43 Chest Injury

43.1 Management of chest injury

Chest injuries can be terrifying to both patient and physician – but most injuries just need at most the placing of a chest drain into one or both sides of the thorax. You must learn this skill and be ready to use it earlier in chest trauma rather than later (43.2). Only 5–10% of chest injuries will need the chest opened (thoracotomy). This is major surgery which is unlikely to be feasible in your setting. *You should learn to recognize those injuries which require referral – and prepare for it early in the course of treatment.*
You must also accept that some injuries (*e.g.* an aortic rupture) are unlikely to be salvageable. They are not even likely to survive the journey to your hospital.

Before you are overwhelmed by the idea of serious chest trauma, *you must realize there is a great deal you CAN do to help these patients*. Try by all means to get a pulse oximeter if you don't have one.

The aim is to make sure that the lungs are well ventilated, these are things you should do:
(1) Secure the airway, and encourage coughing to clear it. It is easily obstructed, especially in a child, and can only too easily be filled by inhaled blood, secretions, or stomach contents. Avoid this by: (a) aspirating the secretions, (b) passing a nasogastric tube, (c) arranging a bronchoscopy, or (d) tracheal intubation, or occasionally (e) tracheostomy, which will reduce the dead space and make a tracheal toilet easier.
(2) Administer oxygen.
(3) Insert a needle for a tension pneumothorax.
(4) Remove air or blood by pleural drainage.
(5) Close an open or sucking chest wound.
(6) Stabilize a flail chest (43-24).
(7) Assist ventilation with a self–inflating bag.
(8) Start a blood transfusion.
(9) Prevent infection.
(10) Relieve cardiac tamponade by pericardial drainage.
(11) Start physiotherapy (11.10)
(12) Monitor the patient carefully.

The great danger with all chest injuries is that retained secretions will cause infection, lung collapse, and ultimately death. *Only active physiotherapy will prevent this consequence.*

N.B. Don't forget that burns can cause significant injury to the airways & lungs through inhalation of smoke! (50.3)

Blunt and penetrating injury vary in the pattern of damage they cause. Unlike a penetrating injury in the abdomen which usually requires a laparotomy, a penetrating wound of the chest does not mandate a thoracotomy.
Remove knives, spears, arrows and foreign bodies embedded in the chest only in the operating theatre!

If the penetrating instrument has already been taken out, you may have great difficulty deciding how deep is the stab wound, or which organs in the chest have been pierced or are bleeding.

If there is air or blood in the pleural cavity, put in a needle or chest drain (43.2).
Remember a penetrating wound of the chest may cause damage in the neck or abdomen as well! *The most important priority in all trauma cases is the airway* (42.1). *Don't skip this step, no matter how dramatic the chest injury may be*.
During the primary trauma survey (42.1), the goal is to identify and treat life-threatening conditions first.
In the chest, this list includes:
(1) Tension pneumothorax (43.2)
(2) Open sucking pneumothorax (43.3)
(3) Flail chest and respiratory distress (43.2)
(4) Massive haemothorax (43.2)
(5) Cardiac tamponade (44.7)

Other injuries which are not life-threatening tend to show up a bit later (often not being obvious on a quick physical examination):
(1) Simple pneumothorax (43.2)
(2) Smaller haemothorax (43.2)
(3) Pulmonary contusion (43.2)
(4) Diaphragm injury (43.4)
(5) Fractured sternum & ribs (43.5)
(6) Blunt cardiac injury (43.7. 44.6)
(7) Traumatic aortic disruption (43.6)
(8) Blunt oesophageal rupture (30.7, 43.6)
(9) Tracheo-bronchial tree injury (43.6)

RAPID ASSESSMENT OF A CHEST INJURY

If the airway is obstructed, clear it (42.1).

If air is going in and out, but breathing is distressed, there may be multiple fractured ribs or severe abdominal pain.

If there are great respiratory efforts, **but the patient is still hungry for air**, think of a flail chest or pneumothorax.

If there is cyanosis in the presence of an adequate airway, there may be a badly damaged lung, a flail chest, or a pneumothorax.

Administer oxygen. Always think whether you need to put a needle or drain into the chest! You will very rarely cause any damage and the act may well be life-saving. Monitor the oxygen saturation, if you can. (Try by all means to get a pulse oxymeter!)

TENSION PNEUMOTHORAX

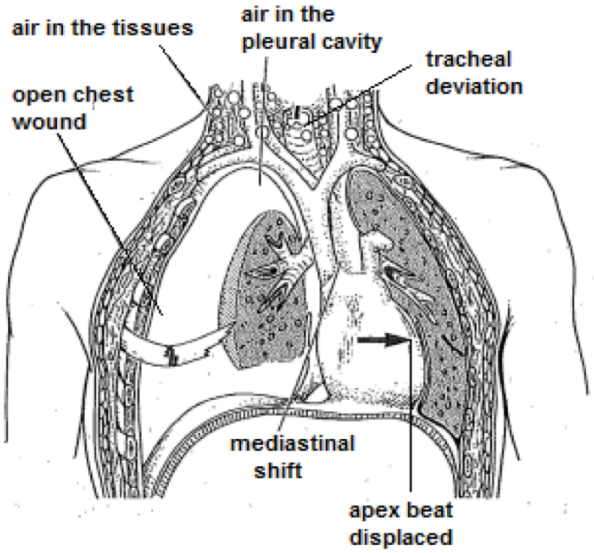

Fig. 43-1 TENSION PNEUMOTHORAX. This causes obstruction to venous return to the heart and is a surgical emergency, needing a needle thoracostomy. (Air in the tissues is known as 'subcutaneous emphysema')

NEEDLE THORACOSTOMY

If there is hypotension, tracheal shift, and a contralateral lack of air entry, a hyperexpanded hemithorax, hypoxia and ribs pushed apart from each other *or any one of these signs*, there may well be a tension pneumothorax: quickly insert a 4-6cm long 14G cannula into the 2nd intercostal space in the mid-clavicular line. If air hisses out, or blood spurts out, insert a chest drain as soon as you can (43.2).

FINGER THORACOSTOMY

If shock persists, insert a chest tube into the 5th intercostal space anterior to the mid-axillary line (53.2). *Don't waste time getting a radiograph done!*

If a patient cannot maintain his own breathing, and you can intubate him, connect him to an intermittent positive pressure ventilator (IPPV), and monitor his oxygen saturation, or keep him ventilated with a self-inflating bag.

(a) History:

Obtain a history of the mechanism of injury, if you can. Assess the force of impact carefully. The greater the force (including being thrown from a vehicle, the height of a fall, a crushing injury, a head-on-collision), the greater the chances of a severe injury, both in the chest and elsewhere.

Find out when the injury occurred. Get some information, if possible, about the victim, especially related to alcohol, drugs, and the past medical history. Ask where the patient has pain: beware if there is back pain because this may suggest an aortic injury (43.2).

(b) Examination

If a patient is conscious, and is now breathing easily, strip him to the waist, and ask him to describe his pain and show you exactly where it hurts. If vertebral injury is very unlikely, and the neck is protected in a rigid collar, you can sit him up (holding his head straight and having 2 assistants to lift the shoulders) so that you can examine the back of the chest.

If a patient is unconscious, remove the clothes and examine the chest carefully. *Don't fail to turn him* (log-roll him with at least 2 assistants maintaining a straight alignment of the spine).

(c) Inspection

Assess the rate and depth of breathing. Broken ribs will soon provoke sharp pain at the fracture site.

Look for evidence of bruising or crepitus at the site of pain (which may be due to air rather than blood). Note bruising due to a seat belt or the imprint of the steering wheel.

Check if both sides of the chest move equally. Look carefully for any areas of diminished chest movement, which may be in one area only, or involve the whole of one side. Look at the chest from the sides and from the head and foot of the patient.

CAUTION! Look carefully for paradoxical movement. This is due to a flail chest (fracture of two or more ribs in two or more places causing the portion of the chest wall to have independent movement).

Look at the movement of a normal area, then compare it with the possibly abnormal one. Is it moving in or out when the normal side is doing the opposite?

Such paradoxical movement may be difficult to see when a patient is shocked and respiratory movements are shallow; it may only appear later, after proper resuscitation.

N.B. Don't mistake this for the indrawing of the lower costal margin common in mild respiratory obstruction, especially in children!

Is one side of the chest hyper-expanded compared to the other (look from the foot of the patient)? Do the ribs seem further apart from each other on one side compared with the other?
Is there cyanosis? Look at the mucous membranes and fingernails. Monitor oxygen saturation if you can.

N.B. Anaemic patients (<50g/l) don't become cyanosed, and may die of anoxia without showing cyanosis.

N.B. Patients with carbon monoxide poisoning (especially from fires) *may still show normal oxygen saturation.*

Is there an open chest wound? Is it sucking in air? *Beware! A bullet may pass into the chest via the neck, abdomen, arm or back!*

Are the jugular veins abnormally distended? This can be caused by anything which impedes the venous return to the heart, *i.e.* tension pneumothorax, mediastinal shift, and especially cardiac tamponade.

N.B. A hypovolaemic patient will not show jugular venous distension.

(d) Palpation:
If a patient is conscious, start palpation in a pain-free area, and then move towards the injured zone. Feel for:(1) tenderness, (2) crepitus when fractured ribs move with respiration, and (3) the crackly feeling of surgical emphysema (due to movement of air in the subcutaneous tissues).

Is there a mediastinal shift? Check if the apex beat in its normal place? Feel the suprasternal notch if the trachea is displaced to one side or the other. (This may be hard to be sure about and will usually require a radiograph to confirm).

If the patient does not complain of pain, gently spring the chest between your hands from front to back, or from side to side. If this causes severe pain, there are probably multiple broken ribs. Feel for the tender fracture sites, which may be easier to feel than see on a radiograph.

(e) Percussion: Tap the chest in all lung fields, especially the lower, comparing one side to the other. Dullness indicates a collection of fluid or lung collapse, and hyperresonance suggests a pneumothorax.

(f) Auscultation:
Listen for breath sounds in all lung fields, noting if they diminished in some area? Note especially: (1) clicking sounds from fractured ribs, (2) coarse crepitation of surgical emphysema, (3) reduced or absent breath sounds on one side, compared to the other, suggesting air or fluid in the pleural cavity, or lung collapse.
If the patient is lying supine, you will only hear this on the sides posteriorly (43-8).

N.B. There is often much noise around the drama of a chest trauma victim: tell those around to keep quiet!

If you don't have imaging, especially in the triage setting, perform a *diagnostic* thoracocentesis. Puncture the pleura through the 4th or 5th intercostal space in the mid-axillary line, and aspirate. If you find blood, this patient needs a chest drain.
Don't try to drain a haemothorax by repeated aspiration on a needle: it takes too long and the blood will clot!

Other signs: Examine *the abdomen* carefully. Note whether it moves with respiration (55.2,3). Note any tenderness, rigidity or distension.
Where the lower left ribs are fractured posteriorly, suspect a ruptured spleen (55.6). If there is tenderness in the right upper abdomen, suspect a ruptured liver. If there is central abdominal tenderness, think of rupture bowel.

Pulse: **Is the pulse stronger on inspiration than on expiration** (*pulsus paradoxicus*)? This a rare but classic sign of cardiac tamponade (44.7). In aortic dissection, there may be a difference in BP between both arms.

N.B. **If there is a focal neurological deficit & no head injury,** think of an ***air embolism*** (blunt or penetrating lung damage allowing air to pass through branches of the great vessels to the brain). This is a dire situation; tough it is an indication for thoracotomy and removing the damaged area of lung, you are unlikely to get this far in resuscitation!

IMAGING IN CHEST INJURIES

NORMAL ULTRASOUND PLEURAL IMAGES

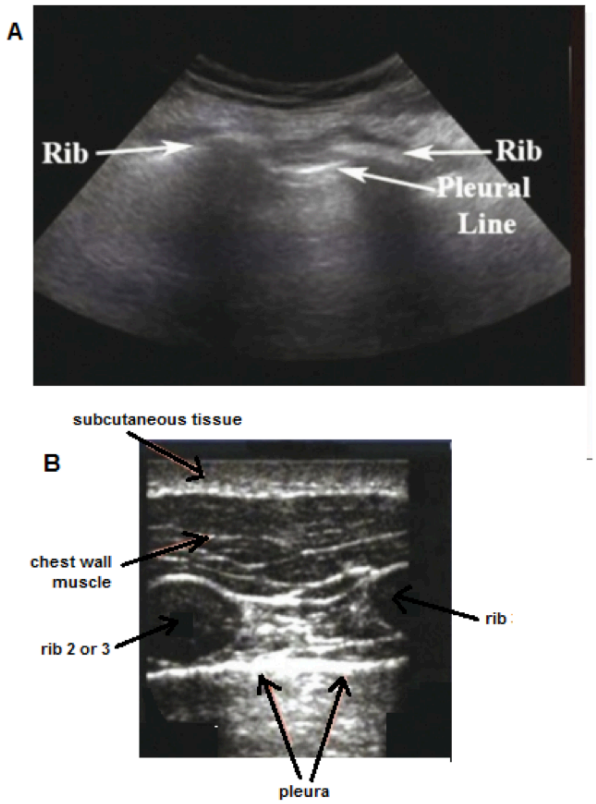

Fig. 43-2 NORMAL ULTRASOUND IMAGES OF THE PLEURA. A, with the probe below in the mid-clavicular line between the 2nd & 4th ribs, the pleural line shows as a bright white line below the ribs. B, the bright pleural line shows a 'wiggle' effect as the pleural surfaces move over each other with normal breathing.

ULTRASOUND IN CHEST INJURIES

Ultrasound is often more reliable in chest injuries than radiography; it is quicker and much more sensitive. You should learn this skill. It is *not* difficult.

ULTRASOUND IN PNEUMOTHORAX:

Air will rise to the uppermost part of the chest. When a patient lies supine, this corresponds to the anterior chest at the 2nd-4th intercostal spaces, below the clavicles, in the mid-clavicular line.

Scan the patient therefore in a supine or near-to-supine position. Place the probe in a longitudinal or transverse position.

Identify the landmarks of 2 ribs with posterior shadowing behind them and visualize the pleural line in between them. If you can't see the ribs, move the probe slowly in a caudal direction (towards the perineum) until 2 ribs appear on the screen. Between these you will see the 2 layers of pleura, parietal and visceral, sliding or 'wiggling' across one another.

NORMAL M-MODE IMAGES

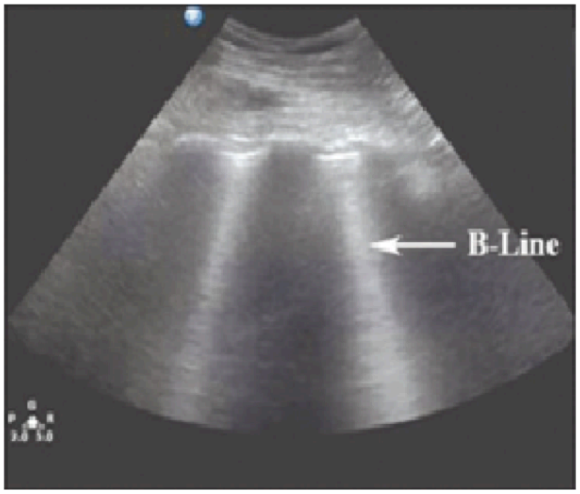

Fig. 43-3 NORMAL M-MODE IMAGES. Artefacts behind the pleural lines disappear in a pneumothorax.

CONTRASTED M-MODE IMAGES

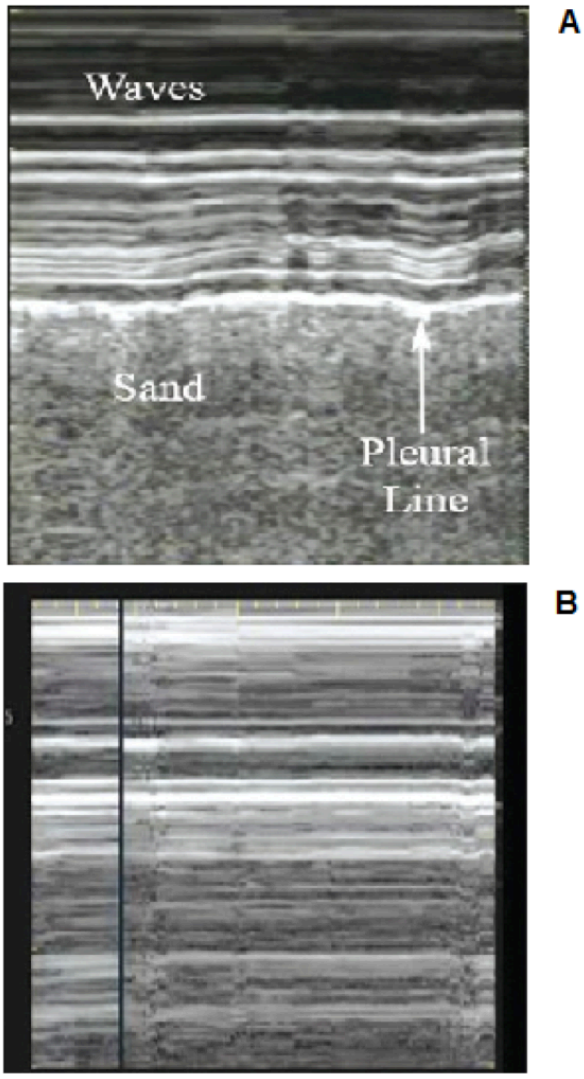

Fig. 43-4 M-MODE IMAGES CONTRASTING NORMAL & PNEUMOTHORAX. A, the normal image where the pleural line represents the 'seashore'. B, a 'Bar Code' image of a pneumothorax.

(1) The normal wiggle (36.1), seen as a bright line below the dark rib, of parietal and visceral pleura sliding on each other with normal respiration is lost with a pneumothorax (43-2). This is the most reliable sign. By moving the probe, you may be able to determine where the limit of the pneumothorax lies.

(2) In the M-mode, 'comet tail' or reverberation artefacts, which arise from the deeper visceral pleura, should normally move with the lung during respiration (43-3). This likewise disappears when a pneumothorax is present.

(3) M-mode detects motion between the 2 pleural lines in the normal situation, much as waves against a seashore, whereas in a pneumothorax, there is no motion, creating the same pattern throughout (43-4)

ULTRASOUND: A LEFT HAEMOTHORAX

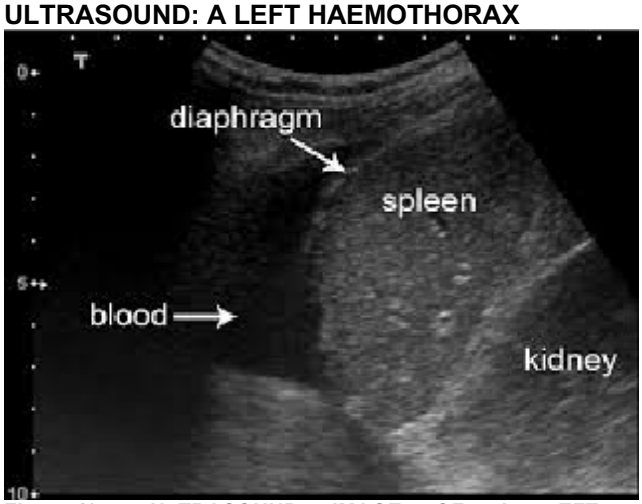

Fig. 43-5 ULTRASOUND IMAGE OF A LEFT HAEMOTHORAX. Blood shows as a dark homogenous zone; you will not be able to differentiate this from other types of effusion.

ULTRASOUND: A RIGHT HAEMOTHORAX

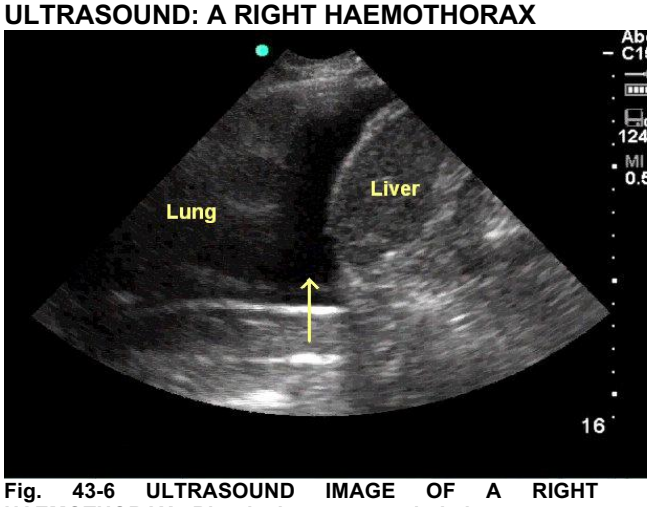

Fig. 43-6 ULTRASOUND IMAGE OF A RIGHT HAEMOTHORAX. Blood shows as a dark homogenous zone between the diaphragm and the lung.

ULTRASOUND IN HAEMOTHORAX

Place the probe at both lower quadrants of the chest, and look for the edge of the diaphragm. Free liquid appears as a homogenous dark zone between the diaphragm and other structures (43-5,6). Check also the anterior quadrants, in case of localized fluid effusions.

ULTRASOUND FOR FRACTURED RIBS

Place a linear probe along the suspected broken rib a little distance away from the site of maximal tenderness. Verify that you can see the rib clearly. Move it towards the point of tenderness. Look for a break in the cortex of the bone, and liquid around it. Then turn the probe 90º and check again for a discontinuity of the cortex (43-7), or ossification from a healing fracture.

ULTRASOUND: RIB FRACTURES

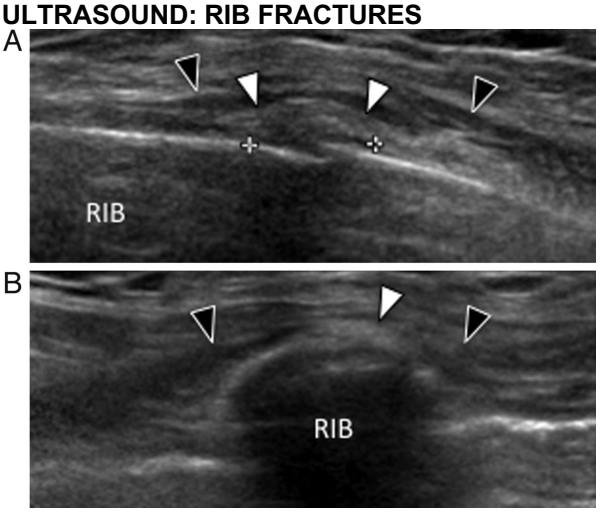

Fig. 43-7 ULTRASOUND IMAGE OF A BROKEN RIB. A clear break in the cortex of the rib is easily visible.
Figs 43-2-7 After Husain LF, Hagopian L, Weyman D, Baker WE, Carmody KA. Sonographic diagnosis of pneumothorax. J. Emerg Trauma Shock 2012; 5(1):76-81.

ULTRASOUND: STERNAL FRACTURE

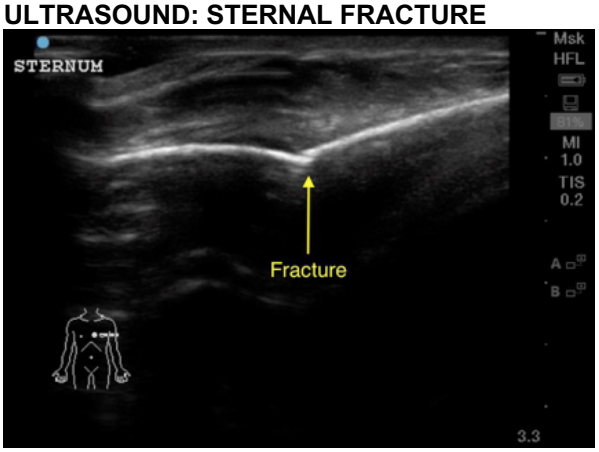

Fig. 43-8 ULTRASOUND IMAGE OF A STERNAL FRACTURE. The irregularity in the edge of the sternum is clearly visible.

Ultrasound can diagnose unossified rib fractures in children, breaks in costal cartilages in the anterior chest, which are *not* visible on radiographs. However, the ribs covered by the scapula and the infraclavicular portion of the first rib are not visible by sonography.

N.B. Don't confuse a fracture for the sterno-manubrial angle or the xiphisternal junction!

ULTRASOUND FOR STERNAL FRACTURES

Place a linear probe along the sternal edge a little distance away from the site of maximal tenderness. Verify that you can see the sternum clearly. Move it towards the point of tenderness. Look for a break in the cortex of the bone. Then turn the probe 90º and check again for a discontinuity of the cortex (43-8).

RADIOGRAPHS IN CHEST INJURIES

Obtain chest radiographs after the primary survey in all patients you suspect of having a serious chest injury. They are often unhelpful and unnecessary to show fractured ribs, or a fractured sternum (which needs a lateral view), though may be useful to check for complications.

Try, if possible, to get an erect or semi-erect image of the chest. You may need to support the patient to obtain such pictures.
Radiographs taken supine are notoriously difficult to interpret. You may easily miss a large haemothorax (which often looks like 'ground glass').

SOME RADIOGRAPHIC FINDINGS

(a) Pneumothorax and sucking chest wound (36.1, 43.2):
The lung markings don't reach all the way out to the edge of the thoracic cage. The pleural edge is visible as a faint line (36-1C,D). *Don't confuse the inner edge of the scapula with this line.*

If the mediastinum (and trachea) are shifted to the opposite side, the outline of the hemidiaphragm flattened, and the ribs appear wider apart than the other side (36-1A), *stop looking at this picture and immediately insert a 14G cannula in the midclavicular line between the 2nd-4th ribs!* This is a **tension pneumothorax**, which has been missed! *Act fast or the patient might die!*

Likewise, for a **bilateral pneumothorax** where no lung vessel markings visible, the trachea is central and the heart has 'disappeared' (36-1B). *Insert a cannula as above on both sides!*

(b) Haemothorax (43.2):
There is a diffuse opacity in a lower lung field, which is more easily seen in an erect film (43-9A).

HAEMOTHORAX

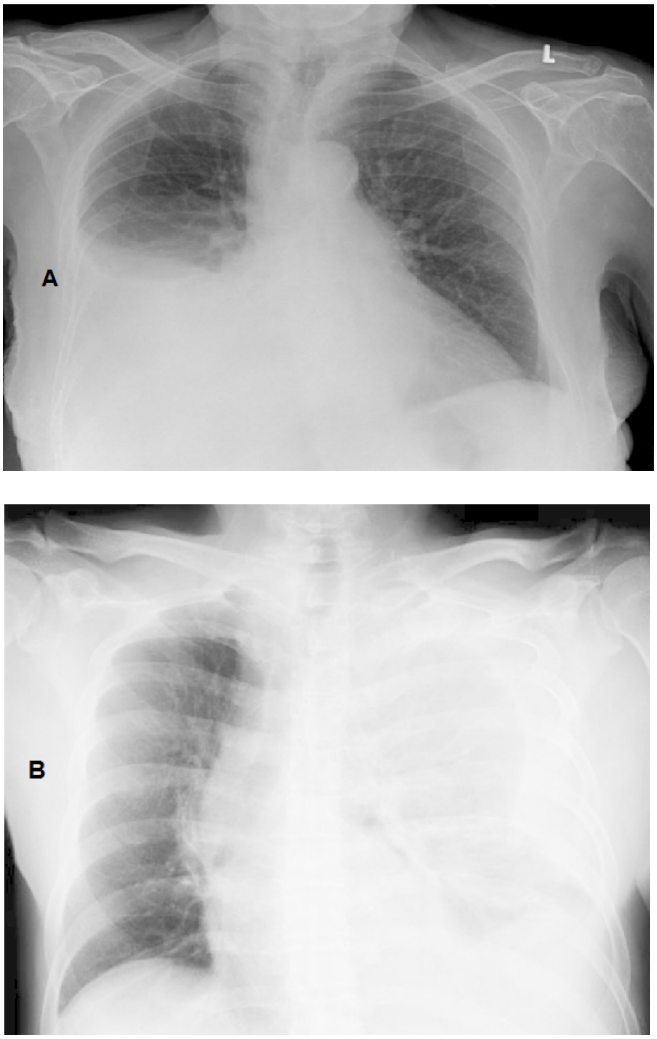

Fig. 43-9 RADIOGRAPHIC SIGNS OF FLUID IN THE CHEST. A, in a semi-erect film, fluid makes a curved interface with air at the pleural edges. B, mediastinal shift in a left tension haemothorax.

A massive haemothorax can fill the entire chest, producing a 'white out' appearance. *Don't confuse this for a lung collapse or the routine postoperative image of a pneumonectomy!*

Rarely there may be so much fluid in the hemithorax that it pushes the mediastinum to the opposite side as above.

This is **a tension haemothorax** (43-9B). *React as for a tension pneumothorax, but use a bigger cannula!* This is a sign of life-threatening bleeding and needs a very urgent chest drain or 2nd one (and possible thoracotomy).

A smaller haemothorax may not be very visible radiologically, especially if you take the picture with the patient supine.

N.B. Remember, in rare cases, a patient may have a pre-existing pleural effusion (from TB, or tumour) *before the injury!*

(c) Cardiac tamponade (44.7):
The only (late) sign is a widened, but typically globular, cardiac shadow.

(d) Fractured ribs and flail chest (43.5):
Identify each of the upper ribs anteriorly and follow them around and back to the vertebral column. Look for any disruption of the cortical layer. The lower ribs are usually identified best posteriorly and followed anteriorly.

Remember that the anterior ribs are cartilaginous and not visible on radiography. Fractures are almost always in adjacent ribs. If you identify a fracture in ribs 3 & 5, there almost always is one in rib 4.

A flail chest is defined as a segment of at least 2 ribs separated from the rib cage. Each rib must therefore be broken in at least 2 places. This segment may move independently, especially 24h after injury, and therefore fails to support proper lung expansion.

(e) Pulmonary Contusion (43.2)**:**
Diffuse mottling with dense patches is visible in the affected lung field, usually below the impact of trauma. These patches may condense in the days following trauma before clearing.

PULMONARY CONTUSION

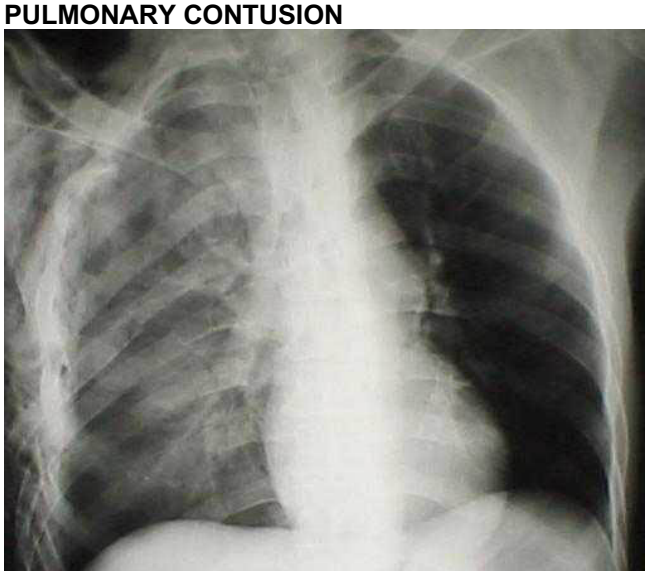

Fig. 43-10 RADIOGRAPHIC SIGNS OF PULMONARY CONTUSION. Mottling may be subtle. Note the rib fractures, and subcutaneous emphysema.

Contusion is usually associated with obvious rib fractures in adults, but may be seen in children without, since their ribs are compliant so that they bend rather than break.
Contusions are frequently found in explosion injuries.

(f) Traumatic diaphragm injury (43.4)**:**
There is a loss of the distinct demarcation of the hemidiaphragm (most often on the left side), with fluid or gas in the left hemithorax; there may be an elevated hemidiaphragm on the right. A nasogastric tube, if passed, will be visible at the oesophageal hiatus below the diaphragm and then curve back into the left hemithorax, if the stomach has herniated into the left chest. There is an elevated gastric gas bubble usually. *Don't confuse this with a haemopneumothorax!* The small bowel (unmistakable) or spleen may find their way into the hemithorax. *Don't confuse this with pulmonary contusion!*

Often the increased volume of content in the hemithorax may provoke a mediastinal shift.

TRAUMATIC DIAPHRAGM RUPTURE

Fig. 43-11 RADIOGRAPHIC SIGNS OF DIAPHRAGM RUPTURE. Note the gas bubble (with the nasogastric tube tip) & bowel in the left hemithorax. There is some mediastinal shift to the right.

(g) Aortic injury (43.6):
Look for a widened mediastinum >8cm in a supine film (or >6cm in an erect film). This is quite a subtle diagnosis: you may need to repeat the radiograph after a while if you are not sure.

You can estimate of the size of the aortic knob (and associated hematoma) by passing a nasogastric tube; measure the distance from the radiopaque line of the tube to the pleural side of the mediastinum. Other signs are listed (43.6).

AORTIC INJURY

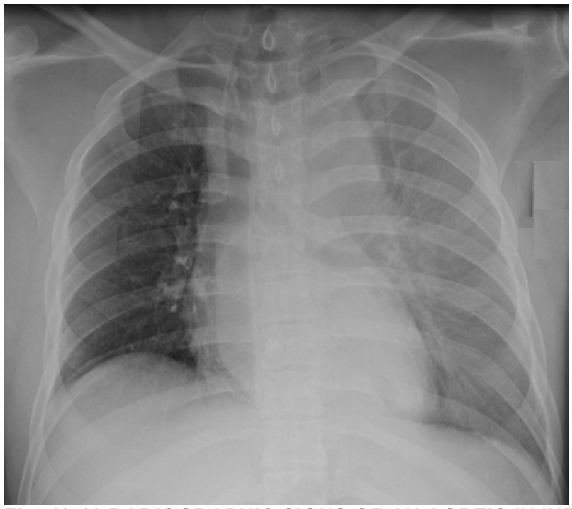

Fig. 43-12 RADIOGRAPHIC SIGNS OF AN AORTIC INJURY. A supine film: note the widened mediastinum, right tracheal deviation, flattened left main bronchus and ground-glass appearance of blood in the left hemithorax.

OESOPHAGEAL INJURY

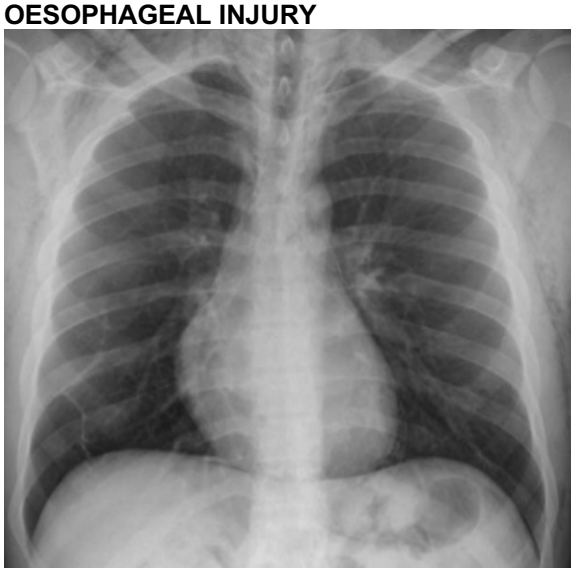

Fig. 43-13 RADIOGRAPHIC SIGNS OF OESOPHAGEAL INJURY. Note the air in the mediastinum (a black line around the heart border) and the subcutaneous emphysema, usually best seen in the neck (43-14).

(h) Blunt oesophageal rupture (30.7, 43.6)**:**
Look for subcutaneous emphysema in the neck or upper chest wall, air in the mediastinum (may be very subtle), around the heart, with or without a small pneumothorax or, rarely, a pleural effusion usually on the left side.
You may confirm the diagnosis by a gastrograffin oesophageal swallow (*don't use barium*).

N.B. The oesophagus can easily be damaged by rigid oesophagoscopy (30.2).

SUBCUTANEOUS NECK EMPHYSEMA

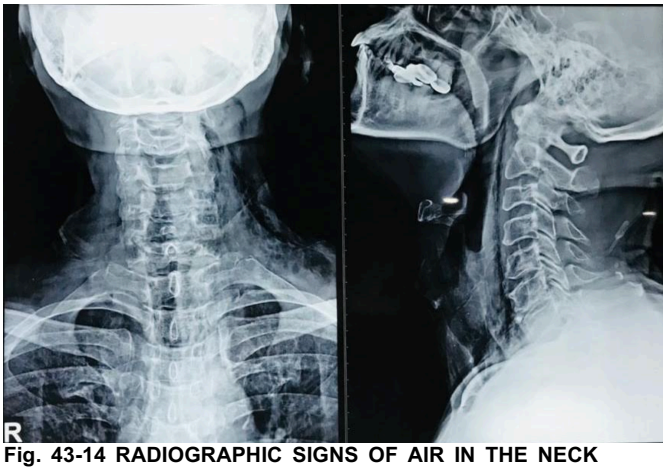

Fig. 43-14 RADIOGRAPHIC SIGNS OF AIR IN THE NECK TISSUES. A, AP view. B, lateral view a copious subcutaneous emphysema in the neck, which can arise from a pneumothorax, perforated airway or oesophagus. *Kindly contributed by Dhananjaya Sharma.*

TRACHEO-BRONCHIAL INJURY

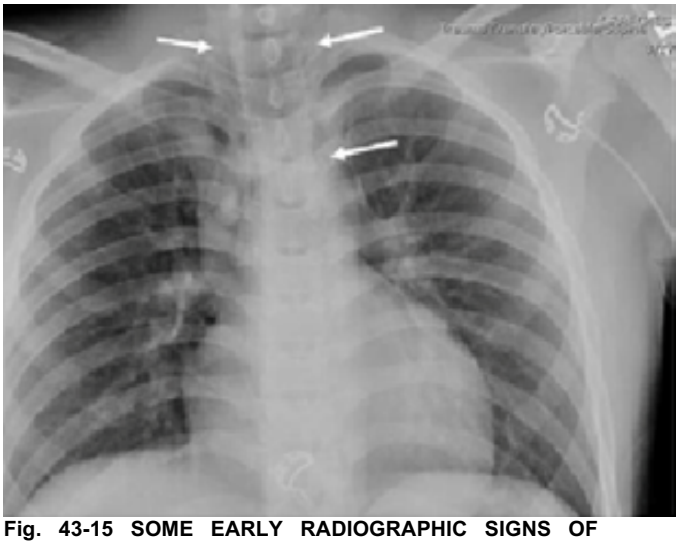

Fig. 43-15 SOME EARLY RADIOGRAPHIC SIGNS OF TRACHEO-BRONCHIAL INJURY. There is cervical surgical emphysema (air in the soft tissues) in the neck & mediastinum, but no pneumothorax. *After Jennings A Joe M, Karmy-Jones R. Tracheobronchial Trauma. JSM Burns Trauma 2017;2(1): 1011.*

(i) Tracheo-bronchial tree injury (43.6)**:**
Look for a large pneumothorax, air in the mediastinum, emphysema in the upper chest, neck or face (depending where the rupture is situated) and sometimes lung collapse. It is more common on the right than on the left; air will continue to bubble out of chest drains despite suction.
It may be difficult to differentiate from, and exist in addition to, oesophageal injury, especially in burns (50.3). You may see the lung apex at the level of the carina.

We assume CT scanning is *not* available. *Don't be tempted, however, to scan a haemodynamically unstable patient!* He is at great risk of dying before you can treat what you might find on the images.

(j) Subdiaphragmatic gas (12.1)**:**
Unless the chest radiograph is taken erect, you are unlikely to see free air under the diaphragm (from a ruptured hollow viscus); this is occasionally visible on a lateral decubitus film.

(k) Foreign bodies:
In penetrating injuries, look carefully for a bullet or other foreign body. It may be obscured behind the heart shadow, so get a penetrated ('hard') film. *Remember that an entry & exit wound don't always mean the same object that has entered has also exited! Remember also that you may find the foreign body far outside the chest!*
Occasionally a large, especially a jagged, foreign body warrants removing electively.

43.2 Emergency measures

INSERTING A CHEST DRAIN (TUBE THORACOSTOMY) (GRADE 1.4)
The pleura should be kept empty. We describe the classic technique for use in the emergency situation. Concentrate on mastering this, use adequate anaesthesia. Ketamine & LA are ideal. *Never use targeted guidewire and trocar-guided chest tube insertion:* they are dangerous.

INDICATIONS
(1) any type of pneumothorax,
(2) haemothorax,
(3) haemopneumothorax,
(4) chylothorax,
(5) a penetrating chest wall injury, in a patient who has been intubated or is about to be intubated for ventilation.

N.B. Not all patients with fluid in the chest need a chest drain. Correct a bleeding disorder as quickly as you can, *but don't delay inserting the chest drain.* Avoid puncture sites where there is a burn wound or skin infection, or where you know there are pleural adhesions. You should put in a chest drain *before* the trachea is intubated!

PREPARATION
Get all you need ready before starting to insert the drain; sterile drapes, disinfectant, LA, a #10 blade on a blade holder or handle, curved Mayo scissors, large & medium Kelly clamps, 2/0 silk sutures on cutting needles, a needle holder, gauze & tape.

Where there is a larger wound to debride or another procedure to perform, or in a very anxious patient, use ketamine as a sedative.

Choose the correct sized drain (for blood):
(1) adult male: Ch28-32
(even 36 for a large haemothorax)
(2) adult female: Ch24-28
(3) child: Ch12-24
(4) infant: Ch12-16
(5) neonate: Ch10-12.

If you are only draining air, you can use a narrow Ch10-14 tube but in trauma patients, there may well be blood with a pneumothorax, so a larger drain is safer.
N.B. Make sure the tube is at least 8cm long to penetrate the thoracic cage!

INSERTING A CHEST DRAIN

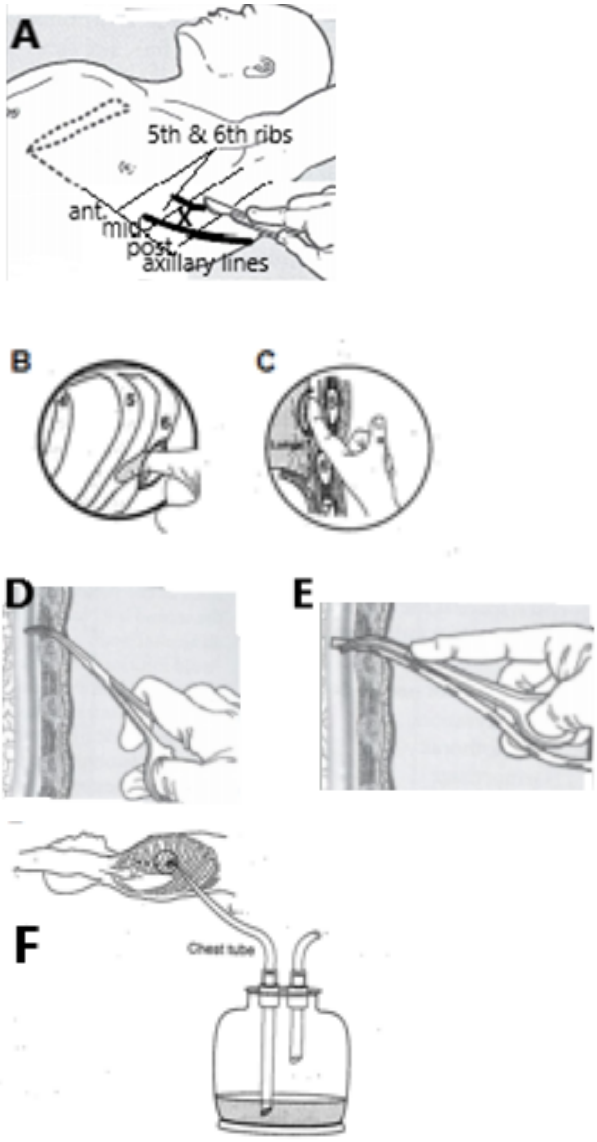

Fig. 43-16 INSERTING A CHEST DRAIN. A, X marks the drainage site (in the 5th intercostal space in the mid- axillary line). B, palpate to confirm you are above the rib. C, palpate inside the pleural space & break down light adhesions, if any. D, increase the size of the hole in order to insert the drain. E, insert the drain held on a Kelly clamp. F, connect the drain to an underwater seal. *N.B. Use the 2nd intercostal space in a child.* *After Nicol A, Steyn E. Handbook of Trauma for Southern Africa, OUP Cape Town 2004*

Prepare a collecting bottle with sterile water & 10ml chlorhexidine inside and a bung with 2 holes. Make sure the collecting tubing fits the chest drain tube, or that you have adaptors which fit.

N.B. Don't use iodine to sterilize the bottle as the colour masks blood.

***If you suspect a large haemothorax and you might need auto-transfusion**, put saline in the chest drain bottles as water causes blood to haemolyze.*

Obtain consent from the patient if time allows.
Position the patient in either the supine with the head up at 45º. This helps against the risk of placing the chest drain below the diaphragm but is not always possible in the trauma patient, especially if he is hypotensive.
Double check the correct side where you intend to insert the drain, and mark the site of insertion with a permanent marking pen.

This is anterior to the mid-axillary line in the 5th intercostal space, in the triangle formed by the anterior border of *latissimus dorsi*, the lateral border of *pectoralis major* (which forms the anterior axillary line) *&* a line superior to the horizontal level of the nipple (in a male). It has its apex below the axilla (43-17).

N.B. In children, use the 2nd intercostal space!

This is the safest area, although sometimes you might need to place a chest drain elsewhere (43-20).

THE SAFE TRIANGLE FOR CHEST DRAINAGE

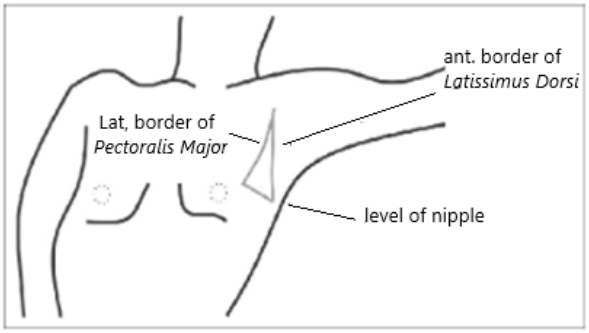

Fig. 43-17 THE SAFE TRIANGLE where you should put in a chest drain. Its edges are the lateral border of *pectoralis major,* the level of the male nipple, & the anterior border of *latissimus dorsi.*

Have atropine available in case the patient has a vasovagal attack when you insert the tube.
Consider using ketamine if a patient is very frightened. *There is no need for LA in an unconscious patient!*
It is best to inject LA before you prepare the equipment for inserting the chest drain, in order to give the drug time to work. Use a long (3-4cm) needle.

Infiltrate LA in the subcutaneous tissues, and then redirect the needle towards 5th rib and inject c.10mL into the periosteum (if you hit bone), muscle in the 5th intercostal space, and pleura.

"Walk" the needle off the rib as you keep injecting LA. Keep drawing back on the needle to check you are not in a blood vessel.

If you aspirate air, fluid, pus, or a mixture of these, your needle is inside the pleural space. Remember the depth and direction of the needle.
Monitor the patient during the procedure and afterwards. Provide oxygen by mask or nasal prongs: (*a serious trauma patient should already be inhaling oxygen!*)

Put on a sterile gown, and sterile gloves: *treat this procedure as any surgical intervention*. Place 4 sterile drapes (or 1 drape with a hole) to isolate the area where you intend to introduce the drain.
Get all your equipment ready (open the packets, and select the size of chest drain you want to use. Fix the blade on the blade-holder, and a long clamp through the eye of chest drain to hold it.

Make a 3-4cm incision along the 6th rib, through skin and subcutaneous fascia (43-16A).

Then use a medium Kelly (or sharper-pointed) clamp to create a track in the subcutaneous tissue *above* the 6th rib (in order the avoid the intercostal nerves and vessels). Aim towards the head.

Open the clamp widely to separate the muscle: (you may find that turning the clamp over so its curve is upward rather than downward helps). This might need some force: the track needs to be big enough for your index finger and for the clamp holding the drain.

When you have reached the top of the rib, palpate with your sterile finger to confirm where you are (43-16B,C). Add more LA at this stage into the deep tissues, and into the pleura.

Put the closed clamp back into the same tunnel, advance it gently but firmly repeatedly. You will eventually enter the pleura (43-16D).

N.B. Don't damage the lung! Make controlled movements! Use your non-dominant hand against the patient's chest wall to hold the clamp as you work it with your dominant hand; this prevents the tip from plunging into the pleura. Once you have entered the cavity, bring the tip of the Kelly clamp back to the level of the inside of the ribs (the pleural level) and spread the clamp wide enough to pass the chest drain easily, *but not too wide to cause a leak!*

Put the index finger of your non-dominant hand into the track to make sure it is above the diaphragm: (check to feel for the liver, spleen or stomach!) Feel inside the pleura 360º to break down any light adhesions.
If you feel dense unbreakable adhesions, choose another site to insert the chest drain, unless you can be certain that you can go round a localized area of adhesions.
Leave your finger in the track. (In obese patients, this may be impossible.) With your other hand, grasp the clamp holding the chest drain. (This is why you must get it ready beforehand!)

Place the curve of the clamp parallel the end of the drain and streamline its entry as much as possible by guiding it along the index finger already inside the track. Insert the drain at least 5cm inside the pleural cavity. Hold the drain as you withdraw your finger and release the clamp, *so the drain does not come out as well.*
Advance it posteriorly and superiorly (for air) or inferiorly (for blood) until *all of the holes in the drain are inside the pleural cavity*.

Make sure all the holes of the chest drain are inside the pleural cavity (usually the last hole is indicated by a break in the radiolucent line of the drain), or else air will collect in the tissues. Fold the sterile drape round the drain with a towel clip to stop it falling onto the floor. Connect the drain to the drainage tubing with an appropriate adaptor.

Don't clamp the drain! Look to see if there is a rush of air, condensation on the inside of the drain, or fluid coming out with bubbles.
You should see a swing in the fluid level of the drainage device with each respiration.

Secure the drain (4-14M). Close the skin with 2 separate simple interrupted sutures on each side of the chest drain, to prevent the patient's routine movements from dislodging the chest drain. *Don't use a purse string round a drain.*

Leave the ends long and tie each suture around the chest drain twice in opposite directions, producing slight indentation (like a roman sandal) on the tube. Mark the depth of insertion of the chest drain on the dressing.

Dress the insertion site with gauze, having an opening made by cutting a "Y"-shaped fenestration in it and securing this with wide adhesive tape to the chest wall. Strap the emerging chest drain on to the lower trunk with a 'mesentery' fold of adhesive tape, as this avoids kinking of the drain as it passes through the chest wall. It also helps reduce wound site pain and discomfort for the patient.

Tape all the tube connections in their long axis to avoid disconnections. *The tape over the connection should not prevent you from examining it:* it is quite possible for the tape to look secure, but the junction to leak. You can use a tongue depressor to splint the connection to hold it in place. Connect the chest drain to an underwater seal.
Avoid using a Y-connector for 2 drains, because it can appear that both drains are working when only one is.

Obtain a chest radiograph to confirm the position of the drain. Make sure all the tube holes are inside the pleura (the outer-most hole is usually marked with an interruption in the radiolucent line). Repeat a chest radiograph to confirm that the lung is fully expanded before removing the drain.

MONITORING

Make sure you check the patient in the 1st h after putting in the chest drain, and then 4hrly till he is stable; note:
(1) that fluid in the drain is coming out or air is bubbling out,
(2) the type of fluid draining,
(3) the vital signs, and pulse oximeter readings,
(4) the pain or discomfort score,
(5) the ability to cough,
(6) the depth of breathing.

MANAGEMENT

Keep the patient in a semi-sitting position.
Don't raise the level of the drainage bottle above the chest!
Encourage deep chest respirations. (*There is no contra-indication to patients walking around with their chest drain bottle hanging down.)*
Provide analgesia (intercostal nerve blocks, NSAIDs, & non-opioids) & chest physiotherapy.
Administer antibiotics for open wounds for 4-5 days.

PVC CHEST DRAINAGE BAG

Fig.43-18 Plastic chest drainage back, with air vent. This can also be used for autotransfusion (44-12). It is known as a Raina Romo bag.

UNDERSTANDING CHEST DRAINAGE SYSTEMS

There are 1,2, & 3-bottle systems. You can also use adapted plastic bags (43-18) which work on the same system, are cheaper and not breakable!

A 1-bottle system has a top with two drains coming out of it. The chest drain connects to the longer drain which reaches a point near the bottom of the bottle. Make a water seal by pouring sterile water into the bottle until 2cm of the drain is underwater. This prevents air from going back up the chest drain into the pleural cavity. The bottle acts as a reservoir for any fluid drainage (43-19A).

This system works well for a simple pneumothorax and small effusions, but if too much fluid drains into the bottle, it requires more and more intra-pleural pressure to force the air out and can prevent complete evacuation of a pneumothorax.

SIMPLE CHEST DRAINAGE SYSTEMS

To solve the problem of evacuating large volumes, use a 2-bottle system. Interpose a 2nd collection bottle between the chest drain and the water seal bottle (43-17B). The tubes coming out of the top of this bottle don't go down very far.

TWO BOTTLE SYSTEM

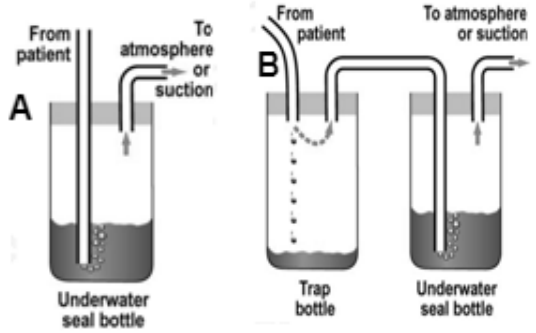

Fig. 43-19 UNDERWATER SEAL DRAIN SYSTEMS. A, a simple 1-bottle system. B, a 2-bottle system, which is ideal if you have a high-volume suction machine which has a method to regulate the degree of suction needed. Without suction, it serves as a simple water-seal with an entire bottle for a reservoir.

If you need to put a 2-bottle system on suction to continue to drain air or blood, and cannot regulate the amount of suction, add a 3rd bottle.

THREE-BOTTLE SYSTEM

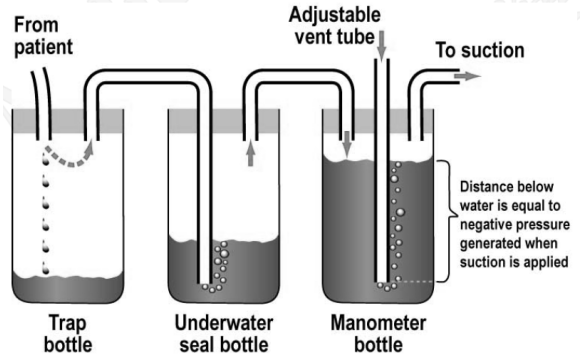

Fig. 43-20 3-BOTTLE UNDERWATER SEAL DRAIN SYSTEM. The stopper on this system has 3 drains: the 1st goes to the water-seal bottle, the 2nd to the unregulated suction source and the 3rd to a point near the bottom of the bottle. Add water until there is 10-20cm (as desired) between the surface of the water and the bottom of the longer tube.

Suction is rarely needed, except for a bronchopleural fistula (36.1), *and it can be dangerous.*

The 3 glass bottles with the appropriate tops and drains can be heavy, difficult to walk around with, and are at best clumsy. There are commercially available collection devices which are designed to accomplish all 3 functions.
Some need you to add a pre-measured amount of water to a chamber to create a water seal; some have mechanical one-way valves built into them and you just add the water to assess whether the drain is still working.
The manometer regulating the suction pressure may require water in a separate chamber; this is so you can use the drain system if there is no machine to regulate the negative pressure you want. These devices are convenient and light-weight but you cannot safely clean them & re-use them; *they are not really worth the expense*.

DON'T CLAMP A CHEST DRAIN !

Never routinely clamp a chest drain, especially if it is bubbling out air, except in the rare case of rapid re-expansion syndrome (36.1). *Always stay with a patient if you do, e.g. when changing a bottle.*

If a chest drain bottle needs to be changed, get ready with the connections, new tubes and bottles, and put on the clamps only whilst you rapidly switch over the units.
Don't clamp a drain to see if it is still needed: it can be dangerous if a pneumothorax recurs while the drain is clamped. If you are not sure if the chest drain is needed, check the bottle several times over 12-24h; if there is no bubbling or <50ml draining, remove it.
N.B. Beware if the drain has been put in the chest where there is a diaphragm rupture! Only remove the drain in theatre at laparotomy.

DIFFICULTIES WITH CHEST DRAINS

If the drain is too far inside (and touches the mediastinum or the heart), **or in a lung fissure,** take down the dressings, cut the securing sutures, and withdraw it an appropriate distance. *Don't pull it out too far so that the tube holes are now outside the chest!*

If the lung does not fully re-expand, and the pleural collection does not empty properly, remember, it is re-expansion of the lung that pushes out what is inside the pleura, so exercise or chest physiotherapy may be all that is necessary, but see 43.7. Check that the patient does not sit tilting to the side and so compress the chest drain: he needs more analgesia!

If the chest drain starts bubbling madly, or air continues to bubble out after 48h, there may be a fistula (36.1). In this case, if the patient is haemodynamically stable, check if the tube is properly in place and its connections airtight. If that is the case, apply suction up to 20cm H_2O.

If the patient is haemodynamically unstable, insert a 2nd chest drain, the actual site being determined by the site of the remaining collection.

N.B. Large haemothoraces or high-flow pneumothoraces often require 2 drains; the air may leak from a torn lung, a ruptured bronchus, or a lacerated trachea (43.6).

If the fluid inside the drain in the underwater-seal bottle does not swing back and fro with the respiratory cycle or with coughing, the drain may be blocked. *This is not uncommon; a non-functioning drain serves no purpose* and provides a route of bacterial migration, so get it working or remove it!

First, take down the dressings and ***make sure that the drain is not kinked*** at any point, especially at the entrance point into the chest. If it is, straighten it out and re-strap it to the chest. ***Then check that the tube is not disconnected.***

If the drain is blocked by semi-solid contents (*e.g.* blood clot), try 'milking' the tube. Clamp it proximally, and try to massage the tube to dislodge the stuck contents out of the tube into the bottle. Or, disconnect the drain and pass a guide-wire up it to dislodge the blockage. Some diluted heparin may help if this is a blood clot.

N:B: If you have connected 2 chest drains to a single drainage source (especially if you are using suction), one drain can continue to function and the other block off.

If the drain has partially come out, you should be able to check how much it has come out by what is marked on the dressing. An important sign is if room air is being drawn into the pleural cavity through a hole in the tubing which is now outside the chest. *Don't push the drain back in*, because you risk introducing infection. Remove the drain and replace it aseptically, as below, if it is still needed.

If the drain has fallen out completely, decide if it is still necessary. If it is, use an aseptic technique as before, cleaning the drain track. Introduce a new drain through this same track. *Do this whenever a patient becomes distressed before a repeat chest radiograph demonstrates his need.*

N.B. If the drain was placed originally for a tension pneumothorax, place a needle thoracostomy (43.1) in the 2nd interspace before you try to reinsert a new drain.

If (a glass) chest drain bottle has broken, cut off the tubing leading from it, and place a sterile glove over the end of the tube, and secure it in place. Cut one finger of the glove off.
This will then act as a Heimlich (one-way) valve (43-21), and give you time to set up the tubing system as before. An alternative is a urine bag with a hole cut in its side.

N.B. Don't clamp a chest drain!

ONE-WAY HEIMLICH VALVE

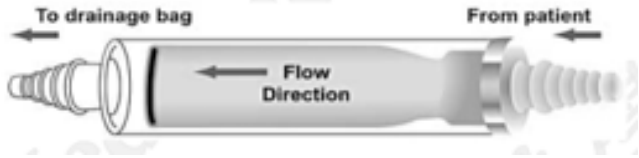

Fig. 43-21 A ONE-WAY VALVE. You can make an effective valve but cutting the finger end of a rubber glove, and tying it onto the end of a chest tube.

If the patient starts to cough (continuing for >15mins)**, complains of severe discomfort, and becomes haemodynamically unstable,** lung oedema may be developing. This is the **rapid re-expansion syndrome.** *It is rare (<1% of cases), but it can be deadly*. It usually occurs in young patients with a large pneumothorax or large pleural effusion (>3l), especially of >7days' duration, rapidly drained, particularly with suction, within the 1st h of drainage.
Clamp the drain, get the patient to breathe 5l/min pure oxygen, monitor and sedate him.

REMOVING A CHEST DRAIN
INDICATION
Remove a chest drain when no more air or <250mL serous fluid drains over 24h, *and* the chest radiograph demonstrates complete lung expansion. Wait till 12h after you turn off any suction.

TECHNIQUE
Remove the dressings, and identify any anchoring sutures. Use these for closing the drain hole. Instruct the patient to take a deep breath and hold it, bearing down without letting air escape from the mouth or nose. Gently, firmly and relatively quickly, withdraw the chest drain in a single motion.
Tie the sutures, or close the hole with a new suture while applying direct pressure to the site. Compress with a dressing for at least 2mins or until bleeding/drainage have subsided.
Try to prevent air being sucked back into the chest, if the skin gapes. Obtain an upright chest radiograph to make sure there is not a recurrent pneumothorax.

COMPLICATIONS OF CHEST DRAINS.
(1) Injury to intercostal nerves:
Lack of local sensation normally recovers.
(2) Injury to intercostal vessels:
The resulting haemothorax usually settles, but if there is a bleeding disorder, you may need to explore the wound to obtain haemostasis. This needs GA and quite a big incision.
(3) Wound infection:
Avoid this by using a sterile technique. *Don't put a chest drain through a penetrating injury*.
(4) Empyema.

Replacing a pneumo- or haemo-thorax by an empyema is a disaster! Always use a sterile technique! Don't push a dislodged drain back!

PNEUMOTHORAX
If a patient has respiratory distress, shock, with lack of air entry, hyperresonance, over-expansion of the hemithorax, and tracheal deviation to the opposite side (this may be hard to be sure about**), and a displaced apex beat, *this is a dire emergency.***

This is a tension pneumothorax and is a clinical diagnosis. *(All these signs may not be present!) Don't wait for a radiograph* to confirm it: insert a cannula through the 2nd intercostal space in the mid-axillary line *immediately*.

You can diagnose a moderately sized pneumothorax by poor respiratory movements, hyper-resonance to percussion, and poor air entry on the affected side. The patient may not be very dyspnoeic, and may not have much pain. Subcutaneous emphysema may be present.
Ultrasound is better and easier in making the diagnosis than a chest radiograph (43-2,3).

A small pneumothorax may not be symptomatic. The air in the pleural cavity is slowly absorbed and needs no treatment.

If there is >3cm air from the chest wall rim on an erect chest radiograph, it is better to drain a pneumothorax. *A pneumothorax may become massively larger under positive pressure ventilation.* So insert a chest drain on all such patients *before starting artificial ventilation*.

N.B. **If the patient is intubated**, manual ventilation will require increasing pressure on the bag to inflate the lungs properly. The development of a tension pneumothorax may then not be otherwise obvious.

A pneumothorax from a serious chest injury may well be a haemopneumothorax, and so deserves formal drainage.

N.B. You should advise a patient to avoid non-pressurized air travel till the pneumothorax is completely resolved, and to avoid smoking and deep sea diving permanently.

HAEMOTHORAX
Bleeding from the lung, chest wall or mediastinal structures can cause blood to collect in the chest. Usually, you find diminished expansion, dullness on percussion and loss of breath sounds on the affected side. Look for associated signs of rib fracture or open wounds.
Tracheal deviation doesn't occur unless there is a massive (tension) haemothorax (43-9B).

This is also a dire emergency. Perform an immediate tube thoracostomy (43.1). Remember to use a large size drain.

N.B. Ultrasound is better and easier in making the diagnosis than a chest radiograph (43-5,6).

Small amounts of blood are very hard to see on chest radiographs. Usually it takes as much as 400-500mL to obliterate the costophrenic angle on an erect chest radiograph (43-9A).
A lateral decubitus film may show layering of fluid consistent with a small haemothorax.

There is no fluid level seen on a supine film as the fluid layers spread out posteriorly throughout the entire hemithorax.

Where you have a good suspicion of a haemothorax in a chest injury, don't hesitate to insert a chest drain. *Delay may prove fatal for the patient!* Record the amount of on-going bleeding.

If the patient remains haemodynamically stable, monitor and observe him. The colour of the blood is also important: dark, venous bleeding is more likely to cease spontaneously than bright red arterial bleeding.

An immediate drainage of 800-1500mL of blood from a hemithorax is *not necessarily* an indication for thoracotomy. The initial volume of blood drained is not as important as the amount of continued drainage. However, if this is >250mL/h and not reducing over 4-5h, a thoracotomy is indicated (43.6). *Make sure the tube is not blocked, kinked or in the wrong place!* Get another radiograph! *Remember drained blood can be used in auto-transfusion* (5.3)*!*

N.B. If you have facilities to refer such a patient, and you don't have the means to perform a thoracotomy, refer the patient earlier than later.

If a haemothorax does not completely drain after 48h, insert a 2nd Ch32–36 drain guided by the repeat chest radiograph. Place this somewhat lower and aimed posteriorly if possible (aiming the drain is not always successful). Repeat the radiograph to determine the result.

PLACING 2 CHEST DRAINS

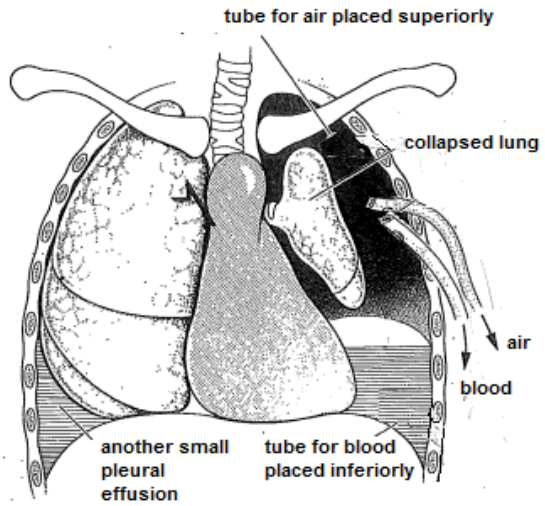

Fig. 43-22 DRAINING A HAEMOPNEUMOTHORAX. 2 drains are often better than 1, although both air & fluid will come out of each. *Kindly contributed by James Cairns.*

A retained clotted haemothorax can result in the development of a constrictive peel around the lung and if that peel is not removed, it can diminish lung function for the rest of the patient's life. *Don't wait too long to insert a 2nd drain;* do so while the blood is still liquid.

If you don't drain a haemothorax adequately in time, a decortication may be necessary, usually 3–7days after the injury.

MECHANISM OF FLAIL CHEST

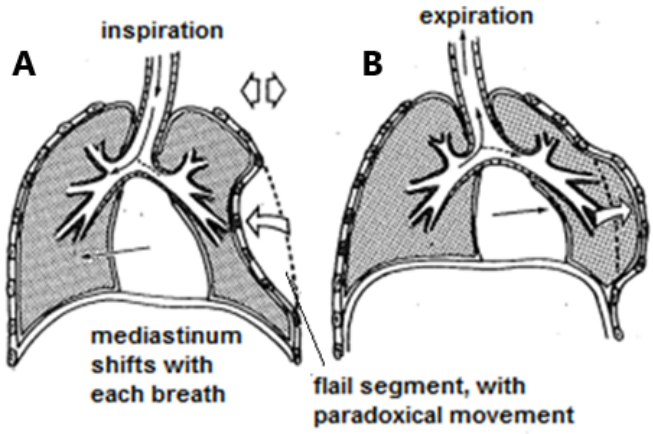

Fig. 43-23 MECHANISM OF A FLAIL CHEST. A, at inspiration, the flail segment sinks in, and the mediastinum shifts to the uninjured side. B, at expiration, the reverse happens, some air passing uselessly from one lung to the other. *Adapted from Netter FH, CIBA collection of medical illustrations.*

TRACTION FOR A FLAIL CHEST

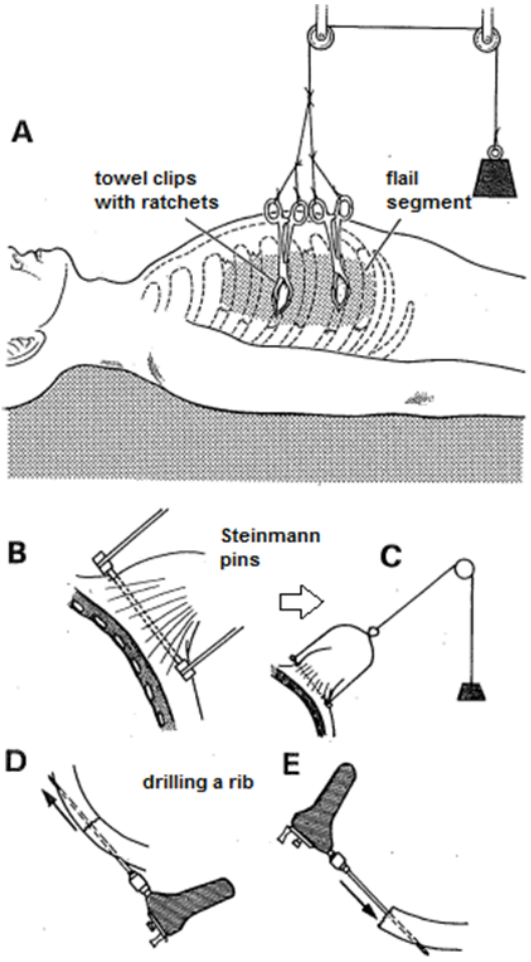

Fig. 43-24 TRACTION FOR A FLAIL CHEST. A, towel clips are usually the most convenient method. B,C, method using a Steinmann pin and stirrup. D, if the injury is open, try drilling into the rib and passing a K-wire. *Adapted by Peter Bewes, after de Palma, Management of Fractures & Dislocations; An Atlas, Saunders 1970 with kind permission.*

FLAIL (STOVE-IN) CHEST

A flail chest is defined as having ≥2 ribs fractured in ≥2 places. It is often caused by collision with a car steering wheel or by a lateral force, breaking the ribs both anteriorly and posteriorly.

This flail portion then moves paradoxically, *i.e.* it bulges outward during exhalation and inward during inspiration.

This causes hypoventilation and difficulties in the exchange of sufficient air, resulting in elevation of CO_2 in the blood. *Most flail chests are associated with pulmonary contusion.* The force breaking the ribs simultaneously crushes the lung. As a result of pulmonary contusion the exchange of oxygen at alveolar level is impaired and so levels of O_2 in the blood fall.

The flailing portion of the chest only rarely needs attention; it is the underlying pulmonary contusion that causes the greatest risk to life. Most patients just need good pain control and good pulmonary toilet (ketamine is useful); they rarely need mechanical ventilation. Use this for those who still have respiratory insufficiency after control of the pain or who have respiratory depression because they need too much opiate for pain control.

This means you may have to intubate such a patient and that will mean a referral if you don't have a ventilator and the capability to monitor the vital signs properly.

A chest drain is almost always necessary for the associated pneumo- or haemo-thorax.

Don't strap the ribs: it adds little and can diminish respiratory excursion. Intercostal blocks (43.5) will help.

A single intravenous morphine injection may make a mildly blue, anoxic, sweating patient quiet and pink. Administer it cautiously and titrate the dose needed.

N.B. Don't use more than is necessary but administer it frequently enough (often every 1–2h), but have naloxone readily available to reverse the opiate as necessary. This means careful monitoring in an intensive care set-up.

If you can't manage this, or refer the patient, you may be able to stabilize the floating segment of the chest wall by applying some form of traction for several weeks. Bilateral flail chest is usually fatal without mechanical ventilation.

But a patient with a unilateral flail chest, provided he has no serious injuries inside the thorax, and he survives the immediate injury, may be a good indication for chest traction.

TRACTION FOR A FLAIL CHEST (GRADE 3.3)

You probably will need to intubate the patient and use a self-inflating bag. A tracheostomy may help with pulmonary toilet, but this is not generally necessary straight away. *The goal is to prevent paradoxical chest movement.*

Using ketamine & intercostal nerve blocks, choose any of the following methods to apply traction to 1, 2, or more points on the floating part of the rib cage.
(1) Grip the flail ribs or sternum with several towel clips, or suitable forceps, and then tie these together with string. The clips or forceps must have a ratchet so that they remain closed (43-23A).
(2) Pass wire or strong sutures under the ribs or sternum.
(3) Screw some sterile cup hooks into the ribs or sternum.
(4) Pass a Steinmann pin under the pectoral muscles close to the ribs (43-24B,C)
(5) Attach cords to any of these traction points, pass them over pulleys, and then tie weights to the cords. Usually, 500g per traction point is enough. You may need 5kg on either side. Fix the pulleys to a frame (58.4), as for fractures.
Continue traction until the chest moves as one piece when the weights are temporarily lifted. This may take several weeks.

MANAGEMENT

Pay great attention to the patient's breathing. Encourage coughing to clear the respiratory tract.

If there are loud rhonchi, this shows that fluid is accumulating, so perform a tracheostomy (29.15, 42.4) to make bronchial suction easier.

If breathing is 'rattly' and coughing feeble, suck out the pharynx. If this fails to clear the airway adequately, perform a bronchoscopic suction (29.14).

If breathing becomes very weak and shallow, apply a self-inflating bag, especially during the 1st 24h.

If >800mL blood is still draining after 24h, or >200ml/h, a thoracotomy is indicated.

If there is a diaphragm rupture, injury to the great vessels or traumatic cardiac tamponade, perform a thoracotomy (44.6)

PULMONARY CONTUSION
Concentrate on treatment of the damaged lung, not the overlying broken ribs (beyond good pain control). Associated haemoptysis may block the airways. The main problem is usually inadequate oxygenation, not problems with CO_2 exchange.

Administer oxygen to all patients (maintaining a saturation of c.94% on a pulse oximeter). If you can, use intermittent positive pressure and positive-end-expiratory pressure ventilation. This may mean you need to try to refer such a patient.

Remember that pulmonary contusion can occur without rib fractures, especially in children (where the ribs bend but don't break) and also in explosions (blast injury).
Be careful in the amounts of fluid you administer. Use enough to treat shock but *don't overload the patient with fluid*. It will make the hypoxia from the contusion worse.
Keep the airways and bronchi clear with frequent suction. A tracheostomy (29.15, 42.4) may be very useful.

43.3 Open chest injury

When there is an open chest wound, air from outside is sucked into the pleural cavity (which is normally at subatmospheric pressure). If the air is sucked in, but cannot escape, the lung collapses, and a tension pneumothorax may arise.
There may be a sucking noise each time he breathes, or froth from the injured lung may come out of the hole in the chest.

An open pneumothorax occurs when the hole in the chest wall allows free passage of air between the outside and the pleural cavity in both directions. This will produce all the signs and symptoms of a simple pneumothorax (43.1): shortness of breath and perhaps hypoxia, but does not get worse.

A sucking chest wound can cause a tension pneumothorax. This can occur when the diameter of the hole in the chest wall approaches 12mm (⅔ the width of the trachea).
To prevent air being sucked in, but allowing it still to come out, stick an occlusive dressing to the hole in the chest but leave it open on 1 side.

N.B. ***If the dressing does not stick properly*** in a diaphoretic patient with a bleeding and bubbling wound, suture it in place.

N.B. A sucking wound under the scapula may only allow air in intermittently depending on the position of the shoulder.

Insert a chest drain (43-16) as soon as you can*, through a separate incision*. An open chest wound needs debridement and closure of the pleura and deep muscle layer. This may mean a limited thoracotomy. Leave the other layers open as a thoracostomy. Once the wound is sealed and the chest drain has stopped bubbling, you can remove it.

43.4 Diaphragmatic rupture

This can be a hard diagnosis to make. Diaphragmatic rupture is uncommon in blunt abdominal trauma, and it may be overlooked because the dominant clinical symptoms or radiographic findings may be related to other associated injuries. *Always think about this possible diagnosis.*

N.B. The diaphragm rises to the 5th intercostal space on deep inspiration.

Patients can be relatively asymptomatic or in great distress from the loss of lung volume owing to herniated abdominal contents.

The mechanism is a lateral compression or crush injury. Most (80%) diaphragmatic ruptures occur on the left side, largely because the liver protects it from the shearing forces on the right. Furthermore, the liver rarely herniates into the right hemithorax, and stops other organs from doing so. A right diaphragmatic injury is indicative of a much greater force and is associated with a higher mortality. Lacerations from penetrating injuries may be anywhere in the diaphragm but those from blunt injuries are usually at the musculo-tendinous junction.

Therefore, insert a chest drain (43.1) in the left hemithorax in cases of severe trauma with extreme care, so as not to injure any abdominal viscera which have herniated up through a ruptured diaphragm. Ultrasound is helpful to guide you.

N.B. Unrepaired ruptures may lead to incarcerated hernias and strangulation, sometimes diagnosed only years later.

DIAGNOSIS

On a plain chest radiograph, look for the loss of a distinct (usually left) hemidiaphragm, fluid or gas in the left hemithorax, or an elevated hemidiaphragm on the right (43-11).

A nasogastric tube inserted beforehand will go down below the diaphragm at the oesophageal hiatus and then curve back into the left hemithorax. It will also relieve some of the symptoms.

Diaphragmatic rupture is uncommon and the radiographic pattern is *easily confused with other conditions (haemo-pneumothorax on the left, and haemothorax on the right, or contusion)*, so keep these diagnoses in mind.
Gastrograffin studies will later demonstrate the herniated organs and constriction at the hernia site. An expert with ultrasound can demonstrate the rupture.

REPAIR FOR DIAPHRAGM RUPTURE
(GRADE 3.4)

Organize an exploratory laparotomy. Make sure a nasogastric tube is passed before anaesthesia. You may need to perform auto-transfusion (5.3). Have a chest drainage set ready. Ask the anaesthetist to use a long endo-tracheal tube and put it down the right bronchus (initially).
Make a midline or oblique incision extending over the anterior left hemithorax.

Inspect and palpate the entire diaphragm meticulously. The diaphragm is rarely injured alone. Other viscera, especially the spleen, stomach and small bowel may be injured, either in the abdomen, or in the left hemithorax.

The mechanism of injury may have sufficient force that pelvic fractures, haemopneumothorax, head injury and long-bone fractures are commonly associated.

Reduce the viscera that have herniated into the left hemithorax into the abdomen. *Don't pull on these organs*, but rather pass a hand into the chest, and ease the organs down from above.
Inspect these organs for injury, and make sure you make a systematic survey of all the abdominal organs as well.
Insert a left chest drain *after all the viscera are out of the chest (opening the abdomen may have created a pneumothorax)*.

I**f there has been gastric or bowel spillage,** proceed to a thoracotomy to clean & wash out the left hemithorax. *You cannot do this properly from the abdomen!*

Grab the edges of the ruptured diaphragm with long Allis forceps and get your assistant to pull these towards you. Repair the diaphragm with continuous figure of 8 #0 non-absorbable sutures, pulling on the suture to prevent the wound from inverting. If there is a massive hole, use a non-absorbable polypropylene mesh to close the defect.

Monitor the patient carefully postoperatively. Ventilation for 24h may be necessary.

ABDULLA (41yrs) was hit in the left flank by a passing car. He had a cold nose, a fast, weak pulse, and a normal blood pressure. The left flank and lower left ribs were tender. A radiograph showed bowel in the chest. He was in the OT in 20mins, by which time 2 IV infusions had improved him considerably. A right upper paramedian incision was made and a hand passed up to the diaphragm. This revealed a hole. The skin incision was therefore extended up into the 8th left intercostal space. It was now seen that the spleen, although not actively bleeding, had been badly lacerated. Splenectomy was easy through the enlarged incision. The diaphragm was repaired with interrupted figure–of–8 sutures in one layer, and the chest closed with two layers of continuous monofilament. He recovered.
LESSONS: (1) Opening the chest, when you have to, may make surgery much easier. (2) Better results follow early intervention.

JABULANI (27yrs) was a lorry driver in a head-on collision which occurred at 6am. He was haemodynamically stable on arrival in hospital, where the junior doctor diagnosed a ruptured diaphragm because he heard bowel sounds in his left chest. (The x-ray machine had broken down.) Because of a problem with the municipal water supply, no sterile instruments were to hand, the last laparotomy set having been used in the night.
Laparatomy was therefore delayed till 2pm, by which time more bowel and the stomach had herniated into the chest, producing a tension effect. The patient had become unconscious in shock. The abdomen was opened without anaesthesia, and a hand passed through a large hole in the diaphragm. The spleen, many loops of bowel, and the stomach were reduced into the abdomen, and the heart manually massaged from within! A regular heart beat returned, and the patient was then quickly closed, by this time sedated with a little ketamine.
LESSON: Much is possible even *in extremis*.

If a chest drain has been inserted into the stomach, (the radiographic images being confused with a haemopneumothorax, and insufficient palpation of the pleural cavity), ***don't remove it except in theatre!*** Wash out the hemithorax copiously: gastric acid is very toxic to the chest. It is best to leave 2 chest drains *in situ* and irrigate the pleural space through these the drains postoperatively (43-20).

43.5 Rib & sternal fracture

RIB FRACTURES

Rib fractures are usually due to a blow, fall or crush injury. Older people and those with osteoporosis or metastases tend to break ribs; remember that some of the fractures are of the rib cartilage and you won't see them on a radiograph (but you can on ultrasound!).

Children may flex their ribs but not break them (however, this increases the amount of the force which is transmitted to the underlying lung and this may result in a pulmonary contusion).

Even if you cannot see rib fractures on a chest radiograph or on an ultrasound, assume if a rib is tender to the touch and hurts with every move of respiration, it is actually broken.

Fractured ribs may be associated with a pneumo- or haemothorax, but more often by pulmonary contusion. They may be a sign of more serious chest or abdominal injury, and of cardiac contusion (44.5)

Fractures of the 1st & 2nd rib are a sign of high force may be associated with major vessel injury.

Fractures of lower ribs may be a sign of liver or splenic injury. It is uncommon for broken ribs alone to be the source of a large haemothorax.

A chest wall injury may bleed profusely from intercostal and mammary vessels. These may be difficult to find.

DIAGNOSIS
Physical examination can often be very accurate. Radiographs are not particularly sensitive (and miss 50% of cases). Delayed images taken after a few days (when decalcification of the fracture line has occurred) may be helpful if documentation and a diagnosis are still necessary.
Regular chest radiographs are still useful in diagnosing underlying injury, although this may be seen better on ultrasound (43.1). If there is a sternal or scapular fracture, look carefully also for rib fractures and soft-tissue injuries.

Treatment. Like most broken bones, ribs hurt and take time to heal, and so may limit good respiratory movements. *Don't be sparing with analgesia to help a patient to breathe properly!* Use NSAIDs. Opioid analgesia depresses respiration and is therefore not ideal, but may allow respiratory excursion without too much discomfort.

Adequate pain control is important to decrease chest wall splinting, prevent alveolar collapse and assist in clearing pulmonary secretions by coughing.
Use intercostal nerve blocks with long-acting LA (*e.g.* bupivacaine) will provide pain relief without affecting respiratory function.

Use the Omoigui diffusion technique: put your left middle & index fingers on the superior and inferior borders of the rib to stabilize it, at a site proximal to the area of pain. Direct a 3 cm 25G, needle onto the midpoint of the rib and inject 2 mL long-acting LA over the rib. *Don't attempt to place the needle in the subcostal groove.* This way you remove the risk of introducing a pneumothorax or damaging intercostal vessels.

Introduce 1 nerve block for each broken rib and the ribs above and below. (You will not exceed the maximum dose of 0·5% bupivacaine for 10 ribs!)

INTERCOSTAL NERVE BLOCK

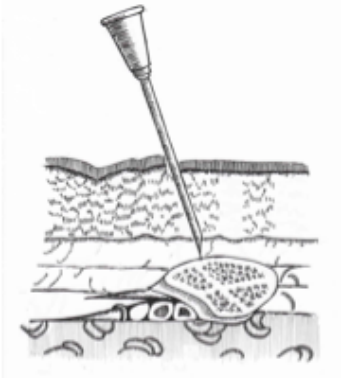

Fig. 43-25 INTERCOSTAL NERVE BLOCK. This is not used enough as analgesia for rib fractures. *Omoigui Diffusion Technique of Intercostal Nerve Block. After Omoigui S, Do Y, Adewumi PA. J Aneasth Clin Res 2013;4:344.*

N.B. Don't bind ribs with strapping: this reduces chest expansion and may lead to lung collapse. *Don't try to fix the ribs,* except occasionally for a flail chest (43-22).

Very few rib fractures don't heal, even though a fibrous capsule may envelope the fracture. A non-union may present months to years after injury and can cause discomfort with respiration due to movement of the fracture site.

N.B. Rib fractures in children represent serious impact, so are associated with greater pulmonary contusion! Think of child abuse if there are multiple fractures of different ages. (47.1)

LIGATING INTERCOSTAL ARTERIES

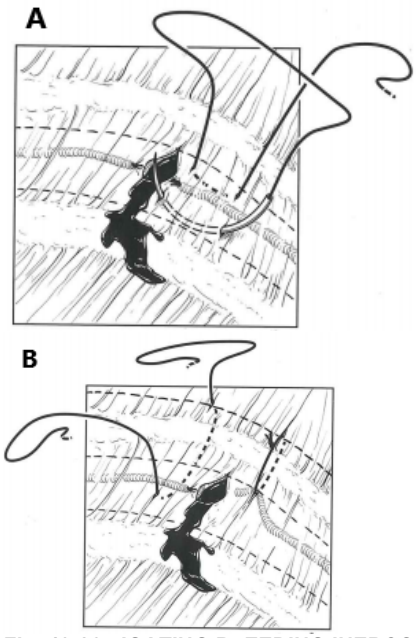

Fig. 43-26 LIGATING BLEEDING INERCOSTAL ARTERIES. (GRADE 3.1**) A, place a figure-of-8 suture with a large needle *parallel* to the ribs. B, make a cerclage of the rib on either side of the bleeding point *(N.B. this will trap the nerve, but it is a small price to pay for haemostasis).*** *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

If the chest wall is bleeding furiously, expose the wound (*though you may find you have to extend the incision to reach the vessels 1-2 spaces above or below*) and ligate any bleeding vessel you can see. The intercostal artery needs a figure-of-8 suture *parallel* to the ribs (43-26A), or rarely a cerclage of the whole rib on both sides of the bleeding site (43-26B).

Occasionally a large injury needs packing, and a large perforation may require inserting a balloon and inflating it to create a tamponade effect.

STERNAL FRACTURE

Although uncommon, an anterior force (such as a steering wheel) may fracture the sternum, especially in the elderly and those with osteoporosis. There is pain at the fracture site, worsened by deep breathing. Very rarely, the sternum can be separated from all the ribs, but such victims rarely survive.

DIAGNOSIS
This is easy with ultrasound, otherwise you need a lateral chest radiograph. *Don't confuse a late ossification centre at 16-18yrs* which can look like a sternal fracture.

TREATMENT
If you can, monitor such patients and get an ECG to detect cardiac contusion (44.5). These patients need adequate analgesia as the fracture is very painful. *Don't try to strap the sternum!*

43.6 Oesophageal burn

Corrosive burn of the oesophagus occurs as the result of swallowing caustic soda (for making soap), sulfuric (battery) acid, or some other corrosive chemical. It also occurs after eating the tropical beach apple (manchineel), which has a number of highly irritant toxins. Occasionally this is the result of a suicide attempt. Burns to the oesophagus may also arise with laryngo-tracheal burns from inhalation of smoke (50.3).

Acid ingestion, as compared to alkali, causes greater injury to the stomach than oesophagus because antral spasm leads to accumulation of acid in the antrum increasing the burn effect. '*Acid licks the oesophagus but bites the stomach*'.

The extent of damage may be misleading at first; redness of the pharynx and mouth is not always present if the victim has taken a large gulp of fluid.

Initial management includes haemodynamic stabilization and ensuring airway adequacy, necessary, by a tracheostomy (42.4).

In a severe case, a plain chest radiograph may reveal air in the mediastinum (43-13) or below the diaphragm suggesting esophageal or gastric perforation. A gastrograffin swallow can confirm and localize a perforation; (*don't use barium which is very irritant to tissues*).

Try to refer for a CT scan (ideal for assessing transmural damage and the extent of necrosis), therapeutic stenting or oesophageal resection.

After the initial injury has settled, perform a fiberoptic OGD within 48h, to determine the extent of damage, to assess the initial damage. Take great care during this procedure, stop if you see a circumferential oesophageal burn. *Don't make any attempt at dilatation or bougienage*. It is much safer to deal with any subsequent oesophageal stricture later.

Treat with a PPI to lessen the risk of reflux oesophagitis and further scarring. Check for this during the next 6-12wks.

If the oesophageal injury is likely to be severe (you can sometimes tell early by the bleaching caused in the mouth and pharynx), *don't hesitate to construct a feeding jejunostomy. Don't make a gastrostomy* as the stomach may be needed later for oesophageal replacement.

N.B. Never administer neutralizing agents (alkali for acid or vice versa): this will cause a chemical reaction producing heat, and so worsen the burn!

43.7 Serious chest injury

A thoracotomy is indicated:
(1) if blood drains >250mL/h over 4-5h from the chest.
(2) if there is a penetrating wound of the heart or the great vessels at the root of the neck.
(3) if >800mL blood continues to drain >24h.
(4) if a haemothorax has clotted.
(5) for air embolism.

There are 3 major types of chest injuries that will be beyond your scope in a district hospital. Try to stabilize these patients and transfer them if you can at the earliest possible time:
(1) Aortic disruption.
(2) Tracheal-bronchial injury.
(3) Oesophageal rupture.

An emergency thoracotomy (needed by <5% of patients) will depend on the resources available, your skill & experience, and that of your support staff. You must decide whether heroic measures are justified, but you should also not just let a patient die because you haven't seen operated on or even such a case before! *Fortune favours the bold!* However, perform such surgery in the theatre *not in an emergency room!*
Don't operate on someone with non-reactive dilated pupils!

SEVERE CHEST INJURY ALGORITHM

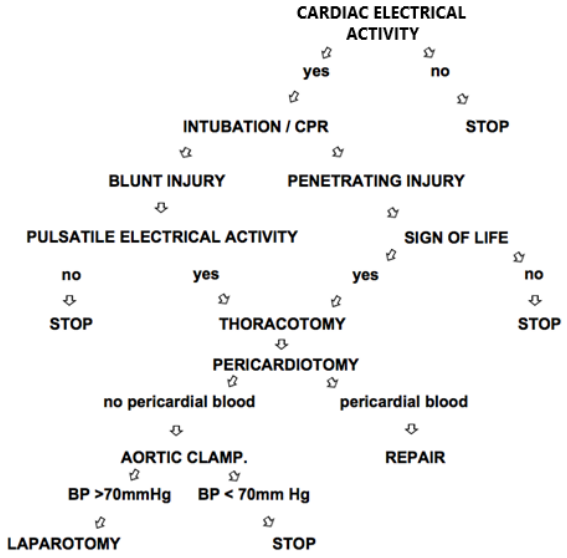

Fig. 43-27 SEVERE CHEST INJURY ALGORITHM. Treat this as a good guide.

AORTIC DISRUPTION
This is due to rapid deceleration (*e.g*. a car hitting a tree, or falling from a horse). The intima of the aorta is torn, usually just distal to the *ligamentum arteriosum*. Most such patients die at the scene because of massive haemorrhage.
In some victims, the amount of bleeding around the aorta may be limited. Such patients may look surprisingly well. They complain of severe upper back pain. The circumference of the neck may enlarge dramatically in 2-3h. The BP may be different in both arms.

DIAGNOSIS
Look carefully for the following signs on chest radiography (43-12):
(1) a widened mediastinum (>8cm when supine, or >6cm when erect),
(2) an indistinct or abnormal aortic contour,
(3) deviation of the trachea or nasogastric tube to the right,
(4) depression of left main bronchus,
(5) loss of the aortopulmonary window,
(6) a widened paraspinal or paratracheal stripe,
(7) a left apical cap,
(8) a left pulmonary hilar haematoma.

If you suspect this condition, administer analgesia, insert a left chest drain, and transfer the patient urgently, preferably with a qualified person. *You must discuss such a case with the referral hospital before sending a victim!*

EMERGENCY THORACOTOMY
Get as much help as possible, especially an anaesthetist, and members of your resuscitation team!
Splash antiseptic over the chest, and proceed as quickly as possible to open the chest. You can do this through the sternum or *via* an antero-lateral thoracotomy (44.6)

MASSIVE HAEMOTHORAX
If there is an initial >2L blood, or >250ml/h in a chest drain, especially if the blood coagulates, prepare for a thoracotomy.

N.B. You will not see a haemothorax from a stab wound of the heart in a patient still alive!
You may find that bleeding is not coming from the lung at all but from the chest wall, this can be very brisk, difficult to find and to control (43.5).

LUNG INJURIES
Perform a lateral thoracotomy (44.6) and find which part of the lung is injured.

If there is a peripheral injury which is bleeding, isolate this, preserving as much healthy lung as you can. Apply 3/0 non-absorbable mattress sutures proximal to where you want to cut the lung, and remove the bleeding portion. A linear stapler is very useful for this (43-28). *Don't use a braided suture!*

PERIPHERAL PULMONECTOMY

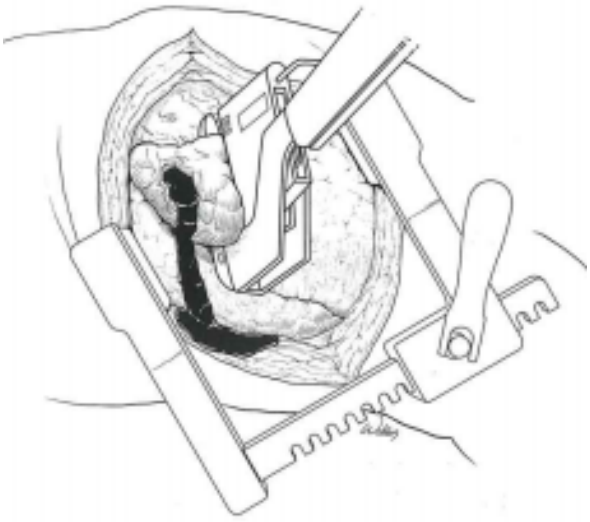

Fig. 43-28 PERIPHERAL PULMONECTOMY (GRADE 3.5)**. Remove the injured part of the lung: a linear staler is ideal for this.** *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

If there is a penetrating wound through the lung, pass clamps (or the linear stapler) through the track to expose the concealed bleeding lung vessels which you can then suture-ligate with 4/0 non-absorbable (43-29).

TRACHEO-BRONCHIAL INJURY
Most victims present with haemoptysis, mediastinal or subcutaneous emphysema, or tension pneumothorax.
Dyspnoea, respiratory distress hoarseness, dysphonia and stridor are common.
Air leaking as a result of a penetrating wound in the neck implies an airway laceration.
In intrathoracic injuries, pneumothorax, often with high volume leakage (seen after insertion of a chest drain) is common; it may be under tension. Look for subcutaneous emphysema in the neck, and signs of lobar or full lung collapse.

HAEMOSTASIS IN A PULMONARY MISSILE TRACK

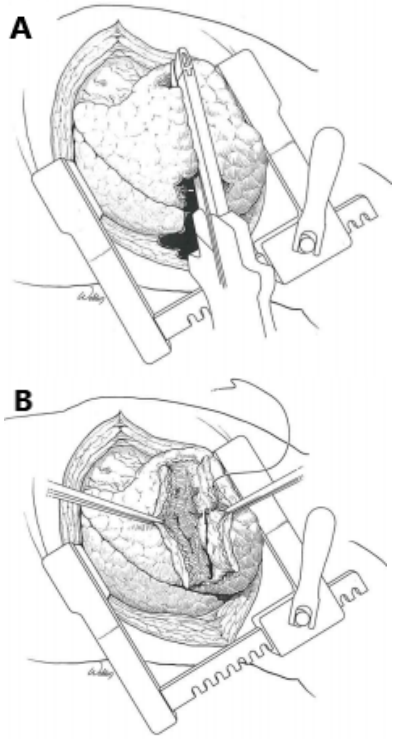

Fig. 43-29 HAEMOSTASIS IN A PULMONARY MISSILE TRACK. A, opening the track. B, suture-ligating the bleeding vessels. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

If there is massive bleeding from the pulmonary hilum, quickly mobilize the lung and grab it from behind and front with your non-dominant hand to squeeze it (43-30). You may just be able to repair the hole in a major vessel.

DIAGNOSIS
Radiographic signs are a large pneumothorax, air in the mediastinum, and emphysema in the chest, neck and face, often with lung collapse (43-15). This may be difficult to differentiate from oesophageal rupture, where the pneumothorax is usually small, and there is usually a pleural effusion associated.

A *careful* flexible bronchoscopy *by the surgeon who can repair the injury* is probably the best option.

GRASPING THE PULMONARY HILUM

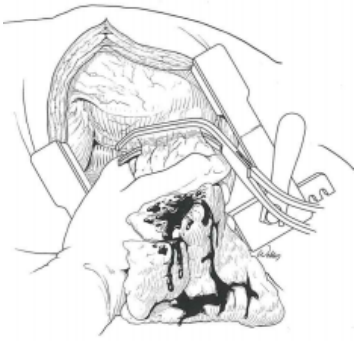

Fig. 43-30 GRASPING THE PULMONARY HILUM. This might just enable you to close a hole in a major vessel. *After Hirschberg A, Mattox KL. Top Knife. Tfm Shrewsbury 2005 with kind permission.*

Most penetrating injuries of the tracheobronchial tree occur in the neck. On the other hand, most blunt injuries occur in the distal trachea and right main bronchus within 2·5cm of the carina.
There are often additional injuries, which have priority for repair.

If you suspect this condition, administer analgesia, insert a left chest drain, and see if you can transfer the patient urgently, preferably with a qualified person. *You must discuss such a case with the referral hospital before sending him!*

OESOPHEAL RUPTURE
Trauma is responsible for only 10% of cases of oesophageal rupture and most are related to penetrating trauma.

A pleural effusion (more often on the left than right) is common. Rarely, you will see air under the diaphragm on an erect chest film. Air in the mediastinum takes at least 1h after injury to accumulate, and may not be present at all (43-13).
N.B. Endoscopy is unreliable in making the diagnosis. Perform a gastrograffin swallow to look for an oesophageal leak.

Administer broad spectrum antibiotics. If there is a pleural effusion, insert a chest drain and test the effluent for amylase (from the salivary gland). This can confirm the diagnosis.
Repair may be complex, but needs to be done early.

COMMON COMPLICATIONS IN CHEST INJURIES:
(a) Lung collapse.
If part or all of the lung fails to expand, 'lung collapse' has occurred. This is often due to retained secretions, which is why getting a patient with a chest injury to cough is so vitally important, painful although this may be.

First try chest physiotherapy (11.10). Encourage deep breathing and coughing. Aspirate the secretions as much as you can. If this does not help, pass a sterile rubber catheter or bougie into the unanaesthetized larynx to start coughing.
If this also fails, perform a bronchoscopy (29.14) within 1h, to suck out what is blocking the bronchi.

If you need to perform >2 bronchoscopies, perform a tracheostomy (29.15, 42.4), so that you can aspirate secretions regularly and more efficiently with a fine catheter. *Oxygen is of no value if it cannot reach the lungs! Antibiotics at this stage are also of little help.*
Lung collapse may complicate *any* chest injury, however apparently minor.

(b) Traumatic asphyxia.
If the face, neck and upper arms are covered with petechial haemorrhages, violent chest compression has forced blood to extravasate from venules in the skin. There may also be retinal and conjunctival haemorrhages. In a child, respiratory insufficiency is likely, so institute intensive care.

If there is associated drop in GCS level, this suggests cerebral haemorrhage as well. Normally the petechial haemorrhage is not serious. A semi-erect position and oxygen helps.

(c) Subcutaneous (surgical) **emphysema.**
Air may leak into the tissues, causing quite alarming facial swelling (43-31). The skin makes a crackly sound on palpation. This is common in pneumothorax or pneumomediastinum, but is seldom serious in itself, and soon disappears.

The swelling may extend from pelvis to forehead. If the eyelids are swollen and there is difficulty seeing, you can 'milk' the air elsewhere away from them. *Treat the underlying cause: insert a chest drain where there is a pneumothorax.* Apart from a pneumothorax, check whether there is evidence of tracheal, bronchial or oesophageal injury.

If severe coughing, by raising intrathoracic pressure, risks enlarging a pneumothorax, perform a tracheostomy (29.15, 42.4).
Subcutaneous emphysema may look very alarming in the face, but the air is absorbed quickly. To speed the process, you can insert a size 4 infant feeding tube (with spiral fenestrations cut into it) into the subcutaneous space, and attach this to a low pressure (10-15cm H_2O) suction.

SUBCUTANEOUS EMPHYSEMA IN THE FACE & NECK

Fig. 43-31 SUBCUTANEOUS EMPHYSEMA may be so severe as to close the eyelids and obscure features of the neck.

(d) Chylothorax.
Rarely, the thoracic duct is ruptured. A large amount of fluid (up to 2L/day) may collect in the pleural cavity. You can recognize chyle by it leaving a creamy upper layer on standing. It goes clear when mixed with ether. Its protein content is 20-30g/l. If the patient drinks dairy cream with a lipophilic dye, the drainage fluid will show this dye. The drainage usually stops after 5-7days, but the patient needs a high protein diet to replace the losses. If the drainage is >2L/day, the thoracic duct tear probably needs surgical closure. If you can't arrange this, you can try talc pleurodesis (as for recurrent pneumothorax, 36.1).