Remarks
ON
FRACTURES OF THE FIRST CERVICAL VERTEBRA.*

BY
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In a previous paper I described at some length the pathological anatomy, mechanism, and symptomatology of fractures of the atlas vertebrae. Having now three more recent examples of this injury to add to the four published then, I may take this opportunity of bringing the history of the subject up to date, and of making such amplifications or amendments as further experience seems to demand. The whole question of atlas fracture is, in reality, indissolubly bound up with the matter of injuries to the occipito-atlanto-axial component of the vertebral column, both bones and ligaments. I shall be compelled by the necessary limits of space to confine my observations strictly to the atlas, and will have to reserve for another occasion the many fields through which a fascinating subject might well tempt us to wander. So much that is dramatic but untrue, so much that is interesting yet founded on legend, obscures the facts in this corner of surgery that it is impossible to take up the thread of the narrative in modern times. A complete survey of the history of the various lesions is required before we can go forward along a sure path. As regards atlantal injury I have previously sketched in the necessary background, but will once more outline the chief features after describing the new cases.

MATERIAL.

In 1920 I described four examples of atlas fracture—two clinical examples and two museum specimens—and collected forty-two other cases from the literature. I have omitted cases of gunshot injury in the present communication. The total material, personal and otherwise, now amounts to sixty-five cases. I am indebted to Dr. Arnison and Dr. Forbes for two of them (see Tables I and II).

CASE I.—*Fracture of the Posterior Arch of the Atlas.*

A man, aged 57, was sent to see me in 1920, some five months after an accident which had left his neck very painful and stiff. He was unable to describe the exact facts, but was drawing water in a slightly stooping position when a telegraph pole, blown over by the wind, struck him on the back of the head. The scalp was not cut, there was no bleeding from the nose, mouth, or ears. He was stunned for a short time and when he became conscious he had great pain in the neck, in the shoulders, and in the arms as far as the elbows. He had been in bed for eight weeks. His arms, he said, were still weak so that he could not raise them high above his head or get his hands easily into his trouser pockets. He had had no difficulty in walking. The outstanding feature of the case had been the pain in the occipital region of the scalp, and although this was improving, it was still very troublesome—so much so, indeed, that he was in the habit of placing a wet handkerchief on his head to chill the burning pain. On examination I found that the head was very stiffly held and that movements of rotation and of nodding were practically abolished. There was an area of scalp analgesia on both sides in the distribution of the great occipital nerves, greater in extent on the right than on the left. He could abduct the arms fairly well, but the right deltoid, biceps, and triceps were flabby without being definitely palsied. There was a small patch of anaesthesia corresponding to the skin areas of root C.5 on both arms. There was no sign of interruption of the pyramidal pathway to the legs on either side. A radiogram disclosed fracture of the posterior arch of the atlas. Seen again a month later he was making slow progress, but the occipital neuralgia was still severe.

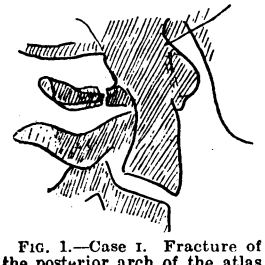

FIG. 1.—Case I. Fracture of the posterior arch of the atlas in two places.

In this case the atlas fracture appears to have been complicated by a slight cord haemorrhage at the level of C.5, but it must have been extremely minute. Alternatively a peripheral injury to the issuing roots of this segment may have been occasioned in some manner.

* Founded on a portion of a Hunterian Lecture delivered at the Royal College of Surgeons of England, February, 1924.

CASE II.—*Fracture of the Posterior Arch of the Atlas and Odontoid Process.*

A woman, 67 years of age, was admitted to the Salford Royal Hospital on February 22nd, 1925, with the history that the previous day she had fallen downstairs in her home, and, as she thought, twisted her neck, which was very painful. It was almost impossible for her to find any comfort in any position in bed. There was no sign of any paralysis in arms or legs. I found on questioning her that the stairs in her house were very steep, and ran across the house, so that the dividing wall was only a few feet from the foot of the stairs. In falling she had struck the top of her head against the wall across the passage. There was a small cut one inch inside the hairy scalp about the site of the coronal suture, near the mid-line, so that the force striking the top of the head might also have extended it. Flexion and extension of the head were impossible, and the power of rotation was abolished. An *x*-ray photograph revealed a bilateral fracture of the posterior arch of the atlas, fracture of the odontoid process, and posterior displacement of the occipito-odonto-atlantal component. The luxation was reduced as far as possible, and the head, neck, and shoulders immobilized in plaster-of-Paris. She resented this control, and after six weeks in hospital was discharged to out-patients. After another month she begged to have the cast removed. This was done and she was promptly lost sight of. I have recently re-examined this patient. Movements of the neck are a little restricted in most directions, but she declares herself to be perfectly well. A radiogram shows the atlas soundly healed in perfect form.

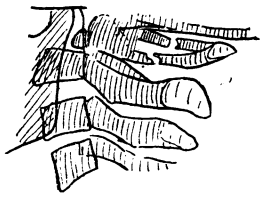

FIG. 2.—Case II. Fracture of the posterior arch of the atlas in two places. Fracture of the odontoid process. Posterior luxation of occipito-odonto-atlantal component.

CASE III.—*Fracture of the Posterior Arch of the Atlas.*

A man, 34 years of age, was admitted to the Salford Royal Hospital on October 20th, 1925, under the care of my colleague Mr. Ollerenshaw, who, knowing my interest in these cases, later kindly transferred the case to me. It appeared that a bag of starch weighing 160 lb. had slipped from a hoist at a dock warehouse and had fallen from a height of five stories on to the upper and back part of the patient's head, knocking him down and temporarily stunning him. He had the usual severe pain in the neck with neuralgic pain streaming up on to the back part of the scalp. There were no signs of cord or root injury. The neck seemed rather swollen and was extremely tender to touch behind. *X* rays revealed a fracture of the posterior arch of the atlas on the left side, with a negligible fracture of the spinous process of C.3. The odontoid process was intact; there was no luxation of the head. The neck was immobilized between sandbags, and after five weeks in hospital he was discharged with a leather collar. I have seen him from time to time during the past year and he has done well. His neck is still a little stiff, but this is probably partly due to apprehension, as he knows he has had a "broken neck." He has complained of tingling along the inner sides of the arms into the inner two fingers on both sides, as if he had "knocked his funny-bones," whilst he gets a similar tingling in his calves, especially when he turns his head far to the right or left. There is an area of hypo-aesthesia to needle-prick over a part of the scalp area supplied by the great occipital nerve. In a skiagram taken in May, 1927, the atlas still shows a deficiency of the left arch; but there was unusual separation of the fragments in this case.

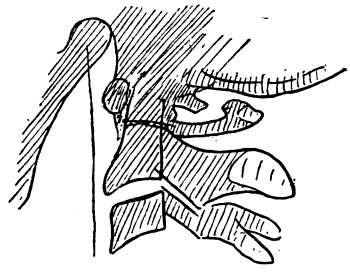

FIG. 3.—Fracture of the posterior arch of the atlas on one side. Case III.

SOME GENERAL CONSIDERATIONS.

If we turn to the standard works we shall strengthen the impression, which was probably implanted in our dissecting-room days, that injuries of the first cervical vertebra are, on the one hand, exceedingly rare, and, on the other, extremely fatal. Both of these ideas are wrong, although a degree of rarity cannot be denied to a condition of which only sixty or seventy cases appear to exist in the world's literature. These figures are probably misleading, for it is strange that I should have seen so relatively high a percentage myself. The fact is that a number of cases go undiagnosed, not because there is any essential difficulty in discovering the true nature of the case, but because the belief in the fatal nature of the condition is so strong that the practitioner does not suspect such a lesion if his patient lives. The stiff and painful neck of atlantal injury is put down to "sprained neck," and it is only when

the condition fails to resolve itself—and some cases get well fairly quickly—that the more wary send their patients for x-ray examination.

It is easy to understand how this belief in the almost uniform fatality of atlantal injury has come about. There are in currency apocryphal tales of slight accident and of pranks leading to sudden death. Many such cases have undoubtedly occurred. The reader may turn to Greene Gascoigne's case, for example, but he will find that, as a rule, in these cases the violence has been considerable, more considerable perhaps than the participators would willingly admit. The classical example of minimal violence leading to death is that of the child lifted up by the head and set down dead. As this refers to rupture of ligaments, and not to atlas injury, I shall not at present make a detailed reference to this case, of which many variations in folklore exist. The origin of this story goes back to France 150 years ago, and is not founded, so far as I can learn, on definite pathological observation. Much more convincing, however, than any fanciful tales were the older, well documented records of atlantal, odontoid, and axial fracture, which are chiefly concerned with fatalities. How else could the clinician of last century and earlier times confirm a diagnosis of fracture of the upper cervical vertebra except by necropsy? If there was cord damage, and often there is none, he was on surer ground, but even then there was no certainty as to the precise nature or even the exact site of the bony injury. Thus we find the earlier history of atlas fracture in essence a record of death, up to the introduction of radiography, since when a change has come over the picture. I find that of thirty-two cases reported since 1900, only six have died, so that one's impression at present is that atlas fracture, though fraught with the possibility of danger, is by no means always fatal. Indeed, when the posterior arch alone is broken—and this is the commonest type—there should be no particular anxiety. The real danger lies in the nature of the force which is required to bring about the lesion, for this may not stop at fracture of the atlas, but may go on to cause other injuries. In order that I may make this clearer it will be necessary to speak of the mechanism of fracture, when we shall see that an injury of much the same type may produce now a fracture of the skull, now a fracture of the atlas, whilst a slight difference in the direction of the trauma causes the injury to fall into the cervical spine at a lower level. For the vast majority of cervical injuries are produced by forces applied to the head and not directly to the neck. This is a fundamental point, and it is essential that the fact should be realized in all its implications.

SITE OF INJURY WHEN FORCE IS APPLIED TO THE HEAD.

If the wounding body is a hard unresilient material a fracture of the skull is naturally the most probable result, the skull being compressed between the spine at the occipital condyles and the injuring agent. Even so, a fracture of the spine may occur as well, and I suspect that these double injuries are more frequent than we think. I have seen one such only. Clinically the head injury quite overshadows all else, whilst at necropsy the pathologist is satisfied when he finds cranial lesions. In the monograph on fractures of the skull by Braquehaye and Laubie (Experience XIV) experiments are recorded in which the posterior arch of the atlas, as well as the skull, was broken by longitudinal compression of the head on the spine. If the injuring body is more elastic and yet heavy (as when a bale of cotton or sugar or starch falls on to the head, or as when a person falls from a height on to sand) the skull will escape and then the lesion may fall into the vertebral column at some point. Where? If the neck is violently flexed the injury will probably be found in the lower cervical vertebrae, at the point where the change in the mobility of the spine takes place (C.5 or thereabouts). If, on the other hand, the head is erect and the force is transmitted along the spine vertically an injury to the relatively weak atlas may result, and this for a special but simple reason. I have described in my previous paper the widening of the atlas ring which occurs by the resolution of the forces acting upon it, but a few words of recapitulation are needed. The lateral masses of the atlas are triangular in coronal section with the wide bases outwards. The upper and lower articular facets look inwards and upwards, inwards and downwards, respectively. When the head is pressed down on to the vertebral column the atlas is squeezed between the occipital condyles above and the axis below, and, owing to the obliquity of its articular surfaces, the wedge-like lateral masses tend to slide outwards. (I have illustrated this diagrammatically elsewhere.) This tendency is resisted by the anterior and posterior arches which bind the lateral masses together, and also by the transverse ligament, which not only holds the odontoid in place, but acts as well as an internal brace for the lateral atlantal masses. This ligament is, contrary to general belief, exceedingly strong, and its rupture is one of the rarest of all accidents in healthy people. If the limits of bony cohesion are passed a tension fracture occurs, the atlas ring gives way.

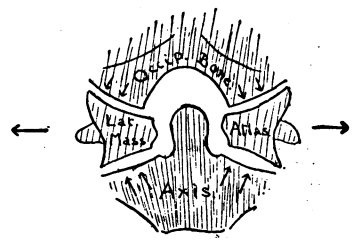

FIG. 4.—Diagram made from a normal skiagram. To illustrate the theory of "atlantal squeeze."

It is usually the posterior arch, where it is weakened by the grooves for the vertebral arteries, that breaks. It is because the force is centrifugal, from the centre outwards, that paralysis is rare in simple atlas fracture; the fragments move in the safe direction, away from the cord. The force which has driven the head and the atlas down on to the axis may stop there, but should it go on further injuries may arise, especially if violent flexion is added. If the neck remains rigidly erect, with articulations locked, and the head alone be violently flexed, the odontoid process will probably be pulled off by the check ligaments (an "abrissfraktur"). Alternatively, should the head and neck be flexed forwards as a whole the additional injury will fall on the spine in the lower cervical region. Examples of both of these happenings will be found in the literature (see Table II). Now what of direct injury? Can the atlas be broken by direct violence?

Direct Injury.

Direct injury applied to the back of the neck may on rare occasions break the atlas. The bone is so deeply situated, and lies guarded by the overhang of the occiput above and by the strong and longer spine of the axis below, that it needs a very accurately localized blow with a narrow heavy implement to miss these and strike exactly over the atlas. Fracture has been caused by this means, but not in any cases I have myself seen. In Hugues's case a woman was struck on the back of the neck with a stick and instantly killed. At necropsy the posterior atlantal arch was driven forwards and jammed inside the lateral masses. In Armstrong's case a man hit by a baseball bat in a somewhat similar fashion died of dislocation of the head from extensive ligamentous rupture. The atlas injury here was of minor importance. In Ridley's case the mechanism is not so clear, and, from the brief account of the case, it seems that the coincident fracture of the base of the skull was a more essential cause of death than the atlas injury. In the whole literature these, together with the cases reported by Sicard and Roger, by Blanc, and by Scott—six in all—represent the sum total of atlantal fracture by this direct mechanism. Gunshot wounds have been ruled out of the present series as they are of no particular interest.

On the whole the theory of transmitted force, of atlantal squeeze, is the one which fits the facts in the majority of the cases. The possibility that the anterior arch might be broken by the pressure of the odontoid process presents itself, and it may well be an accessory mechanism, if not the primary cause. Too much space would be required to discuss the matter in detail here.

Pathological Anatomy.

An analysis of the cases in which the description of the fracture is sufficiently clear shows that fracture of the posterior arch is the most frequent type, sometimes on one

side only, sometimes on both, so that the arch is mobilized. In spite of this little harm ensues, as there is generally little or no displacement and the periosteum may not be ruptured.

Anterior arch alone	8 cases
Posterior arch alone	29 ,,
Both arches	12 ,,
Lateral mass	7 ,,
Transverse process	3 ,,

The posterior arch is more often broken because it is weakened by the grooves for the vertebral arteries. But in addition the long axis of the facets for the occipital condyles, being placed diagonally, may assist by tending to splay the arch behind, opening it like a fan.

Coincidental Injury.

(*a*) Easily the most common associated injury is fracture of the odontoid process, which has occurred at least seventeen times. Authors mention anterior and posterior luxation of the atlas in their records, without seeming to realize that this cannot occur unless one of two things has happened—fracture of the odontoid or rupture of the transverse ligament. The former is more probable. This luxation rather than the atlantal fracture has often been the real cause of death (see Table II).

(*b*) The vertebral artery may be ruptured. The region of the grooves for this vessel on the posterior seems to be a favourite site for fracture, and here the artery is bound down in close contact with the bone by a ligamentous slip passing over it. It is not uncommon to find this ligament ossified, and it then shows clearly in *x*-ray films. If the ligament is only partly ossified it appears in *x*-ray films as a spicule, and may be mistaken by the unwary for the relic of an old fracture. The elasticity of the vessel wall and the usual lack of displacement of the fragments accounts for the relative rarity of injury to this vessel.

(*c*) The great occipital nerve. As was first pointed out by Sicard and Roger, this nerve may be injured, indeed ruptured, in atlantal injury. Several examples will be found amongst the tabulated cases, including some of my own. Occipital neuralgia after injuries to the upper two cervical vertebrae is certainly very common, and is a useful clinical help in drawing attention to the possibility of fracture having occurred in otherwise doubtful cases.

(*d*) Injury to the spinal cord or lower end of the medulla. For the reasons already detailed this complication does not happen often in pure atlantal injury. We have seen that the bone fragments tend to move away from the cord in the average case, and that there is often little or no displacement of bone fragments. Thus in the whole series of uncomplicated atlas fractures, twenty-one in number, the medulla was found injured by a bone fragment in only two (Betz, Boullard). Myelitis, probably traumatic, accounted for two or three more. The presence of suppuration in Marshall's case is not commented on by the author. In the complicated cases the injury to the atlas often sinks into a subsidiary position, and the cord injury is inflicted at the site of the complicating fracture. For example, when the odontoid is broken off there is a great tendency for the occipito-odonto-atlantal component to be dislocated forwards, more rarely backwards, and the cord is then much more likely to suffer. A normal external appearance of the cord may have misled some observers, as this is not inconsistent with the presence of a central haemorrhage and central pulping sufficient to cause death.

SYMPTOMS OF FRACTURE OF THE ATLAS.

Pain and rigidity of the neck, so that movements of the head are slowly and hardly performed, are the outstanding features. The patient in the first few days has the greatest difficulty in finding a comfortable position in bed and is constantly demanding a change in the arrange-

TABLE I.—*Isolated Fractures of the Atlas (20 Cases).*

Author.	Nature of Accident.	Clinical Signs of Cord or Nerve Injury.	Anatomical Diagnosis.	Result.
1. Astley Cooper (Cline's case). 1822.	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.
2. Boullard. 1849...	Basket heavy with moisture fell from a height on upper and back part of head	Pain in neck. No paralysis at first, but cramps developed. Complete paralysis before death	Fracture of posterior arch of atlas, right. Comminuted anterior arch fracture on to inferior articular facet, lateral mass, left	Lived 38 days.
3. Marshall, J. 1875	Fell from second story 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.
4. Betz. 1880 ...	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 haemorrhage in medulla.
5. Hugues. 1897 ...	Healthy woman struck on back of neck with a stick	Instant death	Fracture posterior arch of atlas, right and left, through grooves for vertebral arteries. Arch driven in and impacted. Vertebral arteries torn	Instant death.
6. Ludloff. 1906 ...	Not available	Not available	Fracture left lateral mass of atlas	Recovered.
7. Holding. 1903 ...	Fell down stairs on to back of head	No cord signs. Severe occipital neuralgia	Isolated fracture of atlas	Recovered.
8. Quercioli. 1908	Fell from tree	No limb palsies. Dysphagia.	Atlas broken into four pieces by symmetrical fractures of both arteries	Died 13 days later from pneumonia *ab ingestis*. Cord found uninjured at autopsy.
9. Corner. 1909 ...	Rolled out of chair with head flexed	No cord signs. Severe neuralgia great occipital nerve	Fracture of atlas	Recovered.
10. Schneider. 1911	Fell down stairs	Monoplegia right arm; recovered	Fracture anterior arch of atlas	Recovered.
11. Park. 1913 ...	Not available	Not available	Fracture anterior arch of atlas	Recovered. Caries of atlas, extrusion of sequestrum by the mouth 45 days later.
12. Sicard and Roger. 1916	Bale of paper dropped on to head from a height	No cord signs. Anaesthesia left great occipital nerve	Fracture posterior arch of atlas	Died 1 month later of pneumonia. No injury to cord; left suboccipital nerve almost divided by bone fragment.
13. Sicard and Roger. 1916	Fell 6 ft. on to head	No cord signs. Anaesthesia left great occipital nerve	Fracture posterior arch of atlas, left side	Recovered.
14. Sicard and Roger. 1916	Struck by a beam on left side of back of head and neck	No cord signs. Anaesthesia left great occipital nerve	Fracture posterior arch of atlas, left side	Recovered.
15. George. 1919 ...	Not available	No clinical details	Fracture posterior arch of atlas, two places	Presumed recovered.
16. George (Butler's case). 1919	Not available	No clinical details	Fracture posterior arch of atlas, one place	Presumed recovered.
17. Jefferson. 1920...	Aeroplane crash; fall on to head	None	Fracture posterior arch of atlas, two places	Recovered.
18. Jefferson (Langstaff's case). 1920	Thrown from horse	Laceration brain stem	Fracture posterior arch of atlas, two places	Died immediately.
19. Arnison (private communication)	Man thrown from horse on to head	Pain, rigidity of neck. No signs of cord injury and compression	Fracture posterior arch of atlas	Recovered. Still rides to hounds.
20.	See text			Recovered.

TABLE II.—*Complicated Fractures of the Atlas (45 Cases).*

Author.	Nature of Accident.	Clinical Signs of Cord or Nerve Injury.	Anatomical Diagnosis.	Result.
1. Bell Charles. 1824	Fell fifty 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.
2. Phillips. 1837 ...	Fell off hayrick 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.
3. Spangenbern. 1845	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.
4. South. 1847 ...	Fell down stairs	Tetraplegia, with hyperaesthesia right half of the body	Atlas broken in two places. Odontoid broken off. Fracture 5th cervical vertebra	Died 5 days later. Haematomyelia level of 5th cervical vertebra.
5. Melicher. 1848...	Woman fell backwards down a ladder, 7 ft.	Violent pains in neck and occiput. Weakness of lower limbs progressing slowly to total paralysis	Fracture anterior arch of atlas. Odontoid process broken off	Died 54 days later.
6. Melchiori. 1850...	Fell off ladder	—	Posterior arch of atlas broken in two places. Odontoid broken off. Dislocation atlas on axis	Died instantaneously. Brain stem compressed.
7. Speyer. 1851 ...	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.
8. Gascoigne. 1856	Hat jammed down on to head and pulled from side to side (tavern horse-play)	Head fell forwards, chin on breast. Paralysed	Fracture posterior arch of atlas, and arches of 2, 3, 4 cervical vertebrae. Partial luxation C.3 on 4	Died in 40 minutes.
9. Uhde. 1855 ...	Man fell from tree on to occiput and back	Pain in the neck. Palsy lower extremities, later of upper also	Fracture posterior arch of atlas, also of neural arch of axis. Fracture C. 6, 7	Died 13 days later.
10. Birkett. 1859 ...	Man fell downstairs intoxicated	Completely paralysed below neck	Fracture posterior arch of atlas. C.3 dislocated forwards on C.4	Died in 36 hours.
11. Ridley. 1869 ...	Man knocked down by blow, back of head came against kerbstone	Pain in neck, bleeding from ears. General headache. Deep furrow between atlas and occiput	Fracture posterior arch of atlas. Dislocation of atlas forwards. Fracture of occipital, parietal and temporal bones	Died 3 days later in convulsions.
12. Gayet. 1870 ..	Slipped on stairs, arrested fall with a jerk	Severe pain in neck. Supported head with hand. Palsy appeared four weeks later	Fracture lateral mass of atlas and of axis. Fracture odontoid process.	Died 5 to 6 weeks later.
13. Hamilton. 1872	Fell 40 ft. 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.
14. Milner. 1874 ...	Fell off roof, neck probably flexed	—	Posterior arch of atlas fractured in two places. Complete dislocation of occiput from atlas	Died instantaneously. Medulla, found divided at necropsy.
15. McCarthy. 1874	Fell head foremost down hold	Tetraplegia arms and legs	Atlas broken into five fragments. Odontoid broken off	Died 3½ days later. Cord concussed, no compression.
16. May. 1876 ...	Fell 15 ft. on to back of head	No definite cord signs; fully recovered later	Fracture of posterior arch of atlas. Odontoid broken off. Rotary 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.
17. Eberman. 1879	Fell from steps, struck occiput against ground	Walked to his room supporting neck with hands	Fracture transverse process of atlas. Fracture through body of C.3	Died in 30 minutes.
18. Armstrong. 1885	Man hit on back of neck or head by baseball bat	Died almost immediately	Fracture transverse process of atlas. Rupture alto-axoid ligaments	Died in few minutes.
19. Francis. 1886 ...	Man fell 20 ft., striking upper and back part of head against a plank	Rigid neck, paralysis left lower limb and both upper limbs	Fracture posterior arch of atlas. Vertical fracture of axis through pedicles	Died 37 days after injury.
20. Lannelongue 1888	Fell backwards off cart, struck head on ground	Severe pain, rigidity of neck. Seventeen days later limbs paralysis began and he died in a few hours	Fracture anterior and posterior arches of atlas. Odontoid process broken off at its base. Transverse ligament intact	Died 18 days later.
21. Berndt. 1893 ..	Fell forwards down steps	Diplegia right arm and leg, anaesthesia of left side (Brown-Sequard palsy)	Transverse fracture anterior arch of atlas. Odontoid broken off. Rotary dislocation of atlas on axis	Died one month later. Compression of right half of cord, no gross lesion of brain stem.
22. Kocher. 1896 ...	Fell 10 ft. on to head	None	Probable fracture of atlas and of odontoid	Recovered.
23. Smith and Clegg. 1893	Cab-driver fell off box seat, head strongly flexed under body	Kept alive for 3 hours by artificial respiration. Tetraplegia	Fracture anterior and posterior arches of atlas. Odontoid process broken off. Transverse ligament intact	Died 3 hours later.
24. Picqué (Billot's case). 1900	Fell 11 ft.	Difficulty in swallowing, no limb palsies	Fracture of anterior arch of atlas. Rotary dislocation atlas on axis	Recovered.
25. Scott. 1904 ...	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.
26. Corner. 1905 ...	Museum specimen. History unknown	—	Atlas misshapen 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.
27. Corner. 1907 ...	Fell off horse on forehead	Dysphagia and thick speech. No affection of limbs	Fracture of anterior arch of atlas. Rotary dislocation of atlas on axis. Condition of odontoid doubtful	Recovered.
28. Van Assen. 1908	Fell 13 ft. head foremost	No cord signs. Occipital neuralgia	Fracture both arches at atlas. ? Fracture of odontoid. ? Rotary dislocation of atlas on axis	Recovered.
29. Blackwood. 1908	Fell 4 ft. on to right side of head	Total paralysis below level of larynx. Kept alive for 34 hours and 40 minutes by artificial respiration	Atlas fracture in three places, both arches. Odontoid broken off. Dislocation of occiput on axis	Died 35 hours later. Haemorrhage into cord from level of foramen magnum to third cervical vertebra.
30. Blanc. 1908 ...	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.
31. Mixter and Osgood. 1910	Fell down 13 stairs	Severe occipital neuralgia. No cord signs	Fracture of anterior arch of atlas. Rotary dislocation of atlas on axis	Recovered.
32. Mixter and Osgood. 1910	Railway accident	All four limbs became spastic 2½ months after accident	Fracture posterior arch of atlas. Complete dislocation of atlas on axis	Died suddenly 1 month after laminectomy and 5 months after injury. No autopsy.
33. Mixter and Osgood. 1910	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. Rotary dislocation of atlas on axis	Recovered.
34. Pilcher. 1910 ...	Fell 15 ft. 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. Rotary dislocation of atlas on axis, with which it is ankylosed	Recovered. Seen 9 years later; right hand weak, leg recovered.

TABLE II.—*Complicated Fractures of the Atlas (45 Cases). (Continued.)*

Author.	Nature of Accident.	Clinical Signs of Cord or Nerve Injury.	Anatomical Diagnosis.	Result.
35. Schepelman. 1910	Fell 9 ft. on to occiput	Headache, rigidity of neck. No neurological signs	Fracture posterior arch of atlas, also of 7th thoracic vertebra	Recovered.
36. Boeckel. 1911 ...	Fell some 12 ft. head foremost on to sand	None	Fracture right lateral mass of atlas. Rotary dislocation of atlas on axis	Recovered.
37. Brooks. 1915 ...	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.
38. Jefferson. 1920	Unknown (museum specimen)	Unknown	Fracture of anterior and posterior arches of atlas. Fracture of odontoid	Lived a short time.
39. Smith. 1921 ...	Dived into shallow water, struck head on bottom	Pain, rigidity of neck. No neurological signs	Fracture posterior arch of atlas. Anterior luxation of atlas	Recovered.
40. Bradfield. 1922	Boy fell into a well containing little water	Unconscious short time. Pain and rigidity of neck	Fracture of atlas and anterior dislocation (? fractured odontoid)	Recovered.
41. Williams. 1922...	Blown up by shell, fell on head	Both legs and left arm paralysed for some time	Fracture of atlas and second and third cervical vertebrae	Recovered.
42. Marinesco and Ludovici. 1923	Injured by locomotive	Fractured skull and femur. Tetraplegia	Fractures of atlas and axis vertebrae	Alive 13 months after injury.
43. Forbes	Man thrown into air in a logging accident. Pitched on head	Severe pain in neck and shoulders. Neck held stiffly. Great pain in scalp	Fracture posterior arch of atlas. Fissured fractures through bodies of C. 2 and 3	Recovered. Fracture united 4 months later.
44 and 45.	See text.			

ment of pillows. Some movement of the head is usually possible, as the lower cervical joints permit of a certain degree of movement. Nodding movements, the movements of "Yes" and "No," are particularly difficult. There may be pain streaming up into the occipital portion of the scalp, even when anaesthesia in one of the great occipital nerve fields is present (anaesthesia dolorosa). Sometimes pain and tingling in the limbs may be experienced, even when neurological examination fails to detect any signs of spinal damage. This may persist later, especially on turning the head. I find that if the finger in a *post-mortem* specimen is thrust from above through the foramen magnum into the spinal canal and the head is then rotated from side to side a remarkable diminution in the size of the canal takes place, so that the finger is gently squeezed. This may be the explanation of the clinical fact just mentioned (compare Case iii). Palpation through the mouth gives little help in the uncomplicated type, except that the attempt to examine may disclose how painful is any movement of the head. Dysphagia may be complained of. This seems to be due to mechanical, muscular causes, and does not necessarily indicate injury to the brain stem or cranial nerves, for many patients who have had no nervous lesion have complained of it. When signs of damage to the spinal cord are present the injury is probably at a lower level than the atlas, or the odontoid has been broken as well, and an anterior luxation of the atlanto-odontoid-occipital component is likely to be present. Much greater care is needed in the handling of such cases, and flexion of the head must be prevented at all costs.

Such clinical signs as have been outlined merely suggest that a high vertebral injury may be present. The only certain means of diagnosis is radiography.

TREATMENT.

Once the diagnosis is certain, steps must be taken to immobilize the head, neck, and shoulders, and this is best achieved by plaster-of-Paris. If one could be quite certain that the posterior arch alone was broken it is doubtful whether any special fixation is really necessary save in so far as it relieves pain and makes the patient more comfortable. The anterior arch may also be broken without any very clear evidence of this fact being shown by *x* rays. So that it is safer to treat an apparently uncomplicated atlas fracture on strict lines, for if both arches are broken the transverse ligament is alone holding the two halves of the bone together. The treatment of the complicated cases is beyond the scope of the present article, for in these the complicating factor is generally the more important and the more dangerous.

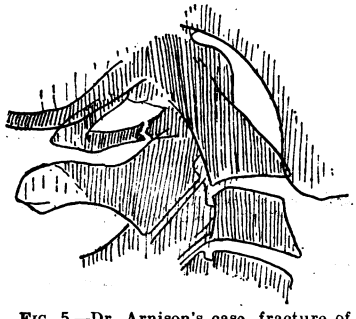

FIG. 5.—Dr. Arnison's case, fracture of the posterior arch of the atlas.

In the following tables a brief synopsis will be found of all cases of atlas fracture the records of which have been accessible to me. I have to thank Dr. W. D. Arnison of Newcastle-on-Tyne for very kindly sending me details of an unpublished case and also a print (Fig. 5). I am grateful for a similar courtesy from Dr. R. D. Forbes of Seattle, Wash., U.S.A. (Fig. 6), a very excellent example.

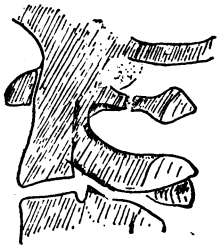

FIG. 6.—Dr. Forbes's case, fracture of the posterior arch of the atlas.

The tables will be found, I trust, self-explanatory. I have omitted injuries caused by firearms, of which there are some half-dozen cases recorded, as these are of no particular interest, save that a person may survive them. This entails the elision of one case of my own which appeared in the 1920 paper. The isolated fracture of the atlas is rarer than the complicated, and the death rate from the latter is distinctly higher. Indeed, in many of the cases it is evident that the atlantal injury *per se* played anything but a dominant part in causing death.

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