THE TRACHEALIS MUSCLE. ITS ARRANGEMENT AT THE CARINA TRACHEAE AND ITS PROBABLE INFLUENCE ON THE LODGMENT OF FOREIGN BODIES IN THE RIGHT BRONCHUS AND LUNG

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SIX FIGURES

According to Galen, the posterior wall of the trachea, where it is contiguous with the esophagus, is membranous in order that the esophagus may easily dilate, without compression, when large pieces of food are swallowed. This Galenic idea of the function of the membranous portion of the trachea seems to have been retained as late as the latter part of the eighteenth century; for I find in a 'System of Anatomy,' compiled in 1795 for the use of Monro's students at Edinburgh, the following:

The trachea consists of segments of circles or cartilaginous hoops, disposed in such a manner as to form a canal open on the back part, the cartilages not going quite round; but this opening is filled by a soft glandular membrane, which completes the circumference of the canal; but this cannot be to give way to the esophagus, for, instead of descending immediately upon the middle of the canal, the trachea inclines a little to the right side, and the same structure is found in the back part of the great bronchial vessels, which are at some distance from the esophagus.

The first part of the above quotation is a literal translation from Winslow, while the last part is evidently a comment made by the compiler or, possibly, a statement made by Monro in his lectures. That there may be some element of truth in this Galenic idea, is possible; for the most frequent seat of carcinoma of the esophagus is the middle third, where it bends somewhat to the left and is situated between the aorta and the beginning of the left bronchus which presents its cartilagenous wall, rather

than its membranous portion, towards the esophagus. The esophagus itself diminishes in diameter in this region and its mucosa would, therefore, be more subject to abrasion at this point during the act of deglutition and to continued irritation following the abrasion.

The trachea is situated anterior to the esophagus; it extends from the intervertebral disk between the VI and VII cervical vertebrae to its bifurcation into the right and left bronchi, which takes place at the IV or V thoracic vertebra. It consists of a framework of horseshoe shaped cartilages united with each other by a dense areolar connective tissue and lined on the interior with a tunica mucosa. Posteriorly, where the cartilage is wanting, the trachea is flattened. Between the external fibrous tunic and the mucosa, bundles of smooth muscle are found connecting the free ends of the cartilages with each other.

Cuvier seems to have been the first to describe the tracheal muscle as being, in some animals, inserted on the outer surface of the cartilages, in other animals, on the inner surface of the cartilages. After a careful analysis of the published cases, in connection with some of my own studies, I fail to find any assignable cause for the variation. With Meckel and with Luschka, I have found in all the carnivora that I have examined that the attachment is external. In monotremes and insectivora the attachment is internal. In animals that live on a vegetable diet the attachment is, as a rule, internal. In the ox the attachment is internal, but in the rabbit it is external. In man, with a mixed diet, the attachment is internal.

Guieysse has also studied this varied attachment of the tracheal muscle and likewise failed to find any reason for the variation.

If a freshly removed trachea with the bronchi attached be placed for thirty-six or forty-eight hours in Ranvier's alcohol, at the end of that time the epithelium can be easily brushed off from its inner surface and much of the connective tissue removed from its outer surface.

The anterior half of the trachea and of the bronchi should now be cut off, dividing the carina as near its center as possible. The posterior half is placed in 50 per cent glycerine to which sufficient picro-carmin has been added to give it a dark red color. It should remain in this mixture until it is stained a uniform red. When this has taken place the specimen is passed through glycerine of increasing strength until it is in pure glycerine; here it can remain indefinitely.

The specimen is next transferred to a compressor and gradually flattened. It may be found necessary to dissect off the greater part of the connective tissue over the outer surface of the trachea, in order that the muscle may be brought clearly into view. In very thick tracheae, as, for example, the adult human trachea, I have found it necessary at times to remove in the same manner the submucosa from the inner surface before a clear view of the muscle could be obtained.

While passing through the various grades of glycerine any excess of stain is removed and the specimen becomes clear and transparent, and the musculature can be studied under high, as well as under low, amplification.

In specimens prepared by the above method the tracheal muscle can be seen spread out in the membranous portion as a layer of branching and anastomosing bands (upper portion of figs. 1, 2, 3 and 5). Through the interstices of this muscular network pass the ducts of the glands situated external to the muscle, nerves and numerous blood vessels.

In the majority of cases the network formed by the muscle is quite compact. The musculature of the adult human trachea differs from that of the other tracheae studied; it also differs in the adult from that of the newborn child. In the adult the bands connected with a given cartilage maintain to a greater extent their independence than in the trachea of the newborn child, in which the musculature forms a network similar to that of other tracheae (fig. 5).

The attachment of the muscle may be external as in the cat (fig. 3), or it may be internal as in the case of the guinea pig (fig. 1).

The mode of attachment does not seem to influence the character of the muscular network.

Stirling has described muscle bands, between the cartilagenous crescents, in the trachea of the cat. Both Verson and Frankenhäuser have described scattered bands of muscle as ending in the mucosa of the human trachea; other authors have described bands of muscle ending in the fibrous connective tissue between the cartilages. I have failed to find any endings of this nature. I have frequently found bands of muscle passing for some distance through the intercartilagenous fibrous connective tissue but they invariably terminated in the perichondrium. Examples of this can be seen in the case of the rabbit's trachea (fig. 2). Guieysse says that in the smaller animals the insertion is directly into the perichondrium, but in the larger animals an elastic tendon is interposed between the muscle and the perichondrium. In none of the tracheae studied have I found tendons of insertion. In each instance the muscle could be traced directly to the perichondrium.

Longitudinal bands of muscle have been described by some authors; by others their presence is denied. It seems to me that the statement made by Cramer and by Luschka, that, exceptionally they may be found, explains these opposing statements in a satisfactory manner. The nearest approach to longitudinal bands that I have found in an examination of fifty tracheae, is shown in figure 4. In the twenty human tracheae examined nothing comparable to longitudinal bands was found. Luschka has pointed out that, whenever these bands of longitudinal muscle are present, they are situated behind the transverse bands.

By the contraction of the muscle the ends of the cartilages are approximated and the lumen of the tracheae correspondingly diminished. Because of this diminution in diameter the mucosa is thrown into longitudinal folds (fig. 6) which are more pronounced in the membranous portion of the trachea than in the anterior portion.

Underlying the mucosa is a layer of closely interwoven elastic fibers which run lengthwise along the trachea. Zuckerkandl correlated the longitudinal folds of the trachea with bundles of

these fibers. I have been unable to find any relation between the folds and the elastic fibers. The elastic fibers appear in the form of bundles because of the folds; the folds are formed by the contraction of the muscle and the inherent elasticity of the cartilages and not by bundles of elastic fibers.

Fig. 1 The arrangement of the trachealis muscle at the carina of the guinea pig. Internal attachment of the muscle. *B*, first bronchial cartilage. The posterior spur triangle is indicated by the clear triangular space. $\times 10$.

If a trachea be divided 25 or 30 mm. above its bifurcation, on looking into the cut end there can be seen running in an antero-posterior direction across the bottom of the trachea, between the two bronchi, a semilunar ridge: the carina tracheae. The margins of the carina diverge as they reach the anterior wall of the trachea and form the lateral boundary of what Heller and

v. Schrötter term the 'anterior spur triangle.' Posteriorly there is also formed a smaller 'posterior spur triangle' which will be described in connection with the musculature.

The carina may be either cartilagenous or membranous. Heller and v. Schrötter found that in about 70 per cent of the tracheae

Fig. 2 The arrangement of the trachealis muscle at the carina of the rabbit. External attachment of the muscle. The cartilages are so translucent that the attachment of the muscle can be seen through their free ends. *B*, first bronchial cartilage. The posterior spur triangle is seen as a clear triangular space. $\times 10$.

they examined the framework of the spur forming the carina was wholly, or in part, cartilagenous; in the remaining 30 per cent it was membranous. According to the same authors the carina was situated to the left of the midline of the trachea in 57 per cent of the cases, in the midline in 42 per cent and on the right

of the midline in the remaining 1 per cent. McKenzie and Semon found, in 100 living individuals, that the carina was on the left of the midline in 59 cases, in the midline in 35 cases and on the right of the midline in 6 cases.

Fig. 3 The arrangement of the trachealis muscle at the carina of the cat. External attachment of the muscle. *B*, first bronchial cartilage. The posterior spur triangle is indicated by the small clear triangular space. $\times 5$.

Under normal conditions the carina has, on cross section, a wedge shaped outline and is situated, as has been shown, to the left of the midline. It also has a rhythmical movement synchronous with the respiration. Anything which interferes with this movement causes the carina to flatten and, in case patholog-

Fig. 4 Carina of a cat. This is the nearest approach to longitudinal fibers that I have found.
B, first bronchial cartilage. $\times 10$.

ical changes take place in its immediate neighborhood, it may be pushed into the midline or even over to the right side. It is possible that this fact has been overlooked in studying the position of the carina and many of the midline and right side cases are in reality pathological.

Fig. 5 The arrangement of the trachealis muscle at the carina of the newborn child. Internal attachment of the muscle. *B*, first bronchial cartilage. The posterior spur triangle is crossed by two bands of muscle. $\times 5$.

The importance of this left side situation of the carina, taken in connection with the more direct continuation of the trachea by the right bronchus, to the lodgment of foreign bodies in the right bronchus and the right lung was first clearly brought out by an American surgeon, S. D. Gross.

Preobraschensky has shown that 41.6 per cent of foreign bodies lodge in the larynx; 35.8 per cent in the bronchi and 22.6 per cent in the trachea. According to the same author 69 per cent

Fig. 6 Posterior half of a trachea of a newborn pig. Shows the rugae formed by the contraction of the muscle. Note the tracheal origin of the right eparterial bronchus. The posterior spur triangle is seen just above the carina as a small white triangle. $\times 5$.

of foreign bodies entering the bronchi, lodge in the right bronchus. Gottstein gives a still higher figure for the right bronchus: 75.4 per cent.

The angle of divergence of the two bronchi also plays an important part in this right side lodgment of foreign bodies; it being for the right bronchus 25.6 degrees and for the left bronchus 48.9 degrees. These figures represent the average of the twenty tracheae measured by Kobler and v. Hovorka. Gottstein states that, in the first year of childhood, foreign bodies are only found in the right bronchus and asserts that this is due to the fact that in children the course of the right bronchus is straighter than in adults. I question this last statement. The few measurements I have been able to make show practically no difference between the two.

While the position of the carina, the presence or absence of cartilage in the carina and the angle of divergence of the two bronchi have received special consideration, the arrangement of the musculature at the carina has been neglected. So far as I have been able to ascertain, Luschka is the only one to mention the presence of special bands of muscle at the carina; he fails, however, to give a detailed description of their arrangement.

The following account is based upon a study of the trachea of the guineapig, the rabbit, the cat, the newborn child and the adult man. The external or internal attachment of the muscle to the cartilages of the trachea does not seem to influence its arrangement at the carina. We have seen that, in the adult human trachea, the muscle attached to any given cartilage maintains to a very considerable degree its independence, differing in this respect from that of the newborn child. As the carina is approached, however, the bands of muscle belonging to the last three or four tracheal cartilages form a network similar to that in the child and in the other forms studied.

Extending from the posterior portion of the carina are diverging bands of muscle which are attached to the extremities of the last tracheal cartilage and, in the case of the left bands to the last two, or even three, tracheal cartilages. By the divergence of these bands of muscle and the transverse bands of muscle

connected with the last tracheal cartilage, there is formed a triangular area of variable extent, free from muscle, which corresponds to the 'posterior spur triangle' of Heller and v. Schrötter (fig. 1). The higher attachment of the left bands of muscle is a constant factor and is brought out in figures 1, 2, 3 and 5.

These carinal bands are situated internal to the musculature of the trachea whenever they cross it. This holds true for both external and internal attachment of the tracheal muscle to the cartilages. In tracheae in which the attachment of the muscle was external the carinal muscle was found in a few instances to be attached to the end of the cartilage; in one instance a band was inserted on the inner surface of the cartilage. In all other cases the insertion of the carinal muscle followed that of the tracheal muscle.

In no instance was a tendinous insertion of the muscle into the carina found, although Luschka describes such insertion. In all the tracheae studied the carina was cartilaginous; a membranous carina was not found in the series. This was unfortunate, for it is quite possible that in a membranous carina the insertion is by means of a tendon as Luschka has described.

The important relation of the left side situation of the carina and the more direct continuation of the trachea by the right bronchus to the lodgment of foreign bodies in the right bronchus and lung was, as already mentioned, emphasized by Gross and has been repeatedly confirmed by subsequent investigators. Moreover, in inspiration, the current of air is stronger in the right bronchus than in the left, since the right lung receives a larger amount of air in a given time than the left lung.

To the above factors can be added the arrangement of the musculature at the carina which must, by its action, draw the carina to the left and at the same time reduce the lumen of the left bronchus facilitating in this manner the passage of any foreign body into the right bronchus and lung.

The right lung is more subject to pathological processes than the left lung. Primary carcinoma of the lung is more frequent in the right than in the left lung. Pneumonias also occur more frequently in the right lung than in the left lung in the propor-

tion of seven to three, and the lower right lobe is more frequently affected than other portions of the lung. It appears not improbable that the above factors which make the right lung more accessible than the left play an important rôle in the preponderance of diseases of the right lung.

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