Opinion on the management of stove-in chest appears to be converging on intermittent positive pressure respiration as a definitive line of treatment.

Since Barrett (1960) summarised the emergency treatment as comprising tracheo-bronchial clearance, tracheostomy and intercostal drainage of pleural cavities with an underwater-seal, a more positive attitude to the treatment of these patients has developed, based on a knowledge of the altered physiology. If paradoxical respiration has reduced the tidal volume to levels approaching that of the dead-space air, then when secretions accumulate in the bronchi (the "wet-lung" of Samson and Brewer 1946) asphyxiation is certain. It is therefore logical to reduce the dead-space air and clear the airway by tracheostomy. These principles were used by Carter and Guiseffi (1951), who treated seven patients with stove-in chest by tracheostomy alone, four of whom survived. Similarly if air or blood is accumulating in either pleural cavity it is logical to re-expand the lungs by underwater-seal drainage.

Opinion is sharply divided concerning the action to be taken after this emergency treatment. Three main lines of treatment are used.

**Traction on the flail segment**—Jones and Richardson (1926) advocated traction on the sternum and Williams (1948) advocated pericostal traction on the flail ribs. Heroy and Eggleston (1951) elaborated the sternal traction technique and Proctor and London (1955) elaborated the costal traction technique. Schrire (1962) described a suction device which he named "the limpet."

**Internal fixation**—Some surgeons feel that with antibiotic cover a stove-in chest should be opened, the pleural cavity cleared out, and the rib fractures immobilised. Klassen (1949) used intramedullary bone pegs in the ribs and Coleman and Coleman (1950) fixed the rib ends with wire sutures. Crutcher and Nolen (1956) described nine patients in whom intramedullary fixation was accomplished with small Rusch pins. Sillar (1961) described a plate for screwing on to the sternum and fixing the flail anterior segment.

**Artificial respiration**—Hagen (1945) described the treatment of multiple rib fractures with a Drinker respirator. Avery, Mörch and Benson (1956), using hyperventilation with intermittent positive pressure respiration, diminished respiratory effort by putting their patients into alkalotic apnoea. This concept has been modified by Windsor and Dwyer (1961) who used intermittent positive pressure respiration at a lower pressure and controlled the patient's attempts at breathing with relaxants.

These three lines of approach offer definitive treatment of these injuries but they become more and more elaborate, requiring increasing amounts of medical, nursing and ancillary aid. A patient on controlled respiration needs frequent assessments of serum electrolytes and of arterial carbon dioxide levels. Windsor and Dwyer (1961) stated that their full régime was needed in only about 7 per cent of severe chest injuries.

It is noticeable that advocates of intermittent positive pressure respiration as the definitive treatment for crushed chests base their choice on the facilities available in a large respiratory unit. But the difficulty arises when a serious chest injury is encountered in a peripheral hospital where the medical, nursing and laboratory facilities for the continuous care of a patient on intermittent positive pressure respiration may not be so easily available.

Much of the accident surgery of this country is managed by orthopaedic surgeons and it is suggested that patients with a stove-in chest can be managed by them without recourse to intermittent positive pressure respiration provided that the surgeon in charge assesses the case correctly. The following patients illustrate this approach to treatment.

**Case Reports**

**Case 1**—A boy of eight ran into a bus injuring the left side of his chest. He had paradoxical breathing from the third to the seventh ribs antero-laterally and radiographs revealed double fractures of these
ribs. Under general anaesthetic a tracheostomy was performed and the airway cleared with improvement in his tidal volume. The next day he was still cyanosed and a left haemothorax was present. This was drained through the second left intercostal space in the mid-clavicular line and 420 millilitres of blood were removed with immediate improvement in his condition. He was allowed out of bed on the eighth day after injury and three days later radiological examination of the chest was almost normal. In this case tracheo-bronchial aspiration through a tracheostomy and drainage of the pleural cavity was sufficient to keep the patient adequately oxygenated.

Case 2—A woman of fifty-eight sustained an anterior stove-in chest from impact on the steering wheel of a motor car in a collision. On admission she was shocked and cyanosed with a "flail" sternum and costal cartilages. She could not cough because of pain. Radiographs showed no fractures of the ribs but costochondral fractures could be felt on both sides. Tracheostomy was performed that day and she remained a good colour without needing added oxygen. In this case there was no deterioration after tracheostomy and no indication for pleural drainage.

Case 3—A man of sixty-two fell through an asbestos roof fracturing his left wrist and right pubis. He also had double fractures of the fifth to the ninth ribs on the right side with paradoxical respiration of this flail segment. His condition was satisfactory for the first day but on the second day he became cyanosed, was gasping for breath and had signs of a classical "wet lung." At operation tracheostomy was performed and the airway cleared but he was still cyanosed and had a small tidal volume. Right thoracotomy was performed and the pleural cavity cleaned out. The rib fractures were reduced and immobilised with intramedullary Kirschner wires. About three inches of the wire was inserted along the medulla of the rib leaving a further six inches protruding through the outer cortex. This was bent alongside the outer aspect of the ribs and brought out through the skin incision. The patient was allowed out of bed on the tenth day after operation and the wires were removed on the twenty-first day.

Case 4—A man of sixty-five sustained a single fracture of the left fifth rib from a steering wheel contusion. He remained well for two days but while turning over in bed he became acutely dyspnoeic. Examination showed paradoxical respiration with an anterior flail segment from fractures of the costochondral junctions on both sides and radiographs showed bilateral pneumothorax. An intercostal drain was inserted into each pleural cavity and connected to an underwater-seal. Tracheostomy was performed but the patient remained cyanosed. Sternal traction was therefore applied through towel clips around the fourth costal cartilages. These were attached over a pulley from a Balkan beam to a nine-pound weight. Three days later the paradoxical movement returned as the towel clips had cut through the costal cartilages. Under a general anaesthetic an aneurysm needle was passed transversely behind the sternum in the third intercostal spaces. Eight strands of thick nylon suture were then drawn back behind the sternum as the needle was withdrawn and attached to the traction system. The paradoxical movement was then controlled. As progress was not considered to be satisfactory he was transferred to the thoracic unit at the Brook Hospital, Woolwich, where bronchial clearance was performed. He travelled the seventy miles in an ambulance with his sternal traction working satisfactorily. The nylon loop was removed two weeks later after being in position for nearly three weeks. He returned to Eastbourne five weeks later fully ambulant. On the night before he was due for discharge he had a cardiac infarction and died. Necropsy showed sound union of the costochondral junctions, fully expanded lungs and stenosed arteriosclerotic coronary arteries. The progression from intercostal drainage and tracheostomy to sternal traction followed in sequence according to the patient's condition.

Case 5—A man of fifty-one was admitted having fallen down a ladder. He had a left lateral stove-in chest and radiographs showed double fractures of five ribs. Paradoxical movement could be seen over this segment but he appeared to be breathing reasonably until the next day when he developed surgical emphysema. Over the next twelve hours this spread to his face as far as the supraorbital ridges. A left thoracotomy was performed and the fractured ribs were immobilised with Rush pins after the manner of Crutcher and Nolen (1956). The chest was closed after putting in an intercostal tube connected to an underwater-seal. Tracheostomy was then performed. He made an uneventful recovery. This patient's injury, like Case 3, was suitable for intramedullary fixation of the ribs. As a result of this he could move around early and did not need artificial respiration.

Case 6—A man of fifty-two sustained a "steering-wheel" injury to the front of his chest after which he was acutely dyspnoeic with a flail anterior segment. Acting on the belief that if a physiological respiratory state was re-established by internal fixation then he should be able to cough, the usual order of treatment was reversed. After applying sternal traction with a nylon loop the tidal volume was restored to about 500 millilitres. It was decided to wait a day before doing a tracheostomy to see whether he could cough and so deal with his bronchial secretions. This proved to be so and tracheostomy was not performed. The sternal traction was removed after three weeks. This illustrates the point of adjusting treatment to the patient's needs rather than following a rigid plan.
Case 7—A man of fifty-six jumped off a railway bridge and sustained double fractures of the second to the sixth ribs on the right side and of the second to the twelfth ribs on the left side. Left thoracotomy was performed and a large haemothorax was evacuated. A large tear in the pericardium was found but was left alone. Intramedullary fixation of the third to the ninth ribs on the left side was performed using Rush pins and the chest closed. The right side of the chest was not opened or drained as the extent of the injury was not correctly assessed. Tracheostomy was performed. He progressed well for four days but deteriorated and died on the fifth day after operation. Necropsy showed a haemothorax on the right side with partial collapse of the right lung and suppurative pericarditis. The left lung was well expanded and the chest wall on the left side showed adequate fixation of the fractures. This patient might have done better on bilateral intercostal drainage, tracheostomy and intermittent positive pressure respiration from the start with no attempt at operative fixation of the ribs (Avery, Morch and Benson 1956). With this method the rib fractures can be left to join up spontaneously.

GENERAL MANAGEMENT OF PATIENTS

All these patients required sedation and analgesia. In the adults Pethilorfan 50–75 milligrams with Largactil 25 milligrams given intramuscularly every four hours for two to three days was usually adequate. These drugs kept the patients comfortable without inducing respiratory depression.

It is always wise to empty the patient’s stomach with a stomach tube before operation. We confirmed the observations of Cameron, O’Rourke and Burt (1949) that acute gastric dilation and paralytic ileus often occur in this condition.

Correction of blood loss with whole blood was necessary in all these patients, care being taken not to over transfuse.

Antibiotic cover was maintained for three weeks. Initially crystalline penicillin 4 million units and streptomycin 1 gramme daily in divided doses were given. The antibiotic was changed later according to the flora and sensitivity of the sputum.

Radiographs of the chest, apart from the initial assessment, were seldom helpful. It is very difficult to interpret antero-posterior views of a chest taken with a portable machine on a distressed patient. We gained much more information by inspection, palpation, percussion and auscultation.

When performing tracheostomy it was found that a cuffed, armoured, latex tracheostomy tube was the most useful type. If a low tracheostomy was performed it was very easy to intubate one of the main bronchi and collapse the other lung. The tracheostomy tube and tracheo-bronchial tree were sucked out hourly with an endobronchial catheter. The nurse was instructed how to suck out the sound side as well as the injured side. We continually found that the catheter was only passed to the end of the tracheostomy tube so as not to distress the patient. It is very difficult to persuade persons that unless the patient is made to cough by the endobronchial catheter he is not receiving adequate treatment. In between bronchial suctions the patient’s tracheostomy was linked to a humidifier.

DISCUSSION

Arising from these points and the preceding case histories it can be seen that patients with crushed chest injuries can be managed in a non-specialised unit provided an adequate assessment of the injury is made and the roles of tracheostomy, pleural drainage, and chest wall stabilisation are critically assessed. Case 7 illustrates this point: failure to realise the limitations of internal fixation probably contributed to this man’s death. The other six patients illustrate certain advantages, namely: 1) the methods are simple and effective; 2) the post-operative care of the patient is much easier if he is not having intermittent positive pressure respiration; 3) the patient can be mobilised early. It has been learned from these patients that there is a dangerously deceptive first period of twelve to twenty-four hours when the patient may seem quite fit and “holding his own.” In none of the patients where this occurred were we in any doubt that the patient should have been treated earlier. Cases 1, 2, and 6 in which treatment was started within twelve hours of the onset of paradoxical
breathing illustrate this point. All had normal chest radiographs and were back at their normal occupation within twelve weeks of operation.

The question arises whether all the tracheostomies were necessary. On theoretical grounds, if pleural cavity drainage and chest wall fixation are adequate, then the patient should be able to deal with the tracheo-bronchial secretions and should not need to have the dead-space air reduced. The only practical experience obtained of this was Case 6 where tracheostomy was not needed.

As a result of this experience the following approach is advocated for patients with chest wall injuries in which there is a flail segment. 1) After clinical and radiographic assessment of the injury the patient is prepared for operation and the stomach is emptied. 2) General anaesthesia is induced and is continued through endotracheal intubation. 3) A decision is made whether the flail segment should be fixed. This may be by sternal traction or by intramedullary fixation. 4) Drainage of the pleural cavity on the affected side with an underwater-seal is usually necessary. 5) If after drainage of the pleural cavity and fixation of the flail segment the patient is adequately ventilated, tracheostomy can probably be avoided. If he becomes cyanosed tracheostomy is indicated immediately. If during the succeeding day the patient has difficulty in breathing or dealing with secretions a tracheostomy can still be done. 6) If the damaged chest is beyond the scope of fixation or if fixation, tracheostomy, and pleural drainage have failed, then intermittent positive pressure respiration should be instituted with a cuffed tracheostomy tube. 7) Tracheostomy tubes can usually be removed on the fifth day. 8) Sternal traction needs to be maintained for three weeks if the "stove-in" has occurred at the costochondral junctions.

SUMMARY

1. A course of treatment is suggested for patients with stove-in chests based on experience with seven patients, only one of whom died from his injury.

2. The literature on this subject is reviewed and it is suggested that treatment may be undertaken by an accident surgeon without recourse to intermittent positive pressure respiration in most instances.

REFERENCES


