

General topics

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FROM: Nickalls RWD. *Notes on thoracic anaesthesia*
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General topics¹

1.1 Syllabus

The thoracic anaesthesia syllabus for the *CCT in Anaesthesia* is detailed in the ‘cardiothoracic’ sections of the *Intermediate*, *Higher* and *Advanced*-level training documents (2nd edition, August 2010) on the Royal College of Anaesthetists website as follows:

- *Intermediate*: [www.rcoa.ac.uk/docs/CCTAnnex C.doc](http://www.rcoa.ac.uk/docs/CCTAnnex_C.doc)
- *Higher*: [www.rcoa.ac.uk/docs/CCTAnnex D.doc](http://www.rcoa.ac.uk/docs/CCTAnnex_D.doc)
- *Advanced*: [www.rcoa.ac.uk/docs/CCT in Anaesthetics Annex E.doc](http://www.rcoa.ac.uk/docs/CCT_in_Anaesthetics_Annex_E.doc)

1.2 General resources

1.2.1 Books

- Searl CP and Ahmed ST (Eds.) (2010). *Core topics in anaesthesia*. 230 pp. (Cambridge University Press) ISBN 978-0-521-86712-2
- Mashour GA (2010). *Consciousness, awareness and anaesthesia*. 274 pp. (Cambridge University Press) ISBN 978-0-521-51822-2
- Lumb A (Ed.) (2010). *Nunn’s applied respiratory physiology*. 7th ed. (Elsevier). 568 pp. ISBN 978-0-7020-2996-3
- Hopkins R, Peden C and Ghandi S [Eds.] (2009). *Radiology for anaesthesia and intensive care*. 2nd ed., 328 pp. (Cambridge University Press) ISBN 978-0-521-73563-6

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

- Kofke WA and Nadkarni VM [Eds.] (2007). New vistas in patient safety and simulation. *Anesthesiology Clinics*; 25 (June), 209–390 (Elsevier, Inc)
[chapters: Anesthesiology national CME program and ASA activities in simulation / Does simulation improve patient safety?: self-efficacy, competence, operational performance, and patient safety / Simulation applications for human factors and systems evaluation / Credentialing and certifying with simulation / Statewide simulation systems: the next step for anesthesiology? / Crew resource management and team training / Simulation: translation to improved team performance / Virtual worlds and team training / Virtual reality simulations / Procedural simulation / Debriefing with good judgment: combining rigorous feedback with genuine inquiry / Integration of standardized patients into simulation]
- Slinger P [Ed.] (2008). Thoracic anesthesia. *Anesthesiology Clinics*; 26 (June), 241–398 (Elsevier, Inc)
[chapters: Evidence-based management of one-lung ventilation / Oxygen toxicity during one-lung ventilation: is it time to re-evaluate our practice? / Anesthetic considerations for airway stenting in adult patients / Perioperative anesthetic management for esophagectomy / Anesthetic considerations for patients with anterior mediastinal masses / The emerging role of minimally invasive surgical techniques for the treatment of lung malignancy in the elderly / Prevention and management of perioperative arrhythmias in the thoracic surgical population / Pulmonary vasodilators—treating the right ventricle / Post thoracotomy pain management problems / Postthoracotomy paravertebral analgesia: will it replace epidural analgesia? / Advances in extracorporeal ventilation]
- Allman KG, Wilson IH (Eds.) (2006). *Oxford Handbook of Anaesthesia*. 2nd. ed. (Oxford University Press) [good sections on (a) THORACIC ANAESTHESIA (pp. 351–383), and (b) DRUG FORMULARY (pp. 1105–1165).]
- Pearce A and Gould G (2005). Thoracics. In: Allman KG, McIndoe AK and Wilson IH (Eds.) *Emergencies in Anaesthesia*, 1st. ed., pp. 193–220 (Oxford University Press).
- Cobbold RSC (2006). Foundations of biomedical ultrasound. (Oxford University Press). 822 pp.
- Chassot PG (2003). Cardiovascular and thoracic anaesthesia.
[see book review: *Br. J. Anaesth.*; 91, 928]
- Kaplan JA and Slinger PD Eds. (2003). *Thoracic anesthesia*. 3rd ed., (Churchill Livingstone, Philadelphia, USA). ISBN: 0443066191 [excellent]
- Marshall BE, Longnecker DE and Fairley HB [Eds.] (1988). *Anesthesia for thoracic procedures*. (Blackwell Scientific Publications). 632 pp.

1.2.2 Articles

- Burwell DR and Jones JG (1996). The airways and anaesthesia; I: anatomy, physiology and fluid mechanics. *Anaesthesia*; 51, 849–857 (September issue). II: pathophysiology. *Anaesthesia*; 51, 943–955 (October issue).
- Campos JH (2009). Update on selective lobar blockade during pulmonary resections. *Current Opinion in Anaesthesiology*; 22, pp 18–22.
- Canet J, Gallart L, Gomar C *et al.* (2010). Prediction of postoperative pulmonary complications in a population-based surgical cohort. *Anesthesiology*; 113, 1338–1350.
- Levin AI, Coetzee JF and Coetzee A (2008). Arterial oxygenation and one-lung anesthesia. *Current Opinion in Anaesthesiology*; 21, pp ?? [107 refs]
- Metzger RJ, Klein OD, Martin GR and Krasnow MA (2008). The branching program of mouse lung development. *Nature*; 453 (5 June), 745–756. [editorial: p. 733–735 (Warburton 2008)]
- Ott HC, Clippinger B, Cobrad C, Schuetz C, Pomerantseva I, Ikonomou L, Kotton D and Vacanti JP (2010). Regeneration and orthotopic transplantation of a bioartificial lung. *Nature Medicine*; 16, 927–933.
- Payen J-F (2010). Toward tailored sedation with halogenated anesthetics in the Intensive Care Unit? *Anesthesiology*; 113, 1268–9. [Editorial]
- Pearce A (2004). Thoracic anaesthesia update. *Update in Anaesthesia* (2004); 18. <http://update.anaesthesiologist.org/> [follow links to thoracic topics]
- Ross AF and Ueda K (2010). Pulmonary hypertension in thoracic surgical patients. *Current Opinion in Anaesthesiology*; 23, pp 25–33.
- Severinghaus JW (2009). Gadgeteering for health care: [The JW Severinghaus lecture on translational science] *Anesthesiology*; 110, 721–728.
- Shafer SL (2007). Did our brains fall out? *Anesthesia & Analgesia*; 104, 247–248.
- Shafer SL (2009). Critical thinking in anesthesia. *Anesthesiology*; 110, 729–737.
- Slinger PD (2003). Acute lung injury after pulmonary resection: more pieces of the puzzle. *Anesthesia and Analgesia*; 97, 1555–1557. [49 refs]
- Warburton D (2008). Order in the lung *Nature*; 453 (5 June), 733–735 [editorial to Metzger *et al.* (2008)].

1.2.3 Book/journal searches

Good starting points are (a) Google books (<http://books.google.com/>), and (b) the *Wikipedia* page on 'book sources' (http://en.wikipedia.org/wiki/book_sources/).

For buying books (secondhand and new) Abebooks (<http://www.abebooks.com/>) is particularly useful, since it is usually possible to find the website & telephone number of the individual booksellers, and then buy from them directly.

- **Science Direct:** <http://www.sciencedirect.com/>
A particularly useful interface for viewing the tables of contents (TOC) of journals.
- **Unbound Medicine:** <http://www.unboundmedicine.com/medline/ebm/>
This is a useful free interface to the MEDLINE search engine.
- **Copac:** <http://copac.ac.uk/>
It is the national, academic and specialist library catalogue. It provides free access to the merged online catalogues of 24 major research libraries in the UK and Ireland, including the British Library, and the national libraries of Scotland, Wales and Ireland.
- **Project Gutenberg:** <http://www.gutenberg.org/>

1.2.4 Anesthesiology Clinics

for TOC² see: <http://www.sciencedirect.com/science/journal/19322275>

1.2.5 Thoracic Surgery Clinics

for TOC see: <http://www.sciencedirect.com/science/journal/15474127>

- Thymoma (2011); 21 (February)
- Chest wall surgery (2010); 20 (November)
- Air leak after pulmonary resection (2010); 20 (August)
- Technical advances in mediastinal surgery (2010); 20 (May)
- Imaging of thoracic diseases (2010); 20 (February)
- Surgical conditions of the diaphragm (2009); 19 (November)
- Thoracic surgery in the elderly (2009); 19 (August)
- Update on surgical and endoscopic management of emphysema (2009); 19 (May)
- Diseases of the mediastinum (2009); 19 (February)
- Thoracic anatomy: Chest wall, airway, lungs. (2007); 17 (November)

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1.2.6 Clinics in Chest Medicine

for TOC see: <http://www.sciencedirect.com/science/journal/02725231>

- Interventional pulmonology (bronchoscopy) (2010); 31 (March)
- Tuberculosis (2009); 30 (December)
- Obesity and respiratory disease (2009); 30 (September)
- Fungal diseases (2009); 30 (June)
- Nonpulmonary critical care (2009); 30 (March)
- Update in sepsis (2008); 29 (December)
- Controversies in mechanical ventilation (2008); 29 (June)
- Contemporary chest imaging (2008); 29 (March)
- Artificial airways (2003); 24 (September).
- Pulmonary function testing (2001); 22 (December).
- Prolonged critical illness: management of long-term acute care (2001); 22 (March).
- Flexible bronchoscopy update (2001); 22 (June).
- Acute respiratory distress syndrome (2000); 21 (September).
- Intensive care unit complications (1999); 20 (June).
- Flexible bronchoscopy in the 21st century (1999); 20 (March).

1.2.7 History

- Comroe JH (1977). *Retrospectroscope: insights into medical discovery*. (Von Gehr Press, Menlo Park, California, USA). ISBN 0-9601470-1-2 [a collection of essays which originally appeared in *American Review of Respiratory Disease* during the period 1975–1977.]
- Swazey JP and Reeds K (1978). *Today's medicine, tomorrow's science: essays on paths of discovery in the biomedical sciences*. (U.S. Department of Health, Education and Welfare, Public Health Service, National Institutes of Health, USA; DHEW Publication No. (NIH) 78-244). [available for download from http://newman.baruch.cuny.edu/digital/2001/swazey_reeds_1978/]
- Maltby RJ (Ed.) (2002). *Notable names in anaesthesia*. (Royal Society of Medicine Press, London). [ISBN: 1853-155-128]. 254 pp.

- Sykes K and Bunker J (2007). *Anaesthesia and the practice of medicine: historical perspectives*. (224 pp.) ISBN 1-85315-674-4
- *Medical History* is the journal of the Wellcome Historical Medical Library, London. A useful resource of historical articles—some of which relate to anaesthesia. All volumes are available on-line at <http://www.ncbi.nlm.nih.gov/pmc/journals/228>. For a list of all the other titles which have agreed to participate in this on-line project see <http://library.wellcome.ac.uk/backfiles>.
- The Wellcome Collection & library. <http://www.wellcomecollection.org/>

1.2.8 Miscellaneous

- P Slinger's thoracic anaesthesia website: <http://www.thoracic-anesthesia.com/>

1.3 Preoperative evaluation

1.3.1 Lung function evaluation

The British Thoracic Society guidelines article (BTS/SCTS Working Group 2001) recommends an $FEV_1 > 2$ litres for pneumonectomy, and $FEV_1 > 1.5$ litres for a lobectomy. Patients with values less than these are 'high risk' and should be evaluated further (transfer factor; exercise test). However, some patients with diffuse interstitial lung disease may well have a low transfer factor in spite of good spirometry, and should be evaluated further. This document gives details of preoperative respiratory and cardiovascular function tests for all such patients, and is well worth reading. Particularly good general reviews are Datta and Lahiri (2003), Powell and Caplan (2001).

Role of supine LFTs? Finally, we should not overlook the possibility that some *supine* lung-function testing (and cardiac testing) might be more appropriate for *supine* patients under anaesthesia—but I have failed to find any literature on this as yet.

- Brunelli A (Ed.) (2008). Preoperative evaluation of lung resection candidates. *Thoracic Surgery Clinics*; 18, No. 1.
- BTS/SCTS Working Group (2001). Guidelines on the selection of patients with lung cancer for surgery. *Thorax*; 56, 89–108. [182 refs] [can be downloaded from: <http://thorax.bmj.com>]
- Datta D and Lahiri B (2003). Preoperative evaluation of patients undergoing lung resection surgery. *Chest*; 123, 2096–2013 [review article]
- Gould G and Pearce A (2006). Assessment of suitability for lung resection. *Continuing Education in Anaesthesia, Critical Care & Pain*; 6 (No 3), 97–100. [BJA related journal] [good overview]

- Kearney DJ *et al.* (1994). Assessment of operative risk in patients undergoing lung resection: impact of predicted pulmonary function. *Chest*; 105, 753–759.
- Kinnear WJM (1997). *Lung function tests: a guide to their interpretation*. (Nottingham University Press, Nottingham, UK). ISBN 1-897676-80-8.
- Mark JBD (Ed) (1999). Perioperative cardiopulmonary evaluation and management. *Chest*; 115 Supplement (May).
- Melendez JA and Fischer ME (1997). Preoperative pulmonary evaluation of the thoracic surgical patient. In: Wilson RS [Ed.] *Anaesthesia; Chest Surgery Clinics of North America*; 7, 641–654. (Philadelphia, PA: WB Saunders, USA).
- Kinnear WJM (1997). *Lung function tests: a guide to their interpretation*. (Nottingham University Press, Nottingham, UK). ISBN 1-897676-80-8.
- Powell CA and Caplan CE (2001). Pulmonary function tests in preoperative pulmonary evaluation [92 refs]. In: Chupp GL (Ed), *Clinics in Chest Medicine*; 22 (no. 4, December)
[this vol of *Clinics in Chest Medicine* also includes useful articles by Pride NB (Tests of forced expiration and inspiration), and Gibson CJ (Lung volumes and elasticity)]
- Rennotte MT, Bacle P, Aubert G and Rodenstein DO (1995). Nasal continuous positive airway pressure in the perioperative management of patients with obstructive sleep-apnoea submitted to surgery. *Chest*; 107, 367–374.
- Rielly JJ (1999). Evidence-based pre-operative evaluation of candidates for thoracotomy. *Chest*; 116 (Suppl 6), 474S–476S.
- Smetana GW (1999). Pre-operative pulmonary evaluation. *N. Engl. J. Med.*; 340, 937–944. [see also the follow-up letters stressing significance of detecting preoperative sleep apnoea: Marx JJ *et al.* (1999), 341, 613–614]

1.3.2 Cardiac function evaluation

- Eagle KA *et al.* (2002). ACC/AHA guideline update for perioperative cardiovascular evaluation for noncardiac surgery—executive summary. *Anesth. Analg.*; 94, 1052–1064. [see editorial by Fleisher and Eagle 2002]
- Fleisher LA (1998). Pre-operative cardiac evaluation before non-cardiac surgery. In: *Baillière's Clinical Anaesthesiology*; Chapter 4, 373–390. (Baillière Tindall, London).
- Fleisher LA and Eagle KA (2002). Guidelines on perioperative cardiovascular evaluation: what have we learned over the past 6 years to warrant an update? *Anesth. Analg.*; 94, 1378–1379. [editorial for Eagle *et al.* 2002]

- Mark JBD (Ed) (1999). Perioperative cardiopulmonary evaluation and management. *Chest*; 115 Supplement (May).

1.3.3 Obesity-related problems

This list is included here since one-lung anaesthesia in obese patients is such a formidable technical exercise. It is sometimes worth considering the use of temporary post-extubation CPAP or BIPAP support in recovery.

- Obesity and respiratory disease. *Clinics in Chest Medicine* (2009); 30 (September)
- Adams JB and Murphy PG (2000). Obesity in anaesthesia and intensive care. *Br. J. Anaesth.*; 85, 91–108 [164 refs].
- Marik P and Varon J (1998). The obese patient in the ICU. *Chest*; 113, 492–498.
- Shenkman Z, Shir Y and Brodsky JB (1993). Perioperative management of the obese patient. *Br. J. Anaesth.*; 70, 349–359. [excellent: 120 refs]
- von Ungern-Sternberg BS, Regli A, Schneider MC, Kunz F and Reber A (2004). Effect of obesity and site of surgery on perioperative lung volumes. *Br. J. Anaesth.*; 92, 2002–207.

1.4 Open lung biopsy

These patients usually have diffuse lung disease and relatively poor lung function, and are generally referred to the surgeons following a failed percutaneous or bronchoscopic lung biopsy. Although a single-lumen tube is often all that is required for a supine procedure (e.g., a mediastinotomy or mediastinoscopy), a double-lumen tube and lateral position is sometimes necessary. Consider selective lobar isolation if lung function is poor (see Mentzelopoulos, Rellos, Tzoufi *et al.* 2003).

- Mentzelopoulos SD, Rellos K, Tzoufi MJ *et al.* (2003). A double-lumen tube technique for selective lobar isolation. *European Journal of Anaesthesiology*; 20, 984–992.

1.5 Tracheal resection

- Cokis C and Strang T (2000). Airway management for carinal tumour resection. *Anaesthesia and Intensive Care*; 28, 570–572.

1.6 Tracheal bronchus

Always check for the presence of a tracheal bronchus on the chest X-ray, CT-scan and at bronchoscopy. See article by Ho *et al.* (2004) for a brief review of the recent literature

- Conacher ID (2000). Implications of a tracheal bronchus for adult anaesthetic practice. *Br. J. Anaesth.*; **85**, 317–321.
- Ho AM-H, Karmakar MK, Lam WW, Lam FO, Lee TW, Ng SK and Chung DC (2004). Does the presence of a tracheal bronchus affect the margin of safety of double-lumen tube placement? *Anesthesia and Analgesia*; **99**, 293–295. [reviews the recent literature on tracheal bronchus — nearly all are on the right-hand side and within 2 cm of the carina; 10 refs]
- Ikeno S, Mitsuhashi M, Saito K, Hirabayashi Y, Akazawa S, Kasuda H and Shimizu R (1996). Airway management for patients with a tracheal bronchus. *Br. J. Anaesth.*; **76**, 573–575.

1.7 Management of flail-chest

- Ahmed Z and Mohyuddin Z (1995). Management of flail chest injury: internal fixation versus endotracheal intubation and ventilation. *The Journal of Thoracic and Cardiovascular Surgery*; **110**, 1676–1680. [Internal fixation (IF) is better; with IF mean period of IPPV was 3.9 days versus 15 days with IPPV only].

1.8 Thymectomy and Myasthenia Gravis

Good articles on the anaesthetic management of myasthenia gravis are few in number; the most useful ones I have found are those by Zielinski (2011), Eisenkraft (1987) and Redfern *et al.* (1987). Note that the February 2011 issue of the *Thoracic Surgery Clinics* is on thymoma.

A patient with myasthenia gravis is typically maintained on oral pyridostigmine tablets. Postoperatively either pyridostigmine (subcutaneously) or neostigmine³ is generally used until the patient's usual oral maintenance dose (pyridostigmine tablets) can be resumed. Note that 60 mg of the oral pyridostigmine preparation is equivalent to 2 mg of the parenteral product.⁴ A typical adult total daily *parenteral* dose of pyridostigmine is approximately 10–40 mg (1–4 mg given 3–4 hrly).

The exact neuromuscular defect (presynaptic vs. postsynaptic) seems not to be fully resolved as yet; see letter by Sosis (1985) for some good (but old) references on this.

³Pyridostigmine is the preferred agent owing to its longer action.

⁴CHN Pharmacy factsheet.

The presynaptic acetylcholine stores and their release are not diminished in myasthenia (Cull-Candy *et al.* 1980).

- Zielinski M (2011). Management of myasthenic patients with thymoma. *Thoracic Surgery Clinics*; 21 (February), 47-57.
- Cull-Candy SG *et al.* (1980). On the release of transmitter at normal, myasthenia gravis, and myasthenic syndrome affected human end-plates. *Journal of Physiology* (Lond.); 299. 621–638 [from Sosis (1985)]
- Eisenkraft JB (1987). Myasthenia gravis and thymic surgery: anaesthetic considerations. In: Gothard JWW [Ed.], Thoracic anaesthesia. *Clinical Anaesthesiology*; 1 (March); Chapter 8, pp. 133–162. [excellent]
- Redfern N *et al.* (1987). Thymectomy. *Ann. Roy. Coll. Surg. Eng.*; 68, 289–292.

1.9 Bilateral Pleurectomy via sternal split

An important aspect of this procedure is taking care to avoid having both lungs partially deflated at the same time! This can easily happen once both pleura are open, and the resulting desaturation can be both severe and slow to recover.

The problem tends to occur when the surgeons have almost finished working on the first lung, as then one of the surgeons may start investigating (& collapsing) the other lung before the first lung has been fully re-expanded. Note there is sometimes quite a long time-lag after re-expanding a lung and the saturation improving.

The fact that the patient is supine compounds the problem, as there is no ‘bottom’ lung receiving most of the cardiac output. This is an important difference, since with a normal thoracotomy in the lateral position not only is the bottom lung always fully expanded but it is also receiving the majority of the cardiac output.

The key principles are therefore (a) use a double-lumen tube, (b) use some PEEP, and (c) make sure the first lung is *fully* re-expanded before allowing the surgeons to start working on the other lung. The same general principles probably also apply for lung-volume reduction surgery, as this is usually a bilateral procedure via a sternal split as well (see below).

1.10 Lung-volume reduction surgery

- Calverley PMA (2003). Closing the NETT on lung volume reduction surgery. *Thorax*; 58, 651–653. [review of the National Emphysema Treatment Trial (NETT)]
- Conacher ID (1997). Anaesthesia for the surgery of emphysema. *Br. J. Anaesth.*; 79, 530–538.

- Cooper JD and Lefrak SS (1999). Lung-reduction surgery: 5 years on. *The Lancet*; 353 (Suppl. 1[surgery]), 26–27. [At 2 years pulmonary function had improved in the surgical group, but had worsened in the control (no-surgery group). By 3·5–4 yrs mortality during follow up was 30% (surgery) and 52% (no-surgery)]
- Cooper JD and Trulock EP (1995). Bilateral pneumonectomy (volume reduction) for chronic obstructive pulmonary disease. *J. Thoracic and Cardiovascular Surgery*; 109, 106–119.
- Szekely LA *et al.* (1997). Pre-operative predictors of operative morbidity and mortality in COPD patients undergoing bilateral lung-volume reduction surgery. *Chest*; 111, 550–558.

1.11 Pneumothorax

1.11.1 Radiology

- O'Connor AR and Morgan WE (2005). Radiological review of pneumothorax. *British Medical Journal*; 330, 1493–1497.

1.11.2 Cavity expansion with N₂O

- Eger EI (1974). Nitrous oxide transfer to closed gas spaces. In: Eger EI *Anaesthetic uptake and action* (Williams & Wilkins Company, Baltimore, USA), Chapter 10, pp. 171–183. [lung cavity expansion is fast: volume doubles with 50% N₂O; vol increases 4-fold with 75% N₂O. Bowel expansion is much slower and less complete; with 75% N₂O bowel gas volume increased 1·8-fold in 2 hrs, 2·5-fold in 4 hrs.]
- Eger EI and Saidman LJ (1965). Hazards of nitrous oxide in bowel obstruction and pneumothorax. *Anesthesiology*; 26, 61–66.
- Gold MI and Joseph SI (1973). Bilateral tension pneumothorax following induction of anaesthesia in two patients with chronic obstructive airway disease. *Anesthesiology*; 38, 93–97.

1.11.3 Chest drains

Chest drains are potentially dangerous, and in May 2008 the National Patient Safety Agency (NPSA) issued an alert following 12 deaths and 15 serious adverse incidents—see the paper by Akram and Hartung (2009).

Two useful free booklets on chest drains are available from Tyco Healthcare UK Ltd (154 Fareham Road, Gosport, Hampshire; Tel: 01329-224226: ask for 'Marketing' [direct dial: 01329-224352]). They are (a) *Treatment with pleural drainage* by L Dernevik, and (b) *A user's guide to thoracic drainage*, by S Westerby; 26 pp.

The sizes of chest drains generally used in thoracic surgery are as follows: ward insertion 28 Fr; theatre insertion 36 Fr.

Pneumonectomy: 1 drain;

Lobectomy: 2 chest drains:- (**a**nterior/**a**pical/**a**ir) - (**b**ack/**b**asal/**b**lood).

Chest drains are sometimes put on suction postoperatively in order to facilitate lung re-expansion (spontaneously breathing patients only). However, in the presence of a lung leak suction can be the cause of a tension pneumothorax if the total drain air flow is significant (i.e., if the suction cannot handle the total flow). Consequently, if you suspect a tension pneumothorax always disconnect the suction until the problem has been resolved. Never apply suction to a ventilated patient.

There is also a nice 'You tube' internet video on "securing a chest drain" (search google for this).

- Akram AR and Hartung TK (2009). Intercostal chest drains: a wake-up call from the National Patient Safety Agency rapid response report. *J. R. Coll. Physicians Edinb.*; 39, 117-120. [a nice review of chest drain-related complications]
- Baumann MH and Strange C (1997). Treatment of spontaneous pneumothorax: a more aggressive approach? *Chest*; 112, 789-804 [132 refs]
- Beauchamp G (1995). Spontaneous pneumothorax and pneumomediastinum. In: Pearson FG, [Ed.] *Thoracic surgery*. (Churchill Livingstone, New York, USA). pp. 1038-1040.
- Cerfolio RJ, Minnich DJ and Bryant DJ (2009). The removal of chest tubes despite an air leak or a pneumothorax. *The Annals of Thoracic Surgery*; 87, 1690-1694 (discussion: 1694-1696).
- Harriss DR and Graham TR (1991). Management of intercostal drains (a review). *British Journal of Hospital Medicine*; 45, 383-386.
- Harriss DR and Graham TR (1990). Management of intercostal drains *British Medical Journal*; 301, 1165.
- Henry M, Arnold T and Harvey J (2003). BTS guidelines for the management of spontaneous pneumothorax. *Thorax*; 58 (Suppl 2), 39-52.
- Hyde J, Sykes T and Graham T (1997). Reducing morbidity from chest drains [editorial]. *British Medical Journal*; 314, 914-915.
- Laws D, Neville E and Duffy J (2003). BTS guidelines for the insertion of a chest drain. *Thorax*; 58, 53-59.

1.11.4 Chest-drain bottles

- Chung DC (2008). Chest drain FAQ. http://www.medicine-on-line/en/documents/skills/s0001_en.pdf
- Hunter J (2008). Chest drain removal. *Nursing Standard*; 22(45), 35–38.
- Kam AC, O'Brien M and Kam PCA (1993) Pleural drainage systems. *Anaesthesia*; 48, 154–161. [excellent]
- Thompson R, Parker E, Sivaprakasam J and Hong V (2007). Observational study of the practice of chest drain removal in postoperative cardiac surgical patients. *Anaesthesia*; 62, 207–208.
- Woodrow P (2005). Caring for patients with intrapleural chest drains. [East Kent Hospitals guidelines] Available on the internet [google key words: clinical guidelines Interpleural chestdrain guidelines (4)]

1.11.5 Subcutaneous emphysema

- Beck PL, Heitman SJ and Mody CH (2002). Simple construction of a subcutaneous catheter for treatment of severe subcutaneous emphysema. *Chest*; 121, 647–649.
- Cesario A, Margaritora S, Porziella V and Granone P (2003). Microdrainage via open technique in severe subcutaneous emphysema. *Chest*; 123, 2162–2163 [letter]
- Herlan DB, Landreneau RJ and Ferson PF (1992). Massive spontaneous subcutaneous emphysema: acute management with infraclavicular “blow holes”. *Chest*; 102, 503–505.
- Leo F, Solli P, Veronesi G *et al.* (2002). Efficacy of microdrainage in severe subcutaneous emphysema. *Chest*; 122, 1498–1499.

1.12 Empyema

- DTB (2006). Managing empyema in adults. *Drug and Therapeutics Bulletin*; 44 (March), 17–21. <http://www.dtb.org.uk/>

1.13 Differential lung ventilation

This is occasionally indicated in patients where the two lungs have a significantly different compliance. The Dräger ventilators have the facility to be linked in pairs such that one functions as the slave of the other, allowing the phase relations of the two ventilators to be easily controlled.

- Hedenstierna G (1985). Differential ventilation in bilateral lung disease. *Europ. J. Anaesthesiol.*; 2, 1.
- Hedenstierna G *et al.* (1984). Ventilation and perfusion of each lung during differential ventilation with selective PEEP. *Anesthesiology*; 61, 369.

1.14 Sickle cell disease

One-lung anaesthesia in patients with a sickle-cell condition is a formidable problem requiring preparation and coordination with the Haematology department. Unfortunately good references which are *useful* for thoracic anaesthetists are few in number.⁵

1.14.1 Anaesthesia

The main principles are: (a) optimise Hb—aim for [HbA] greater than 70%—and treat anaemia, (b) chest physiotherapy and breathing exercises, (c) good hydration, (d) pre-oxygenation, (e) minimise factors which ‘right-shift’ the Hb dissociation curve,⁶ (f) use at least 50% F_{IO₂}, (g) keep the patient warm,⁷ (h) no tourniquets (tourniquet deaths have been reported even with sickle-cell trait), (i) consider regional blocks to facilitate vasodilation, (j) avoid pre- and postoperative sedation.

The most useful references I have come across from a purely practical point of view are marked by a triangle \triangle .

- Bannerjee AK, Layton DM, Rennie JA *et al.* (1991). Safe surgery in sickle-cell disease. *Br J Surg*; 78, 516–517.
- Davies SC, Cronin E, Gill M, Greengross P, Hickman M and Normand C (2000). Screening for sickle cell disease and thalassaemia: a systematic review with supplementary research. *Health Technology Assessment*; 4 (No. 3). <http://sct.screening.nhs.uk/> [see chapter 8: Prevalence of sickle cell and β -thalassaemia in England. (pp. 27–32)].
- Derkay CS, Bray G, Milmoie GJ *et al.* (1991). Adeno-tonsillectomy in children with sickle-cell disease. *South Med J*; 84, 205–208.
- Esseltine DW, Baxter M, Bevan JC (1988). Sickle cell states and the anesthesiologist. *Can. J. Anaesth*; 35, 385–403.
- \triangle Firth PG (2005). Anaesthesia for peculiar cells—a century of sickle cell disease. *Br. J. Anaesth.*; 95, 287–299. [excellent review; 96 refs]

⁵See those I have indicated with a triangle \triangle .

⁶i.e., correct acidosis, and avoid letting ET_{CO₂} or temperature rise above normal.

⁷To facilitate vasodilation.

- △ Firth PG and Head CA (2004). Sickle cell disease and anesthesia. *Anesthesiology*; 101, 766–785. [excellent review; 180 refs]
- △ Gibson JR (1987). Anesthesia for the sickle-cell diseases and other hemoglobinopathies. *Seminars in Anesthesia*; 6, 27–35.
- Henderson K (1994). Sickle-cell disease and anaesthesia. *Update in Anaesthesia*; No. 4, 9–12. <http://update.anaesthesiologist.org/>
- Homi J, Reynolds J, Skinner A *et al.* (1979). General anaesthesia and sickle-cell disease. *BMJ*; i, 1599–1601.
- △ Howells TH, Huntsman RG, Boys JE and Mahmood A (1972). Anaesthesia and sickle-cell haemoglobin. *Br. J. Anaesth.*; 44, 975–987.
- Marchant WA and Wright S (2001). Aortic cross-clamping in sickle cell disease. *Anaesthesia*; 56, 286–287. [letter] [exchanged transfused to Hb 10, HbA 61%, good hydration, warm, mild alkalosis: bypass cross-clamp 9 min; no problems]
- △ McClain BC, Redd SA and Turner EA (1999). Sickle cell disease: a '90s perspective on an old disease. In: Lake CL, Rice LJ and Sperry RJ (Eds) *Advances in Anaesthesia*; 16, 129–161 [97 refs].
- △ Neumayr L, Koshy M and Haberkern C *et al.* (1998). Surgery in patients with Haemoglobin SC Disease. *American Journal of Hematology*; 57, 101–118. [cited from Marchant WA and Wright S, 2001]
- Koshy M, Weiner SJ *et al.* (1995). The co-operative study of sickle-cell disease. Surgery and anaesthesia in sickle-cell disease. *Blood*; 86, 3676–3684.
- Raff JP, Dobson CE and Tsai HM (2002). Transfusion of polymerised haemoglobin in a patient with severe sickle-cell anaemia. *Lancet*; 360, 464–465.
- Vipond AJ and Caldicott LD (1998). Major vascular surgery in a patient with sickle cell disease. *Anaesthesia*; 53, 1204–1206.

1.14.2 The transfusion controversy

These articles discuss two pre-operative treatments: (a) aggressive transfusion aimed at decreasing [HbS] to less than 30%, and (b) a more conservative approach designed simply to increase [Hb] to greater than 10 gm/100mls. While both regimens were equally effective in preventing post-operative complications, the 'conservative' regimen was associated with half as many transfusion reactions.

- Buchanan GR and Rogers ZR (1995). Preoperative transfusion in sickle-cell disease. *N Eng J Med*; 333, 1641. [letter] [reply to Vichinsky *et al.* 1995]

- Haberkern CM, Neumayr LD, Orringer EP *et al.* (1997). Cholecystectomy in sickle-cell anemia patients: peri-operative outcome in 364 cases from the national pre-operative transfusion study. *Blood*; 89, 1533–1542.
- Vichinsky EP, Haberkern CM, Neumayr L *et al.* (1995). A comparison of conservative and aggressive transfusion regimes in the peri-operative management of sickle-cell disease. *N Eng J Med*; 333, 206.

1.14.3 Managing sickle-cell crisis

- Ballas SK (1998). Sickle cell disease: clinical management. In: *Bailliere's Clinical Haematology*, 11, (No. 1, March issue), 185–214.
- Davies SC and Oni L (1997). Management of patients with sickle-cell disease. *Br. Med. J.*; 315, 656–60.
- Konotey-Ahulu FID (1998). Opiates for sickle-cell crisis? *Lancet*; 351, 1438.
- Serjeant GR (1997). Sickle-cell disease. *Lancet*; 350, 725–30.
- Steinberg MH (1999). Management of sickle cell disease. *New Engl. J. Med.*; 340, 1021–1030.
- Vijay V, Cavenagh JD and Yate P (1998). The anaesthetist's role in acute sickle-cell crisis. *Br. J. Anaesth.*; 80, 820–828.

1.14.4 Pathophysiology

- Mozzarelli A, Hofrichter J, and Eaton WA (1987). Delay-time of hemoglobin-S polymerization prevents most cells from sickling in vivo. *Science*; 237, 500–506.
- Serjeant GR and Serjeant BE (2001). *Sickle cell disease*. (Oxford University Press, Oxford, UK)
- Steinberg MH (1998). Pathophysiology of sickle cell disease. In: *Bailliere's Clinical Haematology*, 11, (No. 1, March issue), 163–184.

1.14.5 General treatment

- Vichinsky E (2002). New therapies in sickle cell disease. *Lancet*; 360, 629–631. [L-arginine augments nitric oxide production → anti-sickling and vaso-dilation]

1.14.6 Haemoglobin molecular-chemistry

Max Perutz and John Kendrew received the Nobel Prize in 1962 for determining the structure of haemoglobin.

- Cooper C and Wilson M (1997). Cold feet. *New Scientist*; The Last Word, (February 1st). [a fascinating note on the mechanism by which the amount of heat (ΔH) associated with the exothermic oxygen-binding to haemoglobin—and its reverse—allows the feet of antarctic penguins to remain non-frozen. Its role in other animals is also explored.]
- Perutz MF (2003). The second secret of life. In: *I wish I'd made you angry earlier*. (Cold Spring Harbor Laboratory Press; ISBN 0-87969-674-5). pp. 315-337.
- Perutz MF (1997). *Science is not a quiet life: unravelling the atomic mechanism of haemoglobin*. (World Scientific Publishing Co. Pte. Ltd.; London/Singapore) 636 pp. ISBN: 9810227744 (hardcover); ISBN: 9810230575 (pbk.) [annotated collection of key papers by Perutz relating to the structure of haemoglobin; includes a section on 'molecular pathology of human haemoglobin'.]
- Perutz MF (1990). *Mechanism of cooperativity and allosteric regulation in proteins*. (Cambridge University Press; ISBN 0-521-38648-9). 101 pp.

1.14.7 HbS & O₂ dissociation curve

- Becklake MR *et al.* (1955). Oxygen dissociation curves in sickle-cell anemia, and in subjects with the sickle-cell trait. *J. Clin. Invest.*; 34, 751-755.
 - Gill SJ *et al.* (1979). Oxygen binding to sickle-cell hemoglobin. *J Mol Biol*; 130, 175-189. [cited from Hsia, 1998]
 - Hsia CCW (1998). Respiratory function of hemoglobin. *N Engl J Med*; 338, 239-247.
 - Ueda Y, Nagel RL and Bookchin RM (1979). An increased Bohr effect in sickle-cell anemia. *Blood*; 53, 472-480. [from Hsia, 1998]
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