FRACTURE OF THE ATLAS VERTEBRA.

REPORT OF FOUR CASES, AND A REVIEW OF THOSE PREVIOUSLY RECORDED.

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Fractures of the atlas vertebra form one of those categories of rare accidents possessed of a considerable interest. This is particularly true of the cases in which the injury has not been attended by fatal results. My attention having been drawn to the subject by two recent cases, I turned to the literature, and found that so few cases had been recorded, and these in such diverse places, that it seemed well they should be collected together under one head, so that a clearer picture might be obtained of the types of fracture, its concomitant symptoms, and the results which are to be expected from it. My first impression was that fracture of the atlas would be almost invariably followed by death. Greater

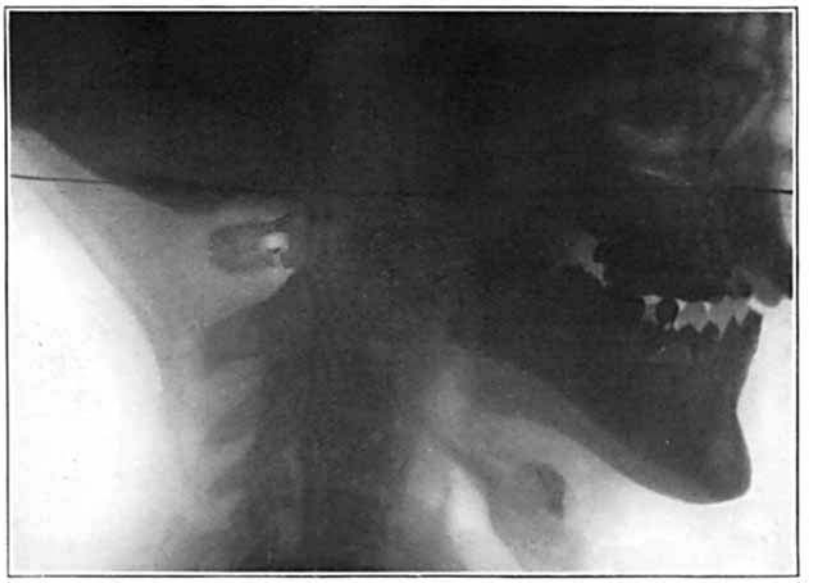

Fig. 370.—Fracture of the posterior arch of the atlas vertebra in two places. Second cervical vertebra intact.

knowledge of the subject has, however, modified this opinion. No doubt, if the atlas was morphologically similar to the other vertebræ, death would be the common result of fracture. But the atlas presents so many peculiarities of shape, function, and relationship, that the accidents which may happen to it present many differences from those to which the other vertebræ are heir. The most interesting aspects of the question are the genesis of atlas fracture, the mechanism by which it comes about, and the displacement which follows. I have attempted below to explain these, and to give a new and more physiologically accurate account of the manner in which injuries, and more particularly fractures, of this vertebra are brought about.

I am able to report one clinical case of fracture of the posterior arch, one of fracture

of the left lateral mass by a gunshot injury, and two pathological specimens hitherto undescribed—one from the Museum of the Royal College of Surgeons, the other from the Pathological Museum of Manchester University.

Case 1.—Lieut. B., R.A.F., dived his machine into a bank of telegraph wires on a misty morning, Jan. 1, 1919. He struck the wires on the level, travelling at about 120 miles per hour. He remembers seeing pieces of propeller, wing, and strut fly past him, and then nothing more. It appears that he was thrown out of the plane, and fell some distance on to his head. He recovered consciousness twelve hours later in a C.C.S. and says "he felt very fit," except that his neck was stiff and sore. No neurological signs were detected; no headache.

He was admitted to No. 14 General Hospital two days later. His general condition was so good, and he made so light of his symptoms, that no serious injury was suspected. The stiffness of the neck persisting, he was radiographed, and I was asked to see him by Captains Gardiner-Hill and D. H. Fraser. The patient complained of deep-seated pain in the upper part of the neck, and inability to nod his head. The most painful movement was extension of the head, no doubt because this movement tends to compress the arch of the atlas between the occiput and the axis. Flexion of the head was possible through a few degrees only, and rotation was quite painless, so that he could look over his shoulder. All movements needed time, and were executed slowly. He raised himself in bed with a very characteristic action, placing his left hand under the suboccipital region as a support, and then, catching hold of the side of the bed-frame with his right hand, he pulled himself up into the sitting posture. On examination there was no swelling of the neck, but there was distinct tenderness on deep pressure in the suboccipital triangles behind. Pressure on the anterior arch of the atlas through the mouth produced no pain, nor was anything abnormal to be felt there. There were no signs of cord injury, a neurological examination being negative; no difficulty in swallowing, and neither neuralgia nor anæsthesia in the distribution of the great occipital nerve. Captain Dale's radiograph (*Fig.* 370) shows the posterior arch of the atlas fractured in two places at the site of the groove for the suboccipital nerve and occipital artery. The fragments are not displaced, being held in excellent position by the ligaments and periosteum. This lack of displacement, no doubt, accounts for the absence of cord or nerve injury. An antero-posterior view through the mouth revealed an intact odontoid process. The fracture is, therefore, an 'isolated' atlas fracture.

A Lorenz plaster bed was made for the patient, and he was transferred to England. A later *x*-ray photograph showed positive signs of new bone formation at the sites of the fracture of the neural arch. He remained in the Lorenz bed for two months; convalescence was smooth.

I saw him again three months later, and he had practically quite recovered. The head was held a little stiffly as he walked, but movements were free and painless:

Case 2.—Pensr. J. C., age 22. Gunshot wound of neck, Oct. 4, 1917. Entrance over the angle of left mandible, exit just below inion. From the position of the wounds it is evident that the track of the bullet involves the left lateral mass of the atlas. The head is held very stiffly; true power of movement in the occipito-atlantal joint is almost nil. He nods stiffly with his neck, flexing and extending through the lower cervical joints. The same is true of lateral movement: His main trouble is occipital neuralgia, which is severe. The scalp is hypersensitive in this area, and he cannot brush his hair. A radiogram shows an indefinite irregularity in the shadow of the left lateral mass. It is difficult to make out whether the occipito-atlantal joint surfaces are affected.

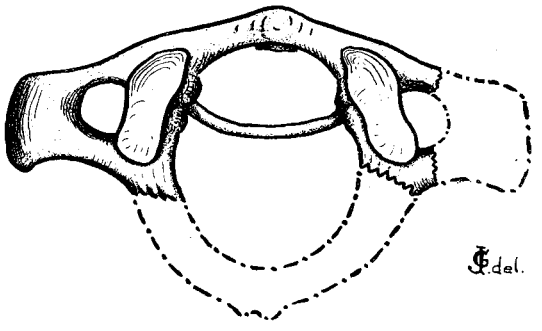

FIG. 371.—Fracture of the posterior arch of the atlas vertebra in two places, with fracture of the right transverse process. Fractured parts missing. Royal College of Surgeons Museum, Catalogue No. 2021.

Case 3.—*Museum Specimen No.* 2021, *Royal College of Surgeons. Series, Diseases of the Vertebral Column.*

This dry specimen (*Fig.* 371), originally in the private collection of Mr. Langstaff, consists of the upper three cervical vertebræ of a man thrown from his horse and instantaneously killed. The posterior arch of the atlas was broken off and is missing. The fracture runs through the groove for the suboccipital nerve and vertebral artery on each side. The right transverse process is also broken off and missing, the fracture passing through the foramen for the vertebral artery. The odontoid process and axis are intact; the transverse ligament is unruptured. The notes in the catalogue state that the spinal cord and dura mater were lacerated, but beyond this there is no description.

Case 4.—*Manchester University Pathological Museum. Specimen No.* 738.

This dry specimen consists of the articulated atlas and axis vertebræ (*Fig.* 372). The atlas ring is broken at two points, the anterior arch near its junction with the left lateral mass, the posterior arch on the left side also. The atlas is a strong one and the posterior arch firmly moulded. The atlas fracture is complicated by a break of the odontoid, the upper half of this process being wanting. No clinical history is attached to this specimen, but that the patient survived the accident for a time is evidenced by a slight bone-formative process in front.

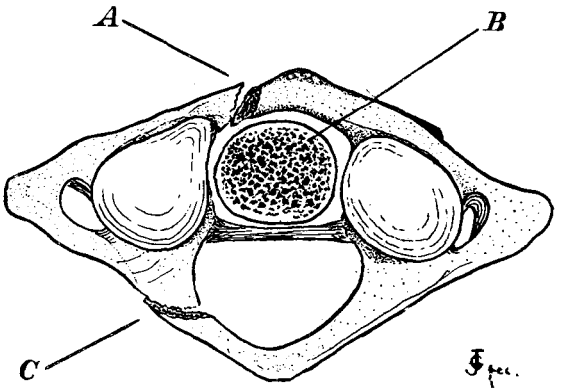

FIG. 372.—Fracture of the anterior (A) and posterior arch (C) of the atlas vertebra. Fracture of odontoid process (B) of axis. Manchester University Pathological Museum, Catalogue No. 738.

Cases 1 and 3 are examples of a precisely similar injury, the 'isolated atlas fracture' of German writers. In *Case* 4 the fracture of the atlas is complicated by an injury to the odontoid. Of the four cases, only *Case* 3 ended in sudden death, from laceration of the lower end of the medulla and cord; *Case* 4 appears to have survived the injury for a time, whilst *Cases* 1 and 2 recovered completely.

From so small a number of cases it is impossible to draw any valuable deductions as to the mode of fracture and its usual result. The injury is not a common one, though not so uncommon as might be thought. I have been at considerable pains to collect the cases in which fracture of the atlas has been described by previous writers. I found 18 cases of isolated atlas fracture, and 24 in which another vertebra had suffered hurt at the same time, 46 cases in all, counting the 4 just described. In the tables appended will be found the salient points of the known examples; the cases are arranged in the alphabetical order of the reporters' names. As the circumstances in which the injury has been brought about are important for a consideration of the mechanism of the fracture, I have indicated the nature of the accident in each case. A bibliography will be found at the end of the paper.

Table I.—**ISOLATED FRACTURES OF ATLAS—21 CASES.**

AUTHOR	NATURE OF ACCIDENT	CLINICAL SIGNS OF CORD OR NERVE INJURY	ANATOMICAL DIAGNOSIS	RESULT
No. 1. Betz	Fell on neck and shoulder	Progressive paralysis of arms and legs	Isolated fracture of posterior arch of atlas	Died 3 months later. Half-cm. piece of bone driven against medulla. Focal hæmorrhage in medulla
No. 2. Cooper, Astley (Cline's case)	Severe fall, injuring neck (3-year-old boy)	None	Both arches of atlas broken across	Died 12 months later (intercurrent disease presumably). No mention of condition of cord at autopsy
No. 3. Corner	Rolled out of chair with head flexed	No cord signs. Severe neuralgia great occip. nerve	Fracture of atlas	Recovered
No. 4. Delorme	Gunshot wound of neck	None	Fracture posterior arch of atlas. Vertebral artery compressed by bone fragments	Died 10 days later as a result of secondary hæmorrhage. Internal carotid had been severed

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Table I, continued.—Isolated Fractures of Atlas.

Author	Nature of Accident	Clinical Signs of Cord or Nerve Injury	Anatomical Diagnosis	Result
No. 5. George	?	No clinical details	Fracture post. arch of atlas, two places	Presumed recovered
No. 6. George (Butler's case)	?	No clinical details	Fracture post. arch of atlas, one place	Presumed recovered
No. 7. Holding	Fell down stairs on to back of head and shoulders	No cord signs. Severe occipital neuralgia	Isolated fracture of atlas	Recovered
No. 8. Jefferson	Aeroplane crash; fall on to head	None	Fracture post. arch of atlas, two places	Recovered
No. 9. Jefferson	Gunshot wound	None. Neuralgia left great occipital nerve	Fracture left lateral mass	Recovered
No. 10. Jefferson (Langstaff's case)	Thrown from horse	Laceration brain stem	Fracture post. arch of atlas, two places	Died immediately
No. 11. Ludloff	? (See bibliographical note)	?	Fracture left lateral mass of atlas	Recovered
No. 12. Marshall, J.	Fell from second storey window	Monoplegia right arm, progressing to triplegia, both arms and right leg	Fracture right lateral mass of atlas	Died 9 days later, infection of fracture, with myelitis of cord
No. 13. Milner	Fell off roof, neck probably flexed	Medulla divided	Posterior arch of atlas fractured in two places. Complete dislocation of occiput from atlas	Died instantaneously. Medulla found divided at post-mortem
No. 14. Park	? (See bibliographical note)	?	Fracture anterior arch of atlas	Recovered. Caries of atlas, extrusion of sequestrum by the mouth 45 days later
No. 15. Quercioli	Fell from tree	No limb palsies. Dysphagia	Atlas broken into four pieces by symmetrical fractures of both arches	Died 13 days later from pneumonia ab ingestis. Cord found uninjured at autopsy
No. 16. Schneider	Fell down stairs	Monoplegia right arm; recovered	Fracture anterior arch of atlas	Recovered.
No. 17. Smith	Shot through mouth (suicide)	Monoplegia right arm	Fracture anterior arch of atlas	Died suddenly 6 weeks later, myelitis of brain stem
No. 18. Stokes	Shot in neck	Clinical signs of spinal meningitis	Fracture right upper articular facet of atlas	Died 6 days later, suppurative meningitis
No. 19. Sicard and Roger	Bale of paper dropped on to head from a height	No cord signs. Anæsthesia left great occipital nerve	Fracture posterior arch of atlas, left side	Died 1 month later of pneumonia. No injury to cord; left suboccipital nerve almost divided by bone fragment
No. 20. Sicard and Roger	Fell 6 feet on to head	No cord signs. Anæsthesia left great occip. nerve	Fracture posterior arch of atlas, left side	Recovered
No. 21. Sicard and Roger	Struck by a beam on left side of back of head and neck	No cord signs. Anæsthesia left great occipital nerve	Fracture posterior arch of atlas, left side	Recovered

Of the 21 cases in *Table I*, 7 died as a direct result of the injury (i.e., *Cases* 1, 10, 12, 13, 15, 17, 18), or 35 per cent, and 3 more from other causes (*Cases* 2, 4, 19). Only 2 were killed outright, and 11 recovered (50 per cent). In 6 the cause of death was injury or infection of the cord and meninges (*Cases* 1, 10, 12, 13, 17, 18). In Quericoli's case the head hung forward on the sternum, the patient could not swallow, and he died from inspiration pneumonia. Delorme's case died of secondary hæmorrhage from the internal carotid (a gunshot wound). There is no evidence that Astley Cooper's case, a little boy of three, died as the result of the injury. Most writers have taken it for granted that he died of intercurrent disease, but actually Cooper says nothing of the cause of death.

Of the 11 patients who recovered, all seem to have done well. It is noteworthy that only Schneider's case had a cord injury, resulting in a limb palsy, and this passed away. Six are stated to have had either neuralgia or anæsthesia of the great occipital nerve.

Table II.—**COMPLICATED FRACTURES OF ATLAS—25 CASES.**

Author	Nature of Accident	Clinical Signs of Cord or Nerve Injury	Anatomical Diagnosis	Result
No. 1. Van Assen	Fell 13 feet head foremost	No cord signs. Occipital neuralgia	Fracture both arches of atlas. ? Fracture of odontoid. ? Rotatory dislocation of atlas on axis	Recovered
No. 2. Bell, Charles	Fell 50 feet on to shoulders	— —	Fracture (? posterior) arch and portion of body of atlas. Odontoid process broken off	Instantaneous death, presumably from medullary injury. Autopsy, but no mention of condition of brain stem
No. 3. Berndt	Fell forwards down steps	Diplegia right arm and leg, anæsthesia of left side (Brown-Séquard palsy)	Transverse fracture anterior arch of atlas. Odontoid broken off. Rotatory dislocation of atlas on axis	Died one month later. Compression of right half of cord, no gross lesion of brain stem
No. 4. Blackwood	Fell 4 feet on to right side of head	Total paralysis below level of larynx. Kept alive for 34 hours and 40 mins. by artificial respiration	Atlas fractured in 3 places, both arches. Odontoid broken off. Dislocation of occiput on atlas	Died 35 hours later, hæmorrhage into cord from level of foramen magnum to third cervical vertebra
No. 5. Blanc	Hit on back of neck with heavy timber, head flexed	Concussion. Diplegia both arms	Fracture of atlas. Fracture of axis. Forward luxation of atlas on axis	Recovered. Palsies improved when seen 6 years later
No. 6. Boeckel	Fell some 12 feet head foremost on to sand	None	Fracture right lateral mass of atlas. Rotatory dislocation of atlas on axis	Recovered
No. 7. Brooks	A fall. No details	Monoplegia left arm. Speech thick	Fracture of both arches of atlas in two places. Odontoid broken off	Died suddenly 24 hours later, presumably from injury to cord
No. 8. Corner	Fell off horse on to forehead	Dysphagia and thick speech. No affection of limbs	Fracture of anterior arch of atlas. Rotatory dislocation of atlas on axis. Condition of odontoid doubtful	Recovered

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Table II, continued.—Complicated Fractures of Atlas.

Author	Nature of Accident	Clinical Signs of Cord or Nerve Injury	Anatomical Diagnosis	Result
No. 9. Corner	Museum specimen, history unknown	—	Atlas mis-shapen by healed fractures: (1) Comminuted fracture right lateral mass; (2) Fracture posterior arch in centre. Atlas ankylosed to occiput. Fracture body of axis	Survived some time
No. 10. Hamilton	Fell 40 feet on to vertex	Paraplegia below the nipple level. Arms normal	Fractures of both arches and right transverse process of atlas. Odontoid uninjured. Fracture 6th cervical vertebra	Died 48 hours later. Cord compressed at level of 6th cervical vertebra
No. 11. Jefferson	Unknown (museum specimen)	Unknown	Fracture of anterior and posterior arches of atlas. Fracture of odontoid	Lived a short time
No. 12. Kocher	Fell 10 feet on to head	None	Probable fracture of atlas and of odontoid	Recovered
No. 13. May	Fell 15 feet on to back of head	No definite cord signs; fully recovered later	Fracture of posterior arch of atlas. Odontoid broken off. Rotatory dislocation atlas on axis. Fracture transverse processes 5th and 6th cervical vertebrae	Died 3½ years later, maniacal, suffocated with piece of meat. Groove for first cervical nerve found absorbed at autopsy. Cord normal
No. 14. McCarthy	Fell head foremost down hold	Quadriplegia arms and legs	Atlas broken into five fragments. Odontoid broken off	Died 3½ days later. Cord concussed, no compression
No. 15. Melchiori	Fell off ladder	—	Posterior arch of atlas broken in two places. Odontoid broken off. Dislocation atlas on axis	Died instantaneously. Brain stem compressed
No. 16. Mixter and Osgood	Fell down 13 stairs	Severe occipital neuralgia. No cord signs	Fracture of anterior arch of atlas. Rotatory dislocation of atlas on axis	Recovered
No. 17. Mixter and Osgood	Railway accident	All four limbs became spastic 2½ months after accident	Fracture posterior arch of atlas. Complete dislocation of atlas on axis	Died suddenly one month after laminectomy and five months after injury. No autopsy.
No. 18. Mixter and Osgood	Fell from a height on to right side of head and neck	Right occipital neuralgia. Monoplegia right arm	Fracture posterior arch of atlas, right side. Rotatory dislocation of atlas on axis	Recovered
No. 19. Phillips	Fell off hay rick on to occiput	None	Fracture posterior arch of atlas in two places. Dislocation of remaining part forwards. Odontoid process broken off	Died 47 weeks later of anasarca (? nephritis). Fracture had done well.

Table II, continued.—Complicated Fractures of Atlas.

Author	Nature of Accident	Clinical Signs of Cord or Nerve Injury	Anatomical Diagnosis	Result
No. 20. Picqué (Billot's case)	Fell 11 feet	Difficulty in swallowing, no limb palsies	Fracture of anterior arch of atlas. Rotatory dislocation atlas on axis	Recovered
No. 21. Pilcher	Fell 15 feet on to forehead	Diplegia right arm and leg, improved by laminectomy. Palsy developed 2½ months after accident. Occipital neuralgia	Fracture lateral mass of atlas, body of axis compressed. Rotatory dislocation of atlas on axis, with which it is ankylosed	Recovered. Seen 9 years later: right hand weak, leg recovered
No. 22. Scott	Hit on back of neck with heavy stick	None. Walked about	Fracture of both arches of atlas in middle. Odontoid broken off	Died 10 days later of tetanus. Cord normal
No. 23. South	Fell downstairs	Quadriplegia, with hyperæsthesia right half of body	Atlas broken in two places. Odontoid broken off. Fracture 5th cervical vertebra	Died 5 days later. Hæmatomyelia level of 5th cervical vertebra.
No. 24. Spangenbern	Fell off horse on to head	None	Fracture posterior arch of atlas. Odontoid broken off	Died 15 months later Osteomyelitis of atlas and axis. Cord normal
No. 25. Speyer	Fell on head	Monoplegia right arm, progressing to other limbs	Fracture both arches of atlas. Odontoid broken off	Died 10 days later. No gross injury to cord. Blood extravasation over medulla

Of the 25 cases in *Table II* of atlas fracture complicated with injury to other vertebræ, 10 died from cord injury (*Cases* 2, 3, 4, 7, 10, 14, 15, 17, 23, 25), 1 from tetanus (*Case* 22), 1 from nephritis (*Case* 19), and 1 was accidentally choked long after the accident (*Case* 13). The last 2 cases might be regarded as recoveries, as was Corner's second case, in which the cause of death is not known (a museum specimen). In the specimen which I have described, the bone reparation is not so extensive as to suggest that the patient long survived. Only 2 of these 25 cases were killed outright (*Cases* 2, 15). Signs of cord injury were present in 3 out of the 10 cases which recovered (*Cases* 5, 18, 21)). Blanc's case had a severe cerebral contusion which may have contributed to the palsies. Only 10 cases recovered (*Cases* 1, 5, 6, 8, 12, 13, 16, 18, 20, 21).

The bone most commonly involved in the injury in addition to the atlas was the odontoid process. The next most common injury was a subluxation of the atlas on the axis, and less commonly a fracture of a vertebra at a distance.

Table III.—Complicated Atlas Fracture.

Nature of Supplementary Injury.		Total
Fracture of odontoid	certain	15
	doubtful	2
Fracture of axis		2
Fracture of lower cervical vertebræ	V.	1
	V. and VI.	1
	VI.	1
Dislocation of atlas on axis	certain	11
	doubtful	1

Taking the whole series of 46 cases, there were 16 deaths from cord injury, and this is commoner in the complicated than in the isolated fractures, roughly in the proportion of three to two. Signs of cord injury were lacking in 19 fractures—11 isolated and 8 complicated. This shows that fracture of the atlas does not itself produce the cord laceration so readily as does fracture of another vertebra.

Site of Fracture of the Atlas Ring.—Before passing to the mechanism of fracture, some necessary information must be obtained as to the site of the break. The reader will perhaps excuse a reference to some elementary, yet fundamental, points in anatomy. The atlas consists of two strong lateral masses which articulate above with the occipital condyles, and below with the axis. The articular facets which the lateral masses bear are very obliquely placed—the superior pair looking upwards, inwards, and backwards; the inferior pair downwards and inwards. The importance of these inclinations will be explained later. The two lateral masses are held together by two bony arches, an anterior and a posterior, so completing the characteristic ring, the long axis of which is from before backwards. The anterior arch articulates by its posterior surface in the middle third with the anterior surface of the odontoid process. The posterior arch is free, and separated from the occiput above and the spinous process of the axis below by a space, which can be only slightly lessened by extreme backward extension of the head. The bones never come into contact normally (*see* Hultkranz, Fick). The two arches are thick in the middle, where the chief ligaments and muscles are inserted, but are considerably thinner at the sides, where they join the lateral masses. This is particularly true of the posterior arch, for the groove for the vertebral artery and suboccipital nerve (sulcus arteriæ vertebralis) reduces the bone to slender dimensions at the sides. The anterior arch is considerably shorter and is stronger than the posterior, owing to the calls made upon it by the odontoid. Ordinarily both arches are fully stout enough to resist the wear and tear of shocks and movement, yet they are the weak points in the atlas ring. The lateral masses are strong and reinforced by trabeculæ, and are not likely points for fracture. That these anatomical deductions are correct may be seen from the following table, compiled from the cases enumerated in *Tables I* and *II* (gunshot wounds being omitted).

Table IV.—Sites of Fracture of the Atlas Vertebra.

Sites of Fracture	In Isolated Atlas Fracture	In Complicated Atlas Fracture	Total
Posterior arch alone	9	6	15
Anterior arch alone	2	4	6
Both arches	2	8	10
Lateral masses alone	3	2	5
Lateral masses and posterior arch	0	2	2

From this it will be seen that the posterior arch was broken in 25 cases in all, the anterior in 16, and the lateral masses in 7 only. These figures confirm our anatomical surmises.

MECHANISM OF ATLAS FRACTURE.

Fracture of the first cervical vertebra, whether in its isolated or complicated form, is so uncommon that it is evident that the forces necessary for fracture must be peculiar. In Gurlt's often-quoted series of 178 fractures of the cervical spine, there were only 6 atlas fractures, no less than 90 being of the 5th and 6th cervical vertebræ; from which it is evident that the spine is more easily broken in its lower part than in its upper. Wagner and Stolper, in their flexion experiments, were able to produce fractures of the lower cervical vertebræ only, although they specifically tried to break the atlas. It is evident that the common mechanism of fracture of the vertebræ, namely flexion and compression leading to compression of the vertebral bodies, cannot be called to account

here, for the atlas has no body. Stephen Smith unsuccessfully attempted to produce fractures of the two upper cervical vertebræ by allowing bodies to fall on their heads, whilst his remaining experiments simply demonstrate the tensile strength of the atlas and axis.

Direct violence as a cause of fracture can be ruled out as of little importance. The atlas is so deeply situated, and so well protected by muscles, that the only form of direct violence which can be relied upon to break it is a gunshot wound. I have included four cases of fracture by firearms. In number they are insignificant in comparison with the atlas wounds which the Great War must have produced. Of such, I have personally seen only one case, outlined above.

Excluding injuries by direct violence, we pass on to those produced by *indirect* means: this is by far the most interesting category, and the three possible mechanisms may be summarized as follows: (1) Fractures of one or both arches by transmitted force causing lateral spread of the bone (the odontoid perhaps broken in addition by pressure of the distorted anterior arch). (2) Fracture of the posterior arch by a crush between the occiput and neural arch of the axis, the head in full extension. (3) Fracture of the anterior arch by means of the odontoid, the head in full extension.

1. **Mechanism of Transmitted Force.**—Reference to *Tables I* and *II* shows that the common accident causing a fracture of the atlas is a fall upon the head. In one or two cases patients have been struck upon the head by a falling object, which amounts to the same thing. The essential feature of the injury lies in the transmission of force from the vertex through the occipital condyles to the vertebral column. In order fully to appreciate the paths that the lines of force must traverse, the mechanics of the injury must be discussed. The man's head on striking the ground is subjected to a force that can be approximately measured.* This force received by the cranium is finally collected at the base of the skull, and transmitted to the atlas by the occipital condyles. But since any force operates equally in opposite directions, each segment can be considered separately as suffering compression between two opposing forces. We may therefore take the skull, the atlas, the axis, and each succeeding vertebra, and consider each as being crushed by a known force. To take the first two only: in the case of the skull, some of the force is distributed to the brain and lost, and, if the cranium itself is distorted beyond its limits of elasticity, a fracture will take place, usually of the basis cranii. If no energy is dissipated through such a happening, the force passes on to the atlas in almost undiminished quantity. The occipital condyles themselves usually escape injury, presumably on account of the elasticity of the cranium upon which they are mounted. A case is, however, recorded by Sir Charles Bell, and another by Kissinger. As the atlas has no centrum, the whole of the force must pass through the planes of its articular facets, and therefore through the lateral masses, the anterior and posterior arches playing no part in its transmission. One would assume from this that fracture of the lateral masses would be the commonest fracture, but we have seen that this is far from being the case. We shall see that the reason for this lies in the inclination of the planes of the articulations on the upper and lower surfaces of the lateral masses.

In order to make this clearer, let us next consider the atlas as being compressed between two opposing forces in the same manner as we have briefly outlined for the skull. The atlas is crushed on the one side between the skull in contact with the ground and the forces operating upwards through it, and on the other side by the axis and the succeeding vertebræ representing the resistance of the body weight acting downwards. The force operating from the cranial side will necessarily be along a line at right angles to the plane of the articular surface of the occipital condyles, i.e., from above downwards and outwards and slightly forwards (*see Fig.* 373).

The resistance to the force presented by the vertebral column passes through the

*The force can be measured, if the patient has fallen from a height on to his head (as in most of these cases), by multiplying the body weight by the height fallen. Thus, an average force will be about 1400 foot-pounds, the weight being taken as 140 lb. and the height fallen as 10 feet.

atlanto-axial joints, and must therefore be charted graphically by a line running upwards, outwards, and slightly backwards (*Fig.* 373). The atlas is therefore subjected to two forces passing through it in opposite directions and on divergent lines. The crush between the occiput and axis is not a vertical one from above downwards; the lines of force diverge

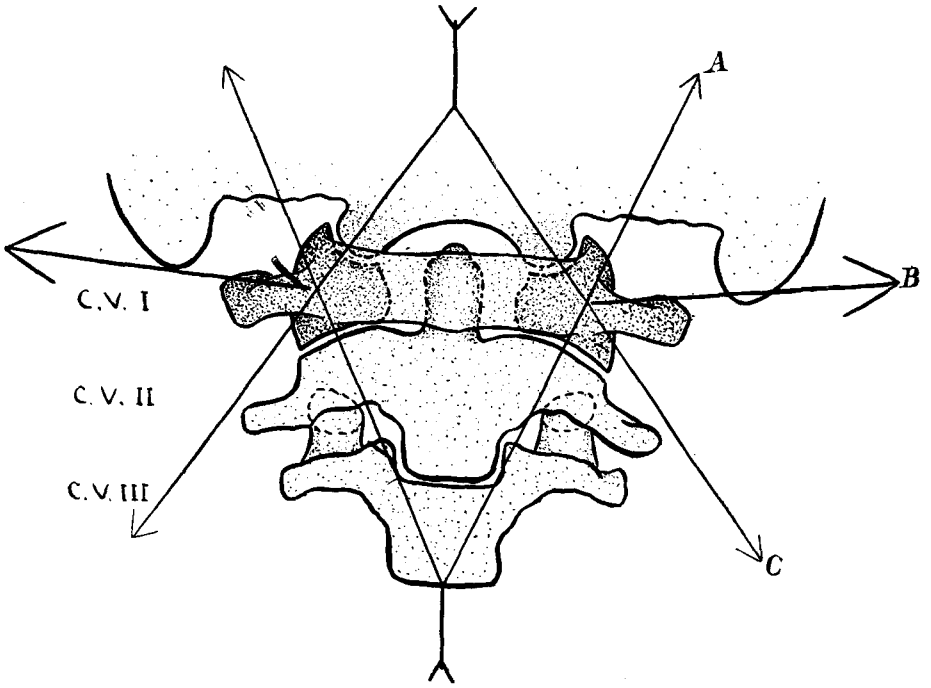

FIG. 373.—Schematic representation of the transmission of force (A and C) through the occipital condyles to the atlas, axis, and vertebral column. Note that the resultant (B) of these forces is more or less horizontal, and 'spreads' the atlas laterally.

widely, and resolve themselves, as a simple knowledge of mechanics tells us, into forces which are the mean of those already described. The direction of this force is a horizontal one, and the nett result of the crush of the atlas is, therefore, a lateral spread, a separation of the two lateral masses from one another, and a consequent tension fracture at one or more of the weak points in the atlas ring (*see Fig.* 374). This explains why the arches suffer more frequently than do the lateral masses themselves, although the latter are the paths through which the forces run.

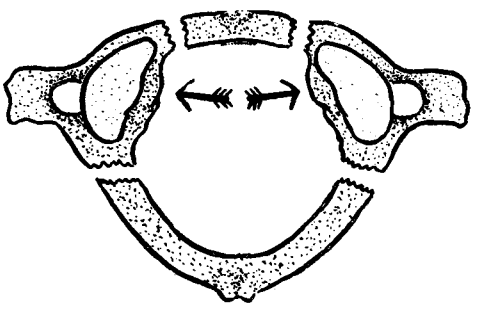

FIG. 374.—Atlas viewed from above to show the result of 'spreading,' the bony arch yielding at its weak points.

The character of the injury to the atlas will vary according as the force passes equally through the two condyles, or passes in greater proportion through one lateral mass, as will occur if the head is deviated from the true sagittal plane at the moment of impact with the ground. When the head is much inclined to one side, as it must sometimes be in these accidents, a more direct compression of one lateral mass than the other will occur, with perhaps a local fracture, but even in this case a tension fracture of one or other of the arches may accompany it.

To sum up, I suggest that fractures of the atlas ring by indirect violence are tension fractures: that they are due to divergent lines of force passing through the bone, separating the lateral masses from one another, deforming the atlas into an oval with its long axis from side to side instead of from before backwards, with consequent fracture at the weak points in the ring. The posterior arch being distinctly weaker than the anterior, this will be the one which most frequently gives way on one or both sides. Individual peculiarities and predisposition to fractures may also influence the site of fracture.

2. **Fracture of the Posterior Arch by a Crush between the Occiput and Neural Arch of the Axis, the Head in full Extension.** — The articulation of the atlas with the skull depends so largely on muscles for its strength, that a sudden blow or jerk is liable to obtain a 'flying-start,' as Corner has expressed it, and the head is thrown violently backwards. When the head is in extreme extension, the occiput, the posterior arch of the atlas, and the posterior arch and spine of the axis become crowded together. Normally these can never be made to touch, but it is just possible that, with a very powerful and severe extension beyond the limits of the normal, such as would occur if a man fell from a height upon his forehead or if his head were suddenly and violently jerked backwards, the bones might come into contact, and the weak posterior atlantal arch be nipped and broken between the occiput above and the axis below. Reference to *Fig.* 370, and to Hultkranz's radiographs of the normal movements of the head (*loc. cit.*, *Plates I* and *II*) will make this clearer. Plausible though this theory sounds, it is probably not the usual mechanism; for, although it is possible to make the bony parts in question approach one another, it is impossible to bring them into contact without dislocating the vertebræ. Nor will it account for fractures of the lateral masses.

Traction on the trunk with the head fixed spares the atlas, but may cause a low cervical fracture. Truesdell figures an excellent example of a birth injury of this nature (*loc. cit.*, *Fig.* 19). Similarly, hanging does not affect the atlas, and, as is now known, rarely injures the odontoid or transverse ligament. The usual injury is a depressed fracture of the neural arch of the axis, severing the cord (*see* Wood Jones' account of Fraser's cases, and Haughton).

A careful study of the accounts of the accidents in the hitherto reported cases affords little evidence that extreme extension of the head has been a common feature. In some cases it is definitely stated that the head was flexed at the moment of striking the ground; in most it would appear that they were the result of falls upon the vertex cranii.

3. **Fracture of the Anterior Arch by means of the Odontoid, the Head in full Extention.**—During extension of the head, the atlas comes into close contact with the odontoid process; and with extreme force, fractures either of atlas or odontoid might conceivably result. By the 'mechanism of transmitted force' the anterior arch of the atlas comes into very close contact with the odontoid, owing to the deformity of the conformation of the atlas ring. It seems at any rate very possible that the atlas and odontoid may both be fractured by this means. It is very difficult to see how either of these two mechanisms (2) and (3) can come into play when the head is flexed at the time of the fall; the secret of fracture must lie in the passage of force from skull to vertebral column. It may be noted that rotatory dislocations around the pivot of the odontoid may occur by a modification of this mechanism, taking into account the direction of the line of force and the screw nature of the articular surfaces of the atlanto-axial joints on which Fick has insisted.

SYMPTOMS AND SIGNS OF ATLAS FRACTURE.

The outstanding clinical signs of fracture of the first cervical vertebra are undoubtedly rigidity of the neck muscles and limitation of movement. The latter is naturally greater in those cases where the fracture actually involves the articular facets; but it is a very definite feature when the arches alone are broken (as in my own case). The movement which is chiefly impaired in an uncomplicated atlas fracture is that of nodding; but it

is to be remembered that limitation of rotatory movements of the head is not diagnostic of a lesion of the odontoid. For in fractures both of the anterior arch (owing to its articulation with the odontoid) and of the lateral mass involving the atlanto-axial articulation, rotation of the head may be restricted or impossible.

In atlas fracture, then, the patient tends to hold himself stiffly as if balancing a weight upon his head, and may support his head with his hands, particularly when making any change from the upright posture. Sir Astley Cooper's description of the patient he saw is very apt: "When he wished to examine any object beneath him he supported his chin on his hands and gradually lowered his head to enable him to direct his eye downwards; but if the object was above him, he placed both his hands upon the back of his head and very gradually raised it until his eyes caught the point he wished to see." These assisted movements, as they may be called, are suggestive of cervical caries, and only the history of a recent injury will raise the question of fracture.

In some cases a protuberance may be felt in the pharynx, at the level of the palate, painful on pressure. This is especially the case when the anterior arch is broken. In my own case of posterior arch fracture this sign was absent, nor would one have expected it. In one recorded instance crepitus has been thus detected through the mouth. More commonly the greatest tenderness is elicited by pressure either on the lateral masses in the neck, or on the posterior arch through the outer fibres of the trapezius. Reference may here be made to those curious cases in which osteomyelitis has developed and a sequestrum finally separated, being exfoliated through the mouth after rupture of a retro-pharyngeal abscess. This occurred in the case recorded by Park; but a more extraordinary case was that of Syme, where the odontoid and a large part of the body of the axis were extruded into the pharynx. Hilton records a similar case. The patients recovered.

Another symptom which not only these cases but also rotatory dislocations sometimes present is that of dysphagia and thick speech. The cases presenting it have not been closely enough examined from the neurological side to establish whether this is of central or peripheral nervous origin; it does not seem to be entirely mechanical.

Nerves.—Owing to the very close relationship between the first two cervical nerves and the posterior arch of the atlas—the one passing over it, the other under—it would be surprising if signs of injury to these nerves were not common. Of the two nerves, the great occipital, passing below the posterior arch, suffers more obviously than the suboccipital which lies upon it. This may be due to the more closely confined canal in which the former nerve lies, the latter traversing a wide groove which it shares with the vertebral artery. It must be remembered, however, that the suboccipital is mainly a motor nerve, and that any paralysis to which its injury gives rise is likely to be overshadowed by the great muscles of the neck, which are not supplied by it and are bent on keeping the broken fragments at rest. A lesion of the great occipital nerve is a great aid to diagnosis, and the presence of an anæsthesia or neuralgia in the area of its distribution should lead to a very careful investigation of the atlas vertebra. Sicard and Roger have recently drawn attention to the value of this sign, and record three cases in all of which it was present, leading them to a certain diagnosis of a lesion that would otherwise have been missed, as the *x*-ray report in one case was at first negative. In my first case there was no evidence of a nerve lesion, although it was carefully sought for. In my gunshot-wound case it was present in a degree which made the patient's life miserable. Sicard and Roger have insisted on the close relationship which the great occipital nerve bears to the posterior arch of the atlas, winding upwards round it. This they have illustrated in their paper, but their diagram is perhaps a trifle too enthusiastic, and *Fig.* 375 represents the state of affairs more accurately.

The Vertebral Artery.—This has been found compressed in one case (Delorme), and was torn by a bone fragment in a patient of Sedillot's (*see* Delorme).

Injury of the Spinal Cord.—As has already been noted, signs of cord injury, varying from a monoplegia to complete paralysis of all four limbs, were present in 19 of these 46 cases, and only 4 of these recovered. Injury to the cord is more often found in

complicated than in isolated fractures of the atlas, and this is due not only to the excessive violence which the complicated fractures imply, but also to the fact that the actual cord injury is sometimes caused by the accessory fracture, the atlas itself having inflicted no injury on the spinal cord. That injury to the various elements of the vertebral column without damage to the contained nervous elements is much commoner than has popularly been supposed is shown by J. and J. Boeckel, who collected no less than 95 cases of fracture of the spine without injury to the cord.

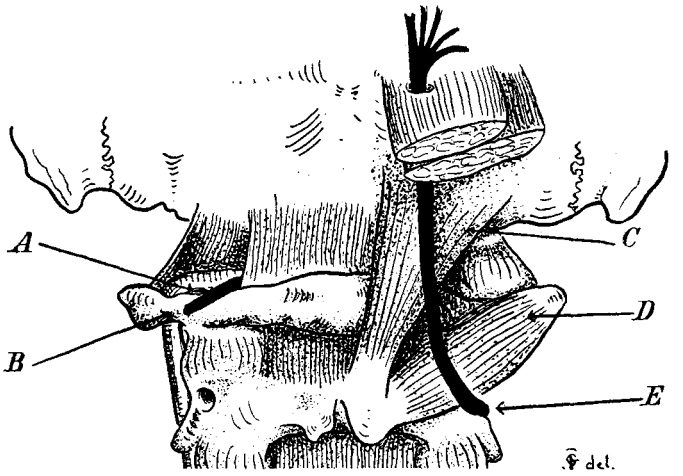

FIG. 375.—The relationship of the suboccipital and great occipital nerves to the posterior arch of the atlas. A, Vertebral artery. B, Suboccipital nerve. C, Rectus capitis posticus major. D, Inferior oblique. E, Great occipital nerve.

There are two factors at work in the case of the atlas, both tending to immunity of the cord from injury. One is the relatively large size of the neural compartment of the atlas ring ; the other is the manner of the displacement of the broken fragments. The last depends on the peculiar mechanism of fracture, which, as detailed above, tends to open out the circumference of the atlas, the fragments travelling in a centrifugal rather than a centripetal direction. It is not surprising, therefore, that the cord should escape damage as often as it does, but rather what one would expect.

DIAGNOSIS.

There is no doubt that fractures of the atlas are far commoner than the literature of the subject would lead one to suppose. The introduction of radiography has led to the discovery of injuries of the atlas and of the axis in cases where, on purely clinical grounds, the diagnosis was uncertain. There should be but little difficulty in diagnosing the condition, provided that one is always ready to suspect it, and insists on radiographs which clearly show the bone. And, greatly though radiography has helped us to establish a more certain knowledge of these injuries, the technique of photographing the upper two cervical vertebræ is difficult, and calls for very expert handling and an abundance of patience on the part of those engaged in the work. George has done much to perfect methods of *x*-ray diagnosis in this region. It is owing to the attendant difficulties that radiography, though no longer a very young science, is only now beginning to be a really reliable aid to diagnosis in injuries of the upper part of the neck. The popular belief that injuries to the atlas and axis are necessarily fatal has been another potent cause for turning suspicion away from these bones. But, given a history of a recent injury (usually a blow or fall upon the head), rigidity of the neck, limitation of head movement, and perhaps neuralgia or anæsthesia of the great occipital nerve, the surgeon should not rest until an

atlas fracture has been established or ruled out of court by perfectly sharp stereoscopic radiograms, on which the whole contour of the bone can be traced. The similarity of atlas fracture to high cervical tuberculosis has already been referred to in the text. The history of injury and the *x* ray should make the differential diagnosis simple.

TREATMENT.

Unless there are positive neurological signs of cord injury, and unless the correlation of the signs with the position of the broken fragments as seen on the *x*-ray plate leads to the belief that good can be done by laminectomy, treatment should be conservative and directed towards immobilization. In only two of the cases in this series was operation undertaken (Mixter and Osgood, and Blackwood), and both patients died. In one other case it was found at autopsy that laminectomy might have led to recovery, for here a small piece of bone had pressed on the medulla and produced gradually increasing paralysis and death. Such cases are rare. Treatment will, as a general rule, be confined to securing immobility of the head, preferably in a plaster case of the Lorenz type or in a 'Minerva' plaster, followed by a leather casket if necessary. In my own case I employed the Lorenz method, making a plaster bed by moulding crinoline wrung out of plaster-of-Paris on to the back of the patient from the top of the head to the loins. These beds are exceedingly comfortable to lie in, and make nursing much easier. Unless the articular surfaces are involved in the fracture, the functional results are good.

In conclusion, I have to thank Professor Keith for permission to publish an account of the case in the Museum of the Royal College of Surgeons, and Professor Dean for a similar kindness with regard to the specimen from the Pathological Museum of the University of Manchester.

SUMMARY.

1. Four cases of fracture of the atlas vertebra are described, and forty-two cases previously recorded in the literature are analyzed.

2. The common cause of the accident is a fall upon the head, and the probable mechanism of fracture is tension of the atlas ring due to lateral spreading of the lateral masses, owing to the divergence of the lines of force passing through the bone.

3. Two other possible mechanisms are outlined, the head being in extreme extension, but neither fits in with the nature of the accidents usually recorded.

4. Atlas fracture is by no means necessarily fatal; 45·7 per cent of the cases have recovered. When complicated by a fracture of another vertebra, the mortality is higher.

5. The commonest of such complications is a fracture of the odontoid process, next in frequency being rotatory dislocation of the atlas on the axis.

6. It is pointed out that inability to rotate the head may occur in some forms of atlas fracture. It is not pathognomonic of a broken odontoid.

7. The accident is probably by no means uncommon, but as very clear and sharp radiograms are necessary in order that the fracture may be detected, the atlas injury is often overlooked.

8. Cord injury is often absent (50 per cent). Useful aid in diagnosis may be obtained from signs of injury to the great occipital nerve.

9. Treatment will generally be conservative, directed to immobilizing the head by a 'Minerva' plaster or a Lorenz bed.

BIBLIOGRAPHICAL NOTE.

Unfortunately I have not been able to refer to the original papers of Ludloff or of Park, and have had to content myself with incomplete abstracts in other journals. In Corner's account of his isolated fracture of the atlas, the fracture is described as if it were of the axis. Corner informs me that this is a misprint. Lahey removed a bullet from within the anterior arch of the atlas, but he does not say whether there was

a fracture or not; I have not included his case. Many Continental writers refer to Stephen Smith's fifteenth case as if it were an atlas fracture. This is not so. I have traced the error to a mistake in Schmidt's *Jahrebuch* for 1872, where Smith's paper was abstracted. Most of the German writers have used this abstract without referring to the original. In neither Carson's nor Wilson's case is there convincing evidence that the atlas was broken. Kocher's *Case* 3 (*loc. cit.*) I have included, as the clinical picture is very typical of atlas fracture; but odontoid fracture cannot be excluded. Marshall's *Case* 2 (*loc. cit.*) may be an atlas fracture, but it cannot be made out in the published radiograph. It is not clear whether Marshall believes that the spur of bone is the result of fracture. This is almost certainly a normal ossification of the ligaments bridging the vertebral artery groove, and should be compared with George's *Figs.* 12, 13, 14. As for the two cases figured by George himself, the fractures cannot be made out in the published prints. Sybenga's case, whilst very interesting, I believe to be, as he himself suggests, a developmental arrest of ossification and incomplete anterior arch. The *x*-ray is an admirable one; the bony ends are clean and rounded, and do not at all resemble a fracture. There is an undoubted luxation in this case, but not a fracture.

I am greatly obliged to MM. Sicard and Roger, and M. Blanc, for sending me copies of journals I was otherwise unable to obtain.

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