THE STOVE-IN CHEST

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The condition of stove-in chest is inadequately described in surgical textbooks. Patients with this condition are usually gravely ill and are unlikely to survive long, unless treatment is early and energetic.

It is hoped to show that, although it is time-consuming and arduous, the treatment of this injury need not be confined to the larger centres with specialized equipment.

The prognosis is poor; Proctor and London[1] reported only 1 survivor in 8 patients admitted to the Birmingham Accident Hospital during the 9 years from 1944 to 1952.

Multiple fractured ribs with damage to the thoracic viscera is not, however, an uncommon injury, though patients with such an injury rarely reach hospital. At the Government Mortuary at Sterkfontein, during the period 1 June 1961 - 31 May 1962, postmortem examinations were performed on 210 cases of unnatural death. Of these, 23 had damage to the thoracic cage and viscera sufficient to cause death, but in only 6 cases was the chest lesion the main one, the other cases having very severe associated injuries which were incompatible with life.

MECHANISM

The injury is caused by any crushing force applied to the ribs or sternum. The driver of a motor vehicle involved in a head-on collision has his sternum forced against an unyielding steering wheel by the weight of his body and is particularly liable to sustain this injury. As our motor-vehicle accident rate increases, so must the incidence of the stove-in chest. Universal adoption of seat belts with shoulder harnesses could be expected to reduce the incidence of this and associated injuries.

PATHOLOGY

The ribs may break in one or more places; on either side of the sternum, anteriorly or posteriorly, and the sternum may also break.

The sternum or ribs, if driven inwards, will injure the lungs or heart, with bruising and tearing of the lungs and/or bruising or rupturing of the heart. The *contrecoup* type of injury to the lungs or heart also occurs.[2] The diaphragm may rupture, although this is more commonly associated with abdominal crushing injuries, forcing the viscera into the thorax.

The sternum, isolated by fractured ribs on either side, is sucked inwards on inspiration and blown outwards on expiration. Isolated segments of ribs behave similarly. Ribs, freed of their attachment to the sternum, are unable to function efficiently. The action of the diaphragm is interfered with, since it requires a fixed purchase for efficient action.

The effect of the unstable thoracic cage is a reduction in vital capacity. Bleeding occurs into the lung parenchyma and into the alveoli, interfering with gaseous exchange.

Air escapes from the lungs if they are torn, and will cause collapse. Further escape of air may build up tension in the thorax, forcing the mediastinum across to the other side.

The patient may be able to maintain an adequate respiratory exchange at first, but is unable to cough. Blood and mucus accumulate in the bronchi, interfering further with respiratory exchange. Eventually, anoxia with carbon dioxide retention supervenes, the respiratory muscles become exhausted, and the patient asphyxiates. Much bleeding may occur from a lacerated lung, from the broken ribs and from torn intercostal vessels. Oligaemic shock may thus complicate the injury.

CLINICAL PICTURE

The restless, cyanosed, anxious patient, struggling to breathe, leaves little doubt that severe respiratory difficulty exists. Patients who have lost much blood may not be cyanosed, but are pale.

Careful inspection and palpation of the chest will usually reveal the floating segment with paradoxical movement, but in heavily-built patients, the abnormal movements may not at first be obvious.

The patients are shocked, possibly severely so, depending on the amount of blood lost. Associated injuries, if present, will increase the degree of shock.

Air entry is poor and moist sounds are present. The physical signs of effusion, pneumothorax or tension pneumothorax may be difficult to elicit in these patients, and therefore an X-ray picture of the chest is a valuable aid to diagnosis.

MANAGEMENT

As a first-aid measure, positive-pressure insufflation with oxygen is indicated. This must be synchronized with the patient's attempts to breathe and may be given *via* a face mask, using the 'pulmoflator' or a re-breathing bag. Endotracheal intubation is preferable, but may not be possible, unless the patient is unconscious from anoxia or associated head injury.

Positive-pressure respiration may convert a pneumothorax into a tension pneumothorax, which, if unrecognized and untreated, may be rapidly fatal.

Definite treatment aims at clearing the bronchial tree, stabilizing the thoracic cage, removing blood and air from the pleural spaces, and replacing the blood lost. If positive-pressure respiration has been used, the possibility of a tension pneumothorax must be kept in mind and, if this is present, provision for underwater drainage must receive priority.

Tracheostomy is performed at the earliest possible moment. This reduces dead-space air and allows the bronchial tree to be cleared of blood and secretions. Oxygen can be given through a catheter, or a cuffed tube can be inserted for positive-pressure respiration. Local anaesthetic is adequate for this purpose if the help of an anaesthetist is not immediately available. If an anaesthetic is given, it would be rational to stabilize the chest first and do the tracheostomy last.

Underwater drains are inserted through the second intercostal space anteriorly, using a large-bore rubber tube; size 26 French gauge is adequate. Small tubes and needles may easily be blocked by clotted blood.

Stabilization

A vitallium bone plate, with at least 6 screw holes, is screwed to the middle of the sternum, using $\frac{1}{8}$-inch diameter screws, $\frac{5}{8}$-inch long. Around this plate is first passed 2 loops of stainless steel wire, which are brought out through the skin incision. Strong traction can then be applied to the sternum, the elevation of which brings dramatic clinical improvement. This operation may be done under local anaesthesia and takes only a few minutes to perform. If the sternum is also fractured, a longer plate may be used and will give satisfactory stabilization of the fracture. Sillar[3] described a specially designed sternal plate, but this plate, being almost as broad as the sternum, would be more difficult to apply than a narrow bone plate and is not suitable for wire traction. Proctor and London[1] described a modified cup hook, which is screwed into the sternum, but which engages in the anterior cortex only. Traction would not be so secure, nor would a fractured sternum be stabilized.

Traction on the sternum may be adequate to restore respiratory exchange, but it is probably wiser in addition to stabilize the ribs on either side of the sternum. An isolated unstable section of the chest will require stabilization by traction. This is accomplished by passing wire around a rib, using a $2\frac{1}{2}$-inch curved cutting needle. Monofilament wire is used, since braided wire will saw its way through a rib in a few hours. In well-covered patients it may be necessary to cut down on the rib, especially the upper ribs where they are covered by the pectoral muscles or breast.

Other methods of stabilization have been described: traction by towel clips gripping the ribs, or wiring, plating or medullary fixation of the individual rib fractures. The use of towel clips would appear to be satisfactory, but they would have to be straight and large enough, so as not to cut into the rib. Operations on individual fractures would be difficult and time-consuming, especially if the ribs were fractured near their angles. Schrire[4] described a simple method, employing a suction cup and a plaster cast, which he used successfully in 3 cases. He did not, however, discuss the application of his method to cases with a flail sternum, or to cases where breast tissue may overlie the flail-rib section. The plaster cast would also interfere with any intercostal drainage apparatus.

Traction is maintained in the ward by pulleys and weights from overhead beams. This is a satisfactory method, since an alteration of the patient's position would not change the force of the traction, but overhead beams preclude the use of an oxygen tent, which is needed for the more severely injured patients. Proctor and London[1] described a thoracic stabilization frame, which may be covered by an oxygen tent. The traction cords may be attached to the frame in any direction and spiral springs are used to provide the traction.

An alternative method is to use metal drip-stands of the type which clamp on to the bed. The stand is bent to the required position and the tension is varied by varying the length of the attaching cord. The springiness of the drip stand has been found to be satisfactory.

Traction on the unstable thorax is essential for inspiration, but it hinders expiration, of course. The force used must thus be adjusted for each individual, just sufficient being used to prevent the paradoxical movement. Since the expiratory phase of respiration is the more difficult, the patients should be nursed flat on their backs, with the foot of the bed raised. This allows gravity to assist the ascent of the diaphragm[5] and also assists in the removal of bronchial secretions.

Continued Management

Suction through the tracheostomy opening may at first be required as often as every 15 minutes and should be done with a sterile soft-rubber catheter, using a non-touch technique. Bronchial secretions and blood clot may be too thick for catheter aspiration, necessitating daily, or twice daily, bronchoscopies. This is easily done in the ward through the tracheostomy opening.

Blood transfusion will be necessary and an attempt should be made to estimate the amount of blood lost, to avoid overloading the circulation, since an anoxic myocardium may be liable to undergo acute failure and a damaged lung to become oedematous. Blood drained from the thorax is measured and loss from other injuries is assessed.[6]

Antibiotics are given according to the culture and sensitivity reactions of the bronchial secretions. The danger lies in acquiring a resistant staphylococcal lung infection, so the patient should be isolated from the onset and every effort made to prevent cross-infection.

Pain is very severe and may be counteracted by injections of pethidine, 100 mg., with 'daptazole', 30 mg.

A patient with a tracheostomy is unable to cough. A cough will be produced, however, if immediately before the expiratory effort begins, the tracheostomy opening is blocked.

The traction is maintained for 2 - 3 weeks and is removed after a trial period has shown it to be unnecessary.

Windsor and Dwyer[7] considered that the treatment of choice is positive-pressure respiration until the thorax has healed sufficiently to prevent paradoxical movement.

They insert a cuffed tube through the tracheostomy opening, curarize the patient and manually control the respiration. Their case 2 was maintained in this manner for 2 weeks, although during the latter part of this period respiration was assisted rather than completely controlled.

This method requires a doctor to be in attendance 24 hours a day, and is clearly suitable only for the large centres which are adequately staffed.

ILLUSTRATIVE CASES

Case 1

Mr. C. J. S., aged 56 years, was admitted to Boksburg-Benoni Hospital on 20 May 1960 at 7 a.m., after having been knocked down by a car while riding a bicycle. There were lacerations of his face, a closed fracture of his right tibia and fibula, and a closed fracture of his right radius and ulna. Many ribs were fractured on either side of the sternum, which had paradoxical movement. Air entry in both lungs was poor, with moist sounds.

A blood transfusion was started and his fractures were splinted. Oxygen was given, but his general condition deteriorated. One hour later he was deeply cyanosed and semi-conscious. It was decided to try to prevent the paradoxical sternal movement by traction. He became unconscious on his way to the theatre. Tracheostomy was performed, and on completion spontaneous respiration ceased. No heart beat was palpable, but after aspiration of blood from the trachea and insufflation with oxygen, the beat returned and his cyanosis disappeared. A 4-inch bone plate was then screwed to the sternum and traction was applied by means of a wire passed around the plate. Spontaneous respiration returned and became adequate as his skin wound was closed. Consciousness had returned by the time he arrived back in the ward, where traction was maintained with a weight and pulley attached to an overhead beam. Oxygen was given through a catheter, and bronchial toilet was frequently performed. Morphine, ¼ gr., with daptazole, 30 mg., was given 4-hourly, and 'terramycin', 200 mg. was given 6-hourly.

A portable X-ray picture of the chest showed fractures of the 5th — 9th ribs on the left, and the 3rd — 9th on the right, patchy lung consolidation and surgical emphysema on the right side of the neck. Dr. A. Gould thought the patchy consolidation was probably due to lung haematomata.

That evening, the systolic blood presure was about 110 mm. Hg and surgical emphysema was present on the right side of the chest. Bilateral underwater drains were inserted and much air was released from the right side. Respiration was still very difficult, but just adequate, expiration being more difficult than inspiration.

On 21 May the patient was fully conscious. Blood pressure was 110/50 mm. Hg. There was slight improvement in respiratory exchange, although some paradoxical rib movement was apparent.

On 22 May there was no change, but the patient had only passed 50 ml. of urine, and he died suddenly at 3 p.m.

Postmortem examination revealed fractures of the 3rd — 9th ribs on the left and all the ribs on the right side. The sternum was also fractured and was mobile. The right lung had several tears. No information is available about the kidneys.

Comment

This case illustrates the importance of early treatment. The puzzling features are the sudden death and the renal failure. The renal failure was presumably due to the initial period of hypotension, and the sudden death may have been due to fat embolism.

Case 2

Mr. J. V., aged 54 years, a chronic bronchitic, was the driver of a car which rolled over several times. He was admitted to Krugersdorp Hospital on 31 May 1962. He was deeply unconscious, had abrasions of his scalp and was cyanosed. His respiratory rate was rapid, with paradoxical movement of the sternum. He also had an intertrochanteric fracture of his right femur.

Tracheostomy was performed and a quantity of blood and mucus was aspirated. His colour improved slightly, but it was not until traction was applied to the sternum, using a bone plate, that his cyanosis was relieved. A large loose segment of ribs on the left side, involving ribs 3 - 6, then became apparent. Stainless wire was passed round a rib in the centre of the flail segment and traction was applied. Traction was maintained, using bent drip stands, and an oxygen tent was placed in position. Six hours later there was marked respiratory difficulty and cyanosis. Bronchoscopy showed that there was clotted blood in the trachea and main bronchi. When this was removed, the respirations again became adequate. The patient had been given 2,000 ml. of blood, and antibiotics were started.

On 1 June there was slight improvement in the cerebral condition. Bronchoscopy was necessary.

On 6 June the cerebral condition had improved. Daily bronchoscopies were necessary, but bronchial secretions were purulent. Culture revealed coagulase-positive *Staph. aureus* and the antibiotic was changed according to the sensitivity reactions. Intragastric feeds were started.

On 10 June the patient began opening his eyes and looking about. There was no response to noise, nor did he make purposeful movements. Daily bronchoscopies were still

necessary, and large quantities of pus were aspirated daily. The staphylococcus was found to be resistant to methicillin. He was given a further 1,000 ml. of blood.

On 15 June the rib traction was removed. There had been no further cerebral improvement and the bronchitis had become much worse. Various antibiotics were tried without response. On 18 June the sternal traction was removed, but the patient's general condition was deteriorating, and he died on 20 June.

Postmortem examination showed some subarachnoid haemorrhage, but no space-occupying lesion or brain laceration. The lungs were consolidated and the bronchi filled with pus. All ribs on either side of the sternum had been fractured and there were double fractures of the 3rd — 6th ribs on the left side. All the fractures showed good callus formation and were fairly firm. The sternal plate had not caused osteomyelitis, and although 3 screws had penetrated the sternum $\frac{1}{8}$ of an inch, no damage had been caused.

Comment

This patient died from an overwhelming staphylococcal bronchopneumonia, in spite of the antibiotics used. Had he been conscious and also not a bronchitic, it is possible that he might have survived. His initial period of anoxia aggravated his head injury and may have been responsible for permanent brain damage.

Case 3

Mr. B., aged 50 years, driver of a car which overturned, was taken to West Driefontein Mine Hospital on 24 July 1962. He was seen by Mr. D. R. Honey, R.N., who found him in a moribund condition. Mr. Honey intubated the patient and ventilated the lungs with oxygen. An intravenous plasma infusion was started and the patient was brought to Krugersdorp Hospital.

He was taken directly to the theatre, where he was found to be unconscious, though making some attempts to breathe. He was pale, but had a palpable radial pulse. The sternum was fractured, as were all ribs on either side. The lungs were very moist and the air entry poor. The plain endotracheal tube was changed for a cuffed one. While this was being done, cardiac arrest occurred. Cardiac massage was commenced through a left thoracotomy and 1,500 ml. of blood were given very rapidly. After a few minutes the heart recommenced beating and the radial pulse returned.

There was much blood in the left pleural cavity and there were 2 upper-lobe lacerations anteriorly, which were sutured. Multiple fractured ribs were noted, some of which had double fractures. Wire was passed round the 3rd and 8th ribs and two underwater drains were inserted through the 2nd and 10th spaces. The thoracotomy was closed and the sternum plated with a 5-inch bone plate, with 8 screws. Traction was applied to the plate, which immobilized the sternal fracture satisfactorily. An intercostal drain was inserted through the 2nd right interspace, and about 500 ml. of blood were released. Traction on the right was applied to the 3rd and 8th ribs with wire loops. Tracheostomy was then performed and the trachea cleared of blood. Oxygen insufflation was continued as spontaneous respirations began to return.

The patient was then transferred to his bed and traction arranged with bent drip stands. His own respirations were, by then, adequate if he breathed high oxygen concentrations. He had received 3,000 ml. of blood and his blood pressure was over 100 mm. Hg, so he was sent to the ward and placed in an oxygen tent, where he died suddenly 25 minutes later.

Postmortem examination showed the fractured sternum and multiple fractured ribs on both sides. Many of the ribs had double fractures. The left upper lobe had 2 sutured lacerations anteriorly and a 4-inch laceration posteriorly. The upper and lower lobes on the right had 2-inch lacerations anteriorly. Both lungs were congested and the bronchi were filled with blood. There was no skull fracture, and no macroscopic evidence of brain damage. Since the patient was a miner, his lungs were sent to the Pneumoconiosis Bureau and Dr. I. Prinsloo found extensive haemorrhage into the parenchyma and air spaces of the left lung, and oedema of the right lung.

Comment

This patient had extensive lung damage, sufficient on its own to cause death. Oedema of the lung may be rapid in onset and may have been the cause of death.

SUMMARY AND CONCLUSION

The mechanism, pathology and suggested management of the flail stove-in chest are briefly described. Three illustrative cases are quoted. It is thought that the management of this serious injury should not be confined to the larger centres and that a successful outcome may be possible using the ordinary equipment available in any hospital. Indeed, even a short delay in starting treatment precludes a successful outcome.

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