ON THE VARIETIES OF THE ATLAS IN THE HUMAN SUBJECT, AND THE HOMOLOGIES OF ITS TRANSVERSE PROCESSES.

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Part I.—VARIETIES.

MY attention having been lately directed to an abnormal atlas in a subject undergoing dissection in the rooms, I have been led to make some inquiries as to the numerous variations exhibited by this bone, with a view to their classification.

These variations are not confined to any one particular part of the bone, but are found most frequently in the transverse processes, and next to them in the posterior arch, while in the anterior arch they are comparatively rare, and, as far as my observations go, the lateral masses are not subject to any striking variation except the slight differences in depth of the superior articular surfaces which exist at the different periods of life.[1]

The following description of those abnormalities is given in their order of frequency, and therefore the specimen which first attracted my notice, although interesting on account of its clinical importance, will not be referred to till after most of the others.

I. TRANSVERSE PROCESSES.—*Normal Anatomy.*—The most constant arrangement of this part is with the arterial foramen piercing its base and its two elements more intimately fused beyond the foramen than in vertebræ lower down the series. The two parts have slightly different directions; the anterior element[2] passes downwards and outwards, while the transverse element proper passes directly outwards, with, in some cases, a slightly upward inclination, and the common extremity is in the form of a rough ridge running obliquely downwards and forwards.

[1] These differences in depth are coincident with the changes of the occipital condyles, which have for their object the perfect balance of the head on the vertebral column, necessitated by the peculiar mode of growth of the skull.—Cleland "On the Variations of the Skull," *Phil. Trans.* 1870, p. 160.

[2] This part, to follow the morphological significance attached to the similarly situated part of the typical cervical vertebræ, should merit the title of "costal," but, as will be seen in Part II., its serial homology is different from what has been supposed.

The same obliquity occurs in the axis. It is a remarkable fact that this obliquity is in the reverse direction to that of the bifid extremity of the transverse processes of the typical cervical vertebræ, and that the only exception is in the case of the *vertebra prominens*, when its costal element bears evidence of being autogenously developed.

This is sufficient to lead one to suspect, what will be afterwards shown, that, in the first two vertebræ the development of the costal element differs from that in the other cervical vertebræ; and that the difference is one of increase, is to be conjectured by the comparison with the *vertebra prominens*.

Abnormal Anatomy.—The anterior element of the transverse process may be absent, leaving the arterial foramen open in front, and the artery protected externally by a large tubercle.

The transverse element proper I have never seen absent, although it may be diminished in size. The abnormalities which most frequently affect it, consist of exaggerated development. Increase of length produces bifidity (fig. 1). Increase in an upward direction may cause a bridge-like expansion of bone to stretch inwards to the external edge of the superior articulating surface, completing a foramen which looks towards the front, to give passage to the anterior division of the first cervical nerve (figs. 3 and 4). This condition is constant in a good many mammals, *e.g.*, ruminants.

In two instances coming under my notice, a strong process passes upwards to the under part of the *processus jugularis* of the occipital bone. In both cases the processes are thick and rounded. One of them (fig. 2), after passing upwards for a short distance, is then directed inwards towards the atlanto-occipital articulation, producing a deep notch by which the anterior division of the suboccipital nerve passes forwards. In the other case (fig. 5) the process passes upwards, and forms a junction with the jugular process, the junction being in the form of a round vertical pillar, having an oblique groove passing round its middle. This groove indicates the original formation of the pillar from two parts which at first articulated by opposed oblique surfaces, but became afterwards fused, as did also in this specimen the opposed normal surfaces of the atlas and occipital condyles.

This articulation between atlantal transverse process and jugular process of the occipital, is analogous to the articulations formed between the lumbar transverse processes of solipeds, in consequence of their increase in an anteroposterior direction.

Normally such a state of matters exists in the human subject at the articulations between the lateral masses of the sacrum. As a proof of the similarity, it may be mentioned that when the last lumbar vertebra has a lateral mass on one side, like a sacral vertebra, united with the sacrum, while only a transverse process exists on the other side, the junction is accompanied with elevation of the lumbar vertebra on that side, and so also in this case the junction of transverse process with jugular process of occipital is accompanied by a similar elevation, as may be seen easily when the side of junction is compared with the normal side (fig. 5).

II. Posterior Arch.—Variations of this part may take the form of either increased or deficient development. The posterior tubercle may be enlarged and form a prominent spine, either single (fig 6.) or bifid.

The laminæ may be increased in depth, but this seems in the majority of cases to be due to a rising upwards of the superior edge. Perhaps this may be connected with the presence of a separate centre of ossification known to be sometimes present in this situation. As a rare occurrence small articular facets are formed between the laminæ and the edge of the occipital bone which circumscribes the foramen magnum posteriorly.

A spicule of bone often has its origin behind the groove, [1] which gives passage to the vertebral artery and suboccipital nerve, and crossing these structures, abuts against the posterior part of the superior articulating surface.

Deficient development usually is seen as a gap between the lateral halves of the arch, but, as will be pointed out further on (IV, 3.), it is doubtful if in all cases want of ossification can be laid down as the cause of the deficiency. One-half of the

[1] The point of origin of this spicule is in the position of the oblique processes of the typical cervical vertebræ, viz., between lamina and pedicle, it is a constant structure in most mammals, and is to be looked upon as the homologue of the superior oblique process.—Cleland *On the Homologies of Axis, Atlas, and Occipital Bone*, in *Nat. Hist. Rev.*, April 1861.

posterior arch may be absent, but, as a rule, this only occurs when adhesion exists between the atlas and occipital.

I have seen one case where the arch crosses the middle line, but presents a gap posterior to the lateral mass of one side to the extent of about a fifth, leaving one to imagine that the four-fifths of the arch were ossified by growth from one side only; this conjecture is strengthened by the fact that from the point of origin behind the lateral mass the arch gets more and more attenuated till it ends in a free point behind the lateral mass of the opposite side. In the case to be mentioned in more detail further on, the posterior arch was altogether deficient. Absence of the posterior tubercle and reduction of the arch to a mere ring, are cases of minor importance occasionally met with.

III. ANTERIOR ARCH.—Normally this part has a centre of ossification appropriated to itself, and osseous growth extends from this towards the lateral mass, from which it is separated by a suture. This suture usually becomes obliterated about the sixth year (Quain's *Anatomy*), but in rare cases it may remain for a considerably longer time.[1]

When the centre for the arch fails to make its appearance, ossification then extends to the middle line from the lateral masses, and in such cases when the osseous growth is feeble, a mesial suture may remain permanently.[2]

A less important abnormality of the anterior arch is the occurrence of an enlarged anterior tubercle, which projects downwards in front of the body of the axis as is normal in many of the monkeys.

IV. VARIETIES INVOLVING MORE THAN ONE PART.—Besides the cases of abnormality which are confined to one of the parts of the atlas, there are others in which variation extends over several parts. Under this head may be mentioned, first, fusion with neighbouring bones; secondly, deficient development of both anterior and posterior arches; thirdly, deficiency of the posterior arch, with the rest of the bone somewhat altered in shape.

1. In fusion of the atlas the junction is usually with the occipital bone, the superior articular surfaces and occipital condyles being

[1] See a case mentioned and figured by Humphry, *Treatise on the Human Skeleton*, p. 131, in which a lateral suture remained up to adult life.

[2] Professor Humphry, *loc. cit.*, describes a specimen showing this peculiarity.

run into one another, but, as a rule, not to such an extent as to obliterate all traces of their original separation.

In addition to the lateral masses, the arches may also be united more or less by their edges to the corresponding margin of the foramen magnum. It has been suggested that these changes are the result of early inflammatory action, and thus it may be explained that in some cases we see adhesion of one part of the atlas coexisting with absorption of other of its parts.

Luschka[1] has described such a case, in which the lateral masses and upper edge of the anterior arch, as well as half of the posterior arch, were joined with the corresponding parts of the occipital bone, while the other half of the posterior arch was absent.

Boxhammer[2] has described another case. In it the lateral masses were completely fused with the occipital condyles; the anterior arch was perfect and free; the posterior arch was open in the middle, one of its halves being free, the other completely fused with the occipital.

Another case has been more recently described by Schiffner.[3] The atlas was so intimately fused with the occipital bone as to be with difficulty detected; also its lateral masses were so little developed and so displaced as to allow the occipital condyles to articulate with the axis directly. The axis, in its turn, was fused with the third cervical vertebra, the assimilation between their arches being so great as to give one the impression that the common spine belonged more to the third vertebra than to the second.

2. The case to which I have referred at the commencement of this communication is one in which deficiency occurred in both the fore and hinder arches. It existed in an aged female dissected in the Anatomical Rooms of this University.

Its peculiarities are as follows :—

The posterior arch is altogether deficient; a symphysis is present in the middle of the anterior arch, and admits of a considerable amount of movement; the transverse processes and

[1] *Die Anatomie des Menschlichen Halses*, 1862, § 35.

[2] *Zeitschrift für rationelle Medicin*, 3 Reihe, Band 15, "Die angebornen Synostosen an den Enden der bewerlichen Wirbelsäule."

[3] Virchow's *Archiv*, vol. lxxiv. p. 320, "Ueber die Architectur des Schädelgrundes in der norm und bei Assimilation des Atlas."

lateral masses, including the articulations, are normal. On making a dissection of the soft parts, the vertebral artery and suboccipital nerve were found in normal relation to the lateral masses, and supported by a strong bundle of ligamentous fibres, which on each side sprang from a slight tubercle behind the lateral mass. The fibres of each bundle traced backwards radiated and interlaced with vertical fibres which united the posterior margin of the foramen magnum with the arch of the axis, and might be looked on as representing the posterior atlanto-axial and atlanto-occipital ligaments directly continuous with one another. The middle part of the anterior atlanto-axial ligament is in the form of a flat band, stronger than usual, which superiorly is bifurcated and attached on each side of the symphysis.

On rotation of the head, motion takes place at the abnormal joint; partly angular, partly rotatory in character. When the occiput, atlas, and axis are placed with their mesial parts superimposed, the normal imperfect apposition of the opposed atlanto-axial articular surfaces is seen, and the anterior surfaces of the halves of the atlas are nearly in the same straight line, but when the head is rotated this straight line is broken into two, which form an angle projecting forwards.

At the same time another movement can be detected; the upper edge of the transverse process which advanced is twisted downwards and forwards, while that of the opposite transverse process is twisted downwards and backwards, these different movements being produced by the superimposed facets of either side being brought into more perfect coaptation, the joint in front allowing this to be more perfect than usual.

During the rotation of the head, and the consequent angular motion induced between the lateral halves of the arch, a slight slackening of the transverse ligament of the atlas takes place, also a slight narrowing of the transverse measurement of the atlantal part of the spinal canal; but displacement backwards of the odontoid process is prevented by an unusually strong suspensory ligament, and the narrowing of the canal compensated for by the absence of the laminæ.

It is unfortunate that the history of the subject is unknown, but it is likely that no injurious consequences resulted from the abnormal condition of the parts.

A case nearly similar to this, described by Kussmohl, and referred to by Luschka,[1] is interesting on account of the clinical history being known. An epileptic boy, aged 12, was observed to have a convulsive attack after every strong movement of the head to either side. After death the atlas was found to have a deficiency in its posterior arch, and a very mobile joint in the centre of the anterior arch. The imperfect laminæ were caused to overlap, whenever the head was rotated, a constriction of the canal being brought about; and this no doubt was the cause of the epileptic seizures, by producing pressure and irritation of the membranes of the cord.

3. A specimen (fig. 8) which I have lately met with is a good example of deficiency of the posterior arch, accompanied with a peculiar alteration in the shape of the ring of that bone. As will be seen anon, it is likely to have some obstetrical interest attached to it. The peculiarities of the specimen consist of a deficiency of the posterior arch, accompanied by an increase of the width of the spinal canal; the anterior arch is perfect, but nearly straight, and the transverse processes are depressed and thrown forwards to such an extent that their front parts lie in the same line as the anterior arch.

By pressing on the sides of the laminæ, their free ends are approximated so as to close the posterior deficiency and reduce the width of the spinal canal to its normal dimensions. By this means also the proper curve is given to the anterior arch, and the tips of the transverse processes made to assume a more natural direction. One can easily see that in this case, deficiency of osseous growth does not account for the abnormal appearance of the bone. The abnormalities seem to me to be due to some force, which had at an early period acted wedge-like between the back parts of the atlantal articular surfaces, and caused their separation, and thus altered the direction of the transverse processes, as well as produced the disjunction between the halves of the posterior arch which had up to that time been united. The effect is such as might result from the forcing of the wide back parts of the occipital condyles forwards between the anterior narrower parts of the superior articular surfaces of the atlas by strong extension of the head on the vertebral

[1] *Anatomie des Menschen.*

column in parturition, in cases of face presentation, and it is highly probable that this is the explanation. The coupling together of the anterior parts of the lateral masses by the transverse ligament, effects the preservation of the anterior arch, and at the same time makes each extremity of that arch act as a centre round which the lateral mass is rotated in the movement outwards of its back part, which is produced by the occipital condyle.

Part II.—The Homology of the Transverse Processes of the Atlas.

The anterior part of the transverse processes of the typical cervical vertebræ is now usually looked on as the homologue of a rib, its extremity being comparable with the body, its point of origin with the head, and the part directly in front of the arterial foramen with the neck of a rib. This part in the atlantal and axial transverse processes has, however, a somewhat different morphological signification from that of the typical cervical vertebræ. This is not easily made out by a comparison of the dry bones, but requires a survey of their attached soft parts as well. If the series of cervical intertransverse muscles be traced upwards towards the head it will be seen that, while the posterior intertransverse muscles pass between the tips of the posterior row of tubercles of all the cervical vertebræ, and are continued up to the head by the *rectus capitis lateralis*, the anterior muscular slips pass in the lower part of the region between the anterior tubercles; but on tracing the series upwards, the continuity with the axis is seen to be effected by a muscular slip which passes, not to the extremity of the tip of the transverse process, but to a rough mark in front of the superior articular surface. A similar slip of muscle is continued up from this roughness, passing across the front of the atlanto-axial articulation to a corresponding roughness in front of the anterior root of the atlantal transverse process, and this muscle is in its turn continued up to the head by the *rectus capitis anticus minor* muscle.

But if the series of anterior intertransverse muscles is continued upwards by the *rectus capitis anticus minor*, similarly as the posterior series is continued by the *rectus capitis lateralis*, it obviously follows in the one case, as in the other, that the portions

of bone to which these muscular slips are attached are also serially homologous.

If it be admitted that the anterior tubercles of the transverse processes of the lower cervical vertebræ are in series with the bodies of the ribs, then the body of the rib is in the atlas and axis represented by the roughness in front of the anterior root of the transverse process in each of these vertebræ; the anterior portion of the transverse process beyond this being homologous with the spicule of bone stretching in the typical cervical vertebræ between the anterior and posterior tubercles; in other words, it is the representative of a greatly elongated rib-tubercle such as exists in the Crocodilia.

Conclusive proof of the correctness of these statements is obtained by observing the mode of exit of the anterior divisions of the spinal nerves; in the lower cervical region they emerge between the anterior and posterior intertransverse muscles, and in the atlas the anterior division of the first spinal nerve escapes between *the rectus capitis lateralis* and *rectus capitis anticus minor;* further, the position of the nerve on the anterior root of the transverse process of the atlas, points out the correspondence of that part with the bridge of bone uniting the anterior and posterior tubercles of the transverse processes of the five lower cervical vertebræ.

Explanation of Plate II.

Fig. 1. Under surface of atlas with bifid transverse process.

Fig. 2. Left half of atlas seen from the front, showing a growth of bone springing from the upper surface of the transverse process and passing towards the jugular process of the occipital bone.

Fig. 3. Atlas from above, showing, *a*, spicule of bone springing from posterior arch at the upper surface of the point of junction of lamina and pedicle, and passing over the position of nerve and artery to the back part of the superior articular surface; *b*, a second spicule of bone passing from upper surface of transverse process to the outer edge of the superior articular surface, and crossing the place of exit of the anterior division of the first spinal nerve. A probe, *c*, is represented passing through the abnormal foramina.

Fig. 4. The same atlas seen from the front, showing the foramen which looks forwards and gives passage to the anterior division of the first spinal nerve.

Fig. 5. Occiput and atlas fused together, posterior view; the abnormal pillar described in the text is shown; also the atlas and base of skull are seen to be further separated on that side.

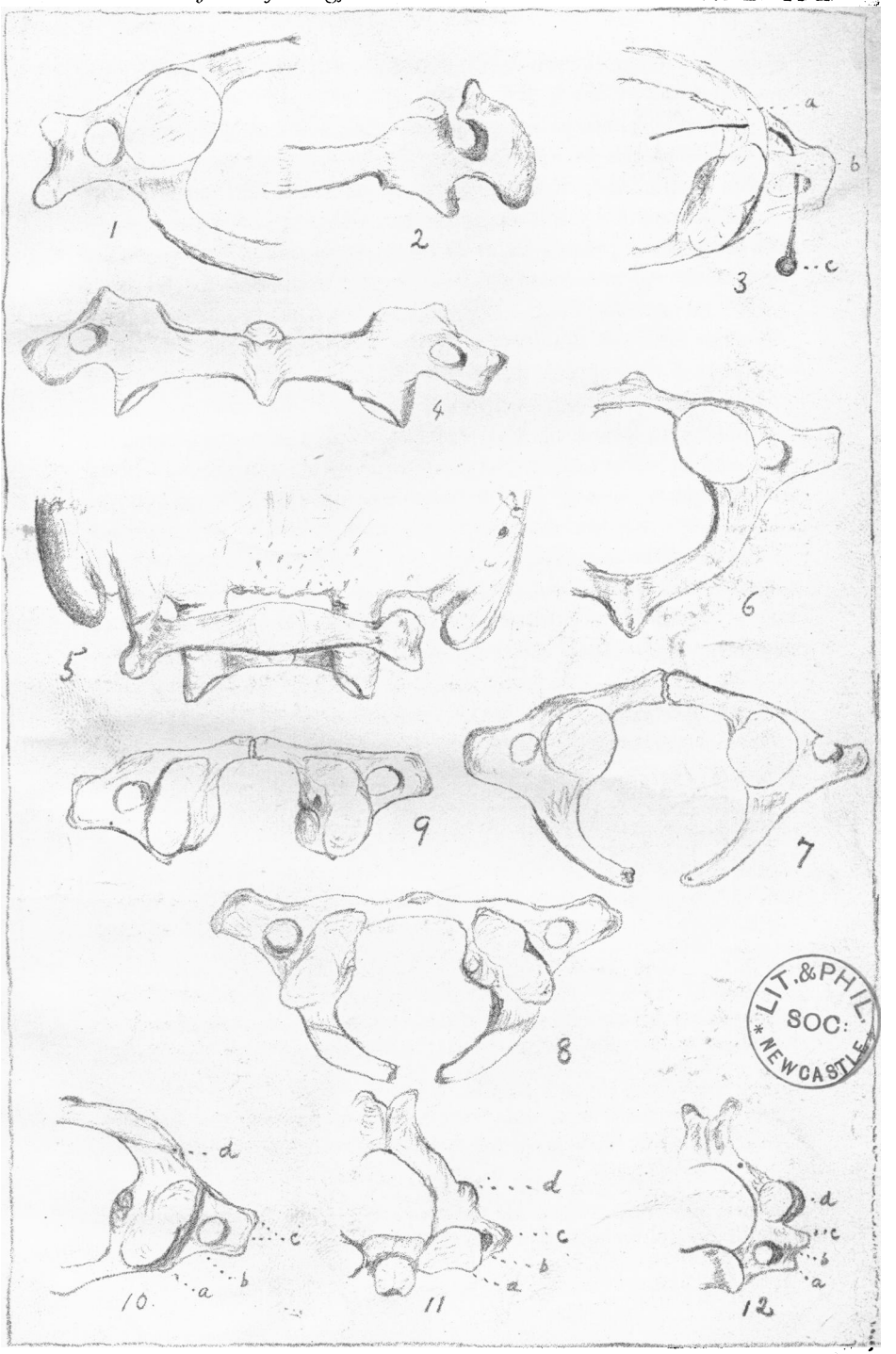

Fig. 6. Shows a large anterior and posterior tubercle.

Fig. 7. Shows an imperfect posterior arch, also a suture in the middle of the anterior arch, and on the left side a deficiency of the anterior root of the transverse process.

Fig. 8. Atlas with posterior arch open and transverse process thrown forwards, probably from the cause suggested in the text.

Fig. 9. Semi-diagrammatic view of the abnormal atlas described, in which the posterior arch is absent, and the anterior in two parts.

Figs. 10, 11, and 12 represent the left halves of a normal atlas, axis, and typical cervical vertebræ; the same letters in each, point to the homologous parts—*a* represents the position of the point in each which corresponds to the tip of a rib, *b* to the rib tubercle, *c* to the tip of the transverse process proper.

NOTE BY PROFESSOR CLELAND ON DR ALLEN'S PAPER.

The remarkable sequence of parts in the transverse processes of the atlas, axis, and succeeding cervical vertebræ demonstrated by Dr Allen, is a most important correction of the views hitherto held on the subject. To me it has an additional interest in connection with the transverse and lateral-odontoid ligaments, the sequence of which with the ligamenta conjugalia costarum of the lower animals I indicated in 1861 (*loc. cit.*). Inasmuch as the whole anterior part of the transverse process of the atlas corresponds with the tubercle of a rib, the lateral mass must be regarded as containing within it, undifferentiated from its vertebral part, a costal element corresponding with the head and neck of a developed rib. It corresponds not merely with that part of the body in other vertebræ which is developed from the arch and supports in the cervical region the joints of Luschka, in the dorsal region the facets for the heads of the ribs, but is the representative likewise of the head and neck of the developed rib, and the part of the transverse process situated in the lower cervical vertebræ in front of the arterial foramen. This is a circumstance to be taken into account when considering the large size of the lateral mass of the atlas; and it completes the correspondence of the transverse ligament with a ligamentum conjugale, inasmuch as the parts to which the transverse ligament is attached have the heads of a pair of ribs incorporated with them. The occipital extremities of the lateral odontoid