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INTERCOSTAL MUSCLES.

BY

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Read before the Boston Society of Medical Sciences, March 25, 1873, and published in the Boston Medical and Surgical Journal.

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THE action of the intercostal muscles has been a subject of discussion ever since they were described by Galen, A.D. 131. It would be superfluous, as well as tedious, to attempt to give a *résumé* of all the views which have been advanced, for it has been frequently more or less perfectly done, no writer ever failing to add some slight modification of his own. Both sets of intercostals have been held to be inspiratory, both to be expiratory, and both to be inspiratory and expiratory, and there is an equal difference of opinion concerning each considered separately; both have also been held to be of service merely as ligaments. In the first half of the eighteenth century, there was a spirited discussion on the subject between Haller and Hamberger, the former maintaining that both layers were inspiratory, the latter that the external layer and that part of the internal one situated between the cartilages were inspiratory, and the remainder of the internal one expiratory. Haller appears to have had the best of the argument, and his views prevailed until Hutchinson, in his celebrated article "Thorax," in the Cyclopædia of Anatomy and Physiology, declared for Hamberger. Since then, the tables have been turned, and, though frequently disproved in several points, Hutchinson's article continues to be quoted as authority by perhaps one half of those dealing with the subject. (In Europe, excepting Great Britain, the proportion of his defenders may not be so large; in America it probably is larger.)

The object of this paper is to show, chiefly by arguments already presented, that Hutchinson's views, resting on erroneous data, are entirely wrong; and secondly, to call attention to some original observations and experiments, and to some points in the laws of muscular action, nervous supply, and in the phenomena of respiration suggesting very different conclusions.

It is evident that the Hutchinsonian theory presupposes that all the ribs have an equal amount of motion, which is not the case. Now if any rib is fixed during any part of the respiratory act, it is clear

that these rules will not apply, and if any rib be hindered from sharing fully in the general motion, it is practically, to a certain extent, fixed, as regards the others, and the relations are disarranged. If one rib be fixed, the tendency of both sets of fibres will be to pull the next rib towards it; but this is made impossible, or more or less difficult, by the connection of the anterior ends of the ribs with the sternum, or with one another, except in the case of the last two. The elasticity of the ribs cannot be overlooked in this connection; from what has just preceded, it may be seen that, under certain circumstances, a rib may be more likely to bend, than to follow the motion of its neighbor, and the difference in elasticity in the different parts of the costal arch, tends to complicate the problem. Let it be remembered, that the ribs form parts of larger circles from above downward, and that in the upper part of the chest, each arch is in all positions outside of the one above it; and let it be remembered, that, besides the motion of rising and falling from the spinal column, the ribs have a rotary motion on a longitudinal axis. Now, in the upper part of the chest, both sets of fibres must pass outward and downward, so that their action might be represented on Hamberger's bars by turning the latter at right angles to their usual position, and putting the elastic bands in the place of those representing the external intercostals, namely, running downwards and away from the fulcrum. Thus, in the upper part of the chest, both layers must tend to raise the ribs. It has been said, with apparent justice, that mathematics furnish no safe guide when applied to the animal economy, and that we should look at nature and see what the fact is, rather than argue what it ought to be; but in this case, such reasoning is more plausible than true, for observation is very difficult, and vivisectors disagree in what they see; some claim to have observed the phenomena as they should be according to Hamberger, but others, and perhaps the more reliable, do not.

Moreover, observations on human beings are impossible, except under pathological conditions which almost necessarily affect the mechanical relations of the parts, and in lower animals the conditions are never the same as in man. Hence it is not unfair nor overhasty to declare Hamberger's views false in theory, and unconfirmed by observation.

At this point, I would call attention to some anatomical considerations before proceeding. The two layers of the intercostals form a double covering to the contents of the thorax, from the angles of the ribs to their cartilages; behind and in front, respectively, of these points, other muscles are found, to prevent any loss of power to counter-balance atmospheric pressure, to wit, the long muscles of the back behind, and the pectoralis major and external oblique in front. The internal oblique is not only in the same plane, but absolutely continuous with the fibres of the internal intercostals in the three or four lower spaces. Coming from the transverse processes of certain cervi-

cal vertebræ, we have three muscles called scaleni, two going to the first, and one to the second rib. In a continuous series with the scaleni, come twelve triangular muscles from the transverse processes of the seventh cervical and eleven upper dorsal vertebræ, to the ribs between their tubercles and angles, and continuous with the fibres of the external intercostals. Arising from the spinous processes, come next the two posterior serrati; the superior passing downward and outward, to be inserted into the second, third, fourth and fifth ribs beyond their angles, thus getting a favorable hold to draw them backward, and also to raise them in part by rotation on the antero-posterior axis. The inferior serrati extend upward to the four lower ribs, in a manner to draw them downward and backward. The quadratus lumborum forms part of the posterior wall of the abdomen, its fibres passing upward to about the inner half of the last rib, which it draws downward and backward. The action of the erector spinæ has a considerable influence on the shape of the chest, and the fibres of its outer division have a special action on the ribs. Its lower part (the ilio-costalis lumborum) sends fibres to the angles of the six or seven lower ribs, in a manner to draw them backward and downward, or at all events to hold them firmly. The upper part (cervicis*) will have a similar effect by drawing the superior ribs upward, and the middle part (dorsi*) will keep all tense by drawing the more movable toward the more fixed.

Leaving the intercostals for a moment out of the question, the combined action of the muscles just enumerated will be, while the erector straightens the spine, to draw the upper ribs upward, the lower downward, and the posterior part of all of them inward in a manner to enlarge the thorax transversely. The diaphragm remains to be considered; it has its firmest attachment to the spinal column, and a less fixed one to the circumference of the lower outlet of the chest. The central tendon is attached to the lower layer of the pericardium, and it is to be borne in mind that this is movable only to a certain degree, after which it acts as a fixed point.

With regard to the nervous supply, the most striking fact is that the diaphragm is supplied by two nerves (the phrenics), which arise chiefly from the fourth cervical, apparently to secure the chief muscle of respiration from the effects of an injury to the back. The intercostal nerves supply not only both intercostals, but the levatores, the triangularis sterni, the subcostals, and, according to Riedlaender, the posterior serrati. That a nerve of the size of an intercostal should supply two muscles, part of one of which is antagonistic to the other and to the other part of itself, and that it should stimulate the antagonists to alternate action, is an anomaly of the most startling kind; there is no parallel case to be found in the body.

Perhaps the fundamental error in most views on the action of these muscles is, that it is held to be a definite one—always the

* According to Henle's nomenclature.

same. This is not correct in this case, if, indeed, it be in that of any muscle. The mechanical function of a muscle may be said to be that of bringing, by its contraction, its two ends nearer together—drawing the more movable attachment to the more stable one. Let us take the biceps as an illustration—its usual action is to draw the hand towards the head; but let the hand be fixed, and it will draw the head toward the hand. Few muscles act alone; and the action of the biceps will be hindered or assisted by the contraction of others. Few if any points in the body can be spoken of as absolutely fixed; the hyoid group affords good examples of muscles whose chief duty it is to hold a structure steady to give support to others during their action; any uncommon contraction or relaxation of the former must affect the whole process. Besides contractility, muscles have also some elasticity, and, under certain circumstances, act purely as ligaments.

The blending of other muscles with the intercostals, particularly with the lower internal ones, goes far to prove that they can hardly have a purely independent action.

Far more astonishing than the difference of opinion about the intercostals, is that concerning the movements of respiration, and more especially the relative mobility of the ribs. Omitting all history, I would give the following as my conclusions, derived from the study of the movements in adult males. In the first place, it should be understood that the movements are not the same in all persons, and that in any person a slight cause is sufficient to modify the nature of the respiration. In the adult male, quiet respiration is almost purely abdominal; when the individual is sitting quite at rest, it is often nearly impossible to detect any movement in the thorax. When the chest takes part, the lower ribs are the first to be affected. Very delicate observation shows that they are for a moment fixed, and then drawn backward and outward, apparently to give greater firmness to the lateral attachments of the diaphragm, and then, if the inspiration should have been strong enough to raise the upper part of the thorax, they may follow the other ribs; but this I believe not to be their primary movement. In forced inspiration, the lower ribs are sometimes drawn decidedly inward.

The first rib is undoubtedly sometimes raised, but this is the point in which I am inclined to think there is the greatest individual variation. The amount of rotation is probably greatest from the sixth to the eighth. In an inspiration but very little stronger than usual, there is a tendency to straighten the spine, which is very marked if the inspiration be forced; this is not only, as Mr. Hutchinson has shown, to allow the ribs to widen the intercostal spaces as they rise, but also to give a firmer origin to the scaleni, the levatores, the serrati and the strips from the erector spinæ.

It has been shown that all these movements can take place without any assistance from the intercostals, other than that of dragging one

rib after another as ligaments might do. Küss accounts for their arrangement in two oppositely oblique layers by the fact that thus, in any position of the ribs, one is always on the stretch, which no doubt is necessary for proper resistance to atmospheric pressure. But though the motions of respiration may be performed without their assistance, it does not follow that they do not even normally take a part.

To gain some observation of the action of these muscles, I irritated them by striking and by galvanism, just after death, in a dog in which the costal cartilages of one side had been divided close to the sternum. The galvanic irritation was made by putting the two wires of the battery in a vertical line at each edge of the same intercostal space. The effect was to bring the two ribs together—the lower sometimes almost overlapping the upper. On cutting away the external intercostal, the same result, though in a less degree, was obtained.

Wishing to see the normal action of these muscles in a dog, although holding that the results would not necessarily apply to man, I had recourse to a vivisection, for the success of which I am greatly indebted to Dr. Amory. A dog was etherized, bound down on its back, and one side of the chest laid bare. The opening, during inspiration, of the angle between the bony ribs and cartilages in the thorax was beautifully shown, and it was evident that the fibres of the intercostals were continually changing their condition. Just what these changes, however, might be, and just when they occurred, were unexpectedly difficult points to settle, and the difficulties were so great that I am inclined to look with increased doubt on the confident assertions of some authors.

I came to the conclusion, that the external intercostals, and the internal ones between the cartilages, did contract during inspiration; but the contraction was very slight, and the doubt grows stronger in my mind whether the bulging attributed to contraction was not really the relaxation caused by the approximation of the ends of the fibres. The lower ribs were fixed and often drawn a little backward at the beginning of inspiration, but in spasmodic inspiration were drawn directly downward. Galvanism was applied between the long ribs, as in the former experiment, with both muscles intact, and sometimes with one, sometimes with the other layer divided. In all these cases the ribs were drawn together. When the internal intercostals between the cartilages of some of the higher ribs were galvanized during inspiration, the superior one ceased to ascend, and the inferior was drawn towards it. If one of the lower ribs was held fast and the muscles galvanized above it, the ribs above were drawn down.*

* Since reading this paper, I have had an opportunity, by the kindness of Dr. H. P. Bowditch, of repeating the experiment, with his coöperation. The only modification of importance was the section of the pneumogastrics, towards the end of the experiment, in order to make the respiration slower and more particularly thoracic. The results were identical with those of the other experiment, but I satisfied myself that my first impres-

Hence I concluded, first, that the action of the intercostals during ordinary respiration is very slight, if, indeed, there be any, other than ligamentous. Second, that for reasons given in an early part of this paper, both sets, at the upper part of the chest, tend to raise the ribs. Third, that owing to the fixing or drawing down of the lower rib, both sets in the lower part of the chest may tend to draw the ribs downward. Fourth, that by sudden contraction, drawing ribs together, they are muscles of spasmodic expiration. Fifth, that position, muscular action, disease, deformity, and various slight undefinable causes, may modify the action of any part of them.

N. B.—The writer would refer the reader to Professor Humphry's lecture, in the *British Medical Journal*, June 29, 1872, to Professor Cleland's paper, in the *Journal of Anatomy and Physiology*, vol. i. p. 209, and to Dr. Arthur Ransome's remarks in the *British Medical Journal*, Oct. 26, 1872. As the writer's views, except in some matters of detail, are nearly the same as those of the last-named gentleman, he would state that this paper was almost finished before he was acquainted with that of the latter.

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sions were right concerning the contraction of these muscles. I never succeeded in demonstrating the contraction of the internal intercostals between the bony ribs during expiration. It should be stated that none of these dogs were allowed to awaken from anæsthesia.