

CONTRECOUP FRACTURE OF THE STERNUM.¹

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CASE HISTORY.—Mr. P., aged forty-three years, on April 28, 1904, while cleaning car-windows, was thrown from the ladder on which he was standing. His fellow-workmen stated that he fell on his head and his body bent forward and "doubled up on itself." In other words, after striking the ground, his body completed a somersault, and he landed on his feet in a doubled-up condition. When called to see him a few minutes after the accident, I found him semidelirious, bleeding profusely from scalp wounds, and complaining during lucid intervals of pain in his chest. An extensive stellate scalp wound over the left parietal eminence made examination of the skull easy; no fracture or depression was noted, and the wounds were sutured. Examination of the thorax showed a distinct protuberance over the sternum at the level of the second and third chondrosternal articulations. Tenderness over this area was exquisite and slight crepitus was probably elicited once, but the great pain forbade confirmation of this symptom. There were no external discolorations, bruises, or marks such as would undoubtedly have been present had the patient's sternum struck any solid body in falling. The man was sent home and put to bed with hot moist dressings over the sternum. The scalp wounds healed *per primam*, and will not be further considered in this paper.

April 29. Patient bedridden; temperature, 101° F.; pulse, 104; respirations, 34. The midsternal region is discolored; the protuberance has increased and tenderness is still very acute. An attempt was made to keep patient's head and shoulders thrown back in order to reduce the deformity, but we had to desist on account of increased pain and discomfort. Adhesive strips over the fractured area were also tried, but promptly discontinued, as they only aggravated the pain. The patient coughs frequently, and on two occasions the sputum was tinged with blood. Respi-

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ratory movements are shallow and extremely painful, and cough is apparently agonizing. On auscultation, a number of large moist râles are heard over both sides of the chest anteriorly. Percussion showed slight dulness over the anterior mediastinum above the fracture. The heart sounds are normal, except for a rather marked accentuation of the second aortic sound, which could be accounted for by the well-marked arteriosclerosis.

April 30. Temperature, 100° F.; pulse, 94; respiration, 32. Patient required opiates for pain. Hot linseed poultices applied to sternum. Cough persists, but pulmonary findings are negative, with the exception of a few fine moist râles over the right lung anteriorly. The patient's general condition improved daily, and no further symptoms developed until May 5, on which date he was seized with cramp-like pains in both upper extremities. He said he felt as though "somebody was gripping his arms tightly." These pains lasted from one to three minutes and reappeared several times daily for about a week. There was coincidentally some pain on pressure over the fifth, sixth, and seventh cervical vertebræ; but no deformity could be made out, and there was at no time any external evidence of injury. There were no motor disturbances, but the man complained for several days of numbness and tingling in both upper extremities. By the end of the first week he was able to walk around the house. The patient's attitude was very characteristic,—body bent forward, head slightly flexed to the left, rapid shallow respiration and immobile thorax. The lungs cleared up satisfactorily, respirations gradually returned to their normal rate and quality as the pain decreased, and on May 19, when patient was discharged, the findings were as follows: At the level of the second costal cartilages, the sternum forms a distinct palpable ridge, the lower fragment overlapping the upper to a very slight extent. The callus is dense; there is no tenderness or pain, and the dulness over the anterior mediastinum has disappeared. Palpation of the spinal column is negative, and there have been no sensory disturbances in the upper extremities for a week. At present writing the patient's condition is satisfactory in every respect.

Fractures of the sternum are extremely rare. Malgaigne¹ saw one case in eleven years' service at the Hôtel-Dieu in Paris; Lounsedale collected reports on two cases out of a total of 1901

fractures in the Middlesex Hospital service; Roland had two cases in five years' service in Guy's Hospital, London. Arbuthnot Lane stated that he had seen four cases of fracture of the sternum alone. Grant,² speaking of fractures of the sternum, said, "I have seen but one case, . . . and that occurred in connection with fracture of the spine." Of indirect or contrecoup fractures, Servier,³ in 1889, could only collect eighteen to twenty cases. In the literature at my disposal I have been able to add seven new cases since 1889. Of these, one was in all probability due to muscular action.

Fractures of the sternum may be due to (a) Direct, (b) Indirect violence, (c) Muscular action. The majority of cases are direct fractures, simple or compound, single or multiple, as a rule associated with other bony or visceral lesions; they differ in no respect from fractures of other bones, and will not be considered in this paper. The rare cases of fracture from muscular action are apparently caused by forcible backward flexion of the vertebral column with coincident tension of the recti and sternocleidomastoidei muscles, wrenching the sternum apart. Chausier⁴ reports two such cases occurring in young women during labor. They were both in a position of extreme opisthotonos when the accident occurred. Lucchetti and Posta,⁵ Comte and Martin,⁶ and David, Sabatier, and Roland quoted by Hamilton,⁷ all mention similar cases. Dubois⁸ gives the history of a clown who, while doing the backspring, fractured his sternum. Irwin⁹ reports the case of a coachman who, while seated on top of his omnibus, was dragged by his unruly team through a low doorway. His body was violently bent backward, resulting in a fracture of the sternum.

Contrecoup fractures and dislocations almost invariably occur at the junction of the manubrium and gladiolus. They are usually transverse, but may be oblique or T-shaped. In 85 per cent. of the cases analyzed, the gladiolus was found to override the manubrium; in 15 per cent., the reverse held true or there was fracture or dislocation without overriding. It is often impossible to differentiate dislocation from actual frac-

ture; the former cannot, of course, be present when bony union has occurred between the manubrium and gladiolus.

Etiology.—Contrecoup fractures or dislocations of the sternum are produced in a variety of ways. A brief description of a few typical cases will help us to understand the mechanism of at least a majority of these lesions.

CASE I.—Costa de Sarda.¹⁰ A male patient, aged forty-five years, threw himself from a third-story hospital ward, landing on his buttocks. Three fractures of the sternum were found post-mortem, but no evidence of external injury over that bone.

CASE II.—Velpéau.¹¹ A middle-aged man fell from a cart, landing on his back. Fracture of the upper part of the sternum was diagnosed.

CASE III.—Lafont.¹² Man, fifty-eight years old, fell backward from a cart, landing on his back. A fracture of the sternum was found, with the lower fragment overriding the upper one. The patient also had a hæmatoma in the left axilla, and died of septicæmia. It was found post-mortem that the fracture had occurred one centimetre above the articulation of the manubrium and gladiolus.

CASE IV.—Rivington.¹³ An acrobat, thirty years old, while turning double forward somersaults, fell ten feet on the back of his head, which was thus forcibly flexed on the chest. There was found a fracture of the intervertebral substance between the sixth and seventh cervical vertebræ, and an oblique fracture of the upper sternum. Rivington believed that the forcible flexion of the chin on the sternum caused the fracture.

CASE V.—Ibid. Man, aged thirty-seven years. While walking in the street, a piece of scaffolding fell on his head, crushing his hat and tearing the scalp from the skull. It was found that he had suffered a fracture of the spinous processes of the third and fourth dorsal vertebræ, also a forward dislocation of the gladiolus on the manubrium.

CASE VI.—Ibid. A heavy bag of seed fell from a height of forty feet on a man's head, striking him between the shoulders. The spinous processes of the six upper vertebræ, the six upper ribs on the left side, and the sternum at the level of the second ribs were fractured.

CASE VII.—Hodgen.¹⁴ A man, aged thirty-eight years, fell a distance of twelve feet, striking on his shoulders and back. The usual type of sternal fracture, with fractures of the spinous processes of the sixth and seventh dorsal vertebræ, were found.

CASE VIII.—Battersham¹⁵ reported the case of a miner who was struck across the shoulders and occiput by a falling mass of coal, which "doubled him up head flexed on chest." A transverse fracture of the sternum was found at the junction of the manubrium and gladiolus.

CASE IX.—Tuttle.¹⁶ A man, thirty-four years old, dived in the surf from a wooden pillar six feet high, striking (presumably) with his hands on the sandy bottom. The attending physicians thought he must have struck his head on the sand, but as none could be found in his hair, and

there was no scalp injury, it was reasonable to suppose that the patient was in the characteristic diver's attitude at the time of the accident. On examination, a dislocation of the first and second portions of the sternum was found, together with a fracture one and three-fourths inches below the luxation.

CASE X.—Mocrlin¹⁷ wrote a thesis based on two cases. One of them was a contrecoup fracture of the sternum produced by a fall from a wagon; the other was probably due to direct violence.

CASE XI.—Cale.¹⁸ A middle-aged man was thrown from his buggy and fell on the back of his head. Extensive scalp wounds were found with a fracture of the sternum.

CASE XII.—Dubreuil.¹⁹ A mason fell from a scaffolding, striking the ground with his back. The sternum was found to be fractured in three places.

CASE XIII.—Watts.²⁰ A woman, fifty-eight years old, fell backward from a wagon, landing on her shoulders, and fractured her sternum.

CASE XIV.—Stone and Cotton.²¹ While doing gymnasium work, a boy, twenty-one years old, fell with his chin flexed on the sternum, the brunt of the fall being received on the occiput and back of the neck. The gladiolus was found dislocated behind the manubrium.

CASE XV.—Van Horn.²² A man, sixty-three years old, fell from a tree a distance of twenty feet, landing on the back of his head and shoulders and forcibly bending his body forward. A fracture at the junction of the first and second pieces of the sternum was found; also a fracture of the fourth costal cartilage on the left side.

CASE XVI.—Turner.²³ An elderly man was caught between a cross shaft and a descending elevator, his body and head forcibly flexed forward. Post-mortem a fracture of the sternum at the level of the second ribs was found, together with a laceration of the trachea and a hæmatoma at the anterior mediastinum.

We can now formulate the following propositions: (1) Contrecoup fractures of the sternum are produced in a majority of cases by falls on the head and shoulders. (2) The thorax is brought in forcible anteflexion, *i.e.*, doubled up on itself. (3) The lesion is nearly always situated at the junction of the manubrium and gladiolus. (4) The gladiolus usually overrides the manubrium. (5) The nature of the lesion will depend on (a) whether bony union of the joint had taken place, (b) on the variety of joint present. Rivington's statistics (*loc. cit.*) show amphiarthrosis, 51 per cent.; diarthrosis, 32 per cent.; intermediate (incomplete separation of the two pieces), 11 per cent.; ossified only 6 per cent. The exact mechanism of these fractures is still an unsettled point. We shall briefly review the

most widely accepted theories and endeavor to evolve from them all a "working theory" which can be applied to a majority of these accidents.

Maisonneuve²⁴ taught that contre coup fractures of the sternum were produced by falls on the scapula. On striking the ground, the scapulæ encounter a resistance which is transmitted through the clavicles to the manubrium. At the same time, the compression of the body-weight caused by the fall is brought to bear on the gladiolus through the ribs and corresponding costal cartilages. This pressure on the gladiolus is all the more powerful if the vertebral column is brought in forcible anteflexion below the level of the manubrium, because flexion of the vertebræ transmits to the gladiolus through the lower ribs a part of the shock incident to the fall. In other words, he believes that the clavicles form a solid buttress, and that in falls on the neck and shoulders they transmit the shock to the sternum from above, while the middle and lower ribs convey it from below.

Arbuthnot Lane²⁵ has shown by experiments on the cadaver that heavy blows on a padded shoulder will produce fracture of the sternum. He claims, however, that in falls causing a fracture of that bone, the force is transmitted, not from the clavicle to the sternum directly, but only through the first and second ribs. The clavicle, he says, rests on the anterior extremity of the first rib, just outside its union with the cartilage. Regarding the clavicle as a lever whose inner extremity is fixed by ligaments which connect it with the upper part of the manubrium, and so form the fulcrum, the short arm of the lever corresponds to the portion of clavicle between its inner extremity and the point where it crosses the first rib, its whole length forming the long arm. If force be applied vertically to the outer extremity of the clavicle, the manubrium is acted on by two forces in different directions, but conspiring to wrench the upper piece of the sternum from the remainder of the bone. The one force is the tension exerted on the upper part of the manubrium by the sternoclavicular ligaments; the other is a much greater force exerted on the manubrium by means of the first rib and cartilage, owing to the pressure exerted on it by

the clavicle. These two forces acting together tend to cause the manubrium to rotate around an anteroposterior axis. The essayist closed his remarks by saying, "I do not wish to convey the idea that I believe the sternum can only be broken by means of the clavicle and first rib, but that it is one means."

T. J. Tuttle (*loc. cit.*) explains contrecoup fractures of the sternum as follows: Fracture may be produced by falling upon the outstretched hands, the force being transmitted hence through the clavicles and first ribs to the upper portion of the sternum. The force thus expended on the manubrium is a downward (with reference to the body) and backward force, while that exerted upon the gladiolus by the momentum of the body and abdominal viscera through the diaphragm and lower ribs is an upward and forward one. These two forces acting at variance, a fracture or dislocation of the sternum is produced.

Helferich ²⁰ thinks that in forcible anteflexion of the head, the chin presses against the upper edge of the manubrium. The sternum is then compressed in its longitudinal axis until it snaps. If such were the case, one would certainly expect to find some injury to the soft tissues of the chin; no mention is made of such a finding in any of the reported cases. Servier (*loc. cit.*) is of the opinion that all contrecoup fractures of the sternum are produced by falls on the neck and shoulders or by pressure on the vertebral column. His theory is that falls on the head, shoulders, or back all tend to force the ribs and costal cartilages forward and upward (the body lying on the horizontal plane), *i.e.*, the ribs tend to meet in the median line. This fact he demonstrated satisfactorily on a manikin provided with flexed wires in lieu of ribs. In order to appreciate the accuracy of Servier's theory, we must consider fully the anatomic conditions confronting us. The thorax is an osseocartilaginous cage, conical in shape, being narrow above and broad below, flattened from before backward and longer behind than in front. Its posterior surface is formed by the twelve dorsal vertebræ and the posterior parts of the ribs. The anterior surface is slightly convex and inclined forward from

above downward; it is formed by the sternum and costal cartilages. The lateral surfaces are formed by the ribs and intercostal spaces (Gray). The posterior part of the thoracic cavity (*i.e.*, the vertebral column) is much more mobile than the anterior or sternal portion. The ribs increase in length from the first to the seventh, and decrease in breadth and strength from above downward. Their movements are along two axes of rotation, both tending to increase the anteroposterior diameters of the thorax.²⁷ The range of motion of the ribs increases from above downward. Movements of the costal cartilages are of necessity accompanied by an upward and forward movement of the sternum to which they are attached, this movement being greater at the lower than at the upper end of the latter bone. Of the component parts of the sternum, the first piece or manubrium articulates with the clavicles, first pair and part of the second pair of ribs. Union with the gladiolus rarely takes place except in old age (Gray, Quain, Debiere). The four segments of the gladiolus begin uniting at puberty from below upward, so that by the age of twenty-five this portion of bone consists of one piece. The gladiolus and third to seventh pairs of ribs may therefore be said to act as a unit. Quite early in life, the first costal cartilages ossify, becoming continuous with the manubrium, of which they now form a part. The second costal cartilages are united to the manubrium in the upper two-thirds of their articular surfaces by fibrillated cartilage, and lower down to the plate of fibrocartilage between the manubrium and gladiolus. The lower third of the articular surfaces of the second costal cartilages form an arthrodial articulation with the gladiolus. This explains why the second pair of ribs remains connected with the manubrium in dislocations or fractures of the sternum (Lane, *loc. cit.*). Intrathoracic pressure, *i.e.*, pressure in the thoracic cavity outside of the air-passages, is ordinarily negative, but becomes positive during forced expiration, especially if there is some obstruction to the exit of air. Sudden blows on the thorax will tend to force air out, provided the glottis is not closed.²⁸

Bearing these anatomical facts in mind, we can follow

Servier's theory, which is briefly as follows: Falls on the head, shoulders, or back press the ribs forward and upward, the range of motion increasing from the first to the seventh pair. This upward motion is perforce transmitted to the sternum, which is thus caught between two forces acting in opposite directions. The weakest portion of the sternum gives way and a fracture or dislocation results. The manubrium, being solidly fixed by the short, strong, upper ribs, retains its position, whereas the gladiolus, articulating with longer, more motile ribs, is thrown upward and overrides the first bone.

Two supplemental forces should, in our opinion, be added to those already mentioned, namely, intrathoracic pressure and the action of the second pair of ribs and costal cartilage. (a) We have already mentioned the fact that intrathoracic pressure becomes positive during forced expiration, especially when there is obstruction to the exit of air from the lungs. This is precisely the condition present at the time of a fall. The person draws a sudden deep breath and closes the glottis. The shock of the fall tends to force air from the lungs, but the tense glottis prevents its immediate escape, and positive pressure is exerted against the thoracic wall. We can thus consider the thorax as a temporarily closed cavity and look upon fractures of the sternum as due in part, at least, to a "bursting" force, similar to that which is present in contrecoup fractures of the skull. (b) The second pair of costal cartilages are united to the manubrium by fibrillated cartilage, but form an arthrodial articulation with the gladiolus. The forward and upward movement of the ribs in falls on the head or shoulders tends to wedge the second costal cartilages between the two portions of the sternum, producing a diastasis or fracture of the intervening cartilage.

SUMMARY OF FACTORS PRODUCING CONTRECOUP FRACTURES OF THE STERNUM.

(1) Falls on the head or shoulders press the ribs forward and upward, the range of motion increasing from the first to the seventh pair.

(2) The clavicles may sometimes act as a lever and help to wrench the manubrium from the gladiolus. This is especially true in falls on the extended hands.

(3) Intrathoracic pressure at the time of the fall exerts a positive pressure on the thoracic wall.

(4) The second costal cartilages act as a wedge, tending to separate the manubrium from the gladiolus.

Pathologic Anatomy.—Rivington's statistics show that only in 6 per cent. of all cases does there exist bony ankylosis of the manubrium and gladiolus. A genuine fracture can therefore only occur in a comparatively small percentage of cases. Rivington's "intermediate cases" (11 per cent.) can be added to the genuine fractures, as in them there is at least superficial ossification of the sutural cartilage. It is probable that in a small proportion of the specimens classed as amphiarthrodial, there was some cartilaginous or fibrous union between the manubrium and gladiolus. We must nevertheless conclude that a majority of the so-called fractures of the sternum are in reality dislocations, with or without rupture of the sutural cartilage. Ashhurst²⁰ correctly said that dislocations were usually due to contrecoup or muscular action, whereas fractures were usually the result of direct violence. He, however, incorrectly advises us to infer dislocation and absence of fracture when the gladiolus overrides the manubrium. The anterior sternal ligament is torn whenever the lower fragment overrides the upper one. The posterior ligament is partly detached but remains intact. The second pair of ribs remains with the manubrium. Union may be bony or fibrous. Arbuthnot Lane (*loc. cit.*) has seen several cases of ununited fracture of the sternum in the dissecting-room.

Diagnosis.—Hamilton (*loc. cit.*) wisely states that "the frequent occurrence of congenital malformations of the sternum should warn us to exercise great care in our examinations, lest we mistake these natural irregularities for fractures." The same writer includes fractures and dislocations of the sternum in all of his remarks, as he very properly asserts that a differential diagnosis between these two conditions is usually impos-

sible. The classical symptoms of fracture or dislocation of the sternum are: (1) Severe pain at the junction of the manubrium and gladiolus; this pain increases during inspiration, coughing, or attempting to move the head in any direction. (2) The patient's attitude is rather characteristic. He stands or sits with head bent forward and usually to one side; respirations are short and shallow, and movements of the head or thorax are slow and cautious. A severe case of torticollis would give the same picture. (3) On inspection, a rather sharp bulging is seen just above the level of the second costal cartilage. (4) Palpation may or may not elicit crepitus; the gladiolus overrides the manubrium in 85 per cent. of all cases. Malgaigne (*loc. cit.*) states that with flexion of the head and overriding of the fragments one can diagnose a fracture due to forward flexion of the thorax; absence of overriding or diastasis of the sternum indicate fracture due to backward flexion of the thorax. (5) Percussion is negative unless a hæmatoma of the anterior mediastinum has formed, in which case we may find impaired resonance over the upper retrosternal region. We have found no cases of compound fracture due to contrecoup.

Prognosis.—The majority of cases make a very satisfactory recovery, regardless of the form of treatment instituted. Fatal issues are all due to associated injuries or complications following the injury. Fracture of the trachea, hæmatoma, emphysema, bronchitis, and fatal shock have occurred in these cases. In uncomplicated fractures, the fragments unite rapidly (three to four weeks), but the fracture is not solid for eight weeks. Union by overlapping is the rule, but function is restored.

Treatment.—The severe pain may require opiates during the first forty-eight hours. The patient should be kept in his room, well protected from sudden chilling of the body, as bronchial affections are to be avoided on account of the extremely painful coughing which they induce. Hot applications in the form of poultices or plastic dressings are very grateful to the patient. When lying down, a small, hard pillow should be placed between the scapulæ, and the head should be low.

Actual reduction of the displacement may be easy or impossible, and once reduced, the fragments tend to spring back to their former malposition. Stone and Cotton (*loc. cit.*) reduced a fracture in the following manner: The patient was placed so that the angles of the scapulæ rested on the end of the operating table, while an assistant lay across him and fixed the legs and pelvis. The spine was then strongly extended by traction downward, applied to the chin and occiput, and the arms were brought upward and outward, the patient resisting the outward rotation. He was then directed to cough and the fragments readily slipped back. The object of the outward rotation of the arms was to give more direct traction, through the tense pectorals, on the upper rib insertion of the muscles and so, indirectly, on the manubrium. Plaster-of-Paris jackets were satisfactorily used by Cale and Hodgen. A pad on the lower fragment, with figure-of-eight bandage to keep the shoulders pulled backward, may be sufficient. A Taylor steel back brace with apron and head support may be necessary in order to immobilize the fragments. Operative treatment is only indicated in the presence of alarming pressure symptoms as evidenced by cynaosis and dyspnoea, or when an abscess of the anterior mediastinum has occurred. A median incision over the upper sternum is made, and reduction accomplished by means of hooks or tenaculæ. A gimlet may be used to elevate the fragment. Trephining the sternum has been resorted to when drainage is required. Ligation of the internal mammary artery has been necessary. While the sternum is broken less often than any other bone (1 per cent. of all fractures, according to Hoffa), we would conclude this paper by advising a routine examination of the anterior thoracic wall after all falls on the head, shoulders, extended arms, or pelvis.

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