Traffic accidents occasionally produce a distinctive variety of fracture (or fracture-dislocation) of the upper cervical spine, characterized by a bilateral avulsion-fracture through the neural arch of the axis without injury to the odontoid process and with or without fracture-dislocation of the 2nd cervical vertebral body upon the 3rd. The similarity of this lesion to that effected by the modern technique of judicial hanging justifies its description as "hangman's fracture" of the cervical spine.

Some years ago one of us (R.C.S.) published a radiograph of a lesion sustained in a traffic accident which revealed just such an avulsion-fracture of the laminar portion of the neural arch of the axis with accompanying marked dislocation of the axis upon the 3rd vertebra (Fig. 1). Though the detailed case history had been lost the author recalled the surprising survival of the patient without neurologic defect; the mechanics of the injury remained unknown. Subsequently two of us (R.C.S., K.E.L.) collected a series of 8 patients involved in traffic accidents in whom this same type of cervical lesion was manifest and for whom both clinical material and the evidence of follow-up examinations were available for consideration. This clinical information has been correlated with an assessment of the mechanics of modern judicial hanging and this anatomicopathological correlation has afforded a plausible concept of the mechanism involved in such fracture-dislocations. The victims of judicial hanging are naturally not available for study, but traffic victims with "hangman's fracture" may survive and thus permit the
evaluation of clinical status, of the ultimate fate of traumatized spine, and of the possible means of prevention and treatment of such injuries.

Case Reports

Case 1. A.J., a 34-year-old mill worker, was admitted to Providence Hospital, Portland, Ore. on March 24, 1962, having been injured several hours previously when he was thrown from his car as it struck a pole. He sustained abrasions of the head and right side of the body.

Although comatose he responded to painful stimuli with slight movement of his left extremities. The pupils were equal and there was bilateral internal strabismus and a continuous rotatory nystagmus. He was areflexic. Roentgenograms of the cervical spine showed bilateral avulsion of the pedicles of the 2nd cervical vertebra with subluxation of the 2nd vertebral body on the 3rd. Slight compression fracture of the 3rd cervical vertebra was noted and there was marked retropharyngeal swelling (Fig. 2). Crutchfield skeletal traction was applied 24 hours later, replacing the halter traction. The patient became more alert but he had difficulty moving his tongue and swallowing so that his condition required a tracheostomy on March 26. Since the traction markedly increased the distraction of the spinal alignment at the site of the fracture-dislocation, the weight was decreased, skeletal traction was removed, and the fracture was treated by immobilization in slight cervical hyperextension in a Minerva jacket.

At the time of the patient’s discharge from the hospital on April 14, 1962 he was able to eat and swallow and no longer required a tracheostomy tube, but he still had a residual left hemiparesis. The Minerva jacket was replaced with a cervical brace, which the patient removed intermittently against advice. When last seen on May 24, 1962 he had regained strength in the left leg but still had a painful and paretic left arm.

Case 2. A.B., a 40-year-old registered nurse, was admitted to Providence Hospital on April 17, 1962, 48 hours after having been thrown from her car when it skidded from the road. The patient had not been unconscious. She complained only of tingling of the left arm and hand but these symptoms disappeared within a few days.

The neurologic findings were normal except for a bilateral diminution of the biceps reflex and a transient left extensor plantar reflex. Roentgenograms of the cervical spine demonstrated a bilateral avulsion of the pedicles from the body of the 2nd cervical vertebra (Fig. 3).
The patient was discharged on April 22, 1962, immobilized in a Minerva jacket, asymptomatic and normal neurologically. At final evaluation on Dec. 21, 1962 the patient had recovered and the radiographs disclosed good healing of the cervical fracture.

Case 3. R.M., a young mill worker, was admitted to Providence Hospital on June 5, 1962, having been injured 24 hours previously in a two-car collision. He was wearing a seat belt. Although stunned he was not unconscious and recalled that his head had flexed acutely forward resulting in the steering wheel catching him beneath his chin. Immediately after the injury his respirations were very labored with stridor and supraclavicular retraction. He could not speak above a whisper and on attempting to swallow fluids a marked retropharyngeal swelling caused him to choke.

There was a complete paralysis of the right vocal cord, marked paresis of the left one, and displacement of the left arytenoid cartilage. Roentgenograms of the cervical spine demonstrated an avulsion of the neural arch of the 2nd cervical vertebra from its body with slight disruption of the pedicles of the 3rd cervical vertebra (Fig. 4). A marked degree of swelling was demonstrated in the retroesophageal area at C4, C5 and C6 vertebrae.

Traction with Crutchfield skeletal tongs was applied shortly after admission to the hospital. A tracheostomy, which improved the patient's respiratory function, was performed 36 hours after the accident. With the exception of the above findings there was no neurologic defect. Skeletal traction was continued until shortly before discharge from hospital 9 weeks after injury and a cervical brace was substituted. At this time the tracheostomy tube was still necessary. Subsequent laryngeal surgery was required to restore the patient's voice.

A follow-up evaluation on Nov. 1, 1963 showed no neurological abnormality except for slight soreness of the musculature of the neck.

Case 4. D.B., a 43-year-old, right-handed factory worker, was involved in a head-on automobile accident on May 12, 1962. He had no recollection of the accident and sustained a 6-day interval of retrograde amnesia. Although he was a racing driver and usually wore a seat belt, he was not wearing one while driving his passenger vehicle. He sustained the typical bilateral avulsion fracture of the neural arch of the axis for which he was placed in halter traction (Fig. 5A). In addition he had a fractured pelvis and fractured left ribs with a pneumothorax.

The patient still remained confused a few days after the accident but was otherwise normal neurologically. After several weeks he recovered sufficiently to be discharged from hospital.

When examined by the neurosurgical consultant on July 25, 1962 he could not move his head toward either side without marked pain. Another lateral roentgenogram of the cervical spine now disclosed an increased anterior subluxation of the vertebral body of the axis on the 3rd vertebra (Fig. 5B). Anterior cervical spinal fusion was advocated at this time, to prevent further slippage, but was declined by the patient. Eventually the patient returned to the University of Michigan Hospital on Sept. 30, 1962, at which time movements of the neck and neurologic status were normal.

However, because of the slippage, a week later Dr. Robert Bailey of the Orthopedic Service performed an anterior cervical spinal fusion of the 2nd and 3rd cervical vertebral bodies using a right iliac bone graft. The patient was placed on a frame and his neck was immobilized with sandbags for 2 weeks. Three weeks postoperatively he was able to ambulate fully, wearing a Taylor back-brace with an attached Forrester collar. On Dec. 14, 1962 the back-brace was removed; the use of the collar was discontinued 2 months later. Roentgenograms of the cervical spine taken then showed a stable fusion of C2 and C3 vertebrae without further subluxation (Fig. 5C).

Case 5. E.S., a 37-year-old woman, was admitted to University Hospital on Jan. 16, 1959, 1 1/2 hours after being involved in an automobile accident. She exhibited signs of mild shock, dyspnea associated with a slight right-sided tracheal shift and a slightly flail left chest. Roentgenograms of the cervical spine showed a bilateral fracture of the neural arch of the axis (Fig. 6A) which was more clearly demonstrated by laminagrams (Fig. 6B). There were in addition fractures of the right fibula, left talus and calcaneus, with multiple fractures of the ribs associated with a left hemopneumothorax.

The patient was treated in head-halter traction with 5 lbs. of weight to maintain position. Upon neurologic examination she proved normal except that she could not see immediately after the accident but gradually recovered slight vision after a week's interval. The ophthalmologic consultant raised the question of a defect in the patient's depth perception which might be related to some degree of aphasia for in general her ocular findings were normal. On the other hand a neurosurgical consultant wondered whether she could have had a spasm of the vertebral arteries with transient vascular insufficiency to the visual centers in the occipital lobes. An electroencephalogram was normal. A recheck roentgenogram of the cervical spine demonstrated solid healing of the cervical fracture without abnormality (Fig. 6C).
Fig. 5. Case 4. (A) Typical injury was demonstrated initially on May 12, 1962. (B) Cervical roentgenogram on July 25, 1962 demonstrating further dislocation of C2 vertebral body on C3 after failure to wear a prescribed support. (C) Anterior cervical spinal fusion of C2 and C3 vertebral bodies had been performed by Dr. Robert Bailey 9 weeks prior to this roentgenogram. Solid bony union was achieved, preventing further dislocation.
"Hangman's Fracture" of the Cervical Spine

Case 6. E.M., a 72-year-old man, was involved in an automobile accident on Sept. 21, 1962. His car had overturned and he was found pinned behind the steering wheel by two physicians who extricated him from the vehicle and took him to hospital in Portland, Maine.

Upon arrival he complained of numbness in both arms although neurologic findings were normal. Roentgenograms of the cervical spine exhibited an avulsion fracture of the neural arch of the axis with minimal anterior subluxation of the vertebral body of the axis upon the 3rd cervical vertebral body (Fig. 7 A).

Cervical traction was applied promptly and the fracture-dislocation was reduced. He was placed in a collar which he refused to wear continuously and progressive dislocation of the cervical spine developed, as demonstrated in films taken on Sept. 26, 1962 (Fig. 7B). However, after again being admonished that he must continue to wear the collar he did so and by Jan. 8, 1963 the C2-C3 intervertebral discal space was completely obliterated from spontaneous fusion in a position of partial subluxation (Fig. 7C). His neurologic status has been perfectly normal since the time of his injury, and at the last evaluation he was asymptomatic.

Case 7. T.H., a husky 17-year-old boy, was riding in the back seat of a car on Nov. 9, 1963 when it was struck from the rear as it was making a left-hand turn into a parking area. He recalled seeing the lights of the oncoming vehicle through the back window but did not remember the crash. He seemed to have an amnesia rather than a true loss of consciousness, for the patient was helped out of the car immediately and was able to walk about.

Upon arrival at St. Joseph Mercy Hospital he complained of some pain in the neck, and roentgenograms of the cervical spine displayed a fracture-dislocation of the vertebral body of the axis on that of the 3rd cervical with associated bilateral avulsion of the neural arch of the axis (Fig. 8A). There was no neurologic defect.

Traction with Vinke skeletal tongs was applied in an attempt to reduce the dislocation. A few days after the accident the patient complained of blurred vision and gradual development of diplopia which became continuous a week after injury. The ophthalmological consultant made a diagnosis of bilateral paresis of the medial rectus muscle, the left side being worse than the right. The neurosurgical consultant believed these signs might be ascribable to vascular insufficiency of the finer

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Fig. 7. Case 6. (A) Initial roentgenogram revealed the fractures through the neural arch of the axis (arrow) but only minimal dislocation of C2 and C3 vertebral body. (B) Patient refused to stay in traction or wear a collar and within 5 days had a more severe degree of dislocation (arrow). (C) After accepting immobilization in a collar, cervical roentgenogram 14 weeks after injury shows almost complete obliteration of C2-C3 intervertebral space.

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Fig. 6. Case 5. (A) Bilateral fracture of neural arch of axis with minimal dislocation of C2 on C3 vertebral body was demonstrated initially on Jan. 16, 1959. (B) Laminagrams made at this time showed further definition of the extent of the fracture. (C) A follow-up roentgenogram 3 months later revealed good alignment with solid bony union.
branches or twigs of the vertebral artery near the nuclei of the 6th cranial nerve. On November 24 the skeletal traction was replaced by a Minerva jacket. Despite increasing amounts of traction and hyperextension the dislocation had not been reduced, but by December 4 a roentgenogram of the cervical spine demonstrated early bony union (Fig. 8B). By the time of his discharge on Dec. 18, 1963 his diplopia had cleared and he seemed to be doing well except for the discomfort of his cast.

Case 8. L.H., a 61-year-old man, sustained an injury of the head and neck in an automobile accident on Nov. 24, 1963 while asleep riding in the front passenger seat. He recalled nothing of his surroundings until 4 or 5 days after his admission to the Central Michigan Community Hospital, Mount Pleasant, Mich.

In addition to pain and limitation of motion of his neck there was an open wound in the left side of the neck with a considerable amount of emphysema of the neck and lungs. A severe laceration of the tongue required 15 stitches. Roentgenogram of the cervical spine showed a bilateral avulsion fracture of the neural arch of the axis and a dislocation of the body of the axis upon the 3rd cervical vertebral body (Fig. 9A). The patient showed no neurologic defect.

Tracheostomy was performed to combat tracheal compression and prevent aspiration of secretions. Traction with skeletal tongs was applied and in succeeding days the patient gradually improved and the tracheostomy tube was removed. On Dec. 27, 1963 he was transferred to University Hospital.

Subsequent laminograms of the cervical spine showed to advantage the fracture (Fig. 9B), confirming the excellent position visualized on the plain lateral films (Fig. 9C). The anterior-posterior view of the laminogram showed the odontoid process to be intact and that, in spite of the excellence of this view, the laminar fractures were not demonstrable because they were not visible in this plane (Fig. 10). The orthopedic consultant recommended that a cervical brace be substituted for the skeletal-tong traction on Jan. 7, 1964, 6 weeks after injury. The patient was told that he would have to wear this support for at least another 8 weeks in order to permit stabilization of his fracture.

The Mechanism of Injury

Of the foregoing cases the first 3 were encountered within a 2-month period by one of us (K.E.L.) who regarded the vertebral lesion as a highly unusual variety of spinal fracture. In 1962 he forwarded the relevant case histories and accompanying radiographs to the second co-author (R.C.S., a neurosurgeon), who likewise considered the spinal...
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lesion to be extremely unusual and yet was able to collect 5 further examples from a review of material assembled over a period of 4 years. At a neurosurgical conference in 1962 held at the University of Michigan Medical Center, a visiting anatomist (G.H.) commented upon the resemblance of this lesion caused by a traffic injury to that resulting from judicial hanging, as reported by Wood-Jones. Correspondence was then begun with another anatomist (A.J.E.C.) who, when formerly Assistant Conservator of the Hunterian Museum in London, had made a special study of the cervical lesion in judicial hanging and had re-examined Wood-Jones' original material (later destroyed in World War II by enemy action). There ensued a profitable and harmonious collaboration be-

Fig. 9. Case 8. (A) Roentgenogram of cervical spine exhibiting the typical initial injury Nov. 24, 1962. (B) Laminagram (retouched) demonstrating good realignment of fracture-dislocation after 5 weeks of skeletal traction. (C) Plain lateral view of cervical spine taken at same time as laminagram showing added advantages of latter procedure.

Fig. 10. Case 8. Anterior-posterior view of laminagram is presented to indicate the odontoid process is intact. The fractures of the neural arch of the axis are not evident in this plane (arrows).
between neurosurgeons and anatomists, of which this paper is the outcome.

Hanging, probably introduced into 5th-century England by theAngles, Jutes and Saxons,\textsuperscript{1} has long been the official mode of execution of the common felon in the British Isles—death by decapitation remaining the prerogative of those of royal or of noble blood. The death sentence generally (as still today) referred specifically to the condemned person's being "hanged by the neck until dead", but no reference was made to the precise mechanism whereby death was to be effected. Originally therefore death ensued primarily from strangulation.\textsuperscript{2,3} There was little, if any, fixed procedure, technical details being at the hangman's discretion. The knot of the noose occupied no canonical position and the victim might be hoisted by the rope or (as became the custom later) turned off a ladder upon which he stood or was left hanging by the withdrawal of the cart which had borne him to the gallows. There was no specified length of "drop". Death was rarely instantaneous and the victim was therefore left hanging sufficiently long for its occurrence to become plainly manifest. If cut down prematurely (i.e. while still alive) resuscitation was possible, and alleged instances of such resuscitation are recorded.\textsuperscript{2,11} Death was sometimes hastened by traction exerted by the executioner upon the victim's legs.

Towards the end of the 18th century a "long drop" in hanging became common, though not invariable, being first employed at Newgate Gaol, London (1784) and then in Edinburgh (1785, 1788). However, in the case of the infamous Burke (of the notorious Burke and Hare partnership), who was publicly hanged in Edinburgh in 1829, the "drop" allowed was one of inches only and death ensued from strangulation. Burke's body was dissected and the skeleton is preserved in the Anatomy Museum of Edinburgh University. It shows no fracture of the cervical vertebrae.

The last Scottish public execution was that of the poisoner, Dr. Pritchard, hanged in Glasgow in 1865. The knot of the noose was adjusted in the subaural position and a reasonable "drop" was allowed. The basis cranii was found to have suffered a characteristic tearing open from leverage exerted upon the temporal bone (Fig. 11).

Employment of the "long drop" certainly brought about the more rapid death of the victim, but its indiscriminate employment was not devoid of unpleasant consequences. Thus a "drop" of almost 15 feet applied to 2 men of roughly equivalent weight in executions in Ireland in 1865 and 1870 resulted in the near-decapitation of the first victim and the complete decapitation of the second. Such untoward incidents prompted Haughton\textsuperscript{4} to devise, in 1866, tables based on mathematical principles which regulated the length and thickness of the rope proportionate to the weight of the body of the condemned\textsuperscript{4,6} and henceforth the amount of "drop" permitted was no longer haphazard.

![Fig. 11. "The lesion present in the Nubian series of hangings and in the skull of Dr. Pritchard. Fractured base of the skull; effect of a subaural knot." (Reprinted from article by F. Wood-Jones\textsuperscript{9})](image-url)
"Hangman’s Fracture" of the Cervical Spine

In 1886 Marshall\(^6\,9\) attended several hangings and became convinced of the humane efficiency of the submental knot, so that 2 years later he devised a padded leather chin trough (Fig. 12) whereby the rope was maintained in the submental position and, upon the drop occurring, the chin was forced violently upwards and backwards, so that the impetus, “taken in conjunction with the sudden and forcible jerk forwards by the posterior segment of the noose, must... have resulted in a dislocation, with rupture of the spinal cord.”\(^8\)

Paterson in 1890\(^10\) reported on the lesions found at necropsy in a man weighing 147 lbs. who had been given a “drop” of 6½ feet. The essential damage to the spine consisted of a fracture-dislocation of the axis upon the 3rd cervical vertebra. The axis was fractured through its pedicles and its neural arch was thus separated; its left transverse process was also fractured. The 3rd cervical vertebra showed fractured transverse processes and its neural arch remained ligamentously attached to that of the axis. A fracture line involved the bodies of these two vertebrae, passing between the upper aspect of the 3rd cervical body and the inferior surface of the 1st intervertebral disc which remained attached to the inferior aspect of the body of axis. The anterior and posterior longitudinal ligaments were ruptured and the posterior atlanto-axial membrane was torn. There was rupture of the vertebral artery and of the muscles attached to the transverse processes of the 2nd and 3rd cervical vertebrae. The spinal cord was ruptured in its 2nd and 3rd segments and its meninges were torn, as were also the roots of the 2nd cervical nerve. The occipital bone, the atlas, the unbroken odontoid process, the body of the axis and the 1st intervertebral disc remained in normal contiguity and the transverse atlantal ligament was intact.

In 1913 Wood-Jones\(^15\) reported on two distinct types of lesions resulting from judicial hanging as evidenced by two series of specimens then preserved in the Royal College of Surgeons Museum, London. The first series was one of the skulls of Nubians hanged during the Roman period; the second comprised five cervical spinal columns from Rangoon Central Gaol (collected by Capt. C. F. Fraser).

In the first series the knot of the noose had been placed below the angle of the mandible and the resultant leverage upon the temporal bone had produced a lesion at the base of the cranium identical with that observed in the skull of Dr. Pritchard (Fig. 11). It was even possible to discern whether the knot had been right- or left-sided.

In the second series, the criminals had been hanged by the “long drop” with a submentally positioned knot. On each of the cervical spines the axis of the vertebra had suffered a fracture-dislocation involving the avulsion of most or all of its neural arch from its body. The odontoid process remained intact and had played no part in causing death.

The lesion in such modern judicial hangings is characteristic. The detached neural arch of the axis, snapped off cleanly, remains attached to the 3rd vertebra, while the body of the axis, the odontoid process and the atlas...
remain united mutually and to the skull (Fig. 13). Wood-Jones believed this characteristic lesion to be produced by the violent submental jerk which thrusts the head suddenly backward so as to snap the axis of the vertebra. His statement that "the spinal cord was cleanly severed by the fracture" is, however, purely conjectural as his observations were confined to the several cervical spines only, and the relevant spinal cords were not available for examination.

In 1927 the late Sir Geoffrey Jefferson informed one of us (A.J.E.C.) that he possessed excellent radiographs of the cervical spine from 2 cases of judicial hanging and that "the fracture line runs through the top of the third cervical vertebra". The odontoid process remained unbroken and in place.

In 1929 one of us (A.J.E.C.) re-examined the now-perished specimens upon which Wood-Jones had reported, and made notes concerning them; this examination confirmed Wood-Jones' conclusions that the lesion in judicial hanging, wherein the submental knot is employed, is a bilateral avulsion fracture of the neural arch of the axis (through either pedicles or laminae) with some dislocation of the axis upon the 3rd cervical vertebra.

The same co-author also examined the upper four cervical vertebrae from a 23-year-old male, hanged in Alipore Gaol in 1914. His weight was 101 lbs. and the "drop" given was 6½ feet. The knot of the noose was placed in the subaural position. The body of the axis was torn across, its odontoid process and superior articular processes retaining their alignment with the vertebral atlas. The neural arch of the axis was avulsed and remained in its customary relationship to that of the 3rd vertebra.

In 1920 Vermooten13 reported on his investigation of the cervical spine in 4 "well-built young coloured men" following their judicial hanging. Unacquainted with Wood-Jones' earlier work on the subject, he considered the cause of death in such instances not to have been investigated previously in any great detail. The lesions reported by Vermooten14 were essentially similar to those reported by Wood-Jones15 for the Rangoon series of spines. Vermooten found that "in all four cases there was a downward dislocation of the second and third cervical vertebrae. The first and second vertebrae were still properly articulated as well as the atlas with the occiput, the ligamentum apicis dentis being still firmly attached to the occiput and to the tip of the odontoid process." The ligamentum transversum atlantis remained in place, without trace of rupture, in all 4 cases (Fig. 14).

An unofficial report from a pathologist7 who examined the necks of 6 victims of judicial hangings wherein the submental knot was employed stated that the essential spinal lesion consisted of a bilateral avulsion of the neural arch of the axis, with a variable degree of sUBLUXATION of the axis upon the 3rd vertebra but without any fracture or dislocation of the odontoid process.

There exists one report in the literature describing the production of the typical "hangman's fracture" by the employment of the subaural knot. In 1928 Wolff14 reported on the cervical findings in 6 subjects
of judicial hanging in South Africa, in whose execution the knot had been placed below the mandibular angle. In 5 of these cases the lesion produced was avulsion of the neural arch of the axis following the employment of the submental knot. It is possible here, however, that an unsecured subaural knot may have shifted forward to a submental position at the time of the drop. Marshall had pointed out the necessity of careful attention to prevent slipping of the knot, to guard against which he had devised the chin trough referred to above.

It may be concluded, however, that in modern judicial hanging the basic spinal lesion produced is an avulsion-fracture of the neural arch of the axis (through pedicles or laminae) and this lesion may be suitably designated "hangman's fracture" of the cervical spine.

To understand the mechanism of a fracture-dislocation of the axis of this nature reference must be made to the anatomy of this part of the cervical spine, to its intimate relationship with the skull and to the mechanics of the craniocervical junction, based on a study of this region made by one of us (A.J.E.C.) some 30 years ago. The term "cervicocranium" may be applied to the cranium and the vertebrae of the atlas and axis, as the first two cervical vertebrae are profoundly modified structurally that they may act as the handmaids of the superjacent cranium and follow the cranium in the movements of flexion and extension. Thus the vertebra of the atlas suffers developmental suppression of spinous process and of pre- and postzygapophyses, together with detachment of its centrum (the odontoid element); contrariwise it retains its hypochordal arch, to undergo chondrification and ossification in fashioning its anterior arch and it likewise retains (unossified) its hyperchordal arch as its immensely strong and vital transverse ligament. The vertebra of the axis suffers suppression of its prezygapophyses while its centrum proper coalesces with the detached atlantal centrum. Ligamentous connections between the skull and the first two vertebrae are invariably of a fibrous, not elastic, nature. These profound morphological changes are effected in subservience of the mechanical role which atlas and axis are called upon to play—since, in Hunterian language, function determines form.

Not only do the joints of the atlanto-axial complex confer upon the skull the requisite range of mobility (flexion, extension, rotation), but the complex itself serves also to transmit the weight of the cranium to the unmodified portion of the cervical spinal column which begins at the 3rd cervical vertebra.

The junction of the "cervicocranium" with the (so to speak) vertebral column proper constitutes a site of mechanical weakness in the spine, and here the 3rd cervical vertebra forms a fixed point. The application of such a disruptive force as that operative in judicial hanging will tend always to detach the "cervicocranium" from the rest of the vertebral column. The situation of the line of fracture in judicial hanging (through the neural arch of the axis or even through its body or through that of the 3rd vertebra) is therefore understandable, particularly when the normal lines of transmission of cranial weight are appreciated (Fig. 15).

The weight of the skull and its contents is transmitted bilaterally through the occipital condyle, the atlantal lateral mass and the superior articular process of the axis, the two lines uniting in the body of the axis caudal.
Pathogenesis of "Hangman's Fracture" in Survivors

Naturally the sequelae of "hangman's fracture" can be studied only in those victims of traffic accidents who have sustained such a fracture and yet have survived. The clinical status of such survivors and the pathogenesis of the vertebral lesion are therefore briefly considered.

Clinical Status

A. Neurologic Lesions. In 5 patients there was a loss of consciousness (Cases 1, 4, 5, 7 and 8). Other abnormal findings consisted of: bilateral rotatory nystagmus (Case 1); delayed diplopia (Case 7); visual loss (Case 5); difficulty in moving the tongue and in swallowing (Case 1). These symptoms may be attributed to acute vertebral-artery insufficiency resulting from spasm, or to latent small-vessel impairment with a mild degree of thrombosis and medullary or pontine infarction. The one patient (Case 1) who had hemiparesis probably sustained his disability from direct contusion of the cervical spinal cord. There were no neurologic findings in 3 cases (Cases 4, 6 and 8). In 2 patients (Cases 2 and 6) there were symptoms of numbness and tingling but no demonstrable objective defect. Only 1 patient (Case 1) continued to have a painful paretic arm, otherwise all of the group were free of neurologic abnormality at the time of follow-up evaluation.

In these victims of traffic accidents there failed to develop prolonged neurologic defect with any frequency because of the proportionately greater space which exists between the spinal cord and the spinal canal in the upper cervical region. In addition, at the time of injury the sudden abrupt deceleration of the cervical spine in hyperextension, together with the avulsion of the neural arch of the axis, accomplished an acute decompressive action which thus averted spinal-cord injury (with the possibility of paralysis) or, even at this level, the more likely occurrence of sudden death.

B. Lesions Other Than Neurologic. Marked retropharyngeal swelling caused inability to swallow or to breathe in 3 patients (Cases 1, 3 and 8), who required tracheostomy. A fractured pelvis and fractured ribs were sustained in 2 patients (Cases 4 and 5). Pneumothorax was present in 3 patients (Cases 4, 5 and 8), and 1 patient (Case 5) suffered severe fractures of the extremities.

Pathogenesis of the Bony Lesion

Although the "hangman's fracture" characteristically consists of a bilateral avulsion fracture of the neural arch of the axis from its vertebral body, the degree of concomitant dislocation may vary very considerably, as is shown by our series of cases. Lateral laminagrams may be of value in demonstrating the extent of the initial bony involvement (Case 5) or in showing the degree of realignment which has occurred secondarily (Case 8). Anterior-posterior radiographs demonstrate the odontoid process
to be intact and the invisibility in this plane of the basic lesion (Case 8).

In general, realignment of the subluxation may be readily accomplished by skeletal-tong traction in the posture of hyperextension. After this is achieved satisfactory bony union occurs if the patient is retained in traction for 6 weeks and then immobilized in a Minerva jacket or well-fitting cervical brace for another 2 months (Cases 5 and 8). Occasionally reduction of the dislocation cannot be effected, but in the young patient healing of the cervical spine in its subluxated position may occur without neurologic defect (Case 7). Finally there are those individuals who refuse to cooperate because they are symptom-free and who sustain further slippage of their fracture-dislocation but whose fractures nevertheless heal after late immobilization (Case 6).

There does not appear to be the same danger of chronic bony deformity with accompanying compression of the spinal cord in the upper regions of the cervical spine resulting in that chronic neurologic defect seen in "tear-drop" fractures of the lower cervical spine. This, too, is related to the great disparity between the capacity of the upper cervical spinal canal and the size of the spinal cord at this level.

Occasionally it may be advisable to perform an anterior spinal fusion for purposes of stabilization (Case 4). This procedure may be somewhat more difficult of accomplishment in this upper region of the cervical spine than in its lower region, but some surgeons believe a decrease in morbidity is accomplished by avoiding the prolonged use of skeletal traction and immobilization in a cast or brace. A word of caution is indicated concerning too early operation for anterior cervical spinal fusion, since in many of these patients considerable local swelling is present and the soft tissues of the neck have suffered damage. An early life-saving tracheostomy in such an edematous field (Cases 1, 3 and 8) predisposes to the possibility of infection, with osteomyelitis and its associated sequelae. The dangers of respiratory difficulties associated with the impairment of pulmonary expansion (Cases 4, 5 and 8), the possibility of vertebral-artery insufficiency and of high spinal-cord damage during the insertion of an intratracheal tube, must be weighed carefully before undertaking a spinal fusion for a lesion which in the vast majority of instances will stabilize itself under conservative management.

Possible Prevention of the Lesion in Traffic Accidents

In this series there were 2 patients who did not lose consciousness in spite of their injuries. One of the patients (Case 3) was wearing a transverse or "lap" seat belt and he recalled that he had caught his chin on the steering wheel. The second patient (Case 6) in this category remembered "hanging" his chin on the dashboard of the car. Although our motorists in this country are gradually adopting seat belts for the prevention of injury in traffic accidents it is clear that a "harness" similar to that used in some foreign cars would afford greater protection in preventing "hangman's fracture".

Summary

"Hangman's fracture" is a rare but distinctive lesion of the cervical spine characterized basically by a bilateral fracture through the neural arch of the 2nd cervical vertebra with or without dislocation of the body of the axis upon that of the 3rd cervical vertebra. The fracture may involve the 1st intervertebral disc or the 3rd cervical vertebra. The odontoid process remains unbroken and in place and the transverse atlantal ligament is unruptured.

This type of fracture-dislocation occurs in modern judicial hanging and in some instances of traffic accidents.

The technique of judicial hanging is briefly considered in order to demonstrate how, by the employment of a long drop and a submental (more rarely a subaural) knot, this particular vertebral lesion is effected.

The detailed case-histories are presented of 8 patients who sustained a "hangman's fracture" in traffic accidents. These demonstrate that permanent neurologic defect
rarely ensues because of the roominess of the upper cervical spinal canal and because a death-averting decompression of the upper cervical cord is accomplished by the lesion itself (i.e. the avulsion of the neural arch of the axis).

Most patients with "hangman's fracture" respond readily to treatment comprising realignment of the cervical spine by skeletal traction and immobilization in a cast or brace without recourse to open reduction of the fracture or to the procedure of spinal fusion.

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