

## Bench surgical training with lyophilized esophageal segments<sup>1</sup>

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### ABSTRACT

**PURPOSE:** To present lyophilized esophageal segments that can be used to learn surgical skills.

**METHODS:** Four esophagus were harvested from four non-esophagus related research dogs at the moment of euthanasia. Each esophagus was trimmed in 3 cm long segments. They were lyophilized and stored during 30 days. The day programmed for surgical skills practice, they were rehydrated.

**RESULTS:** Sixteen segments have been used. After rehydrating, all the segments kept their normal anatomic shape and structural integrity. One incision was made on every esophageal segment and sutured with running stitches of 3-0 polyglactin 910. There were no complications, such as tissue tears, nor esophageal hardening.

**CONCLUSIONS:** The lyophilized esophagus is a high fidelity, practical, reproducible, portable, low-cost bench model. It allows general surgery apprentices to learn how to handle an esophagus, as well as to perfect their surgical and suture abilities before applying them on real patient's esophagus.

**Key words:** Esophagus. Freeze Drying. Surgery. Dogs.

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## Introduction

Training in surgery has been considered an apprenticeship thus teaching technical skills is a crucial task for the academic surgeon<sup>1</sup>. The ethical issues about teaching and learning on human patients, economical concerns, and mainly the patients referred to our hospitals are sicker and have more complex diseases, have limited the attending surgeons in assisting residents to learn surgical techniques and skills in the operating theater<sup>2-5</sup>. Thus, many academic-hospitals have turned toward laboratory-based training programs and have prompted the use of many organic and synthetic materials for bench surgical training<sup>6-9</sup>. High fidelity bench models are the “most realistic” to learn surgical skills<sup>10</sup>. The cryopreserved organs are a high fidelity bench model<sup>11</sup>, and the lyophilized can be considered a good one.

We have experience with organ cryopreservation and lyophilization, which can be preserved for long time, although they are not suitable for human organ transplantation, nevertheless, we have found that due to their long preservation time, a cryopreserved or lyophilized organs bank can be established, thus they can be used in animal research studies as well as surgery residents training<sup>12,13</sup>.

In modern medicine, thermal biopreservation is used to preserve biomolecules, cells, tissues, and organs for future use. The hypothermic biopreservation, the biologicals are cooled to near ice temperature, in order to slow down metabolism and degradation, to extend their life; nevertheless, viable human use of long term organ stabilization has not been achieved. There are five methods to get long term stabilization: Slow freezing, vitrification, low CPA vitrification, freeze-drying and desiccation. They stabilize the biological in an amorphous or glassy phase. The glassy phase is a thermodynamically stable state, with high viscosity and low molecular mobility and activity, where the degradative and life supporting processes are arrested or suspended in a desired glassy phase<sup>13,14</sup>.

Lyophilization or freeze-drying is a dehydration process to preserve biologicals at ambient temperature and make the material more convenient for transport. It works by freezing the material, reducing the surrounding pressure to allow the frozen water in the material to sublime directly from the solid phase to the gas phase.

Lyophilization has been applied to preserve food, pharmaceuticals, diagnostic kits and organic tissues. Preservation is possible because the reduced water content inhibits the action of microorganisms and enzymes that normally would spoil or degrade the substance. The freeze-drying process usually does not cause shrinkage or toughening of the material being dried<sup>13-15</sup>.

The aim of this study is to present a high fidelity low-cost bench surgical model of lyophilized esophageal segments used to learn surgical skills.

## Methods

### *Esophageal harvesting and lyophilization*

These non esophageal research protocol were revised and approved by the Ethic's Committee of the Instituto Nacional de Enfermedades Respiratorias “Ismael Cosío Villegas” (INER) and carried out under the Technical Specifications for the Care and use of Laboratory Animals of the Mexican Official Norm (NOM-062-ZOO-1999) and the Guide for the Care and Use of Laboratory Animals prepared by the National Institutes of Health of The United States of America. The esophagus was harvested from four dogs weighing 15 to 30 kg, regardless sex and age, which were at the end of non-related esophageal research studies.

The animals were prepared before surgery (euthanasia) with 24 h fast for solids and 12 h fast for liquids. Initial anesthesia was induced by IV hydrochloric xylazine 0.1mg/kg, (Rompum, Bayer, Leverkusen, Germany) and propofol 6mg/kg (Diprivan, Astra Zeneca, Edo, Mexico).

The anesthetized animal was positioned in the supine position. Each animal was intubated with an endotracheal tube, placed on mechanical ventilation (Harvard Apparatus and a vaporizer Isotec 3 Ohmeda). Anesthesia was maintained with 2% isoflurane, FiO<sub>2</sub> 98%, tidal volume 15 ml/kg and respiratory rate 20/min. The neck and the thorax of each animal was shaved and prepared with povidone-iodine solution. A midline cervical to epigastric incision was made. The whole cervical and thoracic esophagus was exposed. All the esophagus length from the pharynx to the cardias was harvested and all the surrounding tissue was dissected off and cleansed with saline solution (PISA, Jalisco, Mexico) during 5 minutes inside a cold chamber (Figure 1a). It was mounted on a 16 x 150 mm polypropylene tubes (Fisherbrand, Georgia, USA) (Figure 1 b,c), introduced inside a Kitasato flask (Figure 1d), sealed with polypropylene plug and parafilm paper (Bemis, Wisconsin, USA) and stored during 24 h at -70°C in a REVCO freezer (Thermo Scientific, Georgia, USA). After elapsed this time, the Kitasato flask was introduced into the lyophilizing device (Labconco, Kansas, USA) at -55°C and 10 mBar vacuum pressure during 24 h (Figure 1e). After completing this period time, the esophagus was sterilized with sterrad (low-temperature hydrogen peroxide gas plasma sterilizing process, Johnson & Johnson, New Jersey, USA), and stored at room temperature until

the surgical practice day. In order to rehydrate the lyophilized esophagus, it was put inside a cold glass beakers with saline solution at 4°C, stored in a freezer during 24 h, the day before the scheduled practice. After being rehydrated, it was removed from the polypropylene tube. The esophagus was trimmed into 3 cm long segments (Figure 2 a,b).

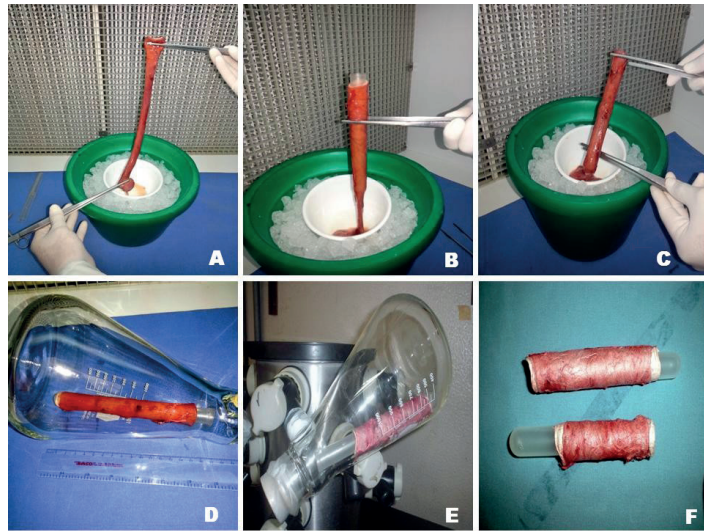


FIGURE 1 - Esophageal preparation and lyophilisation.

#### *Lyophilized esophagus assessment*

On the surgical table, a unisel rectangular piece (30 cm x 20 cm) was covered with a blue surgical champ. In order to fix the esophageal segment to the unisel piece, two 24 fr needles were used (Figure 2a). Each esophageal segment was cut in two segments with a No. 22 surgical blade. It was possible to perform an end-to-end anastomosis with running 3-0 polyglactin 910 (Figure 2 b,c).

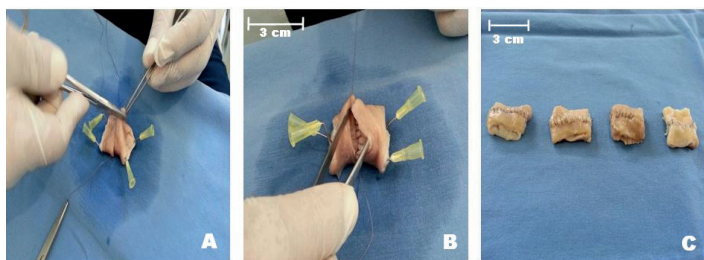


FIGURE 2 - Rehydrated lyophilized esophageal suturing.

The rehydrated lyophilized esophageal segment was given to a senior surgeon or surgery resident who has experience suturing human esophagus, to assess their anatomical characteristics (Semblance, hardness, flexibility, tissue tear, handling), initial and final consistency. At the end of the evaluation, participants completed a questionnaire to ascertain their impressions of the

characteristics and handling of the tissue.

#### **Results**

The lyophilized esophageal segments were stored at room temperature during 30 days. After rehydration, they kept their structural integrity and shape. Sixteen 3 cm long segments were obtained.

Nine experienced general surgeons and seven senior general surgery fellows, performed an end-to-end anastomosis on each segment. There were no complications such as esophageal ruptures, neither tears on the mucosae nor the outer layers. The consensus from the general surgeons and fellows who have experience performing esophageal surgical procedures on human patients, are that the lyophilized esophageal consistency, elasticity, maneuverability, as well as the cutting and suturing are close similar with the live human esophagus (Table 1).

**TABLE 1** - Lyophilized esophagus assessment.

<b>Experience suturing human esophagus</b>	<b>More than 5 esophagus</b>	<b>56.3%</b>
	5 esophagus	18.7%
	Less than 3 esophagus	25.0%
<b>Lyophilized esophagus semblance with the human esophagus.</b>	Identical	37.5%
	Similar	62.5%
	Different	0.0%
<b>Maneuverability</b>	Easy maneuverability	81.3%
	Standard maneuverability	18.7%
	Difficult maneuverability	0.0%
<b>Lyophilized esophagus tearing</b>	No tears	100%
<b>Initial and final consistency</b>	Same consistency	87.5%
	Almost the same	6.2%
	Different	6.2%
<b>Quality of the Lyophilized Esophagus vs synthetic materials</b>	Superior	75.0%
	Average	25.0%
	Lower	0.0%
<b>Would you recommend for surgery training?</b>	Yes	100%

The needle passed through the rehydrated lyophilized tissue without resistance. All the participants, have experience practicing on low-fidelity bench model, mainly silicone tubes and ethylene-vinyl acetate plates, have a 100% preference working with rehydrated lyophilized esophagus.

### Discussion

The acquisition of surgical skills is essential in the training of all the surgical specialities, from medical students to surgical subspecialities, but ethical and economical issues have limited this surgical training<sup>1-5</sup>. Thus, a variety of surgical bench models simulators have emerged with the aim of better preparing trainees for the acquisition of surgical skills<sup>6-9</sup>.

The best surgical bench models are those with the best degree of fidelity or realism with the living human tissue<sup>10</sup>. Cryopreserved tissues or organs can be used to teach surgical skills, since they keep their normal anatomy, structure and consistency; they can be harvested from end research animals and banked for a long period of time, since they are under cryopreservation<sup>12</sup>.

We have also experience working lyophilizing tissues and organs for animal research studies, thus we have considered that the lyophilisation of many different organs and tissues, can be very useful for the teaching and acquisition of surgical skills.

To our knowledge, this the first report in which lyophilized esophagus is used as a potential high fidelity bench model to learn surgical skills, for general surgeons, as well as for other surgical specialities.

The advantage of using a lyophilized esophagus, is that after being rehydrated, it keeps its normal living shape and consistency, is inexpensive, since it is harvested from non-esophageal research animals at the end of the research time, which are going to be euthanized; the cost of preparing the solutions is less than \$20 USD; One esophagus can be trimmed in segments of different lengths. Since they are stored at room temperature, a lyophilized organs bank can be created, giving the possibility to programme the training session with the surgical fellow in accordance with their heavy schedules. It is practical, portable and easy to use. It gives the sensation to be operating a living human esophagus.

This model can evaluate the performance of all the surgical trainees with the previously validated and adapted for surgical application Global Rating Scale.

### **Conclusions**

The lyophilized esophagus model is a high fidelity, practical, portable, reproducible, low cost bench model, that can be banked at room temperature in a sterilized surgical package in an ordinary shelf until the practice day. It allows all surgical trainees how to handle an esophagus, to perfect their surgical and suturing abilities, before applying them on a real's patient esophagus.

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