ON FUSION OF THE ATLAS AND AXIS VERTEBRAE

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INTRODUCTORY

The condition of true, non-pathological fusion of the atlas and axis vertebrae constitutes an extremely rare anomaly—perhaps the rarest of all the many and varied manifestations of irregular segmentation affecting the vertebral axis. But few cases occur in the whole of the literature, a fact which is not very surprising when one considers the functional importance of the atlanto-axial articulation, and the disability necessarily consequent upon any grave developmental disturbance of that mechanism. Additional examples may have been overlooked in the past, since the older anatomists (e.g. Macalister(1)) dismissed all such fusions as entirely the result of pathological change; and although Dwight(2) had in 1901 figured and briefly mentioned an undoubted specimen of complete atlanto-axial fusion, it was not until Elliot Smith(3) in 1907–9 described what must be regarded as the classical case that the correct nature and interpretation of this most interesting vertebral variation was finally established.

In this paper attention is drawn, without apology, to further, if somewhat incomplete, cases.

TYPES OF ATLANTO-AXIAL FUSION

If merely descriptive terminology be employed, the following classification covers all known cases of fusion of the first pair of cervical vertebrae:

Group 1. Fusion of the separated odontoid process with the ventral atlantal arch.

Group 2. Complete (= bilateral) fusion of atlas and axis with or without attempted assimilation of the first vertebra by the second.

Group 3. Incomplete (= unilateral) fusion, one-half of the atlas retaining its independence, with or without some degree of assimilation.

Morphologically speaking, cases in Group 1 are purely atlantal in nature: the atlas centrum is restored to its proper vertebra and may be further separated from the axis centrum by the interposition of a genuine fibro-cartilage. A number of such cases have been recorded. Thus, Le Double(4), though not quoting any personal case, makes mention of three specimens—one in the Siena Museum, one (No. 9966) of Dwight's collecting in the Warren Museum of Harvard Medical School, and, in the same museum, a plaster cast of another specimen of French origin. In 1924 Hunter(5) reported an excellent example,

referring in his paper to a further case in the private collection of Prof. Bolk, showing occipito-atlantal synostosis in addition to the odonto-atlantal fusion.

Group 2 contains the famous cases of Dwight and Elliot Smith, to which a third may here be added from the Hunterian Museum of the Royal College of Surgeons.

Dwight's case (spine *H* 3 in his account) constitutes Group C of Class IV in that author's classification of the anomalous spines in the Warren Museum of the Harvard Medical School. The specimen, from an old insane woman, has the vertebral formula C. 6, Th. 12, L. 6, S. 6, Cocc. 4, "as if the thorax had moved a step upward." Of the six cervical vertebrae, the atlas and axis are indistinguishably fused: the odontoid apex is recognisable; the atlantal posterior arch is well developed and the superior atlantal articular processes are "nearly plane." The VIth cervical vertebra has the characters of a normal VIIth, and the VIIth itself those of the normal Ist thoracic; the last (VIth) lumbar vertebra is sacralised on the left side. Elliot Smith's case was taken from an adult Ancient Egyptian, whose spinal column exhibited a remarkably consistent series of segmental errors, best summarised by Bateson's (6) term *backward homoeosis*, for this spine presented the following features: manifestation of an occipital vertebra; fusion of atlas with axis; a right cervical rib on the VIIth cervical vertebra; the assumption of lumbar characters by the XIIth thoracic vertebra; the assumption of Vth lumbar characters by the IVth lumbar vertebra, and fusion of the real Vth lumbar vertebra with the sacrum.

The atlas and axis, originally separate, were united by ossification of the capsular and anterior atlanto-axial ligaments: the right half of the transverse ligament was ossified and ankylosed to the back of the odontoid process, to the front of which the atlantal anterior arch was further fused: the left half of the first neural arch remained independent both of the axis and of its fellow, this last being much depressed and assimilated by the axial arch below.

To permit of rotary movements of the cranium, the upper atlantal processes had been modified into flat and sloping articular surfaces, i.e. had assumed definitely axial features.

The Hunterian Museum specimen is No. 503, Teratological Series, comprising an adult anomalous cervical spine of only six vertebrae. The atlas and axis are completely fused, the composite piece bearing but one transverse process on the right, and two on the left. The IVth and VIth cervical vertebrae manifest laminar irregularities; the Vth has the characters of a normal VIIth, whilst the VIth also departs markedly from type. There is nothing further known about the vertebral formula, the neck only being preserved.

It is likely that a survey of further teratological material in anatomical museums throughout the country would reveal additional examples of atlanto-axial concrescence, as might also a careful and critical examination of clinical cases of Willet-Sprengel shoulder, brevicollis, and the like, wherein the cervical spine is invariably of anomalous constitution.

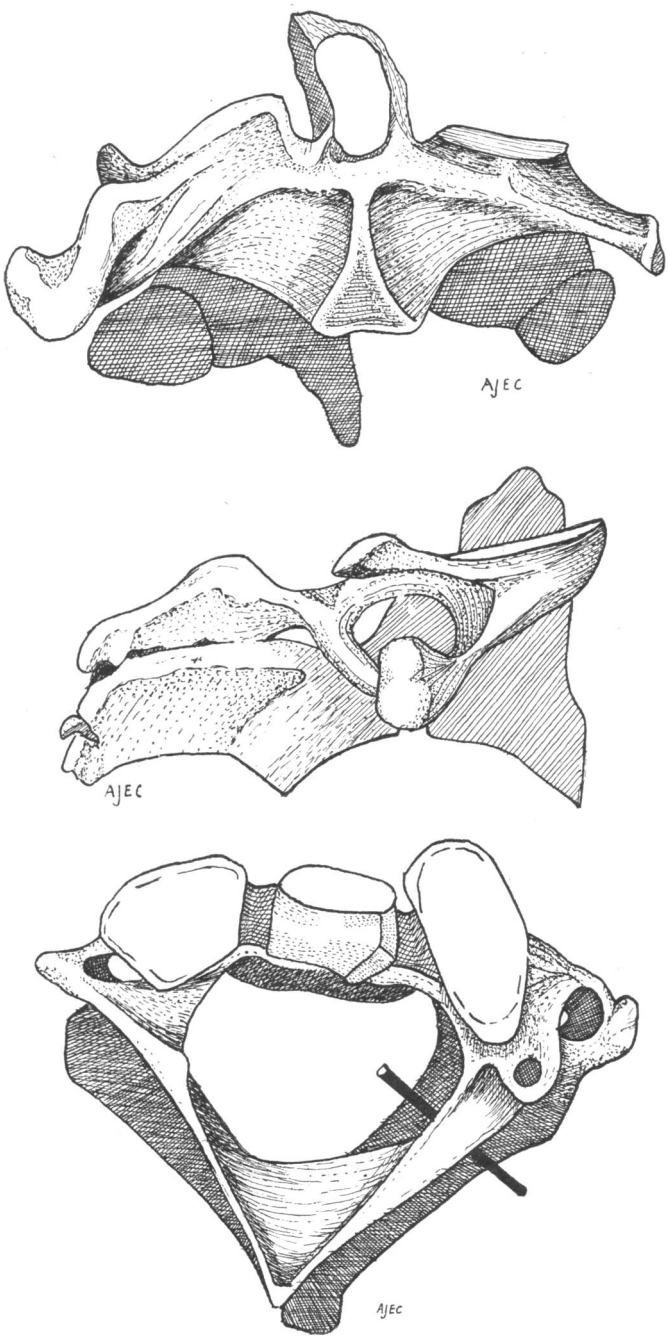

Fig. 1. Specimen *A* (University College, London). Anterior, superior and right lateral aspects of fused (half) atlas and axis.

Recently, Tramontano-Guerritore(7) has mentioned the condition of atlanto-axial synostosis with some familiarity, in connection with metameric variation in the occipito-atlantal region, but his paper does not detail any specific instance.

Group 3 contains the two cases herein briefly described: Specimen *A* (probably of Prof. Thane's collecting) from the Anatomy Department of University College, London, and specimen *B* from the Anatomical Museum of Birmingham University. Neither specimen has any history, the condition and constitution of the spinal column being unknown in both. These two specimens are the sole manifestations of atlanto-axial synostosis encountered during the past few years in a comprehensive study of anomalous cervical material from many sources[1].

Specimen *A* is a composite bony piece made up of an entire adult axis vertebra together with the very intimately incorporated right half or so of its cephalic neighbour, whose left half, present during life, is lacking (see fig. 1). The sturdy odontoid process, bearing a large atlantal facet, is deflected to the right; the left half of the conjoined piece is entirely axial in nature, as evidenced by the characters of the upper and lower articular, and of the transverse, processes. On the right, in the region of the lateral masses, the superior articular process is definitely of atlantal type (though greatly modified), the inferior, of axial type; the bony tissue between these two processes, scarcely thicker (deeper) than the purely axial left portion of the specimen, nevertheless represents both atlas and axis mingled in a fusion so complete and so intimate as to justify the description "assimilation of the atlas by the axis." The large single transverse process, representing the fused processes of the two vertebrae, is atlantal in character; there is not the slightest indication of the dual nature of this process any more than that of the fused lateral masses (see fig. 1). Immediately behind the transverse process an intervertebral foramen gives exit to the second spinal nerve: behind the foramen the atlantal neural arch fuses with the corresponding subjacent structure, though to no severe degree. The atlantal component of the composite arch is readily detectable right back to the middle line where it blends with the left half of the axial neural arch, in the same plane as which it lies throughout its course. In consequence, the subjacent right axial neural arch carrying with it the corresponding half of the spinous process is, despite the synostosis, displaced downwards to a plane much below that of its fellow. An anterior atlantal arch is wanting, being probably part of the absent left portion of the bone. The upper atlantal articular facet is spread out to cover the whole of the articular process, which has extended both antero-medially and postero-laterally. This upper facet is markedly flattened, retaining but faintly its general concavity,

[1] Namely, the Hunterian Museum, Royal College of Surgeons; University College and King's College, London; the Universities of Leeds, Manchester, Birmingham, Sheffield, and Liverpool; University College, Cardiff, and Trinity College, Dublin. I sincerely thank the respective heads of these several Anatomy Departments for their great courtesy in permitting me access to material in their care.

and then mainly in its hinder portion. Rotary movements must certainly have occurred, and with considerable facility, at the right occipito-atlantal articulation.

Specimen *B* (see fig. 2) consists of a complete adult axis vertebra with which is fused the right half of the corresponding atlas, the left moiety of which, undoubtedly present during life, is now lost. The second vertebra is slightly asymmetrical; its right superior articular process is invisible owing to the

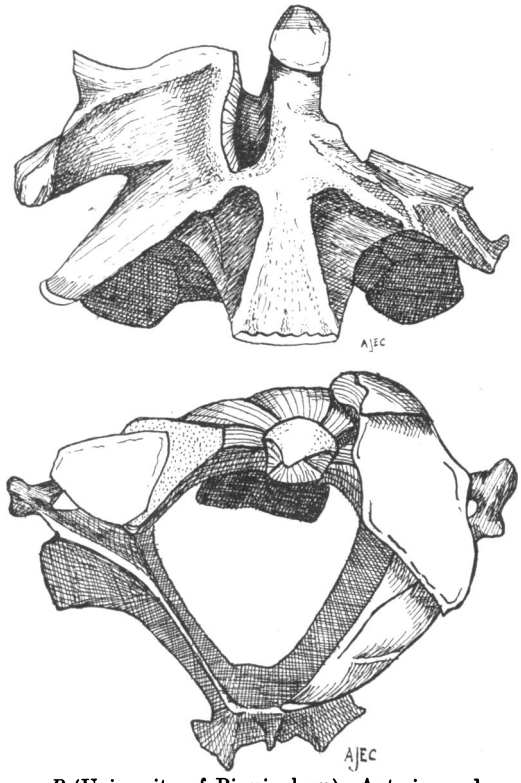

Fig. 2. Specimen *B* (University of Birmingham). Anterior and superior aspects of fused (half) atlas and axis.

fusion, and its spine is atypical, being composed of a tiny median bony spicule flanked on either side by a larger, very irregularly tuberculated prominence. The odontoid process is deflected markedly backwards and to the left, so that its atlantal facet, borne high on its summit, looks upwards rather than forwards and, lying altogether above the level of the ventral atlantal arch, may very well have articulated with the occipital bone: its neck is grooved for the transverse ligament, which apparently existed with more or less its customary connections. Both laminae bear a pronounced groove for the second spinal nerve.

Of the atlas, only the right lateral mass and corresponding half of the

neural arch are present: the former is perfectly continuous with the axis below (a faint lateral groove and a couple of vascular foramina alone giving any hint of previous independent existence), whilst its superior articular process juts out considerably in advance of the axial body, ending abruptly in a sharply recurved lip. There is no trace of anterior arch, the odontoid neck presenting bony continuity with the anterior recurved extremity of the lateral mass.

The (upper) atlantal articular surface has undergone definite modification; whilst generally faintly concave in its long axis and also anteriorly in its transverse axis, yet in its hinder portion it is distinctly convex, tending to assume the characters of the articular shoulders of the axis, and strongly indicative of an attempt at the provision for rotary movement at the occipito-atlantal articulation. That such movement was indeed performed, and especially in the left-to-right direction, is further evidenced by a backward prolongation of the superior atlantal facet and by the impress made by the (now missing) left inferior atlantal process upon the left side of the base of the odontoid process (stippled area in fig. 2).

The right atlantal transverse process is well formed and typical; the right half of the neural arch, deeply grooved by the vertebral artery, runs clear of, though extremely close to, the subjacent arch, terminating posteriorly in unattached fashion.

COMMENTARY

The two cases described are necessarily incomplete for want of information concerning the constitution of the remainder of the vertebral column and the condition of the margins of the foramen magnum. They are advanced, however, in the hope that search for further examples may be induced, and our knowledge of this particular variation may thereby be augmented.

The synostosis involves the identical atlantal portion in both cases, but to a much greater degree in case *A* than in case *B*. In the former (undoubtedly congenital in nature) the features of the lateral mass region and of the compound transverse process indicate the occurrence of the anomaly at a date much preceding the time of fusion in case *B*.

It is difficult to determine with certainty whether atlas and axis enjoyed previous independence, undergoing subsequent fusion, or whether an original atlanto-axial segmental cleavage failed to occur. The available evidence, particularly that offered by the presence of the second spinal nerve, is in favour of an intimate fusion of two originally separate elements.

In specimen *B* the first two cervical vertebrae have formed independently, and have suffered fusion either late in development or (as is likely enough) early in post-natal life. Were the absent atlantal moiety restored, this case would resemble those of Dwight and Elliot Smith in the possession of distinct atlantal and axial transverse processes bilaterally.

In both *A* and *B* a *ligamentum transversum atlantis* was present and provision made (cf. Elliot Smith's case) for rotation of the cranium by com-

pensatory modifications of the right occipito-atlantal—and also in case *B* of the left atlanto-axial—articulations.

No more excellent demonstration could be afforded of the body's potential resources for successfully combating a serious initial handicap or for the bold modification of structure in the maintenance of essential function.

I wish to express my indebtedness to Sir Arthur Keith for information regarding the Hunterian specimen (No. 503, Terat. Ser.), to Prof. G. Elliot Smith, F.R.S., and to Prof. J. C. Brash for generous permission both to examine and to describe the two most interesting specimens which form the main subject-matter of this paper.

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