

TWO CASES, CONSIDERED FROM THE DEVELOPMENTAL STANDPOINT, IN WHICH THE RIGHT SUBCLAVIAN ARTERY AROSE FROM THE ARCH OF THE AORTA BEYOND THE ORIGIN OF THE LEFT SUBCLAVIAN ARTERY; WITH A NOTE ON THE RELATION OF THE SUBCLAVIAN VEINS TO THE CARDINAL SYSTEM. By REGINALD J. GLADSTONE, M.D. Aberd., F.R.C.S. Eng., F.R.S.E., *Lecturer on Anatomy, University of London, King's College*; and C. P. G. WAKELEY, *Assistant Demonstrator of Anatomy, King's College, London.*

THESE cases, as is well known, are due to the persistence in the adult of the distal portion of the right dorsal aorta of the embryo and the severance of its connexion with the fourth arterial cephalic arch. The part of the

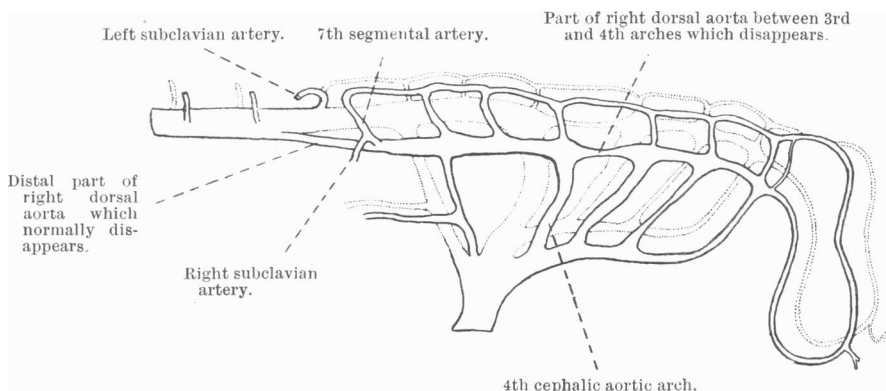


FIG. 1.—Diagram of the cephalic portion of the arterial system. Modified from Cunningham's *Text-book of Anatomy*.

right dorsal aorta which persists is obviously that which lies between the junction of the right with the left dorsal aorta and the origin of the right 7th dorsal segmental artery (fig. 1). The 4th right cephalic aortic arch and that part of the right dorsal aorta between the origin of the 3rd and 7th somatic segmental arteries disappears, except in those cases

in which the right vertebral artery is given off from the innominate artery.

There is some uncertainty, however, as to whether any part or the whole of the distal portion of the right dorsal aorta is normally represented in the adult by anastomosing vessels joining the subclavian artery with the aorta. It is with the object of clearing up this difficulty that we have turned our attention to the condition of the right dorsal aorta and intercostal arteries in the later stages of embryonic development, and the normal anastomosis of arteries in the adult which takes place across the anterior aspect of the upper thoracic vertebræ and ribs.

CASE 1.¹—The subject in which this abnormality occurred was a male aged 71 years. The right subclavian artery (fig. 2) commenced at the level of the 4th thoracic vertebra from the posterior aspect of the arch of the aorta. It pursued an upward course from left to right behind the trachea and œsophagus to the outer border of the 1st rib. It measured 4 inches in length, and gave off the following branches:—

1st part:—

1. Vertebral.
2. Costo-cervical trunk.
3. Inferior thyreoid.
4. A common trunk dividing into transverse scapular, transverse cervical, and internal mammary.

2nd part:—

None.

3rd part:—

5. Posterior scapular (B.N.A., descending branch of transverse cervical artery).
 1. The vertebral artery arose from the upper and posterior aspect of the subclavian, and entered the foramen in the transverse process of the 6th cervical vertebra.
 2. The right costo-cervical artery divided into:—
 - (a) The superior intercostal artery. This vessel supplied the 1st intercostal space, and anastomosed with the 1st right aortic intercostal which supplied the 2nd intercostal space, and with a small branch from the internal mammary.
 - (β) The deep cervical artery which passed upwards and backwards below instead of above the neck of the 1st rib.
 3. The inferior thyreoid artery. This was a large branch which sprang

¹ Dissected by C. P. G. Wakeley.

from the upper border of the main artery. It passed in front of the vertebral artery behind the carotid sheath, and in front of the sympathetic cord.

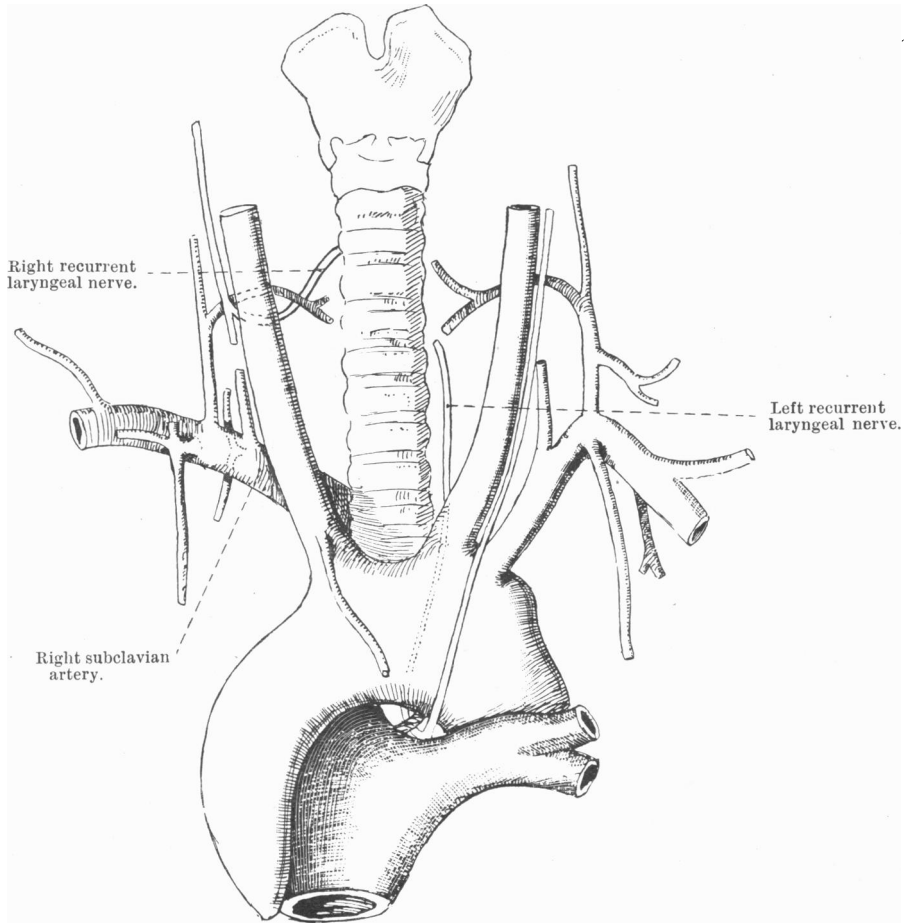


FIG. 2.

4. The common trunk mentioned above was a large branch springing from the anterior aspect of the first part of the subclavian artery. It gave off a lateral trunk which immediately broke up into two branches, the transverse cervical and the transverse scapular. The main artery was continued as the internal mammary.

5. The posterior scapular arose from the upper surface of the subclavian

lateral to the anterior scalene muscle. No "arteria aberrans" was given off from the subclavian artery.

The right common carotid artery arose from the arch of the aorta in front of the trachea and opposite the body of the 3rd thoracic vertebra. It gave off close to its origin a small branch which supplied the thymus gland. The left common carotid and left subclavian arteries arose, close together, from the summit of the aortic arch. The branches given off from the left subclavian were :—

- | | |
|----------------------|-------------------------|
| 1. Vertebral. | 4. Highest intercostal. |
| 2. Internal mammary. | 5. Posterior scapular. |
| 3. Thyreoid axis. | |

The right inferior laryngeal nerve arose from the vagus at the level of the transverse process of the 6th cervical vertebra, it passed downwards, then turned round the inferior thyreoid artery, and finally pursued its usual course upwards between the œsophagus and trachea to the larynx. Where it was crossed by the inferior thyreoid artery it was held down by a slip of fascia. The left recurrent laryngeal nerve was normal with regard to its relations to the ligamentum arteriosum and arch of the aorta.

The thoracic duct on reaching the body of the 4th thoracic vertebra turned to the right along the lower border of the right subclavian artery, its course here being probably determined by the position of the abnormal artery. The duct near its termination split into two parts which opened separately into the junction of the right internal jugular and subclavian veins. On the left side a fair-sized lymphatic vessel passed upward on the vertebral column through the superior mediastinum, and joined a tributary from the left upper extremity to form a common trunk, which opened into the terminal part of the left internal jugular vein.

CASE II. (fig. 3).¹—In this specimen, from a female subject aged 63, the right subclavian artery sprang from the posterior aspect of the arch of the aorta, about half an inch beyond the origin of the left subclavian; it then passed upward and to the right, behind the left inferior laryngeal nerve, œsophagus, trachea, and right vagus nerve to the interval between the anterior and middle scalene muscles. It gave off the following branches :—

- | | |
|--------------------------|---------------------------|
| 1. Vertebral. | 3. Thyreo-cervical trunk. |
| 2. Costo-cervical trunk. | 4. Internal mammary. |

There was no "vas aberrans."

The 1st right aortic intercostal artery supplied the 3rd and 4th intercostal spaces and sent a small branch upward to anastomose with the highest intercostal artery.

¹ Dissected by Mr H. B. Eisenberg and Mr G. K. Burge.

The left subclavian artery gave off:—

- | | |
|-------------------------|-------------------------|
| 1. Vertebral. | 4. Inferior thyreoid. |
| 2. Highest intercostal. | 5. Transverse cervical. |
| 3. Internal mammary. | 6. Transverse scapular. |

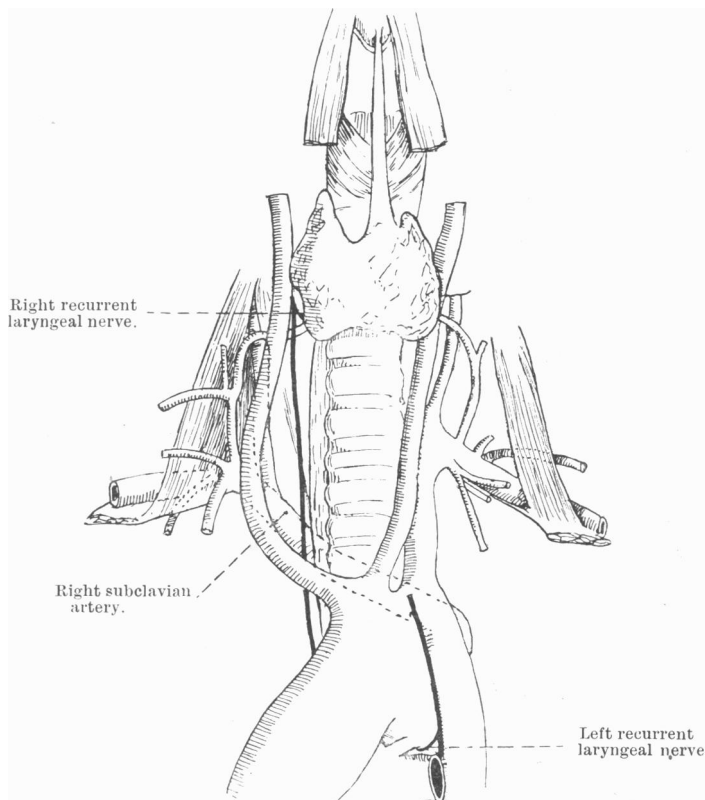


FIG. 3.

The right and left common carotid arteries arose from a short common trunk near the summit of the arch. The right inferior laryngeal nerve was given off opposite the 6th cervical vertebra, and after passing downward for a short distance turned round the inferior thyreoid artery and then passed upward to the larynx, between the oesophagus and trachea, as in Case I. The left inferior laryngeal nerve pursued its usual course. The thoracic duct had the normal course and relations, and terminated as usual at the junction of the internal jugular with the subclavian veins.

In an article by E. Pearce Gould (6), he expressed the view that in

those "cases in which the right subclavian artery arises directly from the arch of the aorta as its leftmost branch, that the abnormal vessel, which is a persistent part of the right dorsal aorta of the embryo, is most probably represented in the normal adult by an anastomosis between the 'vas aberrans' coming from the aorta, and a second aberrant artery given off from the subclavian. The latter is described in some text-books as forming a fairly constant accessory branch of the normal subclavian artery, which arises from this vessel close to its origin, and medial to the vertebral artery." This view differs from the theory previously held, namely, that the abnormal subclavian artery represents a persistent part of the right dorsal aorta of the embryo, *and that this is normally represented in the adult by an anastomosis of a branch of the highest intercostal artery of the right side with the aberrant artery from the aorta or 1st right aortic intercostal artery.* The objections to the latter part of this statement are (1) that according to this view the common longitudinal trunk of the right and left highest intercostal arteries would not be homologous, for the true homologue of the trunk of a right highest intercostal artery would, upon the left side, obviously be a part of the aortic arch, the commencement of the descending thoracic aorta; and (2) according to this theory the point of origin of the right highest intercostal artery in the normal condition ought to be medial to the vertebral artery and other branches of the subclavian artery (see fig. 5).

In a specimen of double aortic arch described by Professor Curnow, and preserved in the Anatomical Museum of King's College, the right arch, which is considerably larger than the left, gives off two branches, namely, the right common carotid and right subclavian; the latter gives off the right vertebral artery, thyreoid axis, internal mammary, and an artery which crosses the neck of the 1st rib and supplies the 1st and 2nd intercostal spaces. This appears to be the highest intercostal artery given off directly from the subclavian. It arises distal to the origin of the vertebral artery, and undoubtedly anastomosed with the 1st right aortic intercostal artery, which supplies the 3rd space. The left superior intercostal artery is also present, and evidently anastomosed with the 1st left aortic intercostal artery.

This specimen obviously supports the view expressed by Mr. E. Gould, namely, that the normal anastomosis of the highest intercostal artery of the right side with the 1st right aortic intercostal artery does not represent the terminal part of the right dorsal aorta of the embryo, for in the same subject there coexists a persistent distal part of the right dorsal aorta and an anastomosis between the highest intercostal artery of the right side with the 1st right intercostal artery, and a similar anastomosis is also

present on the left side, along with the persistent distal part of the left dorsal aorta. Whether the distal part of the right dorsal aorta is represented in the normal adult subject by an anastomosis of the aberrant branch of the aorta with an aberrant branch of the right subclavian is also doubtful.

In sixteen adult dissecting-room subjects in which we have specially looked for the aberrant branch of the right subclavian artery we could find no trace of it, and we therefore conclude that it is certainly not normally present in the adult.

Moreover, on examining a series of human embryos above 17 mm. in length, the distal part of the right dorsal aorta seems to have disappeared as completely as that part which lies between the 3rd and 4th arterial arches.

In a 10-mm. human embryo the distal part of the right dorsal aorta is considerably less than half the diameter of the left (fig. 4). The two vessels join to form the common dorsal aorta at the level of the 1st thoracic nerves. The common stem which divides into the right vertebral and subclavian arteries springs from the dorsal aorta as a segmental branch, which arises at the level of the 8th cervical nerves. The right dorsal aorta gives off one segmental artery of small size, below the origin of the subclavian artery. The next segmental artery (1st right aortic intercostal artery) arises below the point of union of the two dorsal aortæ.

In a 17-mm. human embryo belonging to Professor Waterston, which was obtained at an operation for tubal pregnancy, and which is exceptionally well preserved, the distal portion of the right dorsal aorta has almost disappeared. We have, however, been able to trace it (see fig. 5) from the common stem which divides into right vertebral and subclavian arteries down to its junction with the left dorsal aorta. This junction occurs just below the level of the bifurcation of the trachea.

About the middle of its course between these two points the lumen of the artery is obliterated, and the vessel can only be recognised by the concentric arrangement of the nuclei of its muscular wall. The lumen of the artery is occupied by an unstained hyaline substance which in some of the sections contains degenerated blood corpuscles. At the cephalic and distal ends of the artery, however, the vessel is more easily identified, and its lumen contains nucleated blood-cells continuous with those in the right subclavian artery and the aorta. Below the point of union of the right and left dorsal aortæ the 1st aortic intercostal arteries are given off close together, and course laterally and upward behind the trunks of the sympathetic nerves. Each artery anastomoses, as in the adult, with a descending branch which appears to be the highest intercostal artery of

the corresponding side. The anastomosing vessel thus formed lies behind and lateral to the sympathetic trunk, whereas the aortic arch, the distal part of left dorsal aorta, and the degenerating distal part of the right

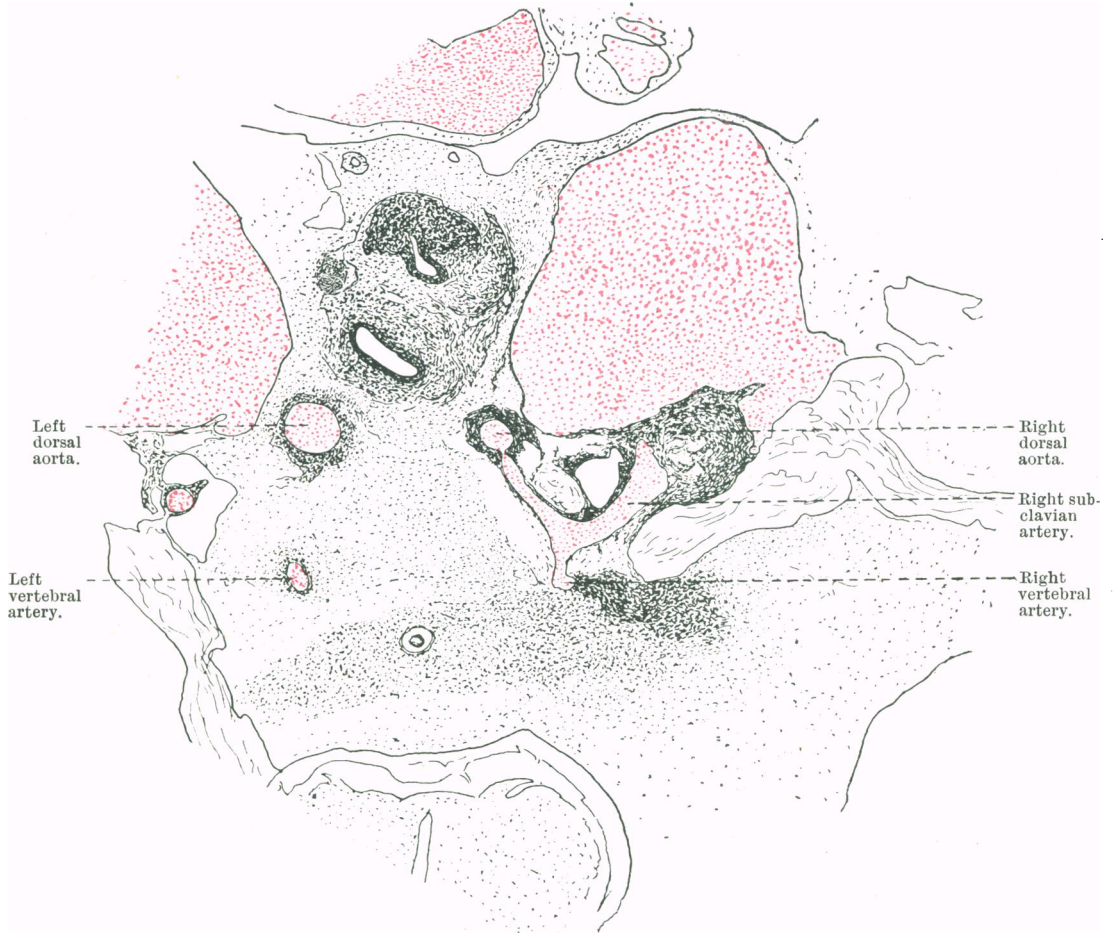


FIG. 4.—Transverse section through a 10-mm. human embryo showing the commencing atrophy of the right dorsal aorta and origins of the right subclavian and right vertebral arteries.

dorsal aorta lie ventral and mesial to the sympathetic trunk. It is obvious, therefore, that this anastomosis of the adult cannot represent the distal part of the right dorsal aorta, for in a 17-mm. embryo both the anastomosis and the right dorsal aorta coexist, and are seen side by side in the same sections. Further, if the first stage of the abnormal right subclavian artery

represented an enlargement of this anastomosis, the abnormal subclavian artery ought to pass dorsal to the sympathetic trunk instead of ventral to it.

Fig. 5, which is drawn from a linear reconstruction of the main vessels of this region, shows that the right subclavian artery consists of two parts, (1) a proximal portion of large size which courses vertically downwards from the bifurcation of the innominate artery to the origin of the common trunk which divides into the vertebral and the distal part of the right subclavian artery, and (2) a horizontal part which courses laterally into the limb bud.

The right vertebral artery is of large size. The left vertebral (not shown in the drawing) is much smaller. It is given off from the posterior aspect of the left dorsal aorta (aortic arch) about midway between the origins of the left subclavian and left common carotid arteries.

It will be observed that the left subclavian artery at this stage of development still arises below the junction of the "ductus arteriosus" with the left dorsal aorta, and is quite separate from the left vertebral artery, which as mentioned above, springs in this specimen as an independent branch from the posterior aspect of the left dorsal aorta.

The drawing also shows the position of the right and left inferior laryngeal nerves. The former passes backwards in the angle which is formed between the innominate artery and the first part of the right subclavian artery, and the latter round the termination of the "ductus arteriosus."

The "ansa subclavia" (*a. Vieussensii*) on the right side surrounds the common trunk which divides into the vertebral and the distal part of the right subclavian artery.

Both subclavian arteries arise at a relatively low level when compared with the position which they occupy in the adult. Moreover, the vessels springing from the arch of the aorta (innominate, left common carotid, and left subclavian) are separated by considerable intervals. At a later stage, when the heart has sunk down into the thoracic cavity and the lungs have grown upward on each side of these vessels, they come to lie close together at the summit of the arch.

In embryos of 20 mm. length and over the distal part of the right dorsal aorta has entirely disappeared, the right subclavian artery has become straightened out, and both this vessel and the left subclavian artery appear to have travelled upward with regard to their relation to the aortic arch. The left subclavian artery has apparently migrated in a direction towards the head along the dorsal aorta; its origin thus comes to be cephalad to the junction of the "ductus arteriosus" with the dorsal aorta and near the summit of the arch. This change in position is obviously

due to the sinking of the heart and its main vessels from the upper into the middle region of the thoracic cavity. The distal parts of the sub-

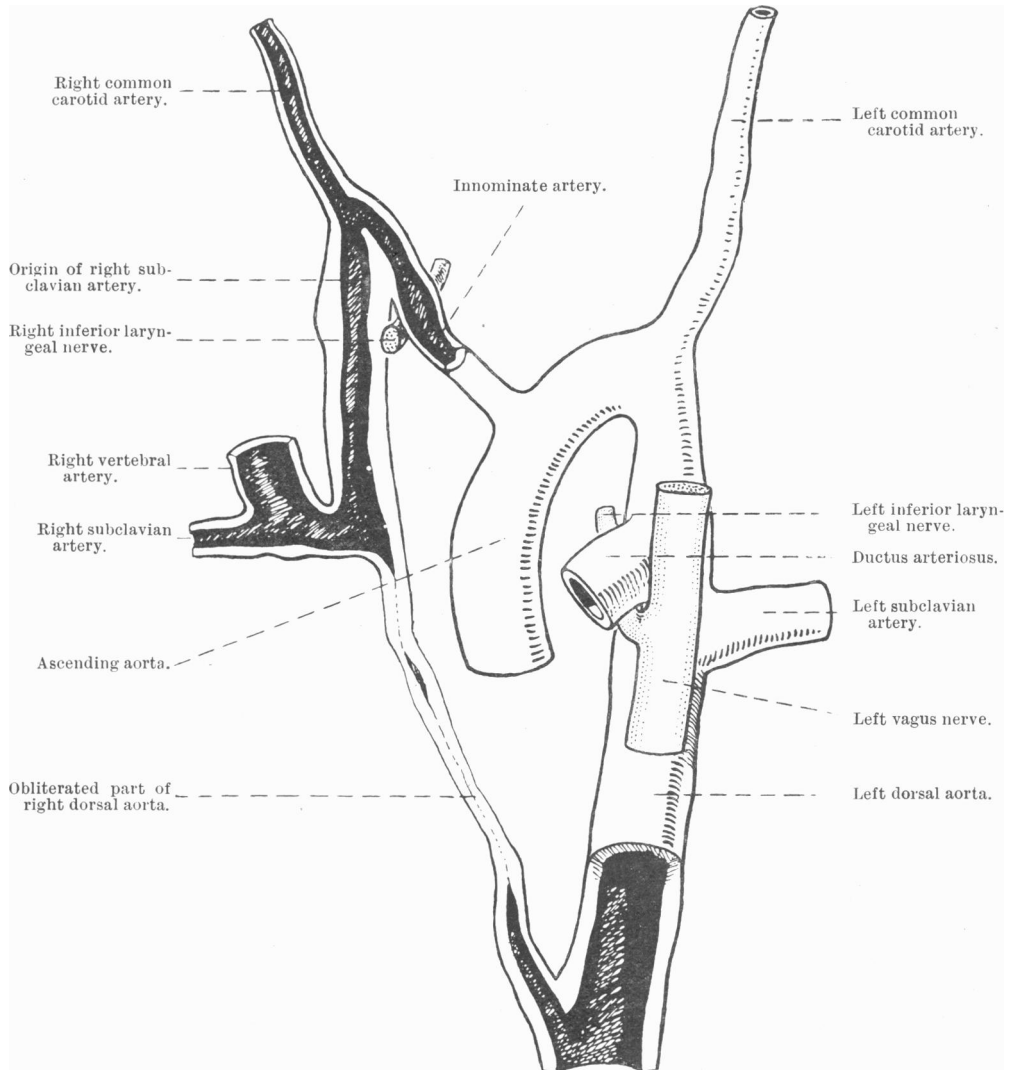


FIG. 5.—Linear reconstruction of the main blood-vessels of a 17-mm. human embryo, showing the obliteration of the distal part of the right dorsal aorta (mag. $\times 7^0$).

clavian arteries, which pass out over the 1st ribs into the arms, do not participate in this movement. The origin of the right subclavian artery from the innominate artery is, however, brought down to below the level

of the 1st rib, and thus instead of pursuing a downward course it has to pass upward, in order to reach the 1st rib. The origin of the left subclavian artery, on the other hand, is displaced upward towards the summit of the arch.

It may be worth while here to draw attention to the remarkable manner in which the origin of certain arteries, when once these vessels are definitely formed, travel along the main trunks from which they spring. Thus the subclavian arteries are represented in a reconstruction of the arterial system of a 3·4-mm. human embryo as arising from the 7th dorsal segmental arteries caudad to the origin of the primitive coeliac arteries. In a reconstruction by Ingalls of a somewhat later human embryo (4·9 mm. long), the subclavian arteries arise cephalad but quite close to the coeliac artery. It will be observed also that they lie opposite the constriction in the alimentary canal, between the dorsal pancreas and the caudal end of the stomach. The coeliac artery when once established as a single vessel (see reconstruction of a human embryo of 5-mm. length, Broman) migrates in a caudad direction to its permanent position opposite the upper border of the 1st lumbar vertebra. The position of the subclavian arteries relative to the vertebral column and the first ribs, however, remains much more fixed, and it is this fixity in their position which causes the changes to take place in their relation to the larger blood-vessels which are drawn into the thoracic cavity along with the caudad movement of the heart.

A table showing the position at different stages of development of the three main ventral branches of the abdominal aorta, viz. the a. coeliaca, a. mesenterica sup., and a. mesenterica inf., is published in Keibel and Mall's *Manual of Human Embryology*. The table is followed by a discussion of the various theories which have been put forward in order to explain the method by which this "migration" is accomplished, and the author of the article, Dr Herbert Evans, sums up the evidence in the following words: "It seems to me most probable, however, that the identity of the three main vessels is established permanently very early, and that the great shifting is due to an entirely different phenomenon—namely, to the unequal growth of the dorsal and ventral walls of the aorta." The importance of recognising this means by which the relative position of different arteries or veins arising from the same trunk vessels become changed will be appreciated by a consideration of the changes which, during development, take place in the relative position of the subclavian and the cardinal veins.

The subclavian veins when first formed by the enlargement of the primitive ulnar veins enter the posterior cardinal veins caudad to the heart

and the common cardinal veins or ducts of Cuvier. As development proceeds they appear to travel cephalad, so as eventually to open into the anterior cardinal veins (figs. 6 and 7). The explanation of this change in position appears to be due to an unequal growth in the dorso-lateral and ventral walls of the upper part of the posterior cardinal vein. This is associated with a migration in a caudad direction of the common cardinal veins, which are drawn with the heart from the cervical region into the thorax. The junction of the common cardinal veins with the anterior and posterior cardinals becomes enlarged so as to form a triangular sinus, which

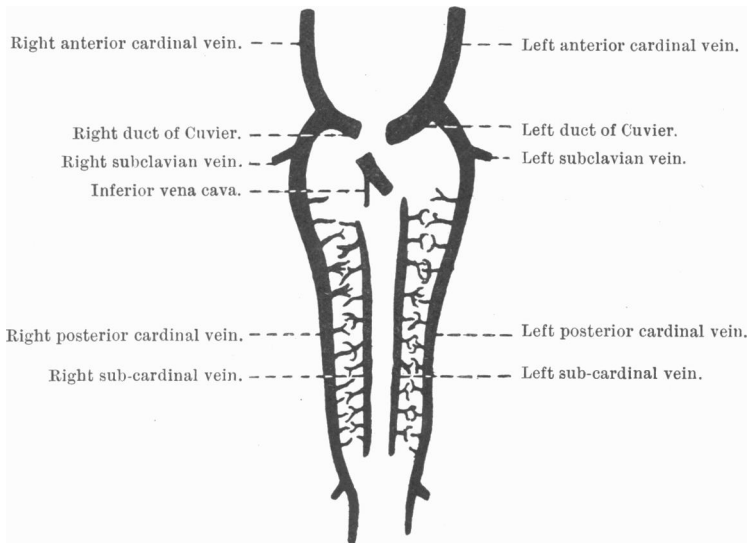


FIG. 6.—Early stage in the development of the veins, after Hochstetter, showing the entrance of the subclavian veins into the posterior cardinal vein.

receives the primitive ulnar vein (subclavian) on its postero-lateral aspect. This vein when first formed occupies a position opposite the interval between the 4th and 5th cervical nerves, but subsequently, when the embryo has reached a length of 10 mm. in its greatest diameter, it is found opposite the 8th cervical nerves, a position which it retains in the adult. The subclavian veins thus instead of migrating towards the head are at first drawn downwards in the opposite direction, and afterwards remain stationary, being fixed when these are developed by the 1st ribs, which prevent any further displacement downwards into the thorax.

The permanent innominate vein of the right side, and that part of the superior vena cava which lies above the entry of the vena azygos, will thus be formed, as far as their lateral wall is concerned, from the expanded upper

end of the posterior cardinal vein, viz. that part which lies below or caudad to the entrance of the subclavian vein. Similarly, on the left side the commencement of the left innominate vein, and the termination of the left superior intercostal vein, will be derived from the posterior cardinal vein and not the anterior cardinal, as is usually supposed.

To return from this digression to the immediate subject of our paper, we find that in the older embryos the anastomosis of the right and left highest intercostal arteries with the 1st aortic intercostal arteries may be

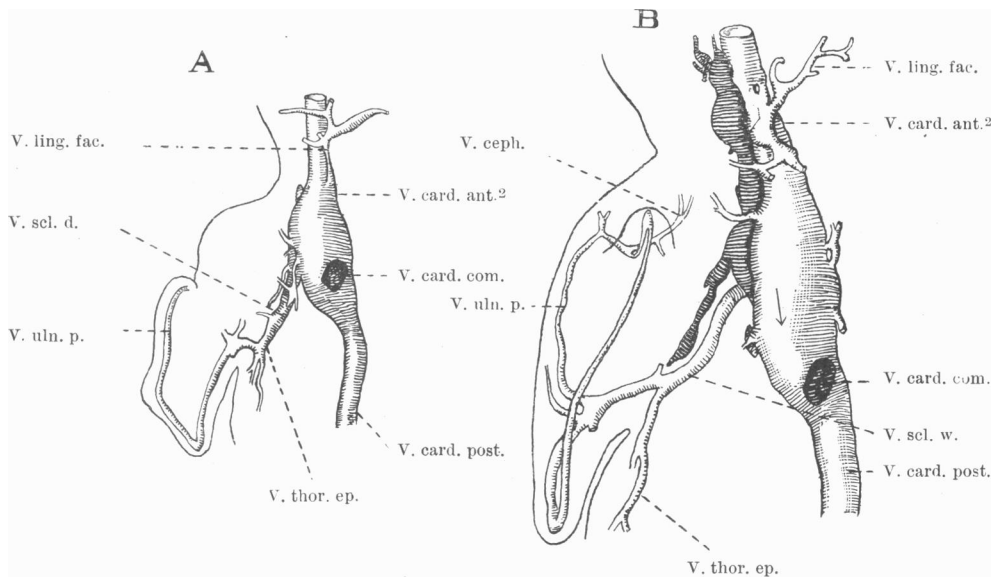


FIG. 7.—Reconstruction of the veins of the right arm in human embryo A, 11·5 mm., B, 16 mm. long. After F. T. Lewis.

quite easily traced. Moreover, the costo-cervical trunks, which give off the highest intercostal arteries, originate from the subclavian arteries, as in the adult, lateral to the origin of the vertebral arteries.

Now, if the anastomosis of the aberrant branch of the highest intercostal artery with an aberrant branch of the aorta or 1st right aortic intercostal artery represented the persistent right dorsal aorta, we should expect the costo-cervical trunk from which the intercostal branch arises to lie medial to the origin of the vertebral artery (fig. 5). Too much stress must not be put on this point, however, for the costo-cervical trunk or its highest intercostal branch is sometimes found to arise medial to the vertebral artery in the adult, as was pointed out by Professor Geddes in

an article published in the *Journ. of Anat. and Physiol.*, vol. xlv. p. 197. This relation might be explained on the assumption that as the proximal part of the subclavian artery is drawn downwards the origin of the terminal or distal part of the right dorsal aorta might be displaced to the lateral side of the vertebral artery.

The coexistence of the two vessels, viz. the abnormal right subclavian artery, and intercostal anastomosis in the same subject, in Professor Geddes's specimen, our own, and other cases previously alluded to, and also the development of the intercostal anastomosis in the 17-mm. human embryo, before the distal part of the right dorsal aorta has become completely obliterated, appears to us conclusive evidence that the abnormal origin of the right subclavian artery is usually due to the persistence of the distal part of the right dorsal aorta, and is not due to an enlargement of anastomosing aberrant arteries of the intercostal vessels.

In conclusion, we should like to express our thanks to Professor Waterston for the use of his valuable embryological material, and to Mr Walpole Champneys for the skilful manner in which he has executed the drawings.

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