European Archives of Oto-Rhino-Laryngology (2019) 276:3539–3542
https://doi.org/10.1007/s00405-019-05660-w

HEAD AND NECK

# Ex-vivo surgical model for "Barbed Snore Surgery": a feasibility study

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Received: 5 August 2019 / Accepted: 16 September 2019 / Published online: 10 October 2019


## Abstract

**Introduction** The "Barbed Snore Surgery" is one of the last technical innovations in palatal surgery for Obstructive Sleep Apnea. The availability of a low-cost surgical model able to replicate tissue consistency and main anatomical structures could be fundamental for the spreading of this surgery. The aim of this study was to assess the feasibility of an ex-vivo ovine model in the surgical training of BSS.

**Methods** After adequate preparation of adult lamb heads, a post-graduate student with no surgical expertise was guided by a skilled surgeon in the execution of two BSS procedures: "Barbed Roman Blinds Technique" and "Barbed Anterior Pharyngoplasty". Anatomical limitations and similarity with the human tissue were assessed and recorded during the simulation.

**Results** All the procedures were successfully completed. Despite proportional differences, the palatal tissue was assessed as similar in consistency and thickness to the human tissue. The simulation was considered satisfactory and suitable for surgical training.

**Conclusion** This ex-vivo ovine surgical model could represent the right tool for BSS training thanks to readily available and inexpensive specimens. Moreover, it appears to present the realistic anatomy and tissue consistence essential for an adequate surgical simulation.

**Keywords** Ex-vivo · Surgical model · Surgery · Barbed · Sleep apnea

## Introduction

The development of surgical models is now widespread in the otolaryngology field [1]. Several surgical simulators are used to expedite the surgical learning curve of residents and fellows. The American College of Surgeons–Accredited Education Institutes (ACS–AEI) promote surgical simulation in the education and training of residents, and indeed, it represents an important requirement for accreditation of surgical residency programs in the US [2]. Although some synthetic models have been developed to obtain a realistic simulation, the specific tissue consistence and the presence of all anatomical structures may not always be provided [3]. On the other hand, human cadaver models are increasingly less available as a consequence of ethical issues and cost for institutions.

In this context, several animal models have been proposed to overcome these challenges. Although animal right concerns and cost limit the usefulness of live animals in surgical training [4], some ex-vivo models have been described as adequate solutions for a low cost and realistic simulation [5, 6].

This article is part of the Topical Collection on sleep apnea syndrome. Guest Editors: Manuele Casale, Rinaldi Vittorio.

**Electronic supplementary material** The online version of this article (https://doi.org/10.1007/s00405-019-05660-w) contains supplementary material, which is available to authorized users.

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Although the role of surgical training is clear for post-graduate students and residents, it is equally true that also more skilled surgeons could benefit from training sessions in the case of new techniques and technologies. Palatal surgery has been reaching a central role in Obstructive Sleep Apnea (OSA) surgical management, and the "Barbed Snore Surgery" (BSS) represents one of the last innovative technique in this field [7]. Barbed sutures, specifically driven across the palate according to the collapse pattern, allow the surgeon to lift and strengthen the soft palate to increase airway patency and reduce collapsibility [8].

According to the increasing popularity of this technique, the availability of a low-cost surgical model able to replicate tissue consistency and main anatomical structures could be fundamental for the spreading of this surgery. The aim of this study was to assess the feasibility of an ex-vivo ovine model in the surgical training of BSS.

## Methods

A post-graduate student with no surgical expertise was guided by a skilled surgeon in the execution of two BSS procedures: "Barbed Roman Blinds Technique" (BRBT) [7] and "Barbed Anterior Pharyngoplasty" (BAPh) [9]. The same procedures were previously performed by the skilled surgeon as a demonstration for the student. The duration of each procedure was recorded. Anatomical limitations and similarity with the human tissue were assessed and recorded by the surgeon during the simulation. The tissue consistency and anatomical proportions were compared to human anatomy through visual and palpatory impression, other than tissue resistance to barbed sutures by an expert surgeon who performed more than a hundred BSS procedures before the simulation. Two different adult lamb heads were used for each training session. The lambs were farm-raised animals obtained from a slaughterhouse at a cost of approximately 5$ each. The heads were stored at 4 °C for at least 3 days to minimize the post-mortem rigor mortis and facilitate jaw opening and oropharynx exposure during the training session. The muzzle was dissected on the coronal plane to reduce the oral cavity deepness. In addition, the cheeks were slightly dissected bilaterally (transversally) to facilitate palatal reaching with surgical instruments. The prepared head was placed on a stable, as shown in Fig. 1a. The oral cavity and the oropharynx were exposed using a Davis–Boyle Mouth Gag (27 × 105 mm blade) (Fig. 1b). Surgical landmarks (posterior nasal spine, PNS; the pterygoid hamulus, PH; and the pterygomandibular raphe, PMR) were marked with blue ink to guide the procedure. Barbed sutures (size 2–0, mounted on 37 mm semi-circular needle; V-Loc™ 180, Medtronic®) were used during all the procedures.

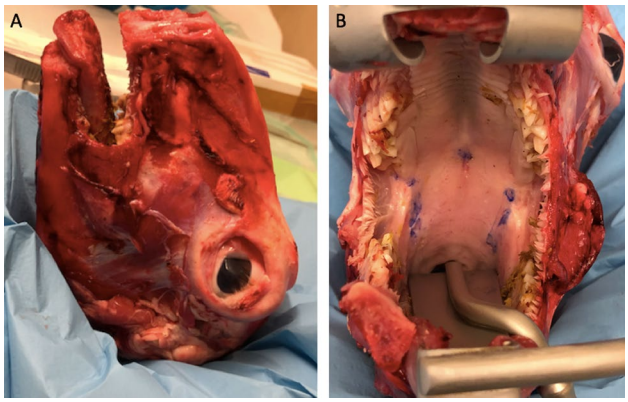


**Fig. 1** Prepared adult lamb head placed on a stable. **a** Lateral view showing the anterior–posterior diameter of the lamb head after muzzle dissection. **b** Exposure of the soft palate with surgical landmarks (PNS, PH, PMR) marked with blue ink

## Results

All the procedures were successfully completed. The post-graduate student was able to perform both BRBT and BAPh determining the shortening, lifting, and advancement of the soft palate. BAPh main surgical steps are shown in Fig. 2. The BRBT performed is available as electronic supplementary material. The operative time was slightly superior for the post-graduate student (BRBT 17.40 min, BAPh 15.20 min) compared to the skilled surgeon (BRBT 12.50 min, BAPh 11.40 min). Despite proportional differences, all surgical landmarks were easily found and marked during the procedures. In particular, the most important difference observed in the anatomical structure was the proportionally greater palatal length (35–40 mm from the PNS to the uvula), but this did not affect the training session and the efficiency of the surgery. Some anatomical differences between human and ovine pharynx were detected. Ovine pharynx is globally shorter and narrower compared to human anatomy, and the epiglottis is closer to the soft palate due to its more cranial location. However, these differences are not relevant for BSS and do not influence the simulation. Palatal tissue was assessed as similar in consistency and thickness to the human tissue. PMR tissue consistence was slightly different from that of a human: the application of excessive tension leaded to the tearing of the tissue, as shown in Fig. 2e.

## Discussion

Several otolaryngology-head and neck surgical techniques could be performed using ex-vivo ovine models as already demonstrated by numerous papers [5, 10, 11].

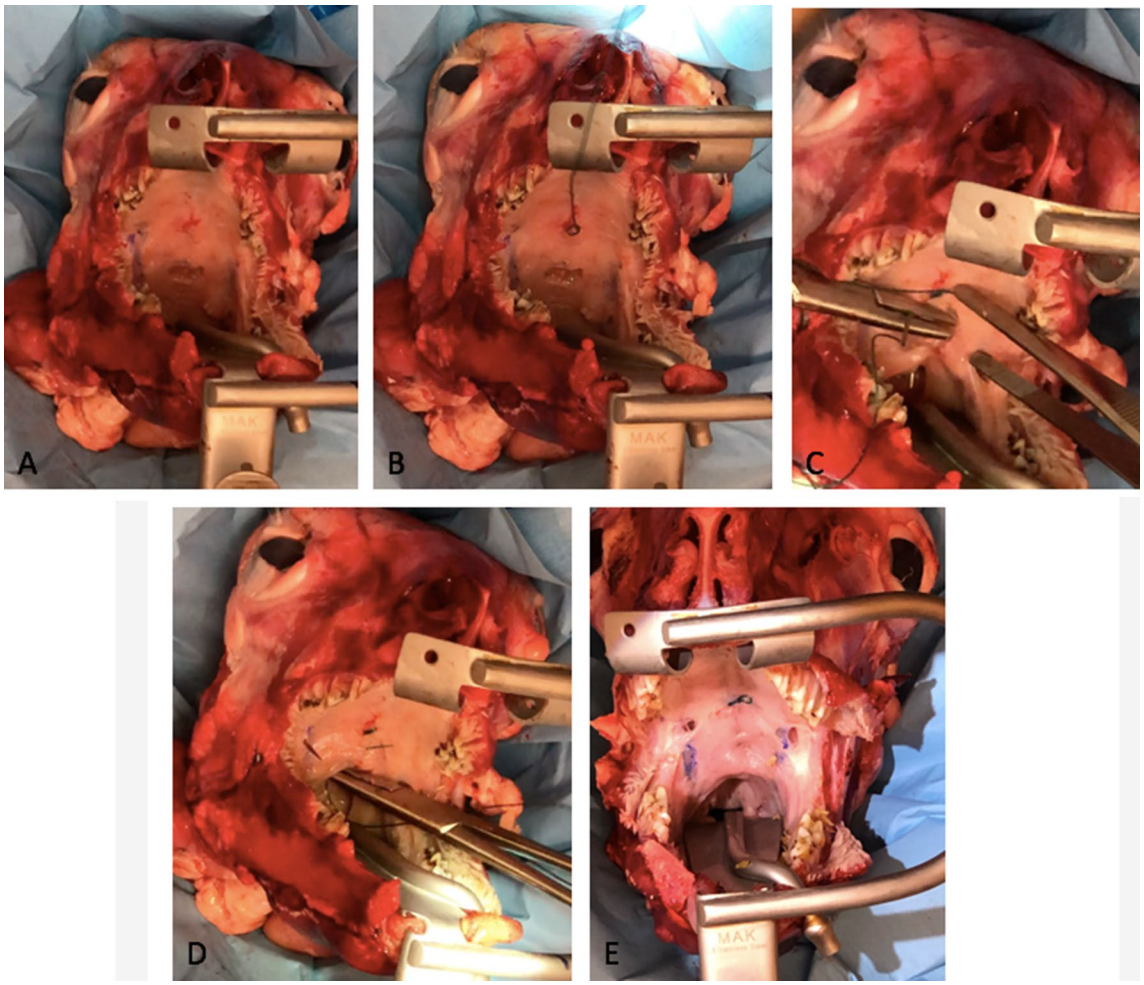


**Fig. 2** Main surgical steps of *Barbed Anterior Pharyngoplasty* on the ex-vivo ovine model. **a** Soft palate after the removal of a semilunar mucosal strip using cold blade. **b** Central pivotal loop anchored to the PNS was created. **c** Needle is driven downwards through the muscles until it perforates the mucosa adjacent to the ipsilateral base of the uvula. **d** Needle is directed sideways along the palatopharyngeal muscle to reach the PH. **e** Palate is lifted and shortened bilaterally at the end of the procedure

To our knowledge, this is the first ex-vivo surgical model for BSS described in the literature. Although there is no animal capable of perfectly simulating human anatomy, the repeated execution of surgical procedures on animal models can be a low-cost method able to facilitate surgical training before performing the real surgery.

BSS surgical training must provide the possibility of an easy, repeatable hands on experience able to improve confidence with barbed sutures and tissue consistency. This ex-vivo ovine model faithfully reproduces the human small surgical field, providing a realistic and more difficult maneuvering of the hands able to improve surgical skills. In addition, the possibility of recognize main surgical landmarks is not secondary considering that these represent the palatal anchoring point. The capacity of identify these landmarks and the execution of the proper surgical steps ensure the success of the procedure, determining an adequate lifting of the soft palate. Furthermore, the muzzle dissection leads to a more realistic anatomical proportion according to the exaggerated anterior–posterior diameter of the lamb head. The different palatal proportion is not a relevant limitation for these surgical procedures. Barbed sutures have been developed to perform multiple passages to reach main surgical landmarks. In addition, also during real surgery, several needle passages could be necessary in some instances.

According to this preliminary study, the lamb head provides an inexpensive, realistic, and easily repeatable palatal surgical training. The possibility to obtain farm-raised animals from an abattoir after lamb carcasses evisceration allows to obtain numerous lamb heads at approximately 5$ each. In this cases, an adequate preparation should be carried out prior to the training session. The post-mortem preservation of the specimen for at least 48–72 h is fundamental to avoid trismus [10]. A tonic muscular contraction of the

masseter does not allow the proper surgical access to the soft palate, especially considering its deeper location in the oropharynx. According to the skilled surgeon experience, although some anatomical differences were highlighted, the tissue consistence and the presence of all surgical landmarks provide an adequate surgical simulation. Furthermore, although the post-graduate student was totally "naïve" in this kind of surgery, all surgical steps were easily performed under supervision.

## Conclusions

Given the recent emphasis on BSS, the possibility to perform a realistic and easily repeatable surgical simulation could be extremely important for the spreading of these techniques. An ex-vivo ovine surgical model could represent the right tool for BSS training thanks to readily available and inexpensive specimens. Moreover, it would seem to present the realistic anatomy and tissue consistence essential for an adequate surgical simulation.

**Funding** No funding was received for this research.

### Compliance with ethical standards

**Conflict of interest** All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge, or beliefs) in the subject matter or materials discussed in this manuscript.

**Ethical approval** Because of the nature of this project, no institutional review board approval was necessary.

**Informed consent** This article does not contain any studies with human participants or live animal performed by any of the authors.

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