Clinical review

Radiological review of pneumothorax

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Spontaneous pneumothorax is relatively common in the community.[1] The incidence of iatrogenic pneumothorax is difficult to assess but is probably increasing due to the more widespread use of mechanical ventilation and interventional procedures such as central line placement and lung biopsy. Correct interpretation of chest radiographs in this clinical setting and knowledge of when to request more complex imaging techniques are essential. In this review we discuss the role of the chest radiograph in the assessment of pneumothorax before and after treatment along with the value of computed tomography and radiologically guided chest drain placement.

Summary points

- A large pneumothorax is radiographically defined as one with >2 cm from pleural surface to lung edge; this is an objective indication for drainage
- In the supine patient, pneumothoraxes are best seen at the lung bases and adjacent to the heart
- Skin folds, companion shadows, the scapula, and previous lung surgery or chest drain placement may all mimic pneumothoraxes
- Blind chest drain placement into a loculated pneumothorax may lead to an iatrogenic air leak from direct trauma to the pleura, worsening the patient's clinical condition
- An immediate post-treatment radiograph is essential to detect complications and ensure a satisfactory drain position

Sources and selection criteria

We reviewed textbooks of chest imaging and radiological normal variants. We also searched Medline for articles relating to both imaging appearances and clinical management of pneumothorax.

Pretreatment evaluation

The radiographic diagnosis of pneumothorax is usually straightforward (fig 1). A visceral pleural line is seen without distal lung markings. Lateral or decubitus views are recommended for equivocal cases.[2] On standard lateral views a visceral pleural line may be seen in the retrosternal position or overlying the vertebrae, parallel to the chest wall.[3] Shoot-through lateral or decubitus views may be used in ventilated patients or neonates. Although the value of expiratory views is controversial[4] many clinicians still find them useful in the detection of small pneumothoraxes when clinical suspicion is high and an inspiratory radiograph appears normal. The British Thoracic Society guidelines[2] divide pneumothoraxes into small and large based on the distance from visceral pleural surface (lung edge) to chest wall, with less than 2 cm being small and more than 2 cm large. A small rim of air around the lung actually translates into a relatively large loss of lung volume, with a 2 cm deep pneumothorax occupying about 50% of the hemithorax.[2] A large pneumothorax is an objective indication for drainage.[2]

Fig 1 (left) Classic appearances of left sided pneumothorax with readily apparent visceral pleural line (arrow)

Fig 2 (right) Supine projection showing air collected at lung base. Absent lung markings and a visceral pleural line (arrow) are still visible (P=pneumothorax). Left basal chest drain is noted

In the supine patient, air in the pleural space will usually be most readily visible at the lung bases (fig 2) in the cardiophrenic recess and may enlarge the costophrenic angle (the deep sulcus sign). Adherence of inflamed pleura to the chest wall may confine a pneumothorax to a loculated portion of the pleural space around the site of the air leak (fig 3). A drain placed remote from this area will be ineffective at best. If the operator enters the chest at a site of adherent pleura, parenchymal damage and a severe air leak may follow (fig 4). For this reason, in the authors' opinion, loculated pneumothoraxes are best approached under direct fluoroscopic and occasionally computed tomography guidance. Emphysematous bullae may also

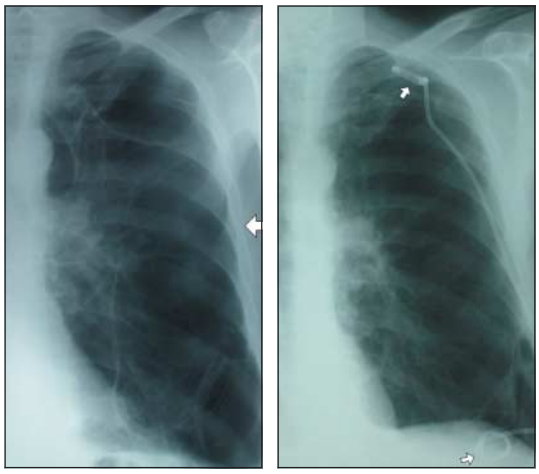

Fig 3 (left) Loculated left sided pneumothorax in a patient with severe chronic obstructive airways disease. Placement of chest drain into fifth intercostal space (arrow) might have entered lung parenchyma and would most likely not have achieved complete drainage of this loculated collection. (right) Percutaneous pigtail catheters (arrows) placed in apical and basal components of pneumothorax under fluoroscopic guidance. After several days of drainage the lung re-expanded completely

mimic a loculated pneumothorax, particularly when there is a background of chronic lung disease. Sometimes internal lung markings are visible in a bulla using a bright light. If there is clinical doubt in a patient with symptoms then computed tomography is helpful.

The chest radiograph should also be carefully examined for evidence of underlying parenchymal lung disease (fig 5). The most common of these predisposing to pneumothorax are emphysema, pulmonary fibrosis of any cause, cystic fibrosis, aggressive or cavitating pneumonia, and cystic interstitial lung diseases such as Langerhans' cell histiocytosis and lymphangiomyomatosis. Detection of an underlying condition is important for several reasons. Firstly, therapy of the parenchymal lung disease may be possible. Secondly, unlike primary spontaneous pneumothorax, patients with secondary air leaks are not candidates for early discharge and require inpatient observation.[2] Finally, all but the smallest (defined as apical or less than 1 cm in depth) secondary pneumothoraxes require treatment, even when symptoms are minimal.[2]

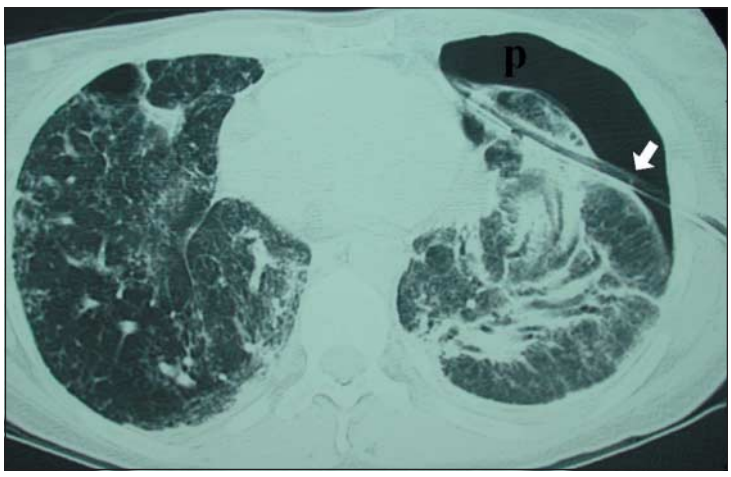

Fig 4 Extensive pulmonary fibrosis and left pneumothorax (p) treated by blind chest drain placement. Axial computed tomograpy shows that drain (arrow) has traversed lung parenchyma. This led to a deterioration in patient's clinical condition

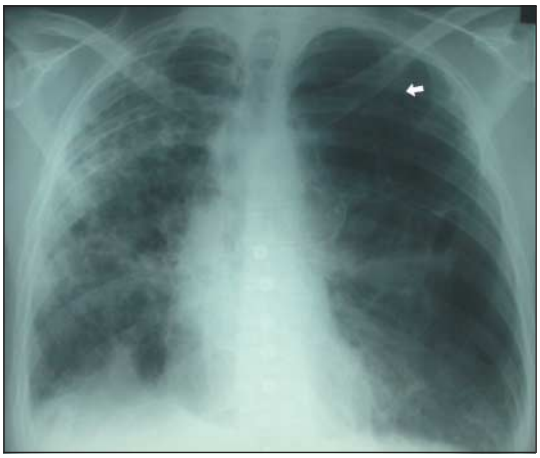

Fig 5 Background fibrotic lung disease (underlying ulcerative colitis), which places patient at risk of secondary pneumothorax. Although medial border of scapula (arrow) is easily recognisable as such on this radiograph it can sometimes be misinterpreted as a visceral pleural line

Several well known artefactual appearances can mimic the presence of a pneumothorax and should always be remembered during evaluation of a chest radiograph. The medial border of the scapula can imitate a lung edge but once considered can be traced in continuity with the rest of the bone, revealing its true nature (fig 5). Skin folds overlying the chest wall (fig 6) can simulate a visceral pleural line and with the relative lack of lung markings in the upper zones can lead to erroneous diagnosis, particularly in children. Once considered, however, their true nature is readily apparent. Skin folds are usually seen to pass outside the chest cavity, are straight or only minimally curved, and do not run parallel to the chest wall as with a true visceral pleural line. If closely scrutinised, distal lung markings are seen. Clothing or bed sheets may produce a similar artefact. Skin folds also form a dense line—sharp on one side and blurred on the other—in contrast to the less dense visceral pleural line. The latter distinction can, however, be rather subjective. Occasionally, doubt persists. In this situation, repeat radiography after removal of clothing and repositioning of the arm will be conclusive. Radio-opaque lines are often seen accompanying the inferior margins of ribs, which may simulate a visceral pleural line. These are often called

Fig 6 (left) Skin folds (arrows) overlying right hemithorax. Distal lung markings are readily apparent. Note folds are relatively straight unlike curved visceral pleural line of pneumothorax

Fig 7 (right) Prominent companion or accompanying shadow below left sixth rib (arrow). Line is relatively parallel to accompanying rib, and distal lung markings are evident

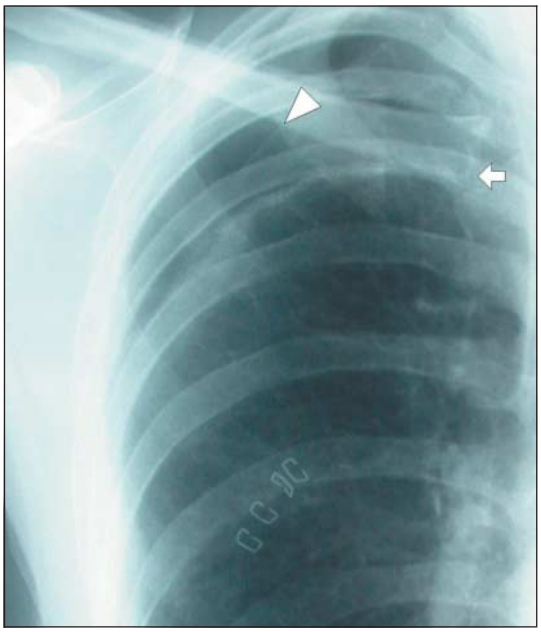

Fig 8 This patient underwent pleurectomy for recurrent pneumothorax. Suture material at right apex (arrow) is thicker than visceral pleural line and should not be confused with recurrent air leak. Compare with adjacent apical pneumothorax (arrowhead)

companion shadows although some restrict this term to densities accompanying the first and second ribs.[5 6] They are caused by protruding extrapleural fat or the subcostal groove. This normal variant is characterised by its faithful relation to the inferior margin of the accompanying rib, whereas visceral pleural lines diverge from the rib to parallel the chest wall. Although usually close to the adjacent rib, companion shadows may sometimes protrude inferiorly for a variable distance, giving a confusing appearance (fig 7). After pleurectomy for recurrent pneumothorax a radio-opaque line may be visible at the operative site due to suture material or staples (fig 8). This may be misinterpreted as a new air leak, especially if compared with preoperative radiographs or in ignorance of the history of previous surgery.

Post-treatment evaluation

A post-drainage chest radiograph is essential after intervention to document resolution of the pneumothorax, detect complications, and ensure a satisfactory drain position. If tissue dissection at a drain insertion site is too superficial, a subcutaneous or intramuscular plane may be identified by the operator's finger and lead to drain placement outside the pleural space in an ineffective position. This is more likely to occur if the drain is sited at a posterior location, and subsequent radiographic position may appear satisfactory on the frontal film (fig 9). A lateral view or computed tomography examination will detect this problem. An

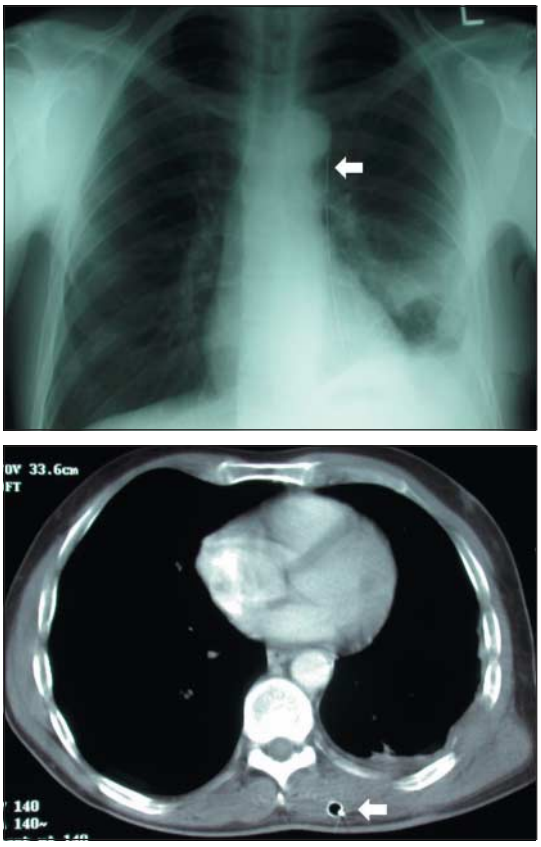

Fig 9 (top) Chest radiography shows unremarkable appearance of intercostal drain (arrow), apart from its medial location. (bottom) Axial computed tomography shows drain (arrow) is located in subcutaneous tissues. More superior images showed that the drain terminated in this superficial position

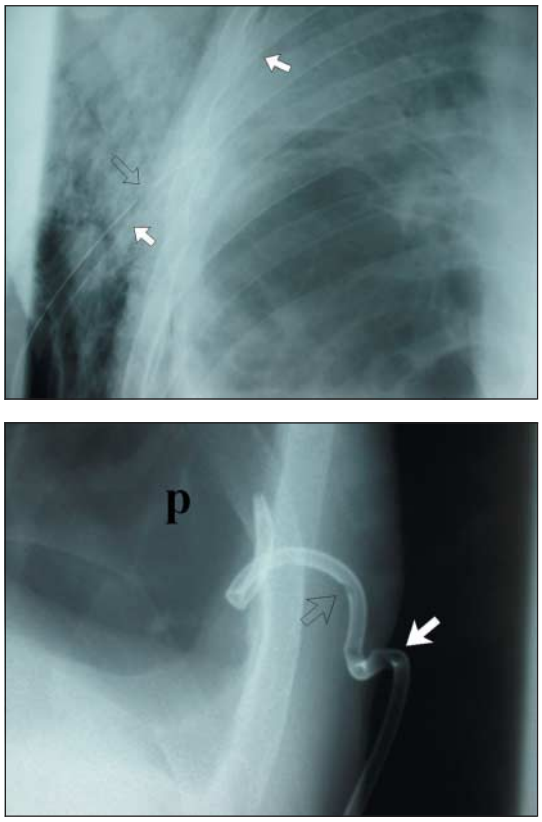

Fig 10 (top) Two large bore chest drains in a patient who developed a pneumothorax secondary to cavitating pneumonia. Lower drain (white arrows) is satisfactorily sited, but upper drain (open arrow) has side holes protruding into subcutaneous tissues, leading to extensive air leak. (bottom) Small pigtail catheter inserted into basal pneumothorax (p). Progressive traction on drain has led to extrusion of side holes into subcutaneous tissues (open arrow) and through skin surface (white arrow)

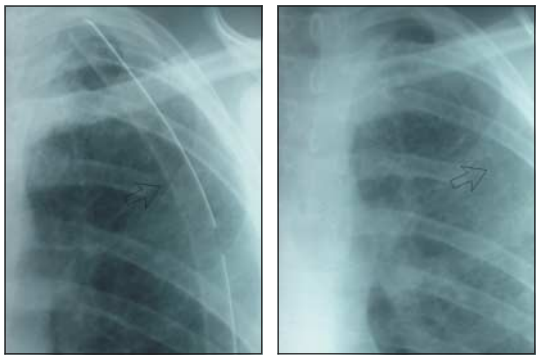

Fig 11 (left) Left apical chest drain (open arrow) in satisfactory position after lobectomy. (right) Chest radiograph after removal of drain next day shows faint radio-opaque line (arrow), known as a "drain track." This was seen to resolve on subsequent radiographs

adequate length of drain must also be inserted so that all side holes are contained within the pleural space. Failure to do so leads to inadequate drainage and air passage into subcutaneous tissues. The length of the tube with side holes can be identified on standard surgical chest drains by a gap in the radio-opaque marker line (fig 10). After satisfactory resolution of the pneumothorax, the drainage catheter can be removed and a further follow-up radiograph obtained to detect recurrence. A straight radio-opaque line is occasionally seen here along the line of the removed tube, known as a "drain track" (fig 11). This may be misinterpreted as a recurrent air leak, but its straight course and precise relation to the drain position on the radiograph before removal are usually conclusive. Presumably this finding is due to indentation of the pleura by the drain.

After placement of a chest drain, the tubing is connected to an underwater seal or flutter valve.[7] The patient usually undergoes daily chest radiography until the pneumothorax has resolved. Care must be taken to ensure that an unclamped chest drain bottle is not placed on the trolley above the level of the patient's thorax during the trip to the x ray department. This may result in accumulation of air and fluid in the pleural space, producing a hydropneumothorax on the radiograph. If the drain bottle is later returned to a dependent position without the physician's knowledge, then inappropriate suction or additional drainage procedures may be carried out. This possibility should be considered in unexpected deterioration on radiographs, especially in the absence of clinical signs. Questioning the patient may be helpful. This problem can be prevented by emphasising to nursing and portering staff the importance of the bottle position.

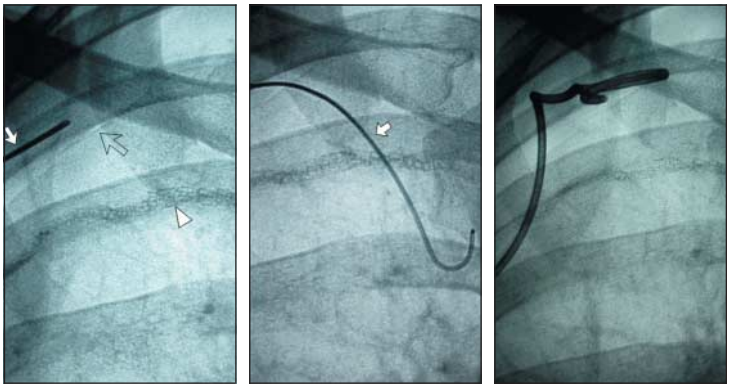

Fig 12 (left) Small pneumothorax post-pleurectomy at right apex (open arrow). Fluoroscopic guided needle puncture (white arrow) is being carried out. This unusual approach through the first intercostal space could damage subclavian vessels, which can be avoided by preliminary ultrasound examination of the needle path (arrowhead=suture material). (centre) Wire (arrow) is placed through the needle after aspiration of air. (right) Pigtail catheter coiled in pneumothorax and connected to underwater seal

Additional educational resources

American College of Chest Physicians (http://www.chestnet.org/education/cs/pneumothorax/interactive/index.php)—superb interactive site providing information on many of the practical aspects of management of pneumothoraxes that are often passed over in other reviews

British Thoracic Society (http://www.brit-thoracic.org.uk/c2/uploads/PleuralDiseaseSpontaneous.pdf)—guidelines for the management of spontaneous pneumothorax

American College of Chest Physicians consensus panel (http://www.chestnet.org/education/cs/pneumothorax/qrg/index.php)—interesting to compare the views of this panel with those of the British Thoracic Society guidelines

British Thoracic Society (http://www.brit-thoracic.org.uk/c2/uploads/PleuralDiseaseChestDrain.pdf)—guidelines for insertion of a chest drain

Radiological anatomy (http://www.radquiz.com/Chest.htm)—links to many excellent resources on chest radiology

Patient information

Aetna InteliHealth (http://www.intelihealth.com/IH/ihtIH/WSIHW000/9339/23666.html)—description of pneumothorax and details of treatment and prognosis, with links to other similar sites

Clamping of the chest drain before radiography is often carried out to detect small air leaks. British Thoracic Society guidelines[7] do not generally recommend this but consider it acceptable under the supervision of trained nursing staff in the ward environment. The merits of clamping of the drain are, however, a matter of some controversy among chest specialists.[8]

Computed tomography

The main indication for computed tomography in this clinical setting is to distinguish an emphysematous bulla from a pneumothorax, which can be difficult on standard radiographs. High resolution computed tomography may also be helpful when underlying parenchymal lung disease is suspected but not clearly identified or characterised by a chest radiograph. Extrapleural or intrapulmonary catheter placement is readily seen on computed tomography. Cross sectional imaging guidance is occasionally necessary for drainage of loculated pneumothoraxes in difficult locations.

Drainage under radiological guidance

Loculated pneumothoraxes are best approached by direct needle puncture under fluoroscopic guidance. The patient can usually be positioned supine under the image intensifier, making the approach more comfortable for patient and operator. Small apical pneumothoraxes in patients with chronic lung disease who may

have pleural adhesions can be approached through the axilla with the patient sitting on a stool and the image intensifier rotated for an anteroposterior projection. Occasionally a lateral approach is not possible, in which case anterior chest wall puncture in a sitting patient is required in the second or even first intercostal space (fig 12). Small pigtail drains of 8-10 French gauge with locking suture devices are the most commonly placed radiological catheters in our department. They are cosmetically acceptable, more comfortable than large bore 20 or 28 French gauge tubes, and are easier to site satisfactorily in small air collections. In addition, small bore catheters have been shown to be as effective as larger drains in the treatment of pneumothorax.[2] Traction on small non-sutured catheters by the drain bottle may, however, lead to progressive extrusion, with prolapse of side holes. If such drains are used, they should be well supported with tape and adhesive dressing. A securing suture should be placed around the catheter if the drain is to be placed for a long period (more than 24 hours) or the patient is uncooperative.

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An event that changed my life

Mere grade B's in botany, zoology, and chemistry in higher school certificate (A levels these days) were enough, with the aid of a good "viva," to get me into Newcastle Medical School in 1948. These days those A level grades wouldn't get me on to a medical course anywhere.

A quarter of entrants were straight from (mostly) public school sixth forms, with a ratio of men to women of about 4:1. The remaining entrants were former servicemen.

Our training began with two years of anatomy and physiology: to look after people medically, it was deemed essential that you knew in considerable detail the structure and function of their bodies. That somewhat fundamental foundation nevertheless stood me in good stead for 36 years in general practice. Behavioural sciences, communication skills, interpersonal relationships, and such matters were learnt either at home or by relating to other students.

There were two professors of anatomy, various readers and lecturers, and six "demonstrators." The biggest space in the medical school was the dissecting room, where dozens of formalinised body parts lay about on cold steel tables for students in groups of four or five to painstakingly dissect. My group were four friends from the town's public school—one of us very clever, one a brilliant violinist, one a "bit of a card," and myself.

After the constraints of sixth form, the freedom we found in second year medicine was somewhat intoxicating. Accordingly, we larked about—and we dissected very badly, despite trying to follow our *Cunninghams*. Our somewhat unruly behaviour was disapprovingly noted by the demonstrators (recent graduates bent on surgery and repeating anatomy as part of their training), whose task it would be to examine us after two weeks: the so called sign-up.

The first region of "leg" was the femoral triangle. Our examiner towered over us as we hunched on our stools around the hole that we had made at the top of the leg. He produced a seeker (an appropriately named bent metal rod), delved into the darkness of our dissection, produced a tubular structure, and asked us its name. Considering that we had never seen the saphenous artery before (for such he said it was), it came as no surprise that none of us could respond. We did know about the saphenous vein since we had come on that early on in our dissection and had duly cut it and consigned it to the bucket under the table. Inquiries as to the course of the artery and its relationships and functions elicited almost nothing from a future celebrated neurologist, a Scandinavian drug firm executive, an Australian consultant psychiatrist, and a northern GP.

Matters went from bad to worse, and when the marks went up on the noticeboard all four of us had an R (referred), meaning that the sign-up would have to be retaken in 10 days time.

When I got home that evening my mother inquired anxiously, "How did you get on?"

"I failed," I said, and she burst into tears. When my father got home from the bank and heard the news, he looked extremely grave. I was so despondent that I shared with them my doubts that I wasn't clever enough to be a doctor. It was a solemn evening, followed by a sleepless night.

So great was the impact of this initial failure that my subsequent diligence throughout my course knew no bounds: I even recorded on graph paper every hour of home study that I did during those five wonderful years. And from that day to this I never failed another test or exam.

Geoffrey Marsh *retired general practitioner, Stockton-on-Tees (marsh@bolam25.freeserve.co.uk)*

We welcome articles up to 600 words on topics such as *A memorable patient, A paper that changed my practice, My most unfortunate mistake,* or any other piece conveying instruction, pathos, or humour. Please submit the article on http://submit.bmj.com Permission is needed from the patient or a relative if an identifiable patient is referred to. We also welcome contributions for "Endpieces," consisting of quotations of up to 80 words (but most are considerably shorter) from any source, ancient or modern, which have appealed to the reader.