

A Special, Modified, Double-Lumen Tube for One-Lung Ventilation in Pigs

by *Konrad Schwarzkopf^{1,2,*}, Lars Hueter³, Niels-Peter Preussler¹, Florian Setzer¹,
Torsten Schreiber^{1,3} & Waheedullah Karzai³*

¹Department of Anesthesiology and Intensive Care Medicine, University of Jena, Germany

²Department of Anesthesiology and Intensive Care Medicine, Klinikum Saarbruecken, Germany

³Department of Anesthesiology and Intensive Care Medicine, Zentralklinik Bad Berka, Germany

Summary

Animal studies in pigs often depend in thoracic anaesthesia on effective lung separation. In this report we describe the use of a modified double-lumen endotracheal tube for one-lung or differential lung ventilation in pigs resulting in excellent lung separation and unimpaired hypoxic pulmonary vasoconstriction.

Introduction

During thoracic surgery one-lung ventilation (OLV) is frequently required. Endotracheal intubation with a double-lumen tube is considered the gold standard for airway and ventilation management under this condition.

Alternative techniques of airway management permitting OLV include endobronchial intubation with a single-lumen tube and conventional endotracheal intubation in combination with the use of airway-blockers. These techniques share the disadvantage of limiting access to the non-ventilated lung, which may be required for endobronchial suctioning off for therapeutic or diagnostic bronchoscopy during OLV.

With these techniques, bronchoscopy of the actual non-ventilated lung during lung separation requires interruption of OLV for a while, a situation, which is often undesirable.

In contrast, with the use of a double-lumen tube, unrestricted bronchoscopy of the non-ventilated lung

is easily possible.

Experimental research in the field of thoracic anaesthesia has been conducted in various animal models (*Michelet et al., 2005; Karzai et al., 1999*). To simulate clinical scenarios, models need to be suitable for invasive hemodynamic monitoring and for ventilation strategies commonly applied in clinical practice.

However, the double-lumen tubes commonly used in clinical practice are highly developed devices reflecting human airway size and anatomy and thus may not always be appropriate in animal models. For example, due to the special anatomical situation, commercially available double-lumen tubes are not suitable for use in pigs: in this species a tracheal bronchus (right cranial lobe bronchiole) originates from the right side of the trachea. In the left lung the cranial lobe bronchioles are usually absent (*Nakakuki, 1994*). A short left main bronchus branches out into several bronchioles forming the bi-lobed middle and caudal lobes (Figure 1-4).

Description and Methods

We here describe in detail a modified double-lumen tube adapted to the porcine airway anatomy, which we used in our studies focussing on effects of inhalational anaesthetics on oxygenation, lung perfusion and hemodynamics in a porcine model of

*Correspondence: Konrad Schwarzkopf, MD
Klinik fuer Anaesthesiologie und operative
Intensivmedizin, Klinikum Saarbruecken, Winterberg 1,
66119 Saarbruecken, Germany
Tel +49 6819632648
Fax +49 6819632815
E-mail kscharzkopf@klinikum-saarbruecken.de

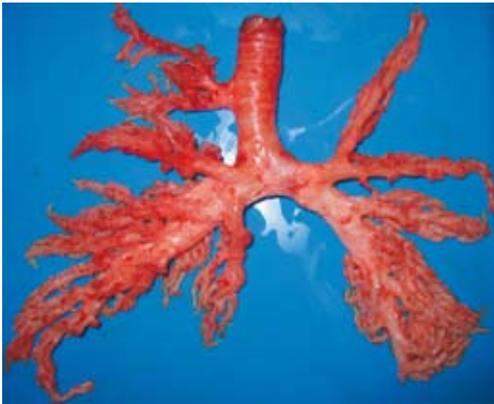


Figure 1. Bronchial tree of the pig.



Figure 3. View in the non-intubated trachea of a pig. On the right side of the trachea the access to the right cranial lobe is visible. The main carina is located in the center.

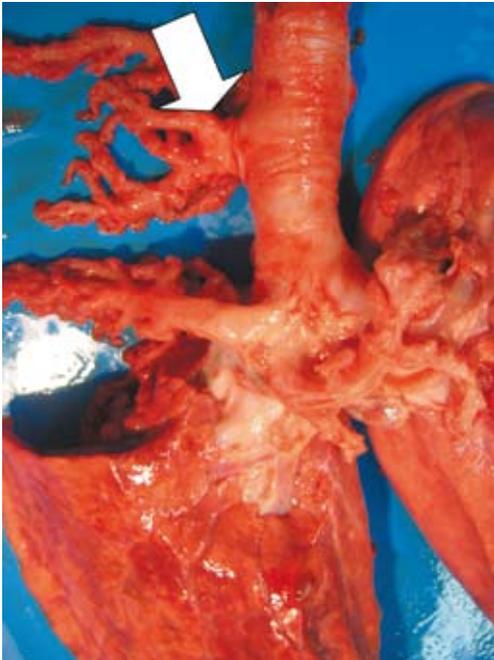


Figure 2. The right cranial lobe bronchiole arising from the trachea.

OLV (Schwarzkopf et al., 2003; Schwarzkopf et al., 2005; Schwarzkopf et al., 2009). This tube allows unimpeded ventilation of the right cranial lobe, providing adequate lung separation and providing

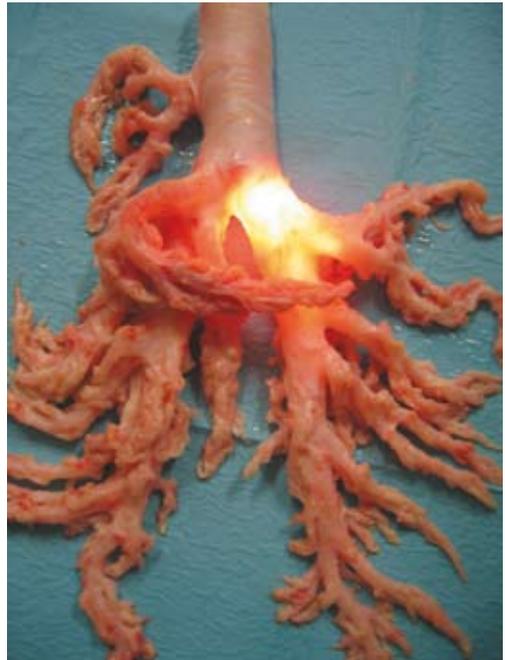


Figure 4. Diaphanoscopy of the short left main bronchus of the pig.

bronchoscopic access to both the ventilated and non-ventilated lung.

The specific design of the tube is borrowed from Lesser et al. (Lesser et al., 1998). The tubes used in our studies have been made by a manufacturer of anaesthesia equipment (Mallinckrodt, Dublin, Ireland) according to our specifications. The basic design is deduced from a 39Ch double-lumen endotracheal tube (Broncho-Cath™).

The tube has the following modifications:

The right (tracheal) lumen of the tube ends 95 mm cranial of the left (bronchial) branch of the double lumen tube. The comparable distance in the Mallinckrodt Broncho-Cath™ endobronchial tube for human use is 60 mm (Figure 5).



Figure 5. Comparison of the modified double-lumen tube (on the top) with a 39Ch double-lumen tube for human use.

The bronchial tip of the endobronchial tube is modified to make ventilation of all lobes of the left lung easier. Whereas in the tube for human use the distal end of the bronchial cuff is 10 mm cranial of the bronchial tip, this distance is only 1 mm in the modified tube. This modification on the one hand prevents occlusion of bronchi of the left lung by the tip of the double-lumen tube, while on the other hand assuring that the bronchial cuff is completely located in the short left main bronchus (i.e. does not project into the right main stem bronchus or into the trachea), thereby providing adequate lung separation when it is inflated (Figure 6, 7).

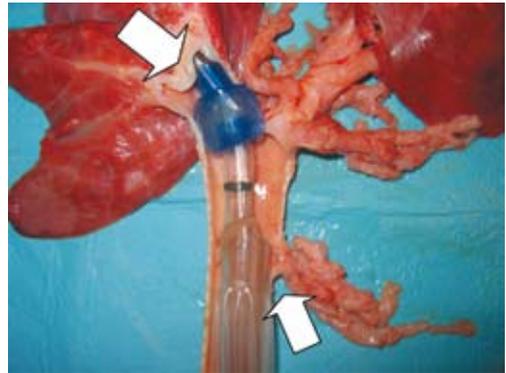


Figure 6. The 39Ch double-lumen tube for human use, positioned in the trachea of a pig. Access to the right cranial lobe is inhibited, the bronchial tip may be occluded often and access to the left upper lobes is difficult for the most part.

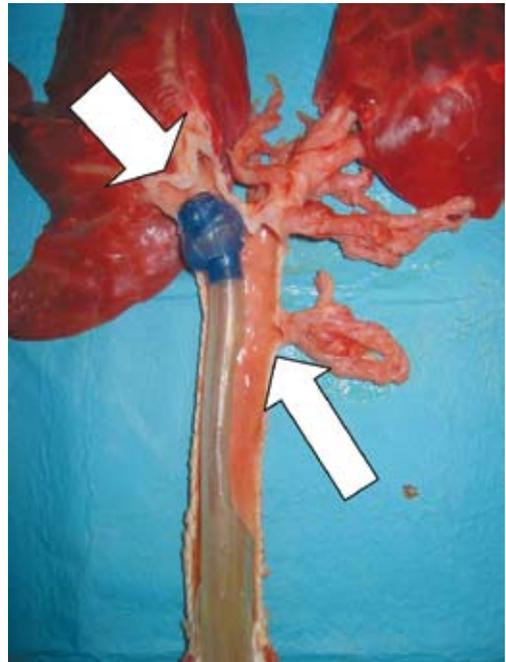


Figure 7. Our 39Ch double-lumen tube specially designed for use in pigs, positioned in the trachea of the same pig. Access to the right cranial lobe is uninhibited, the bronchial tip is not occluded and access to the left upper lobes is possible.

We successfully used this specially designed double-lumen tube to provide one-lung ventilation or independent lung ventilation in more than 120 pigs (German Land Race) with a body weight ranging from 22 to 50 kg. Ventilation periods ranged from 4-10 hours. We found that at a body weight of less than 22 kg placement of this tube may fail, because the left main bronchus is too small.

Since in our studies the anesthetized animals are sacrificed at the end of the ventilation period, we commonly place the double-lumen tube via a surgical tracheotomy. However, we also successfully performed orotracheal intubation with these tubes in animals with a bodyweight of 30 to 45 kg.

In our opinion, fiberoptic control of the position of the double-lumen tube is always mandatory. For this purpose bronchoscopy using a flexible bronchoscope should be performed via both lumen of the tube and particular attention should be paid to the orifice of the tracheal bronchus and to the origins of the left middle and caudal bronchi in order to verify

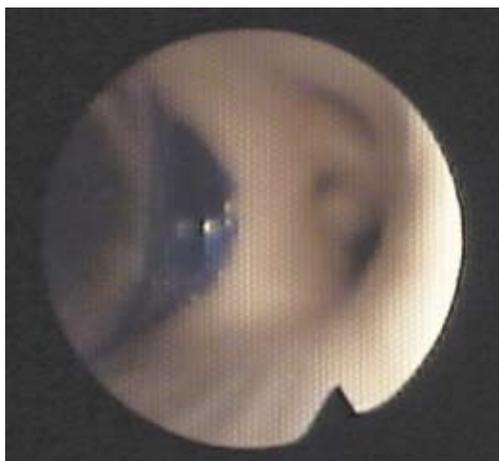


Figure 8. View of the main carina of a pig, intubated with the modified double-lumen tube as described in the text. On the right side ventilation and access to the right middle and lower lobes is uninhibited. On the left side the correct position of the bronchial cuff in the left main bronchus (“Halfmoon-like”) is demonstrated.

that these are unobstructed (Figure 8). In our experiments we repeat bronchoscopy after each change of body position and after each manipulation at the endotracheal tube.

References

- Karzai W, J Haberstroh & HJ Priebe:* The effects of increasing concentrations of desflurane on systemic oxygenation during one-lung ventilation in pigs. *Anesth Analg.* 1999, *89*, 215-217.
- Lesser T, S Klinzing, H Schubert, U Klein & M Bartel:* Lung flooding- a new method for complete lung sonography. *Res Exp Med.* 1998, *198*, 83-91.
- Michelet P, A Roch, D Brousse, XB D'Journo, F Bregeon, D Lambert, G Perrin, L Papazian, P Thomas, JP Carpentier & JP Auffray:* Effects of PEEP on oxygenation and respiratory mechanics during one-lung ventilation. *Br J Anaesth* 2005, *95*, 267-273.
- Nakakuki S:* Bronchial tree, lobular division and blood vessels of the pig lung. *J Vet Med Sci.* 1994, *56*, 685-689.
- Schwarzkopf K, T Schreiber, N Preussler, E Gaser, L Hueter, R Bauer, H Schubert & W Karzai:* Lung perfusion, shunt fraction, and oxygenation during one-lung ventilation in pigs: The effects of desflurane, isoflurane, and propofol. *J Cardiothor Vasc An.* 2003, *17*, 73-5.
- Schwarzkopf K, T Schreiber, E Gaser, N Preussler, L Hueter, H Schubert, H Rek & W Karzai:* The effects of xenon or nitrous oxide supplementation on systemic oxygenation and pulmonary perfusion during one-lung ventilation in pigs. *Anesth Analg.* 2005, *100*, 335-339.
- Schwarzkopf K, L Hueter, T Schreiber, N Preussler, V Loeb & W Karzai:* Oxygenation during one-lung ventilation with propofol or sevoflurane. *Middle East J Anesthesiol.* 2009, *20*, 397-400.