

Fibreoptic bronchoscopy

© RWD Nickalls,
Department of Anaesthesia,
Nottingham University Hospitals,
City Hospital Campus,
Nottingham, UK.

dick@nickalls.org
www.nickalls.org

5 Fibreoptic bronchoscopy	68	5.7 Anaesthesia for bron-	
5.1 History	68	choscopy	75
5.2 Carina	69	5.7.1 Short duration . .	75
5.3 Right subcarina & beyond	69	5.7.2 Long duration . . .	75
5.4 Left subcarina & beyond .	71	5.7.3 Local anaesthesia	
5.5 Bronchoscopy simulators .	73	& sedation	76
5.6 Image orientation	73	5.7.4 Venturi jet ventila-	
5.6.1 Axial rotation . . .	73	tion	76
5.6.2 Bending	74	5.7.5 Complications . .	77
5.6.3 Camera-mode . . .	74	5.7.6 Intubation	77
		5.7.7 History	77

FROM: Nickalls RWD. *Notes on thoracic anaesthesia*
revision: 2009 α

Chapter 5

Fibreoptic bronchoscopy¹

FIBREOPTIC bronchoscopy is a valuable tool for viewing bronchial anatomy, and for facilitating correct placement of single and double-lumen endotracheal tubes, bronchial blockers and tracheostomies. In the Intensive Care Unit it is also used for bronchoalveolar lavage (BAL) and for secretion control.

- BTS (2001). British Thoracic Society guidelines on diagnostic flexible bronchoscopy. *Thorax*; 56 (Suppl I), i1–121.
<http://www.brit-thoracic.org.uk/c2/uploads/Bronchoscopy.pdf>
- Hawkins N (2000). *Fibreoptic intubation*. (Greenwich Medical Media Ltd, Lond.)
- Jolliet PH and Chevrolet JC (1992). Bronchoscopy in the intensive care unit. *Intensive Care Medicine*; 18, 160–169.
- Mehta AC (Ed) (2001). Flexible bronchoscopy update. *Clinics in Chest Medicine*, 22 (June). (WB Saunders Company, London). [contains many useful articles]
- Wang Ko-Pen, Mehta AC and Turner JF (2004). Flexible bronchoscopy. 2nd ed. (Blackwell Publishing, UK). [see the excellent cardio-thoracic anatomy diagrams in chapter 5, showing how the vessels are related to the bronchial tree (Applied anatomy of the airways) by Kavuru MS and Mehta AC (2004), pp. 36–38]
- Watson CB (1987). Fibreoptic bronchoscopy in thoracic anaesthesia. In: Gothard JWW [Ed.], Thoracic anaesthesia. *Clinical Anaesthesiology*; 1 (March); pp. 33–60.

5.1 History

Although the Englishman John Tyndall described the optical properties of flexible glass fibres in 1870, it was not until 1957 that the first ‘gastro-fibrescope’ was developed by B. Hirschowitz in the USA. An improved version was subsequently developed in Japan by the Machida Endoscope Co. Ltd in 1962. In 1964 the Japanese physician Shigeto Ikeda, in collaboration with the Machida Endoscope Co. Ltd, started developing a fibreoptic bronchoscope, which was eventually manufactured in 1967 (Ikeda *et al.* 1968; Ikeda 1974). Ikeda’s conference presentation of an early prototype in 1966 is remembered by Drs Olsen and Ono as follows:

When Dr Shigeto Ikeda attended the Ninth International Congress on Diseases of the Chest in Copenhagen in August 1966, he demonstrated the prototype of the present day bronchofibrescope. He brought a motion picture with him which showed that the instrument could be used for bronchoscopic cinematography. We were greatly impressed by Dr Ikeda’s presentation.

¹<http://www.nickalls.org/dick/papers/thoracic/hand-bronch.pdf>

Olsen AM (Foreword); In: Ikeda (1974).

It was at this transitional period of decreasing pulmonary tuberculosis to increasing lung cancer that a flexible bronchofibroscope came to be recognized. The credit for the first to report on the subject must go to Dr Shigeto Ikeda. He demonstrated it with motion pictures . . . in Copenhagen in August 1966. Also, Dr Ikeda was first to publish an article on the use of the flexible bronchofibroscope which appeared in the Journal of Japan Broncho-esophagological Society and Keio Journal of Medicine in 1968.

Ono J (Foreword); In: Ikeda (1974).

- Ikeda S (1974). *Atlas of flexible bronchofiberscopy*. (Igaku Shoin Ltd., Tokyo). [Chapter 1 describes the historical development of the flexible bronchoscope]
- Ikeda S, Yani N and Ishikawa S (1968). Flexible bronchofiberscope. *Keio J. Medicine*; 17, p. 1. [First journal article on the use of the fibreoptic bronchoscope]

5.2 Carina

The position of the carina is surprisingly variable, and depends on body shape, size, posture, operation (e.g., laparoscopy). Factors which alter the position of the diaphragm generally move the carina in a similar direction. Consequently, one should have a low threshold for using the fibroscope to check the position of the tube—when in doubt—and especially in the various cases described in Section 4.6. The TEPID database predicts the distance to the carina in supine patients reasonably well (see Section 6.4.3).

To measure the distance between the end of the ETT and the carina, first place the tip of the fibroscope on the carina and then grip the fibroscope at the ETT connector. Now, while maintaining the same grip on the fibroscope, slowly withdraw the fibroscope until the end of the ETT just comes into view. Now the distance between your grip on the fibroscope and the ETT connector is the required distance.

5.3 Right subcarina & beyond

Figure 5.4 shows the anatomy as seen down the bronchoscope by an anaesthetist positioned at the head end of a supine patient (*without* the camera attachment.²) While the entrance to the right upper lobe is straightforward to recognise, its exact distance from the carina is fairly variable. The part between the right upper lobe and the middle lobe bronchus is known as the lower part of the right main bronchus.³

The key bronchoscopic features to note are (a) the entrance to the right upper lobe, and the configuration of its immediate subdivisions,⁴ (b) the orifice of the bronchus to the apical⁵ segment (yellow) of the lower lobe at the 6 o'clock position, and (c) the orifice of the middle lobe bronchus at the 12–2 o'clock position.

²See Section 5.6.3

³Historically known as the *bronchus intermedius*—see Section 4.2.1 for correct nomenclature.

⁴Typically three symmetrical sub-bronchi as shown in Figure 4.1

⁵Sometimes known as the *superior* segment.

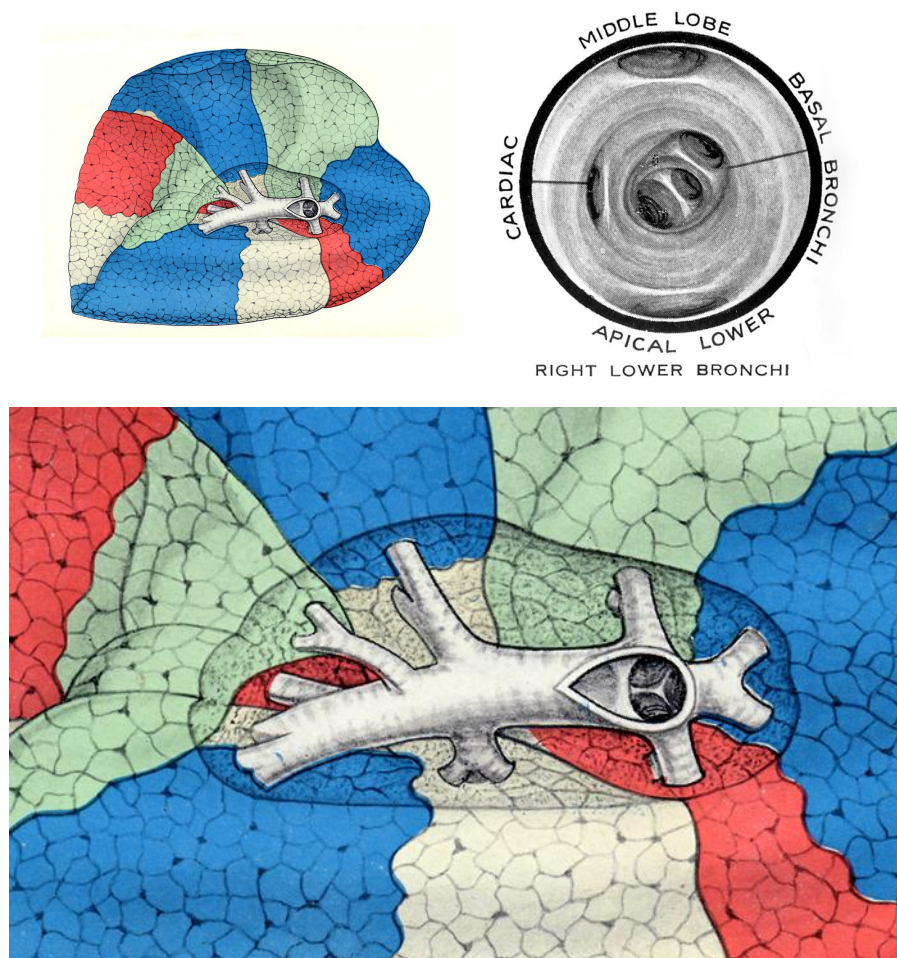


Figure 5.1:

Top left: Right lung medial supine view. **Top right:** Supine view of right lower lobe bronchus. **Bottom:** Close up view of the right supine hilum.

Note that the lung in these views is shown in the supine position (cf. Figure 4.6). The orifice of the bronchus to the apical segment (yellow) of the lower lobe is typically in the 6-7- o'clock position just as in the left lung. The orifice of the middle lobe bronchus is at the same level but in the 12-2 o'clock position. (*From Brock (1942-1944), with permission.*)

5.4 Left subcarina & beyond

Figures 5.1 and 5.2 show the anatomy as seen down the fibrescope by an anaesthetist positioned at the head end of a supine patient (*without* the camera attachment.⁶)

The key features to note are (a) the orifices of the second-order bronchi either side of the left subcarina lie on a line running from top left to bottom right, (b) the first part of the left lower-lobe bronchus is characterised by the orifice of the bronchus to the apical segment of the lower lobe at the 6–7 o'clock position, and (c) the orifice of the lingula bronchus (lower division of the upper lobe bronchus) lies to the right as a division of the left upper lobe bronchus. (see Section 4.2.1 for nomenclature).

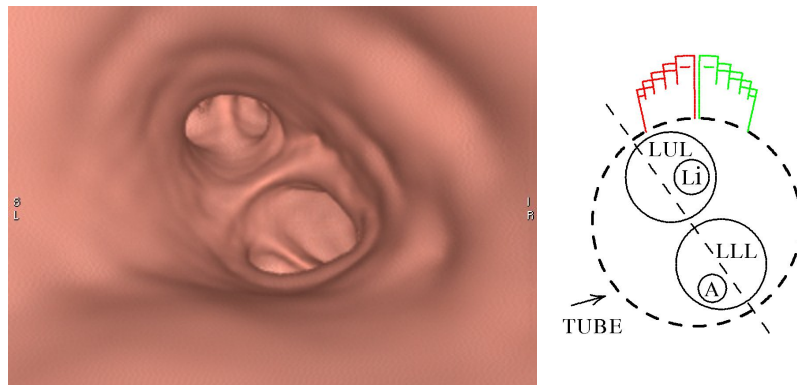


Figure 5.2:

Left: The left subcarina viewed from the carina, constructed from a CT-scan (so-called ‘virtual bronchoscopy’), showing the typical orientation of the left upper and lower second-order bronchi when viewed from the head end in a supine patient. *Copyright © RWD Nickalls & J James 2005*

Right: Schematic of the left picture, showing how the left upper-lobe bronchus divides into the lingula bronchus (Li) and the left upper division bronchus (LUL). In addition we see the characteristic position of the orifice of the apical bronchus (A) of the apical segment of the left lower-lobe (LLL) just inside the entrance of the left lower-lobe bronchus. Note the typical orientation (straight dashed line) of the second-order bronchi either side of the subcarina. The schematic shows the view associated with the closest safe approach of the end of the double-lumen tube (dashed circle) with respect to the second-order bronchi. *Copyright © RWD Nickalls 2005*

⁶See Section 5.6.3

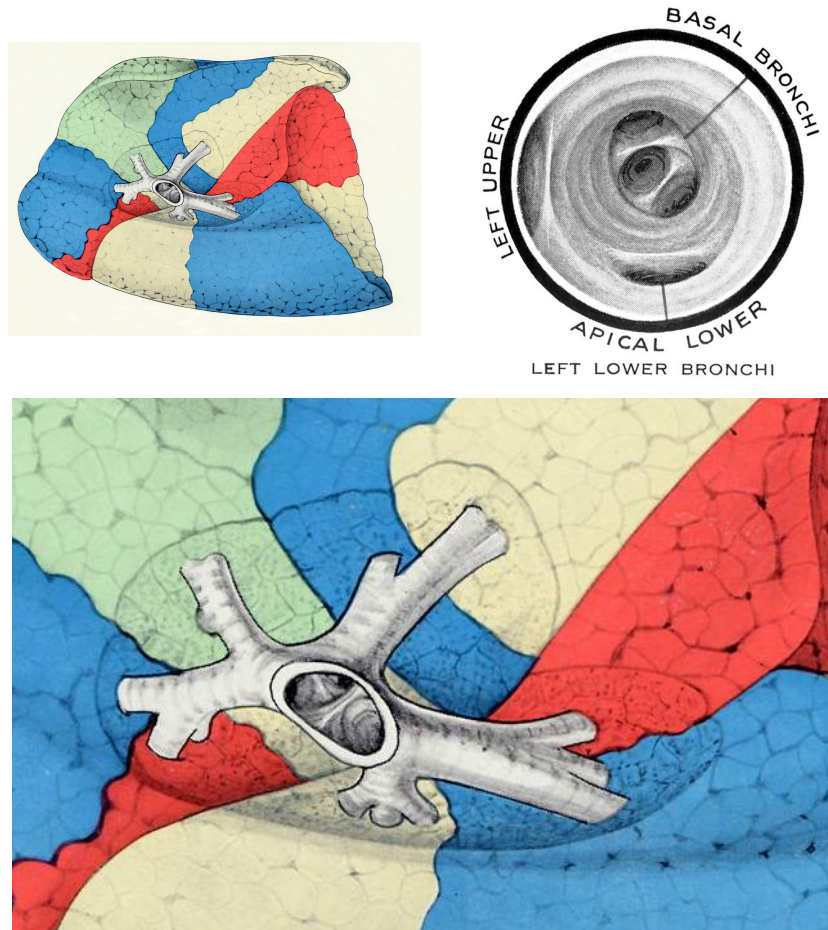


Figure 5.3:

Top left: Left lung medial supine view. **Top right:** Supine view of left lower-lobe bronchus.

Bottom: Close up view of the left supine hilum.

Note that the lung in these views is shown in the supine position (cf. Figure 4.7), and hence the orientation of the left subcarina here is fully consistent with the images in Figure 5.1. Since this view also has the same orientation as that seen down the bronchoscope (from the head end), it makes the anatomy much easier to understand. For example, we can now see clearly how in the supine position the bronchus to the apical segment (yellow) of the lower lobe descends vertically down from the first part of the lower lobe bronchus (see also Figure 5.1 opposite). (*From Brock (1942–1944), with permission.*)

5.5 Bronchoscopy simulators

There is an excellent simulator for demonstrating bronchial anatomy on Peter Slinger's thoracic anaesthesia website (<http://www.thoracic-anesthesia.com/>). You first have to take a brief test on double-lumen tube placement, giving a username and password, after which you can access the simulator. Importantly, you are then free to log-in and use the simulator anytime thereafter. Unfortunately the video images in the test are poor and unclear, but the simulator is good value and very realistic.

5.6 Image orientation

A significant but seemingly neglected aspect of the fiberoptic bronchoscope (fibrescope) is the influence of the 3-D geometry of the combined set of optical fibres on the fidelity of the perceived *orientation* of the viewed image associated with (a) axial rotation, and (b) bending of the fibrescope. This is an interesting, if somewhat non-intuitive, feature of fiberoptics which has a significant bearing on the interpretation of the viewed images. Surprisingly, I have not as yet found any texts which discuss this.

It is important to be aware of this aspect of fiberoptic geometry, since appreciation of position within the essentially fractal structure of the bronchial tree is largely a matter of orientation and knowledge of asymmetric anatomical features. In my experience axial rotation (Section 5.6.1) can cause gross distortion of image orientation, whereas that associated with bending (Section 5.6.2) is generally minimal in a clinical setting.

To further complicate matters, these effects vary depending on whether the fibrescope is being used normally (*monocular-mode*) or with the camera attachment (*camera-mode*). We will address *camera-mode* at the end, but in the meantime unless specified, we will assume that we are dealing with normal *monocular-mode*.

5.6.1 Axial rotation

Under normal circumstances (*monocular-mode*) when a fibrescope is rotated axially (and able to freely rotate throughout its length), the visual image remains fixed (on the retina)—providing the observer's head is fixed—and hence the image does not rotate. However, if, during manual proximal axial rotation, the fibrescope is gripped distally (i.e., fails to rotate synchronously with the proximal end) then the observer (fixed) will see the image rotate with, and in the same sense as, the proximal end of the fibrescope.

Consequently, I routinely use the following simple manoeuvre to determine whether a given image reflects the true orientation of the object, namely:- *manually rotate the fibrescope (axially) back and forth slightly and observe whether the image rotates accordingly or not*. If the image fails to rotate (i.e., the fibrescope is *not* gripped or restricted distally) we can be confident that the image shows the **true orientation** of the object, in which case the observed orientation can be safely used to guide the observer regarding true location within the bronchial tree.

If the image *does* rotate with the fibrescope (i.e., the fibrescope *is* gripped or restricted distally), then a situation of **false orientation** can be said to exist, and hence the orientation must be assumed to be false unless proven otherwise,⁷ in which case the user should not place any reliance on the perceived orientation of the image when determining location. In this case, only those anatomical landmarks having a known asymmetry can be relied upon for determining location within the bronchial tree.

For example, the left upper- and lower-lobe orifices are orientated either side of the left subcarina typically on a line running from top-left to bottom-right when viewed in a supine patient from the head end (see Figure 5.1). If the fibrescope is gripped sufficiently so that 'false

⁷In the same way that although a 'stopped' watch will *occasionally* be correct (twice a day if it is an analogue watch), in practice the time shown must be assumed to be false until proven otherwise.

orientation' exists, then the apparent orientation of the left subcarina will vary with the rotation of the fibrescope. Consequently, the anaesthetist may be misled by the perceived orientation unless the existence of 'false orientation' is checked for and recognised. If 'false orientation' is confirmed, then the anaesthetist will need to check for known asymmetries (e.g., the location of the bronchus to the apical segment of the left lower lobe) in order to confirm that the object in question is actually the left subcarina.

5.6.2 Bending

As the fibrescope passes further into the bronchial tree, it is necessarily bent in various directions. For example, in order to look at the left subcarina the fibrescope must pass down the trachea (inclined approximately 15 degrees below the horizontal) and then down the left main bronchus (deviated about 45 degrees towards the left). Bending the fibrescope successively through these two directions results in the tip of the fibrescope being rotated axially in a clockwise direction (compared with a straight fibrescope held horizontally in the direction of the trachea), resulting in a small 'false' anti-clockwise rotation of the image of the left subcarina. The magnitude of the image rotation is the product of the first angle multiplied by the *sine* of the second angle, and in this particular example would be a barely noticeable 10 degree anticlockwise rotation,⁸ namely $15^\circ \times \sin 45^\circ = 10.6^\circ$.

This represents another interesting, if somewhat even more non-intuitive, example of orientation distortion arising from the 3-D geometry of the fibrescope. If you removed the left main bronchus, mediastinum and right lung so as to be able to look directly at the left subcarina in the supine position (see Figure 5.2) you would see the true orientation, as shown by a CAT scan (see Figure 5.1).

5.6.3 Camera-mode

A camera attachment is often used with the fibrescope for teaching purposes, and also to facilitate visualisation during percutaneous dilational tracheostomy.

It is important to appreciate that camera-mode introduces significant differences with respect to image orientation compared with monocular-mode—in essence, it *reverses* the axial rotation effect on the screen image, and hence the orientation must be assumed to be false unless proven otherwise.

For orientation to be correct during camera-mode, the camera position relative to the bronchoscope needs to be 'calibrated' against reality; i.e. on attaching it, one rotates it relative to the 'bronchoscope in order to align the screen image appropriately with the patient before locking it in position. For example, when using camera-mode while performing a tracheostomy, then we first 'calibrate' by rotating the bronchoscope-camera system until anterior movement on the trachea corresponds with vertical motion on the monitor/screen.

Again, there are two scenarios to consider: (1) fibrescope free to rotate, and (2) fibrescope gripped distally.

1. **Fibrescope free to rotate:** When the fibrescope-camera unit is rotated axially the screen image rotates in the opposite direction, since the image mapping from the camera to the monitor screen is fixed [in monocular-mode there is *no* rotation]

This is typically the situation when surgeons use the camera attachment on a fibrescope passed down the lumen of a rigid bronchoscope, since in this setting the fibrescope is always free to rotate as there is nothing to grip it.

⁸Note that assigning a negative sign to the directions Lower and Left (and conversely)—when viewed monocularly from the head-end of a supine patient—associates anticlockwise with +ve, and clockwise with -ve image rotation. Thus, in the above example of the left subcarina, we have $(-15^\circ) \times (\sin -45^\circ) = +10.6^\circ$, i.e., there is anticlockwise image rotation.

2. **Fibrescope gripped:** If the fibrescope is gripped distally while the proximal end is manually rotated, then the screen image does *not* rotate. [in monocular-mode there *is* rotation in the *same* direction]

This situation often arises when the fibrescope is passed down an endotracheal tube, since the fibrescope is usually gripped to some extent by the rubber air-tight seal at the entrance of the endotracheal tube.

5.7 Anaesthesia for bronchoscopy

5.7.1 Short duration

Intermittent boluses of propofol, suxamethonium and remifentanyl⁹ increments.

5.7.2 Long duration

Propofol TIVA is particularly useful for prolonged bronchoscopy (e.g., for reboring tracheal tumours, multiple biopsies, insertion of stents.¹⁰) With the Alaris pump use the Schnider algorithm for propofol TCI,¹¹ and the Minto algorithm for remifentanyl TCI (Absalom and Struys 2007), since both of these use the Lean Body Mass (LBM) calculated from the entered total body weight and height. An arterial line is worth considering, especially with frail patients and difficult cases.

An induction plasma concentration (C_p) target of 7 $\mu\text{g/ml}$ followed (once the rigid bronchoscope has been inserted) by a maintenance target of about 5–6 $\mu\text{g/ml}$ plus a narcotic (e.g., remifentanyl) generally works well (reduce these somewhat if the patient is frail). Consider an initial remifentanyl bolus of about 100 μg (for a 70 kg patient) followed by about 250 $\mu\text{g/hr}$. Sometimes it is more convenient to give the remifentanyl as intermittent boluses rather than run a second pump. A long acting relaxant is generally best, but sometimes it is worth starting with intermittent suxamethonium and converting later if necessary.

Historically, a suxamethonium infusion would often have been used in this setting; it can still be useful on occasions. The technique is to use 500 mg in 500 mls saline—run at about 3 mg/min (a normal blood giving-set has 25 drops \equiv 1 ml, so 3 mg/min is 75 drops/min). Avoid using the infusion for more than about 30 mins (in order to keep total suxamethonium dose less than about $3 \times \text{kg}$), and always use a nerve stimulator to help keep the total dose down to a minimum to avoid type-II block (take care to label the infusion very clearly).

- Absalom AR and Struys MMRF (2007). Overview of target controlled infusions and total intravenous anaesthesia. 108 pp. (Academia Press, Ghent, Belgium; <http://www.academiapress.be>) ISBN 978-90-382-11077 [excellent small book sponsored by Cardinal Health, Basingstoke, Hampshire, UK; tel: +44(0)1256-388462]
- Aly EE (2002). Anaesthesia for bronchoscopy. *Anaesthesia*; 57, 93–94. (letter and reply) [using propofol and remifentanyl]
- McKeage K and Perry CM (2003). Propofol. A review of its use in intensive care sedation of adults. *CNS Drugs*; 17, 235–272. [excellent]
- Prakash N *et al.* (2001). Effects of remifentanyl on haemodynamic stability during anaesthesia for rigid bronchoscopy. *Anaesthesia*; 56, 576–580. [see Aly 2002]

⁹See Section 8.2.

¹⁰e.g., Montgomery tubes (see Section 3.9)

¹¹Note that there is a potential problem when using TCI with lean body mass (LBM) algorithms in obese patients. For any given height the calculated LBM rises to a maximum and then falls as weight increases, and so in obese patients you need to use that body weight which generates the maximum LBM—see Absalom and Struys (2007), pp. 30–33 for details and useful charts.

- Russell D (2002). Practical aspects of target-controlled infusion. *Anaesthesia Rounds*; (TMG Healthcare Communications Ltd., 62 Stert Street, Abingdon, Oxfordshire, UK). 27 pp. + CD ROM. [Sponsored by AstraZenica, <http://www.astrazenica.com/>]

5.7.3 Local anaesthesia & sedation

- Conacher ID and Curran E (2004). Local anaesthesia and sedation for rigid bronchoscopy for emergency relief of central airway obstruction. *Anaesthesia*; 59, 290–292. [describes use of oral and trans-cricothyroid lignocaine, propofol and midazolam]

5.7.4 Venturi jet ventilation

The first practical venturi jet system for ventilating down a rigid bronchoscope was developed in 1967 by Richard Douglas Sanders (Buckley 1992; Sanders 1967; Aikens and Bancroft 1977; Maltby 2002). See article by Baraka *et al.* (2001) for details of its use for ventilating down an endotracheal tube (above a tracheal stenosis). The potential dangers (e.g., pneumothorax) associated with jet ventilation via exchange catheters is addressed by Benumof (1991). (see also Section 3.10 on difficult airways).

- Baraka AS, Siddik SS, Taha SK, Jalbout MI and Massouh FM (2001). Low frequency jet ventilation for stent insertion in a patient with tracheal stenosis. *Can. J. Anaesth.*; 48, 701–704.
- Buckley JJ (1992). Richard Douglas Sanders, MD. Anesthesiologist, inventor, painter (1906–1977). In: Fink BR, Morris LE, Stephen CR (Eds.) *The history of anaesthesia third international symposium*. (Wood Library-Museum of Anesthesiology). p. 72–77. [cited from Maltby 2002]
- Benumof JL (1999). Airway exchange catheter: simple concept, potentially great danger [editorial] *Anesthesiology*; 91, 342–344.
- Carden E, Burns WW, McDevitt NB and Carson T (1973). A comparison of venturi and side-arm ventilation on anesthesia for bronchoscopy. *Can. Anaesth. Soc. J.*; 20, 569–574.
- Carden E and Schwesinger WB (1973). The use of nitrous oxide during ventilation with the open bronchoscope. *Anesthesiology*; 39, 551–555.
- Carlon GC, Ray C, Griffin *et al.* (1983). Tidal volume and airway pressure on high frequency jet ventilation. *Crit. Care Med.*; 11, 83–86.
- Cromwell SB, Hirshman CA, McCullough RE and Cohen PJ (1975). Simplified delivery of volatile anesthetics for bronchoscopy. *Anesthesiology*; 43, 377–379.
- Maltby RJ (Ed.) (2002). Sanders injector: Richard Douglas Sanders (1906–1977). In: *Notable names in anaesthesia*. (Royal Society of Medicine Press, London). p. 187–189. [ISBN: 1853-155-128].
- Miyasaka K, Sloan IA, and Froese AB (1980). An evaluation of the jet injector (Sanders) technique for bronchoscopy in pediatric patients. *Can. Anaesth. Soc. J.*; 27, 117–124.
- O’Sullivan TJ and Healy GB (1985). Complications of venturi jet ventilation during microlaryngeal surgery. *Arch. Otolaryngol.*; 111, 127–131.
- Patel C and Diba A (2004). Measuring tracheal airway pressures during transtracheal jet ventilation: an observational study. *Anaesthesia*; 59, 248–251. [carinal pressure changes were small; approximately 13 mm Hg only]
- Sanders RD (1967). Two ventilating attachments for bronchoscopes. *Delaware Med. J.*; 39, p. 170–176.
- Spoerel WE and Grant PA (1971). Ventilation during bronchoscopy. *Can. Anaesth. Soc. J.*; 18, 178–188.

5.7.5 Complications

- Suratt PM, Smiddy JF and Gruber B (1976). Death and complications associated with fiberoptic bronchoscopy. *Chest*; 64, 747–751.

5.7.6 Intubation

- Murphy PA (1967). Fibre-optic endoscope used for nasal intubation. *Anaesthesia*; 22, 489.
- Taylor PA and Towey RM (1972). The bronchofibrescope as an aid to endotracheal intubation. *Br. J. Anaesth.*; 44, 611.
- Mason RA (1992). Learning fiberoptic intubation: fundamental problems. *Anaesthesia*; 47, 729.
- Mason RA (1998). Education and training in airway management. *Br. J. Anaesth.*; 81, 305–307.
- Morris IR (1994). Fiberoptic intubation. *Canadian J. of Anaesthesia*; 41, 996.
- Ovassapian A (1996). *Fiberoptic endoscopy and the difficult airway*. 2nd ed. (Lippincott-Raven, Philadelphia, USA).

5.7.7 History

- Shore JM and Lippman HN (1965). A flexible choledochoscope. *Lancet*; i, 1200.
-