overview of the straight (A) and bent larynx (B).

Because this procedure is so invasive and rarely used, it has not been widely practiced. In addition, the use of cadavers and also pig throats, is quite expensive and cumbersome to use. So other options are being explored. In general, for the training of residents two types of phantoms can be used. The first option is the use of biological tissues; human cadavers or animal tissues, which retain most of the mechanical properties of tissue. However, due to practical and ethical issues, the use of biological tissues is not always a feasible option. Alternatively, tissue mimicking materials are used. Such phantoms can be customized to the needs of specific research activities or training, are readily available, and in general more durable. To reflect different aspects of reality the phantoms need to mimic the mechanical properties of human tissue [3] and generate representative forces that arise when interacting with the training phantoms [9]. Previous research has mainly used puppet models and shows that using a pig larynx in practice leads to better results [2]. But the extraction and preparation requires much time and effort, and the porcine larynx is not always available. For these reasons, an easy-to-manufacture artificial larynx needs to be constructed that has the same or improved learning curve as the currently used method. Moreover, it should be reusable and facilitate frequent practice sessions.

3 The Coniotomy Procedure

The training coniotomy procedure consists of the following six steps (Figure 1):

(1) First of all the larynx has to be covered with a few layers of tape. These layers of strong tape are a substitute of the median cricothyroid ligament.
(2) The larynx has to be slided into the housing structure. This ensures keeping the larynx in place, creating the bending option and clamping the skin as the main features of the housing structure.
(3) The setup should be covered by artificial skin that has to be clamped by the device. Covering the larynx with skin is essential to mimic the real procedure and makes it harder to find the right position.
(4) By palpation the exact position of the vertical cut has to be determined. By touching the skin with fingers, surgeons are able to feel the different structures of the larynx. The small opening between the larynx and the trachea (blue area in Figure 1) has to be located.
(5) After the vertical cut, the ligaments have to be cut horizontally for a few centimetres to facilitate the insertion of the tube.
(6) The tube can be inserted deep enough to be able to ventilate the patient.

Figure 3: Overview of the demo setting, in which participants can safely perform an incision using our proposed phantom larynx setup.

4 Design

The human larynx consists of three main parts relevant to this research. These are the upper part of the larynx, the thyroid, the lower part of the larynx, the cricoid, the trachea, and finally, the median cricothyroid ligament (which holds these parts together). This ligament is cut during coniotomy, and intubation is done. Furthermore, research has shown that the puncture force required to cut this ligament is close to 1 N [4]. This is very important to consider when finding a substitute. To make room for the tube, the doctor can lower the inferior part of the larynx with his finger. An artificial larynx should provide a structure that simulates the sensation and force required to cut a ligament and provide similar strength and flexibility to artificial cartilage. In close cooperation with medical experts, we designed a 3D human larynx model (Figure 2), which was iterated multiple times with professional doctors. This design of the larynx with the trachea plays the role of the human organ's "touch and feel" and helps surgeons find the right spot for the incision. The flexibility of the larynx and the stiffness of the cartilage rings in the trachea are essential to mimic the procedure as realistically as possible. Pushing the trachea down a little has the same effect as bending the patient's head backward to stretch the neck and open up the gap a little further. A large piece of artificial skin, consisting of silicone layers with a nylon power mesh reinforcement, can be clamped on top of the printed larynx and reused 10 to 20 times. The ligaments on the larynx are mimicked with a few layers of sports tape that have to be renewed after every cut.

5 Demo Experience

Every interested visitor can have a "first time" experience making the incisions and inserting the tube. With the Larynx covered by the artificial skin, visitors must find the right position using palpation. After the first cut, the ligaments must be found with a finger before the horizontal cut can be made. After the last cut, the stiff cartilage rings of the trachea can be felt with the finger. This is an essential check to be sure the cuts were made in the trachea and NOT in the esophagus. Now, the guide wire is used to insert the ventilation tube. The example of a demo setup is shown in Figure 3.

6 Conclusion

In this paper, we demonstrate our implementation of a phantom larynx setup to experience and potentially practice a coniotomy procedure. Our solution consists of a 3D-printed polyurethane larynx with silicon rubber to simulate skin and accommodate multiple incisions. With this setup, we aim to provide visitors with an interactive and safe experience by performing the coniotomy procedure using a scalpel on the right spot and placing the ventilating tube. Additionally, we aim to expose and educate visitors without medical background about a coniotomy procedure by employing learning by doing.

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