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FACTORS LEADING TO THE DEVELOPMENT OF A JOINT BETWEEN THE MANUBRIUM AND THE MESOSTERNUM

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The sternum, though present in some form in the vast majority of vertebrates and always more or less constant in its position, is, nevertheless, a bone which varies greatly both in its form and in its function. For example, it may be broad and flat and devoid of joints, as in the tortoise; or it may be long and narrow and composed of many segments, as in the cat.

One could argue that the Chelonian sternum is flat because tortoises take pleasure from lying on their bellies in the sun, or, conversely, it may be equally valid to propose that the Chelonian, having a flat sternum, is thereby permitted to adopt this habitual posture. In like manner, the multi-jointed sternum of carnivores may be attributed to their lithe habits of weaving through undergrowth in search of prey, or, conversely, their preying habits may be held to result, *inter alia*, from the sternal segmentation which, in their case, permits such litheness. Whether one supports or contests the Lamarckian viewpoint in these matters it is impossible to deny the existence of a very definite association of some kind between the structure and the function of the particular sterna under consideration. Therefore, it may be assumed that the tendency for man to have a rather flat and wide sternum which presents a special form of joint between its first two pieces is, likewise, an expression of functional peculiarities. It is well recognized that in man the manubrio-sternal joint is utilized during respiratory effort (Keith, 1903; van Gelderen, 1924). It may even be considered by some that the joint is present solely for the purpose of permitting the increased ventilation of the lungs which is required during the exertions demanded by man's ambitious inquisitiveness, as in the perpetual quest for athletic achievement. On the other hand it is an undoubted fact that this particular joint develops early in foetal life—long before it would be required for such a function. Furthermore, as the present inquiry shows, the development of the joint could well result from certain mechanical factors operating in early embryonic stages and be quite independent of any function with which the definitive joint may subsequently be associated.

THE LITERATURE, PERSONAL OBSERVATIONS, AND DISCUSSION

According to Tarin (1753), Ruge (1880), and Paterson (1904), the human presternum normally becomes demarcated from the mesosternum by a fibrous lamina which develops across the cartilaginous sternum during foetal life at the level of the second costal cartilages. As recorded elsewhere, this fibrous lamina is the anlage of the secondary cartilaginous joint which is usually to be found between the manubrium and mesosternum in the adult. If the fibrous lamina should fail to develop, then the manubrio-sternal joint has the characteristics of a primary cartilaginous joint and will be prone to ossify early in life (Ashley, 1954).

Paterson found the junctional region to be "fibrous" in 76.4% of 236 foetal sterna. In close accord with this, I have found a fibrous band across the sternum in 39 of 50 foetal sterna examined histologically. Photomicrographs of stained sections of a selection of foetal sterna are shown in Fig. 1.

The fibrous band is to be observed in specimens A, B, C, and D, but is obviously lacking in specimens E and F.

Rarely, as Paterson pointed out, the fibrous lamina across the cartilaginous sternum is found at the level of the third costal cartilages instead of at the level of the second. He attributed the occasional occurrence of a so-called hylobatean-type of sternum in man to this accidental alteration in position of the fibrous lamina. Sterna of this type have been described by Struthers (1874), Shepherd (1881), Lane (1885), Dwight (1890), Paterson (1893), Keith (1896), Lickley (1904), and Harris (1938). Keith went so far as to state, "Its occurrence in man, I think, may be regarded as the persistence

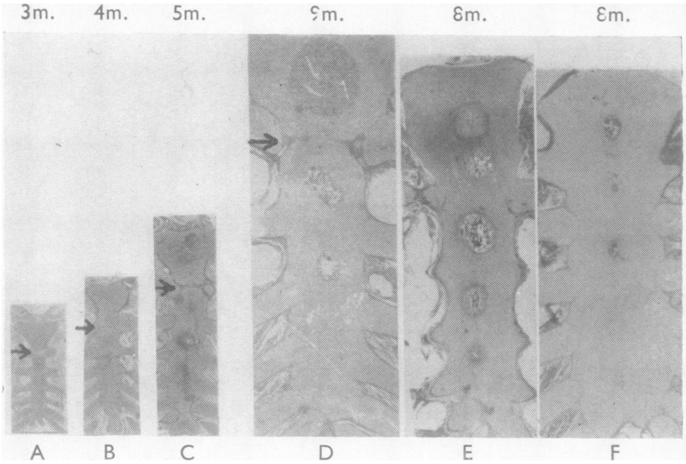

FIG. 1.—Photomicrographs (natural size) of stained sections of foetal sterna showing (A, B, C, D) the presence of a fibrous band (arrowed) across the sternum at the level of the second costal cartilages, and (E, F) the absence of such a band. Foetal age is indicated in each case.

in a very few individuals of a simian, or, more properly, a hylobatean character." Paterson's view concerning the immediate causation of this type of sternum in man is probably correct, but it does not explain why or how such accidental alterations should occur. Before entering into consideration of this matter it is advisable to determine the reason for the development of the normal manubrio-sternal joint.

From the teleological point of view it may be felt that a mobile manubrio-sternal joint develops in anticipation of respiratory movements. Teleological argument is notoriously suspect, and its use would seem to be quite unjustified when simple mechanical processes can be found to explain the development of any particular structure. In the case under consideration an adequate mechanical explanation is readily forthcoming. Study of sagittal sections of early embryos reveals two facts of major importance. First, the relatively enormous size of the embryonic heart, and secondly, the intimate relationship of the heart to the overlying mesosternum. Fig. 2 depicts the state of affairs in a 28 mm. human embryo.

From the arrangement of structures shown it is easy to imagine the pulsating heart exerting a

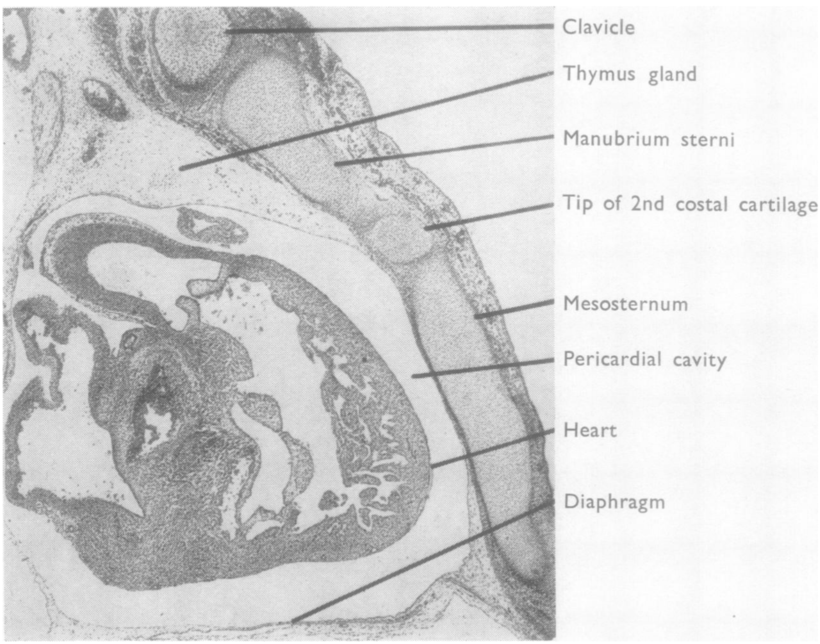

FIG. 2.—Paramedian sagittal section of a 28 mm. human embryo to show the relation of the heart and pericardium to the overlying mesosternum.

repetitive thrust against the mesosternal portion of the overlying sternum. The manubrial portion of the bone is normally firmly united with the first ribs, and so is held in a fixed position, but the mesosternum is caused to move respectively anteriorly and posteriorly during each systole and diastole of the heart. It is suggested that, as a result of this repeated movement, a transverse joint develops between the fixed and the movable parts of the bone. Such a joint would naturally develop at the weakest point of the sternum, that is, normally, opposite the second costal cartilages (Hanson, 1919). Bryson (1945) has shown that rib growth affects the width of the various parts of the sternum, retarded rib growth resulting in a wide sternum such as is found in screw-tail mice. The rare occurrence in man of a so-called hylobatean-type of sternum could be explained by the third ribs growing too vigorously and so approaching nearer to the ventral midline than do the second ribs, perhaps in relation to a relatively small heart. In such cases the narrowest and weakest point of the sternum would be opposite the third costal cartilages as in the examples of hylobatean-type human sterna shown in Fig. 3.

If the sternum is not especially compressed at any rib level and, in consequence, no weak point develops, then it may be that no movable manubrio-sternal joint will develop. This would explain the relatively high incidence of synostosis of the joint in the broad type of sternum reported by Lubosch (1920). In other cases a weakly beating heart might fail to cause sufficiently marked movement of the mesosternum and so fail to stimulate the formation of a joint. In very rare cases the joint may fail to develop in the presence of a forcibly beating heart, which would then tend to rock the whole sternum about the transverse axis of the paired first costal cartilages leading to the formation of synovial joints between the first ribs and the sternum. Such cases have been reported by Tschaussow (see Paterson, 1904).

Conclusion

Simple mechanical factors resulting from the close relationship of the precociously developing heart to the overlying sternum offer an adequate explanation for the development of a joint between the manubrium and the mesosternum. Different degrees of incoordination between the development of the heart and the development of the thoracic cage may well be aetiological factors leading to any or all of the following abnormalities: (1) Synostosis of the manubrio-sternal joint; (2) shifting of

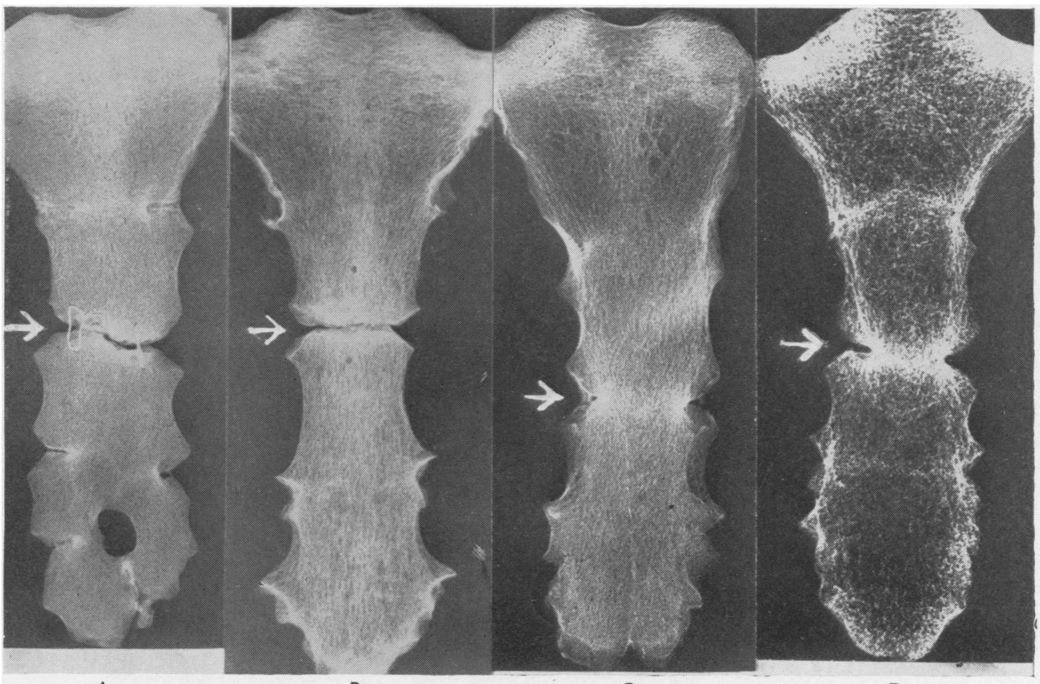

FIG. 3.—Examples of hylobatean-type human sterna, showing the manubrio-sternal joint (free A, B: synostosed C, D) at the narrowest part of the sternum, in each case opposite the third costal cartilages.

the joint to the level of the third costal cartilage; and (3) the presence of synovial joints between the sternum and the first costal cartilages.

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