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Surgical simulation: an animal tissue model for training in therapeutic and diagnostic bronchoscopy

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Abstract
A series of surgical simulation exercises has been developed using an animal model to allow trainees to practise basic instrument handling and develop psychomotor skills in bronchoscopy, without risk to patients. A pig model was found to be most suitable. After suitable preparation the model can be used for diagnostic and therapeutic exercises in bronchoscopy, including lavage, biopsy and the removal of various foreign bodies. The model is a safe, inexpensive and convenient means of bronchoscopic training for otolaryngology trainees. For the trained specialist who has to remove bronchial foreign bodies infrequently, the model is a useful way of maintaining skills.

Key words: Technical training; Surgery; Bronchoscopy

Introduction

The advent of flexible fibre-optic bronchoscopy has meant that diagnostic bronchoscopy has increasingly been performed by respiratory physicians rather than surgeons. This has made it more difficult for otolaryngologists to acquire skills in rigid bronchoscopy. Yet otolaryngologists may be required to provide a rigid bronchoscopy service for infants and children and for foreign body removal at all ages. This is especially so in centres lacking a thoracic surgery service. A retrospective review of 201 bronchoscopies performed in our department between June 1995 and December 1998, revealed that six cases were for foreign body removal and six cases for airway obstruction. The infrequent presentation of patients with bronchial foreign bodies means that adequate training for all trainees is not always possible. Where a sufficient case load exists, supervised operating is invaluable, but presupposes both a basic competence in instrument handling by the trainee, and a trainer with sufficient expertise to monitor and teach. It is now well accepted that training in these procedures on live patients should not add a significant risk factor to the procedure (Carter *et al.*, 1994). One solution to this dilemma is to ensure that trainees have attained basic skills in instrument handling on simulators before they operate on live patients. This principle has applied to trainee otologists prior to mastoid surgery for decades.

Obtaining a realistic simulation of bronchoscopy for training purposes is not straightforward. Synthetic simulators are available (Storz, UK, Denoyer-Geppart International, Chicago, USA). These are made of plastic without an attached oropharyngeal unit. While they offer a reasonably accurate reproduction of tracheobronchial anatomy, tissue quality is unrealistic and the difficulties encountered during bronchoscope insertion through the upper airway are not replicated. Human cadaver material including plastination models offer a good simulation but there are ethical problems with its use, and material is often difficult and expensive to obtain. Further the anatomy Act (H.M.S.O., 1984) in the United Kingdom restricts the sites where these tissues may be stored and used, and this may not always correspond with the ideal location for the trainee or the trainer. The Surgical Skills Unit at the University of Dundee, UK, has already developed a number of animal models for other endoscopic procedures (Carter *et al.*, 1994; Gardiner *et al.*, 1996). Using this experience we looked at the availability of suitable and commonly available animal tissue and found the pigs tracheobronchial tree offered a simulation closest to that of the human.

Rigid bronchoscopy, especially in children, requires the skills of an experienced team. The bronchoscopist and the anaesthetist are competing for the same limited airway and it is essential that each is fully aware of the other's requirements. Rigid bronchoscopy should be undertaken in a planned controlled fashion and the bronchoscopist and the anaesthetist should fully discuss the planned course of action prior to the induction of anaesthesia. The surgeon must be acutely aware of the need to

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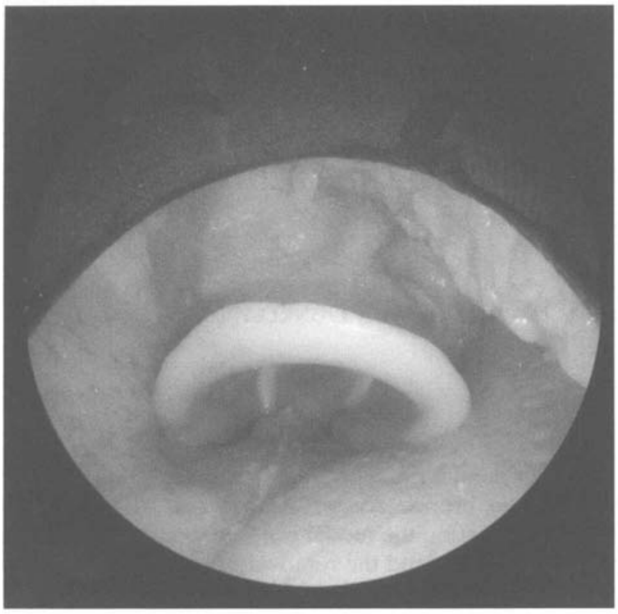

FIG. 1
The pig epiglottis.

maintain adequate ventilation and oxygenation of the patient at all times and must be responsive to the anaesthetist's requests. The scrub nurse requires to be thoroughly familiar with the instrumentation to be used and the surgeon should review all equipment likely to be used with the scrub nurse prior to anaesthesia. If a bronchial foreign body is suspected then ideally an identical foreign body should be obtained and the appropriate bronchoscope, telescope, forceps and suction identified and removal of the foreign body rehearsed prior to anaesthesia. Paediatric bronchoscopy is a procedure fraught with many potential dangers and ideally should be undertaken by an experienced team in the controlled environment of a fully equipped endoscopy theatre.

Materials and methods

The size and tracheobronchial anatomy of the yearling pig mimics the respiratory tract of an eight- to 12-year-old child, and most exercises can be achieved using a size 7.0 ventilating bronchoscope (Storz, UK). While the anatomy of the pig's tracheobronchial tree is very similar to the human, there are some noteworthy differences. The epiglottis is longer (Figure 1) and over-hangs to a greater extent. The larynx is more anteriorly placed relative to the tongue base. The right upper lobe bronchus often arises just proximal to the primary carina and the tracheal rings are not as prominent as in the human. The quality of the mucosa and compliance of the tissues are very realistic. The pigs are purchased fresh from an abattoir. The anterior 12 cm of the snout are removed with a saw to shorten the oral cavity and make the distance between the mouth and the vocal folds approximate to that of the human. The lower torso below the diaphragm is removed and used for general surgical training. After preparation the animals can be frozen until required. The upper torso is mounted using sandbags in a sink (to allow drainage), and positioned with the truncated snout facing the operator. On defrosting there is a tendency for frothy exudate to accumulate in the tracheobronchial tree which requires suction and this forms a valuable introductory exercise in tracheobronchial toilet and lavage. Bronchoscopy may then be undertaken. A beam splitter may be attached to the end of the lens system of the Hopkin's rod telescopes (Storz, UK) and then connected to a video camera. This allows continuous observation by the trainer.

Use of the model

Progressing from simple handling and assembly of bronchoscopes, and the use of the various forceps and other accessories, we have found a sequence of techniques useful in using the model (Table I). Naked eye, endoscopic and video-endoscopic bronchoscope techniques can be practised on the model with an anaesthetic ventilation circuit connected. For a right-handed person the endoscope is held in the right hand while the left hand is used to open the mouth. The bronchoscope is inserted through the right-hand side of the oral cavity. The tongue base is lifted from the posterior pharyngeal wall by pulling the mandible forward. The tip of the bronchoscope, which may also be used to lift the tongue base, is then followed through until the epiglottis is identified. Using the left hand as a fulcrum for the bronchoscope the epiglottis is gently elevated revealing the posterior glottis and the arytenoid cartilages. As the whole glottis comes into view the bronchoscope is rotated through to 90 degrees, with the tip to the right. When the view of the left vocal fold becomes centred the bronchoscope is advanced until the tip of the bronchoscope has passed through the anteroposterior axis of the glottis. The bronchoscope is now rotated 90 degrees anti-clockwise to inspect the trachea. The bronchoscope is further advanced until the sharp outline of the normal carina is reached. To enter the left main

TABLE I
VARIOUS BRONCHOSCOPIC EXERCISES AND THEIR OUTCOME MEASURES

Exercises	Outcome measures
Bronchoscope assembly	Achieved independently
Bronchoscope insertion	Achieved independently/Degree of trauma
Tracheoscopy	Achieved independently/Degree of trauma
Diagnostic bronchoscopy	Achieved independently/Degree of trauma
Flexible bronchoscopy	Achieved independently/Degree of trauma
Tertiary carina biopsy	Achieved independently/Degree of trauma
Foreign body removal	Achieved independently/Degree of trauma No. of drops

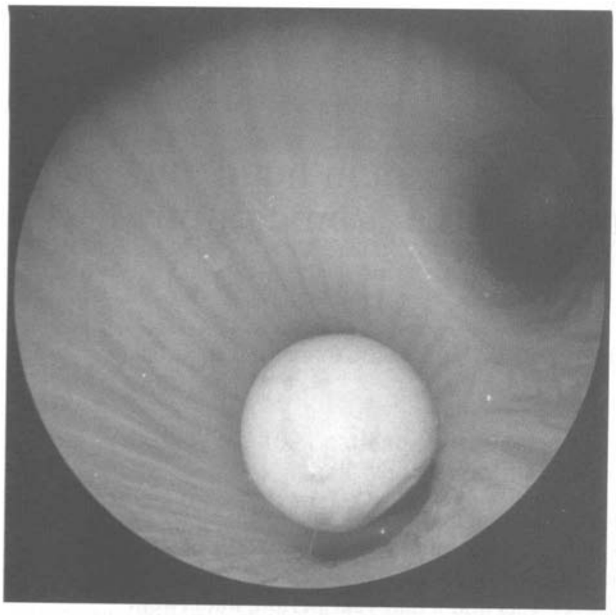

FIG. 2
Foreign body lying in the right main bronchus of the model prior to removal.

bronchus the head of the model is rotated slightly to the right bringing the long axis bronchoscope into line with the bronchial lumen. The endoscope is further advanced to view the secondary/segmental bronchi. As the right main bronchus is shorter and more vertical the bronchoscope readily passes into the right main stem with minimal head rotation. In the pig model the right upper lobe bronchus comes off at an acute angle which makes it difficult to view without the use of an angled telescope. Foreign bodies of a varied nature may be inserted by the trainer and their positions documented (Figure 2). The trainee then attempts to remove each one using the appropriate forceps. The trainer assesses the trainee for time taken to completion, and the number and severity of abrasions caused during both diagnostic and therapeutic aspects of the exercise. Procedures are carried out repeatedly until a required standard is met. Using the above model 25 trainees undertook various bronchoscopic exercises. Each trainee was then asked to rate these exercises individually and their results are presented (Table II).

Discussion

It is not our intention to advocate this surgical simulation as a replacement for clinical experience, but rather to complement it. Bronchoscopy has traditionally been a procedure in which the anaesthetist competes for the patient's airway with the surgeon. The technique requires precise control with little room for error. It is important that the surgeon wishing to perform rigid bronchoscopy fully understands the basic instrumental techniques involved. It is essential that patients are not placed at risk by surgeons taking their first steps in acquiring these new skills. From an ethical point of view, it is unacceptable for surgical skills training, or the lack of it, to become a significant risk factor in the patients outcome (Carter *et al.*, 1994).

There is no substitute for learning the complexities of human anatomy by operating on the human, in the operating theatre. The model described allows basic skills to be acquired and developed under controlled conditions and without risk to patients, and as such is the ideal precursor to such supervised live operating. Endoscopic techniques should only be performed by those with adequate training (Cuschieri, 1992). Many institutions now insist that surgeons who wish to undertake minimal access surgery must attend a recognized training course or workshop before they are allowed to perform the procedures themselves (Dent, 1991). Such courses provide a more structured approach to technical training in surgery. The use of model based simulations or cadavers with an emphasis on 'hands on' experience is also rated highly by trainees (Steele and Munro, 1989). Models for training in bronchoscopy must possess certain attributes. There must be a realistic presentation of the anatomy and tissue quality. We believe that the pig model described fulfils these criteria, and is an effective, practical and safe medium for training. The procedures can be constantly monitored by the trainer, and this allows the trainee to gain rapidly the necessary psychomotor skills involved in rigid bronchoscopy.

TABLE II
RATING OF BRONCHOSCOPY EXERCISES BY 25 TRAINEES

Exercises	Scores Rating (0–5) Minimum	Maximum	Mean
Bronchoscope assembly	3	5	4.3
Bronchoscope & biopsy	2	5	4.3
Bronchoscope & F.B. retrieval	2	5	4.3
Model suitability	1	5	4

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