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Percutaneous dilatational tracheostomy: haemorrhagic complications and the vascular anatomy of the anterior neck. A review based on 497 cases

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Abstract. In a series of 497 PDT procedures done in the intensive therapy unit at Morriston Hospital between 1992 and 1999, PDT was abandoned because of bleeding in 6 patients and was noted to be a problem in a further 18 cases (overall incidence 4.8%). In all cases, haemorrhage was successfully arrested. Surgical tracheostomy was necessary in 6 of these 24 cases. The source of bleeding in 4 of these patients was attributed to the inferior thyroid vein (2 cases), high brachiocephalic vein, and possibly an aberrant anterior jugular communicating vein, respectively. In one patient, the vessel presumed injured could not be identified and in another patient, bleeding was related to multisystem disease. We conclude that the risk of bleeding, although low, can be minimised if the operator maintains a high index of suspicion for aberrant vascular anatomy and investigates possible abnormalities with diagnostic ultrasound. Injury to vessels low in the neck can be reduced by not fully extending the neck and siting the stoma at the upper tracheal rings. The possibility of developing a tracheoarterial fistula is reduced if the stoma is situated above the 4th tracheal ring and fibreoptic endoscopy is used to confirm correct tracheostomy tube placement.

Key words: PDT; haemorrhage; vascular anomalies; diagnostic ultrasound; neck extension; siting of stoma.

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Percutaneous dilatational tracheostomy (PDT) is not a new technique. However, it was not until Ciaglia et al.[5] introduced a simple technique using a needle, catheter and guide wire that PDT become regarded as a possible alternative to open surgical tracheostomy. The original description of Ciaglia et al.[5] was of blind puncture at the subcricoid level and subsequent dilatation to accommodate a tracheostomy tube, but it is now generally agreed that the stoma should be between the upper tracheal rings. Ideally it should be done no lower than the fourth tracheal ring. At many intensive care units, PDT is not performed blindly but with the assistance of fibreoptic endoscopy as reported by Marelli et al.[9] However even with fibreoptic endoscopic control, PDT can give rise to serious complications similar to those encountered with open surgical tracheostomy. PDT is commonly performed at the bedside in the intensive care department. It is done with minimum exposure of the pretracheal tissues so options are limited if serious problems with bleeding arise. Minimising and avoiding these difficulties has to be a priority.

Puncture of a large vessel is more likely to occur in those patients with aberrant vascular anatomy in the neck. This article reviews the incidence and sequelae of haemorrhage as a complication of PDT in a series of 497 PDT

procedures and suggests ways to minimise the risk.

Retrospective review

An audit of immediate complications from PDT is ongoing and records are available for over 500 consecutive PDT procedures. Four hundred and ninety seven records were analysed and further detail was obtained from case notes. The PDT procedures were done by the medical team from the intensive care unit (ICU) under general anaesthesia, with full monitoring, fibreoptic endoscope control, and ultrasound guidance for selected patients. Details of the technique used have been previously reported[9,10]. Five of the six open surgical tracheostomies, referred because of problems with bleeding, were done by the maxillofacial team at Morriston Hospital.

Results

In our series of 497 cases, haemorrhage was the most common complication, occurring in 24 (4.8%) cases (Table 1). In 11 patients, minor bleeding stopped after a short while, without any intervention. In 5 patients bleeding was arrested with local pressure alone, whilst in 4 other patients ligation of one or more bleeding vessels at the bedside was also required. Immediate surgery to stop the bleeding was required in 2 patients (cases 8 and 22). Fresh frozen plasma and platelets were required for 1 patient (case 1) after attempted PDT and elective open surgical tracheostomy. In 1 patient (case 2), the local measures used to stop bleeding could not be ascertained. PDT was abandoned because of bleeding in 6 of these 24 patients.

In one patient (case 13), two attempts at PDT were abandoned because of bleeding. At subsequent surgery, the left brachiocephalic vein was found to have an abnormally high course across the trachea. Tracheostomy was only achieved after ligation of this vessel and division of the thyroid gland. Ultrasound examination of a patient (case 20) with a pulsating neck swelling in the pretracheal region showed a large vein traversing the anterior neck from left to right and an absent left internal jugular vein. The vessel could have been an aberrant anterior jugular communicating vein. This patient had bleeding problems with both PDT and open surgical tracheostomy. A high inferior thyroid vein, a recognised variation of normal anatomy, led to bleeding problems in two of our PDT cases (cases 8 and 22).

One patient (case 1) with an abnormality of clotting continued to bleed despite transfusions with platelets and fresh frozen plasma. It was not until the 5th day after elective open surgical tracheostomy that the bleeding finally stopped.

In addition to aspirating blood from the trachea after completion of PDT, one patient (case 15) had also developed a pneumothorax. Using fibreoptic endoscopy, a 5 cm tear of the membranous wall of the trachea was detected. Another patient (case 16) developed bleeding from within the trachea the day after PDT. Endoscopic examination revealed the source of bleeding to be a mucosal tear of the posterior wall of the trachea. The bleeding stopped spontaneously.

Table 1. Haemorrhage as a complication of PDT and outcome

Case	Outcome of PDT and comments	Open surgical tracheostomy Yes (Y)/No(N)
1 F 73	Severe metabolic acidosis. Abandoned because of bleeding despite transfusion with platelets and fresh frozen plasma. Also transfused post surgery.	Y
2 F 44	Trachea entered but PDT abandoned because of bleeding.	Y
3 F 63	Moderate bleeding stopped with pressure.	N
4 M 63	Small amount of bleeding stopped with pressure.	N
5 M 73	Bled after PDT. On heparin for haemofiltration.	N
6 M 68	Small amount of bleeding stopped with pressure.	N
7 M 69	Initial moderate bleed, which stopped spontaneously.	N
8 F 50	Under fibreoptic control T3, T4 ring punctured. No bleeding whilst dilator in place. Immediate surgery revealed thyroid vein punctured.	Y
9 F 85	Bleeding controlled with ligation and pressure.	N
10 F 69	Moderate haemorrhage arrested with ligation and pressure.	N
11 F 77	Bleeding stopped by ligation of vessel.	N
12 M 65	Slight bleeding which stopped spontaneously.	N
13 M 74	Bleeding stopped with ligation. Two attempts at PDT unsuccessful due to high left brachiocephalic vein.	Y
14 M 77	Vessel punctured low in sternal notch. Bleeding stopped with compression.	N
15 M 86	5–10 ml blood aspirated from tube. On further investigation pneumothorax and posterior tracheal wall tear found.	N
16 M 70	Moderate bleed from within the trachea, the day after PDT. Endoscopy revealed a mucosal tear to the posterior tracheal wall. Bleeding stopped spontaneously.	N
17 M 68	Bleeding only at time of insertion.	N
18 M 67	Initial puncture at T4/T5 led to venous bleeding. Tracheal puncture at T1/T2 successful.	N
19 M 71	Venous bleeding stopped spontaneously.	N
20 F 65	Bleeding with PDT, ultrasound showed an enlarged jugular vein. Stopped with pressure.	Y
21 M 36	Moderate venous bleeding, stopped spontaneously.	N
22 M 77	Torrential bleeding from aberrant thyroid vein. Vessel ligated in operating theatre	Y
23 F 67	On haemofiltration. Bled following day from stoma. No cause found on external examination and endoscopy. Bleeding stopped spontaneously.	N
24 M 61	Venous bleeding, stopped spontaneously.	N

Discussion

Bleeding occurred in 4.8% of our patients, which is similar to other large studies[7]. Multi-system disease, sepsis and renal failure (case 1, case 5 and case 23) can contribute to problematic coagulopathies even after performing PDT[7]. For most PDT procedures, control of bleeding can be achieved through the application of local digital pressure and ligation of small visible

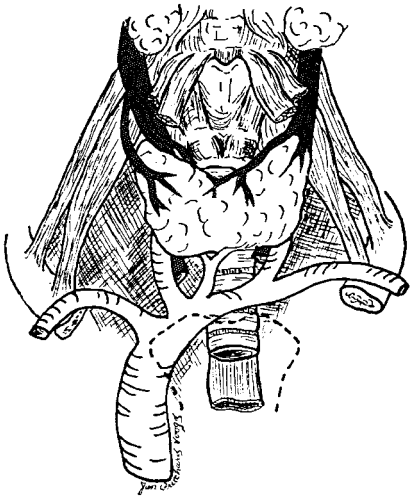

Fig. 1. Diagram showing the anomalous course of the left brachiocephalic vein as in case 13. Reprinted with permission from the American College of Surgeons, Journal of the American College of Surgeons (Formerly known as Surgery, Gynecology and Obstetrics) 1957, Vol. 105, page 328.

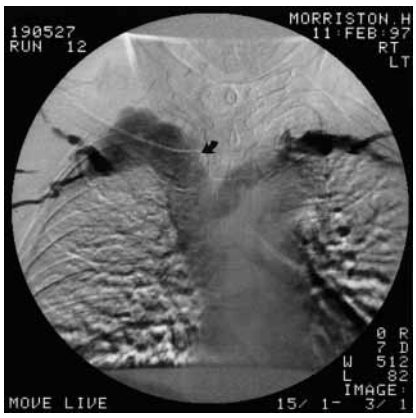

Fig. 2. Dilatation of the right brachiocephalic vein (black arrow) at the base of the neck. The patient had a previous operation to excise her cystic hygroma on the right side of her neck.

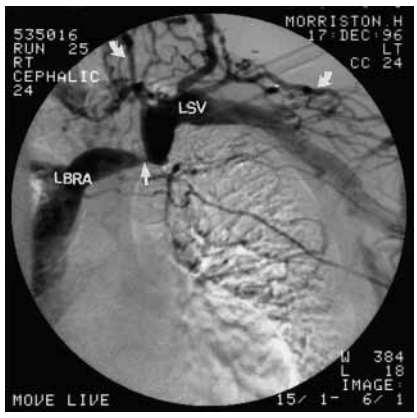

Fig. 3. A venogram showing significant stenosis at the proximal third of the left subclavian vein (straight arrow). Collateral vessels crossing the midline of the neck and the shoulder (curved arrows) are clearly shown. LBRA – Left brachiocephalic vein. LSV – Left subclavian vein.

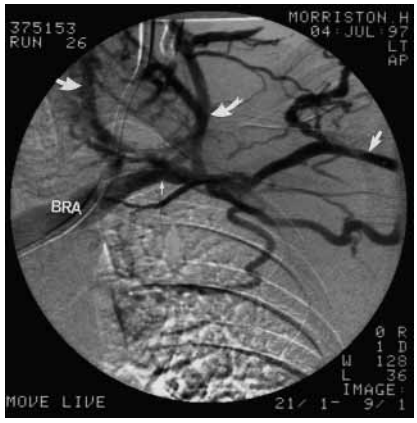

Fig. 4. A venogram showing subclavian vein narrowing (small arrow) and the presence of collateral veins running from the cephalic vein (medium white straight arrow) through the shoulder and across the neck to the jugular network of collaterals (curved white arrows). BRA-Left brachiocephalic vein.

vessels. Tamponading with a tight fitting tracheostomy tube may also stop bleeding[6].

Serious haemorrhage and fatalities[1,3,11,16,17,19] can complicate tracheostomy. Bleeding arising from within the trachea, especially in the presence of a pneumothorax or surgical emphysema, merits urgent fibreoptic endoscopic investigation. These findings suggest a mucosal tear or a serious posterior tracheal wall injury (case 15 and case 16). Although stomal granulations account for most episodes of late bleeding after tracheostomy, the serious possibility of a tracheoarterial fistula must not be overlooked.

Vascular complications from PDT can be minimised through knowledge of the variations in pretracheal vascular anatomy, their cause, and the technical measures used to ensure its safe practice.

Variations in venous anatomy

The inferior thyroid vein courses from the thyroid isthmus to the left brachiocephalic vein. Midline veins can easily be transected[4] (case 8) or punctured (case 22) during PDT. Sometimes venous drainage from the thyroid gland is via several thyroid veins or a venous plexus. Attempted cannulation of the trachea at the level of these veins may have been responsible for bleeding in cases 14 and 18. On occasions the left brachiocephalic vein can course quite high (Fig. 1), crossing the trachea suprasternally (case 13). This is more commonly the situation in children, with the left brachiocephalic vein being at risk of injury in open surgical tracheostomy.

Cystic hygroma can be associated with venous aneurysms in the neck or thorax[8], which may present later in life. A dilated brachiocephalic vein (Fig. 2) situated in the low anterior neck could give rise to problems with PDT. Sacrifice of the internal jugular vein as occurs in radical neck dissections can give rise to aberrant venous drainage of the head and neck.

Thrombosis of subclavian or internal jugular veins from central venous catheterisation can give rise to the development of a collateral venous drainage across the anterior neck[14] (Figs. 3 and 4), which could pose problems with PDT. Injury to possibly an enlarged anterior jugular communicating vein was responsible for surgery on one of our patients (case 20) being abandoned during PDT.

Variations in arterial anatomy

The thyroidea ima artery is present in about 3% of patients[18]. It can arise from the brachiocephalic artery, arch of the aorta or the right common carotid artery. As it emerges from the superior mediastinum, it comes to terminate in front of the trachea and gives off several branches, which could be hazardous for PDT.

Congenital vascular anomalies occupying the anterior neck are rare. An example of such an anomaly is the high, almost cervical aortic arch as seen in Figs. 5a and 5b. The arch of the aorta, which is normally a structure in the superior mediastinum, is lying in front of the upper tracheal rings in this patient. Attempted PDT in such a patient would be dangerous, as it would risk injuring the aorta.

This patient also had an anomalous right subclavian artery (Fig. 6) which passed superiorly to lie behind the trachea. Between 0.5 and 2% of the population have an aberrant right subclavian

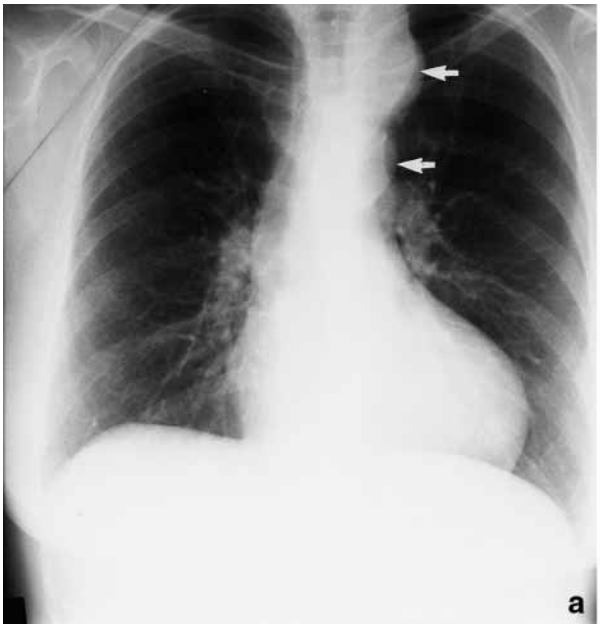

Fig. 5a. Radiograph of chest showing an apparently double-notched aorta (white arrows). This patient had a cervical aorta as is shown in the subsequent MRI scan (Fig. 5b).

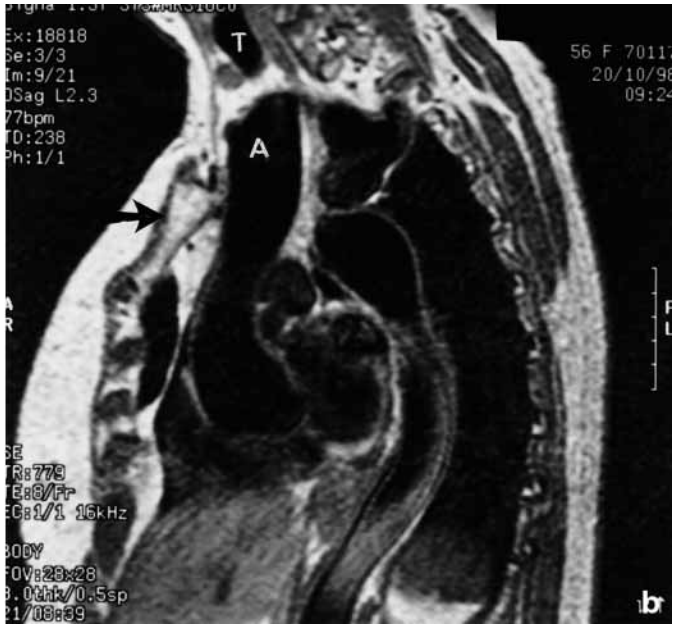

Fig. 5b. MRI scan of the same patient in Fig. 5a but taken as an oblique sagittal slice. It shows the aorta climbing above the manubrium (black arrow) into the suprasternal region. Part of the trachea is visible (T) on this view. A – cervical aorta.

artery (RSA). Fatal haemorrhage may occur if the posterior wall of the trachea is perforated on cannulation of the trachea and then subsequently dilated. Another potential complication that might occur with a RSA crossing behind the trachea is the development of a tracheosubclavian artery fistula. This complication could arise with an inferiorly sited stoma if the tip of the tube is lying against the posterior wall of the trachea. This is a situation that can occur at the time of cannulation or later from displacement of the tube through movement or transfer of a patient. With time, the tip of the tube could erode through the posterior wall of the trachea and adjacent aberrant subclavian artery, leading to serious haemorrhage. The scenario just outlined emphasises the importance of confirming correct tube placement and the need to secure tracheostomy tubes correctly.

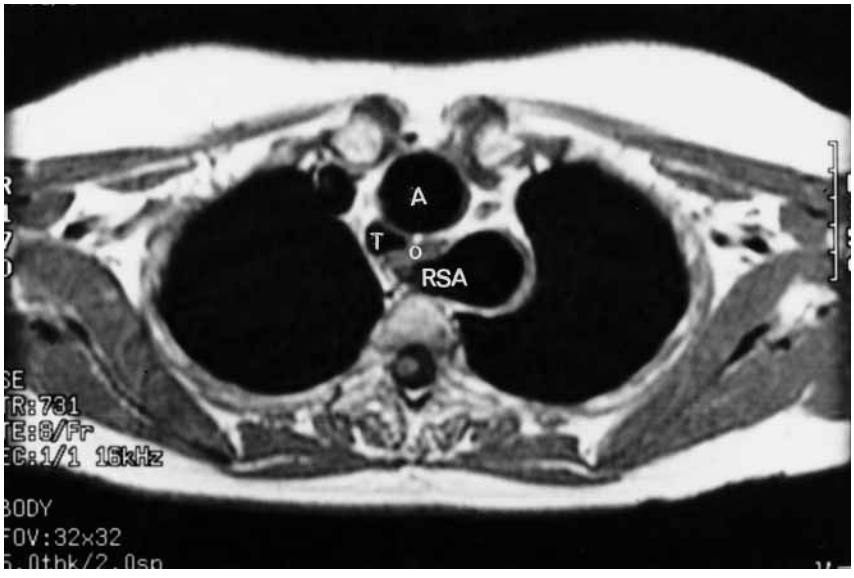

Fig. 6. MRI scan cross-sectional slice showing an aberrant right subclavian artery (RSA) as it arises from the aorta, before passing superiorly and to the right to lie behind the trachea. O – oesophagus. A – ascending aorta. T – trachea.

Another rare complication of tracheostomy is a tracheoinnominate (tracheobrachiocephalic) artery fistula. SCHLAEPFER[16], in a review of the literature, found more than 100 cases of fatal haemorrhage after open surgical tracheostomy. The cause of bleeding in the majority of these cases was the innominate (brachiocephalic) artery.

A tracheobrachiocephalic artery fistula may arise if the stoma is sited below the 4th tracheal ring[3,17] (Fig. 7a) or if the tip of a misplaced tracheostomy tube erodes through both the anterior wall of the trachea and posterior wall of an adjacent brachiocephalic artery. In the presence of an aberrant brachiocephalic artery, a fistula may even occur if the stoma is situated at the level of the 2nd tracheal ring[3]. This is fortunately a rare event. A tortuous brachiocephalic artery secondary to atheroma could also pose problems with PDT (Fig. 7b). A tracheoarterial fistula has been reported as a fatal complication of PDT[1].

Fatal haemorrhage from a tracheobrachiocephalic artery fistula may occur within days or months after tracheal cannulation[3,13,16]. Early detection

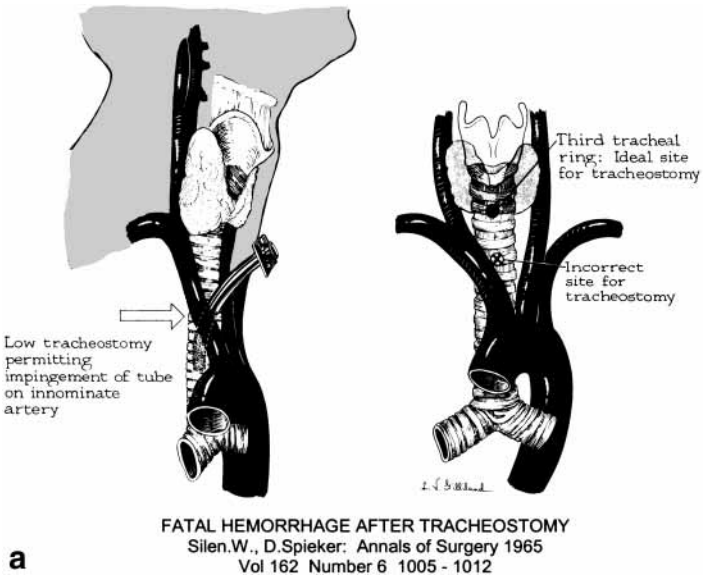

Fig. 7a. Fatal haemorrhage after tracheostomy. From SILEN & SPIEKER 1965[17].

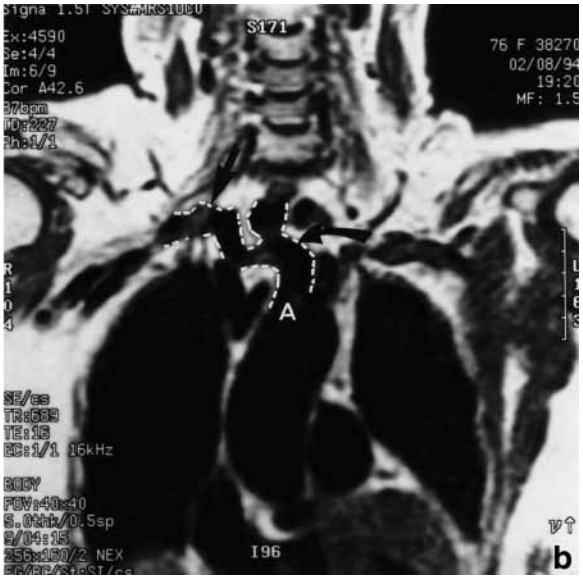

Fig. 7b. MRI scan of a patient showing dilatation of the proximal subclavian artery (straight black arrow). The second portion of the brachiocephalic artery appears tortuous (curved black arrow), looping into the base of the neck. The patient presented with a pulsate swelling in the base of the neck. A-ascending aorta.

of a tracheobrachiocephalic artery fistula is difficult, as most episodes of bleeding post tracheostomy are from stomal granulations. Bleeding which stops on inflation of the tracheostomy tube cuff or is present on changing tracheostomy tubes is suggestive of a tracheobrachiocephalic arterial fistula. Another sign which may raise clinical suspicions and assist with diagnosis is the presence in some patients of a pulsating tracheostomy tube at an inferiorly positioned stoma.

Siting the stoma above the fourth tracheal ring and endoscopically confirming the position of the tracheostomy tube in relation to the wall of the trachea on completion of PDT should minimise this complication. If identification of the upper tracheal rings is difficult, PDT can be done under ultrasound guidance[10]. A misplaced tube can be detected with fibreoptic endoscopy using either the translaryngeal route or the stoma.

A study by BERTRAM et al.[2], involving the use of ultrasound to assess the vasculature of the anterior neck, found that in 15% of patients, the common carotid artery was less than 10.5 mm from the fourth tracheal ring. In order to do PDT on patients with a predominantly retrosternal trachea, it may appear reasonable to fully extend the neck to raise the trachea and bring it closer to the skin surface. However, both SCHELDRUP[15] and BERTRAM et al.[2] have advised caution when placing a patient's neck into maximum extension, prior to tracheostomy, as vessels (Figs. 1, 2, 5b, 7a, and 7b) previously lying above the superior mediastinum may come to lie close to the upper tracheal rings. The risk of injuring these vessels during PDT is increased and has potentially serious consequences. Inadvertent cannulation of the inferior tracheal rings[12] may also arise from lifting the intrathoracic trachea out of the mediastinum after hyperextension of the neck.

We feel that the inclusion of certain measures as a necessary part of PDT should prevent or minimise problems with bleeding. We would therefore offer the following suggestions based on our own experience and a review of the literature. The operator performing PDT should take a thorough medical history attaching importance to congenital vascular problems, previous operations on the neck and thorax, and central venous cannulations. The patient should be carefully examined for the presence of scars on the neck and thorax and for any signs of a vascular abnormality. Old scars or a pulsatile swelling may be the only clues indicating previous surgery or altered vascular anatomy in patients often unable to give a history.

Clinical suspicion or doubt about the presence of anomalous vascular anatomy requires investigation with diagnostic ultrasound[10] before proceeding with PDT. If possible, avoid maximum neck extension as this may lead to a stoma situated at the inferior tracheal rings and risk injury to vessels lying in the root of the neck as they become displaced superiorly into the pretracheal region.

Perioperative and late vascular complications can be minimised if initial cannulation of the trachea is no lower than the 4th tracheal ring and preferably between rings 2 and 3. Ultrasound guidance can assist in the identification of the correct tracheal rings[10]. Moreover, fibreoptic endoscopy can be used to confirm correct tracheostomy tube position. An abnormality of blood clotting, which cannot be corrected, is a contraindication to PDT.

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