THE ANATOMY OF THE INTERCOSTAL NERVES

By F. DAVIES, R. J. GLADSTONE AND E. P. STIBBE

From King's College and the London Hospital Medical College

As long ago as 1916 Walmsley (1) drew attention to certain inaccuracies in the orthodox description of the intercostal nerves and muscles. In 1930, two of the present writers (2) again invited the attention of the Anatomical Society to this subject and stated that the intercostal nerves (and vessels) lie *deeply* to the internal intercostal muscles, and that their manner of branching and distribution is not in accord with the usual descriptions. The present paper is the result of investigations carried out independently in two departments, the data having been accumulated over a period of nearly a year before any comparison was made. These data comprise a large number of dissections of adult and still-born subjects, and the examination of serial transverse and longitudinal sections of young embryos. On comparing results, sufficient common ground was discovered to lead to the postulation of the following as the correct description of the anatomy of the intercostal nerves and muscles.

The intercostal nerve, two of its terminal branches, and the accompanying vessels lie deeply to the internal intercostal muscle in their whole extent. The conception that the intercostal nerve is embedded in the internal intercostal muscle is due to the fact that a muscular stratum lies deeply to the nerve. We agree, however, with Walmsley (1) in regarding this deep stratum not as an intrinsic part of the internal intercostal muscle but in recognising it as an independent "intracostal" muscle.

Before reaching the angle of the rib, the trunk of the intercostal nerve gives off a branch to the external intercostal muscle, and then divides into three main branches: an upper (anterior cutaneous) which occupies the subcostal groove and is the principal or main nerve for the greater extent of the intercostal space; a lower which runs for a varying distance along the upper border of the rib below, and which we call the collateral branch; and an intermediate, the lateral cutaneous branch. Usually each nerve has also a communication with the neighbouring intercostal nerve by a fine filament crossing the deep aspect of the rib. The above description applies also to the disposition and distribution of the nerves occupying the lower spaces. The arrangement in the abdominal wall is similar to that in the intercostal spaces, but the intercommunications are rather more complex.

Certain features of this description may now be discussed in detail.

(1) *Plane of the intercostal nerves.* The lateral cutaneous branch of each nerve has a short course between the internal and external intercostal muscles before finally piercing the latter. With this exception, *at no part of the intercostal space can any large nerve be found between the external and internal intercostal muscles* (fig. 1). In other words, *in no part of its course does the intercostal nerve trunk before division or its terminal continuation the anterior cutaneous nerve lie between the external and internal intercostal muscles.*

The intercostal nerve trunk and its two terminal cutaneous branches are separated from the pleura by two strata:

(*a*) A definite thin plane of muscle, whose fibres have the same direction as that of the internal intercostal muscle, which we regard as the intracostal muscle. The upper part of this immediately below the rib above the space is thin and membranous.

(*b*) An immediately extra-pleural stratum consisting of subcostal muscles posteriorly, transversus thoracis anteriorly, and between the two a fascial plane (the sternocostal fascia, Stibbe(3)).

Owing to the thin membranous nature of the internal covering (sterno-costal fascia and upper membranous part of the intracostal muscle) the chief nerve trunks in the intercostal space are plainly visible on the inner aspect of the undissected thoracic wall (fig. 2). This is correctly represented by Henle(4), but in no other work accessible to the writers.

(2) *The muscles of the intercostal spaces* are four in number, namely from without inwards (fig. 3): external intercostal, internal intercostal, intracostal, subcostal. The upper attachment of the internal intercostal is not to the inner lip, but into the *floor* of the subcostal groove (figs. 3 and 4). Its fibres spread out to form a sort of carpet lining the groove, and on the deep aspect of this lies the nerve. This appearance is well seen in the embryo (figs. 4 A, B, C) where the distinction between external and internal intercostals is less striking than that between the internal intercostal and the intracostal.

The intracostal muscle is approximately co-extensive with the internal intercostal fibres, but becomes more membranous in its anterior part. Muscular below, its fibres end above in a thin membranous sheet which is attached to the inner (upper) lip of the subcostal groove (fig. 3), and through which the nerve can be seen as above described.

(3) *Branching of the intercostal nerve.* We find that the conception of a single nerve running the length of the space is incorrect. At any part of the inter-costal space anterior to the angle of the rib two nerves will be found, the main nerve (anterior cutaneous) above, and the collateral branch below; while, between the angle of the rib and the mid-axillary line are three nerves (fig. 3), the additional nerve (incidentally the largest of the three) being the lateral cutaneous. The orthodox description should accordingly be modified as shown in figs. 1 and 2. The fibres of the collateral branch constitute an additional anterior cutaneous supply. Commonly the collateral joins the main (anterior
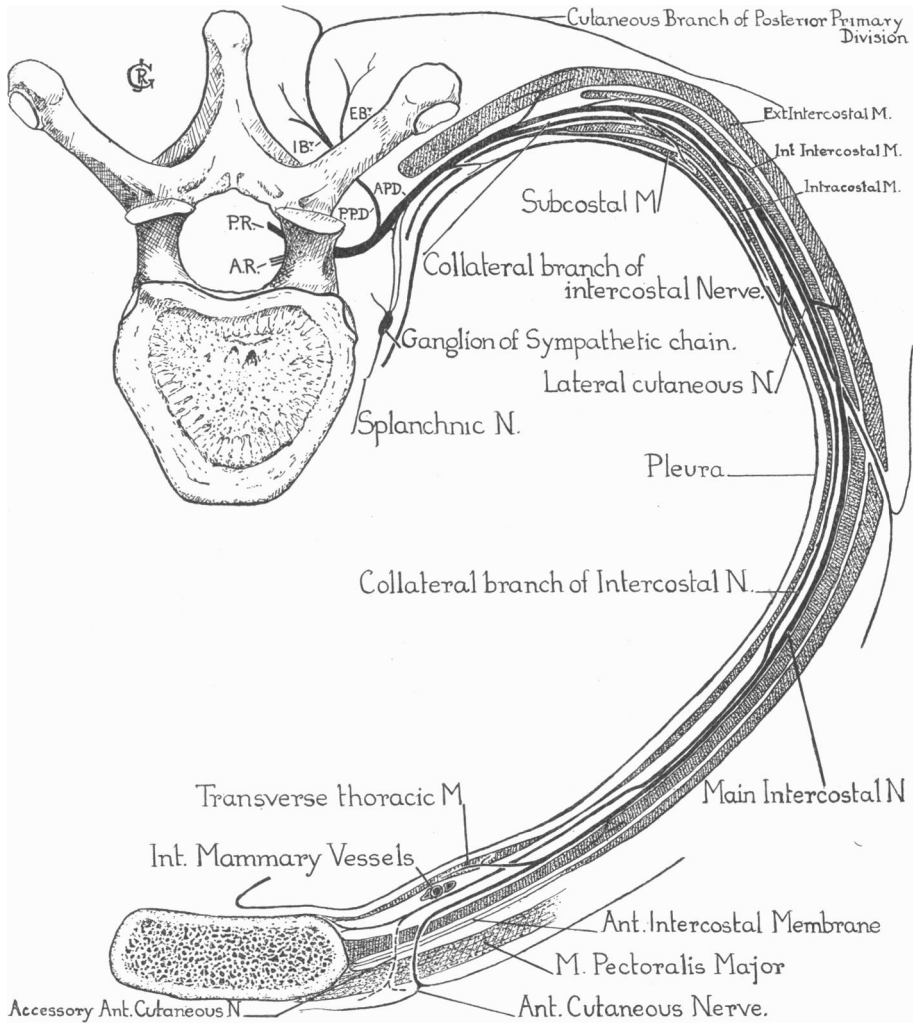
Fig. 1. Diagrammatic representation of a horizontal section through an upper intercostal space. The scheme shows the position of the intercostal nerve and its main branches between the intracostal muscle and the internal intercostal muscle. It also shows the division of the main nerve into three principal branches: (1) the main anterior cutaneous nerve, above; (2) the lateral cutaneous nerve, intermediate; (3) the collateral branch, below. It will be observed that the collateral branch rejoins the main anterior cutaneous nerve in the anterior part of the space. After coursing forward with this for a variable distance it frequently leaves it, and may pierce the internal intercostal muscle, anterior intercostal membrane and greater pectoral muscle to terminate as an accessory anterior cutaneous nerve. In addition to the nerves indicated in the diagram, communicating branches are frequently present which join the intercostal nerve above or below the nerve of any given space.
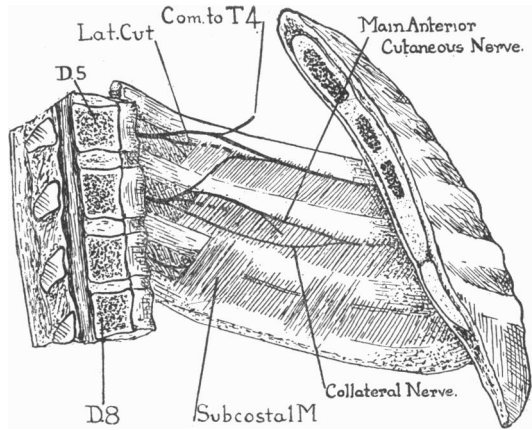
Fig. 2. From a dissection by Dr E. P. Stibbe. The fifth, sixth and seventh intercostal spaces of a full-time human foetus. In the fifth and sixth spaces the subcostal and intracostal muscles have been removed so as to expose the intercostal nerves lying upon the insertion of the internal intercostal muscle into the floor of the subcostal groove. The sixth intercostal nerve gives off a large communicating branch to the fifth nerve. In the seventh intercostal space the subcostal and intracostal muscles have been left in position, and the main anterior cutaneous branch of the intercostal nerve is just visible through the thin membranous insertion of the internal intercostal muscle into the upper border of the subcostal groove.
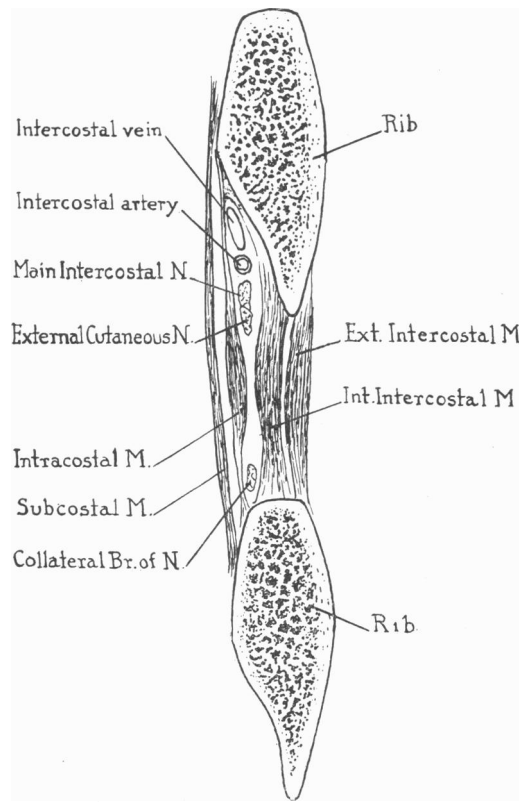

Fig. 3. Diagram of a vertical section through an intercostal space, showing the relationship of the vessels and nerves to the muscular layers.
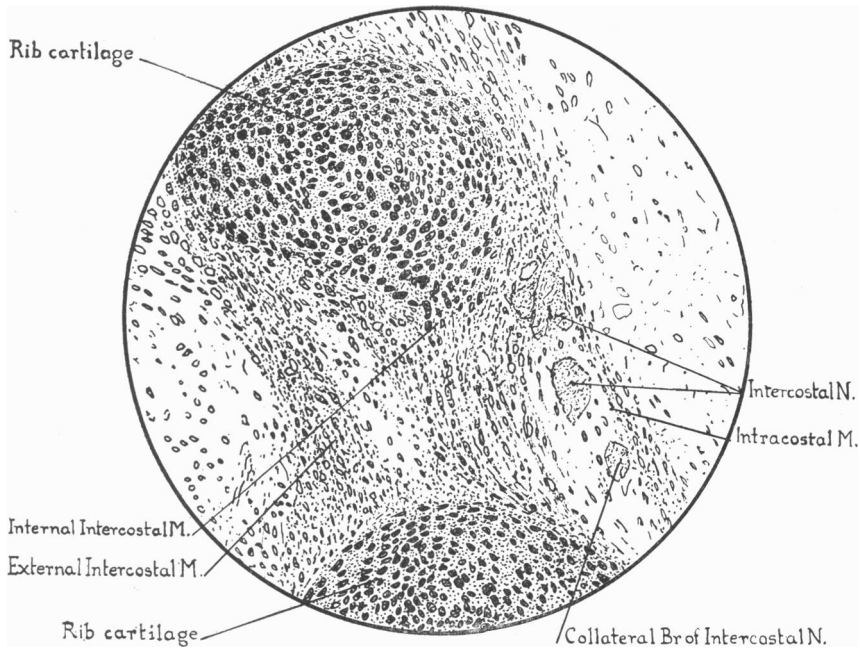
Fig. 4 A. Sagittal section through the fourth intercostal space of a human embryo 12 mm. in length, showing the main intercostal nerve and its collateral branch situated between the extrapleural stratum of muscle and the internal intercostal muscle.
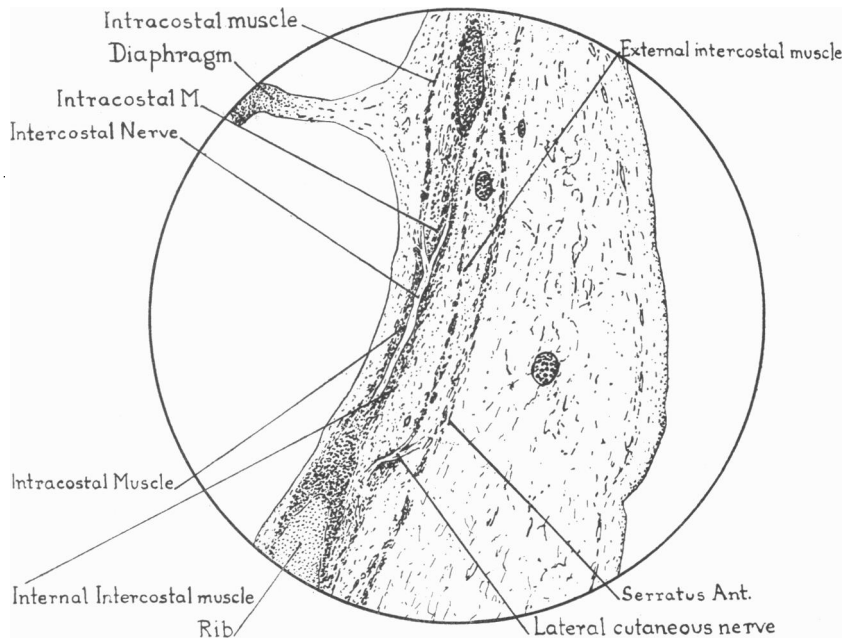

Fig. 4 B. Section passing obliquely through an intercostal space in the mid-thoracic region of a 20 mm. human embryo showing five muscular strata, which from within outwards are: 1, subcostal; 2, intracostal; 3, internal intercostal; 4, external intercostal; 5, serratus anterior. The main intercostal nerve lies between the intracostal muscle and the internal intercostal muscle.

cutaneous) nerve anywhere between the mid-axillary line and the anterior end of the rib, in which case it finally leaves the nerve to be distributed as a lower additional anterior cutaneous nerve. There are thus two anterior cutaneous nerves in each intercostal space, just as there are two in each "segment" in the anterior abdominal wall. Not infrequently the collateral branch remains independent throughout its course.
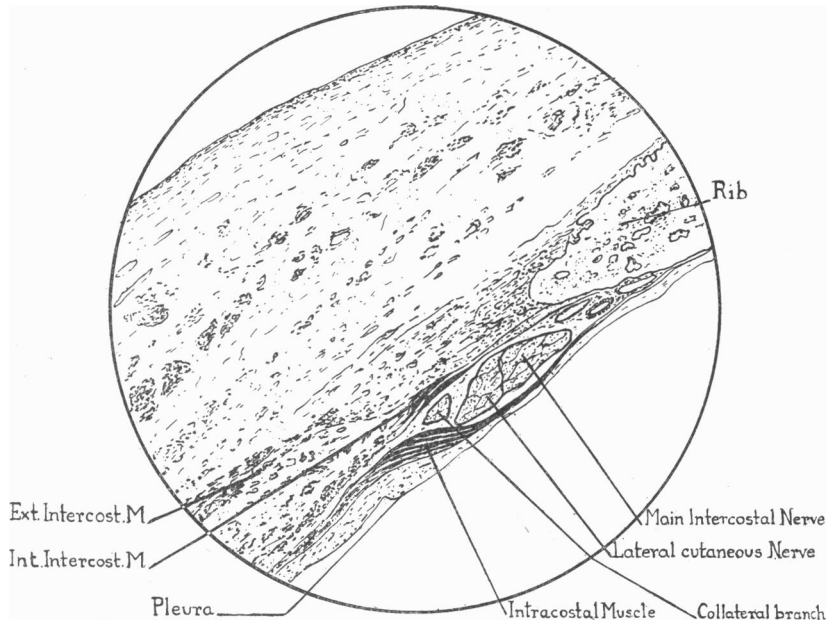

Fig. 4C. Oblique section through the upper part of an intercostal space of a 4·5 cm. human embryo, showing the intercostal vessels and nerves lying in the space between the intracostal muscle and the internal intercostal muscle. The subdivision of the intercostal nerve into three branches is clearly visible, namely: (1) main anterior cutaneous branch of the intercostal nerve lying above; (2) lateral cutaneous nerve intermediate and at this part of its course bound up in the same sheath as the main nerve; (3) collateral branch, below and separated by a short distance from the lateral cutaneous nerve.

The lateral cutaneous nerve remains in the deep plane with the other branches until it has nearly reached the level of its exit from the space, where it pierces the internal and external intercostal muscles obliquely. The course of this nerve between the two intercostal muscles is thus very short (fig. 1).

(4) *Course of the lower six intercostals.* Each of these commonly pierces the diaphragm as a single trunk, the collateral branch having already rejoined the main (anterior cutaneous) nerve (fig. 5). Sometimes, however, two nerve trunks (main and collateral) pierce the diaphragm and join in the anterior abdominal wall (fig. 6). Between the transversalis and internal oblique muscles there is a very free plexus formation (figs. 5, 6, 7). By "stripping" the

nerves backwards from the lateral border of the rectus it can be shown that any one nerve in this region contains fibres from at least two, and sometimes three,
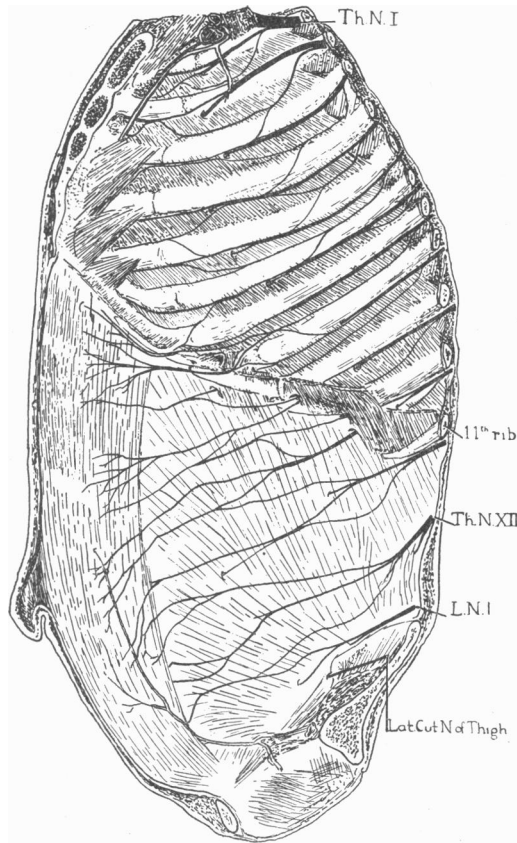

Fig. 5. From the dissection of a human foetus by Dr F. Davies. The pleura, subcostal, intracostal and transverse abdominal muscles have been removed, and the thoracic and abdominal muscles exposed from the inner side. A typical intercostal nerve is seen to divide into three main branches: (1) an upper which terminates as the principal anterior cutaneous nerve; (2) an intermediate branch which is bound up in the same sheath with the main branch for a variable distance before leaving it to become the lateral cutaneous nerve; (3) and a collateral branch which is given off in the posterior part of the space and then courses along the lower part of the space for a considerable distance. It may then rejoin the main nerve and finally terminate with it as the anterior cutaneous nerve, or it may again separate from the principal nerve and terminate as an accessory cutaneous nerve. Communicating branches are seen crossing the inner surfaces of the ribs. The same subdivision of the main nerve into three principal branches and communications with adjoining intercostal nerves is seen in the abdominal wall as that which takes place in the thoracic wall.

intercostal nerves. Moreover, any one nerve at the lateral border of the rectus is distributed to two segments of the muscle. It is certain, therefore, that the rectus segments do not receive a "segmental" nerve supply, but that each
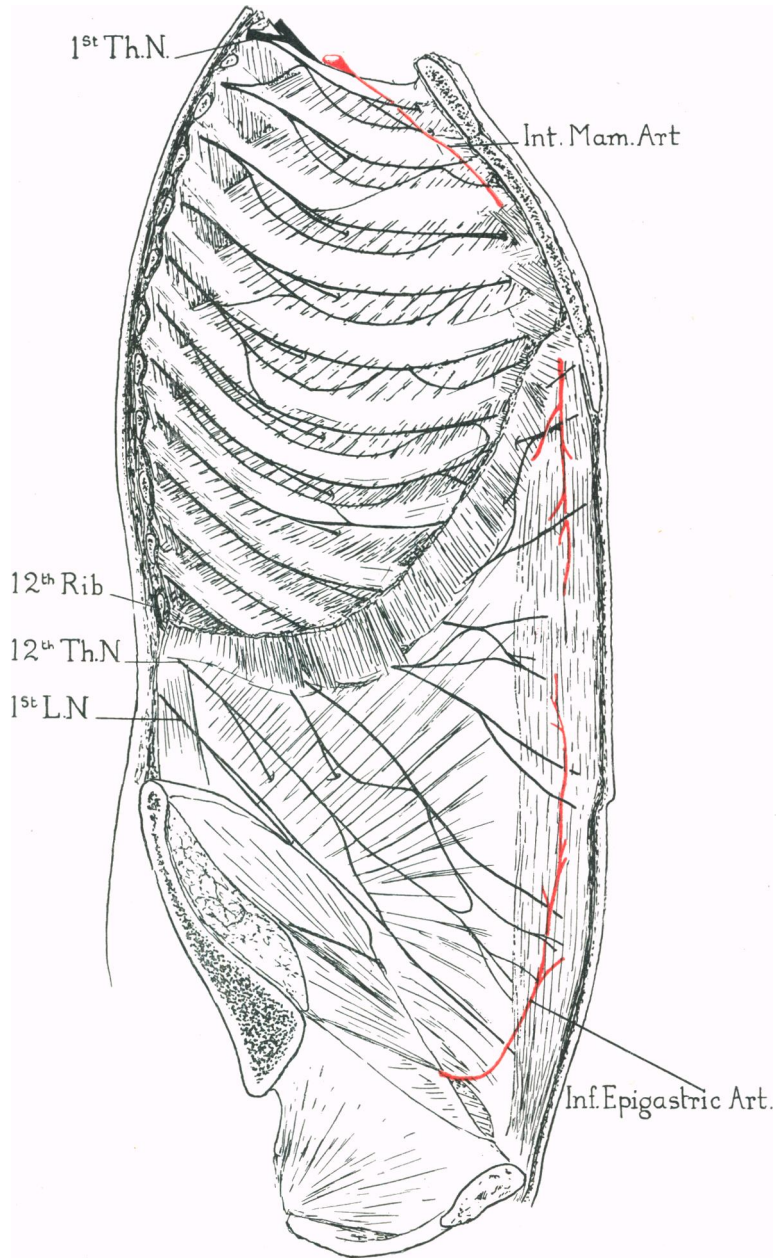
Fig. 6. Diagram of the distribution of the intercostal nerves founded on dissections made by Dr
E. P. Stibbe. The figure represents the left side of an adult human subject seen from the
inside. The pleura, peritoneum, subcostal, intracostal and transversus abdominis muscles
have been removed, and the thoracic and first lumbar nerves exposed, lying on the inner
aspect of the internal intercostal and internal oblique muscles. The division of the main nerve
into three principal branches is shown, and also the communications between the intercostal
nerve of one segment and the nerve above or below it in the series. No communication how-
ever was found between the tenth and the eleventh thoracic nerves. The relation of the nerves
to the superior and inferior epigastric arteries is also indicated.

segment is supplied by three "segmental" nerves at least. The twelfth thoracic nerve communicates freely with the ilio-hypogastric.

(5) *Distribution to the diaphragm.* Each of the intercostal nerves from the seventh downwards gives a twig to the diaphragm; this may be derived from the collateral branch or from the "main" nerve, or there may be two branches, one from each division. The branch from the seventh is usually single, large, and given off from the single trunk of reunion of collateral and "main" divisions. Kiss and Ballon[5] conclude that these branches are sensory, though Felix[6] attributes motor function to the branch from the twelfth intercostal. The results of clinical avulsion of the phrenic nerve seem to show that it is the only motor supply of the diaphragm.
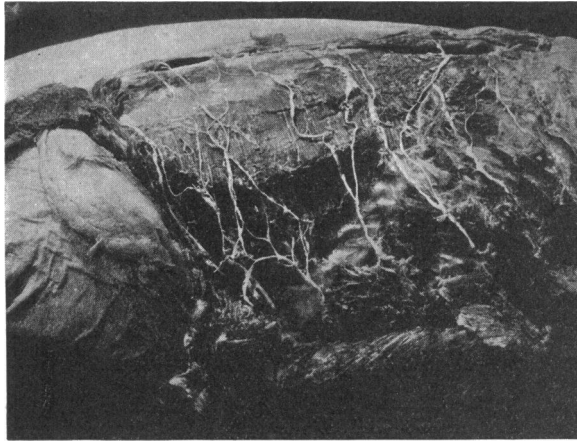

Fig. 7. Photograph of a dissection by Dr E. P. Stibbe, to show plexus formation of intercostal nerves in anterior abdominal wall.

(6) *Distribution in rectus muscle and overlying skin* (fig. 8). At the lateral border of the rectus muscle, each nerve divides into two branches, an upper and a lower; the lower branch represents the collateral branch (cf. anterior ends of intercostal spaces).

The upper or "chief" nerve enters the back of the muscle in the region of the tendinous intersection and near the lateral border of the muscle. It courses inwards for a short distance and divides into three sets of branches: one to the muscle segment above, one to the muscle segment below, and an anterior cutaneous. The latter enters the skin near the linea semilunaris, and is a member of the lateral series of anterior cutaneous nerves.

The lower or collateral branch enters the muscle below the corresponding tendinous intersection, courses inwards, communicates with the upper branch, and ends as the medial anterior cutaneous branch usually just below the linea transversa and just outside the linea alba.
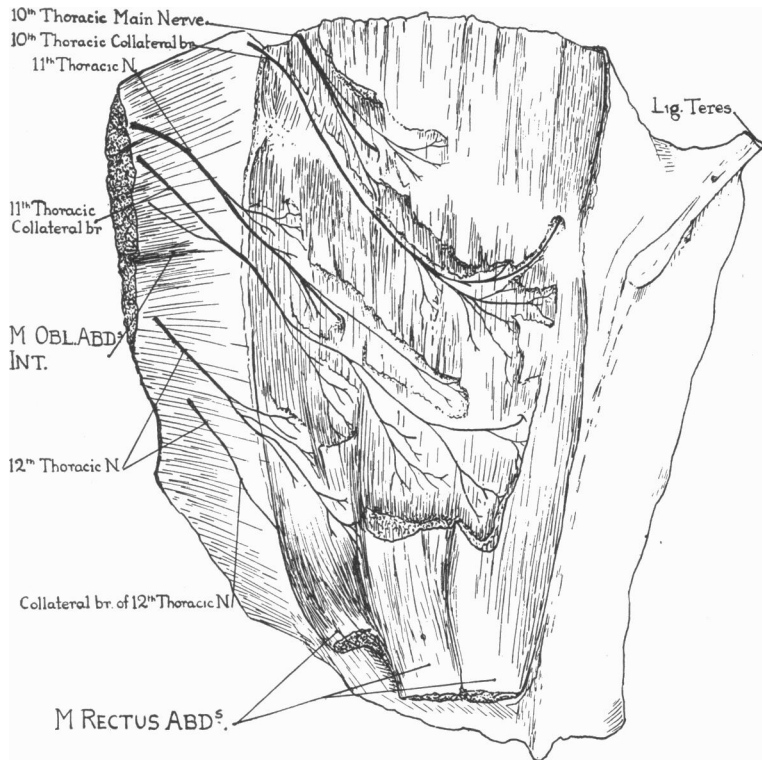
Fig. 8. From a dissection by Dr F. Davies. A portion of the abdominal wall is viewed from behind. The transversus abdominis muscle and the posterior wall of the sheath of the rectus abdominis muscle have been removed. The terminal distribution of the tenth, eleventh and twelfth thoracic nerves is seen to consist of an upper and lower branch. The upper branch, after having given off muscular branches to the rectus muscle, ends as the lateral anterior cutaneous branch. The lower branch gives off branches to the muscle and finally terminates as the medial anterior cutaneous branch. The drawing also indicates the relationship of the nerve fibrils to the lineae transversae and the superficial, intermediate and deep strata of the rectus muscle.
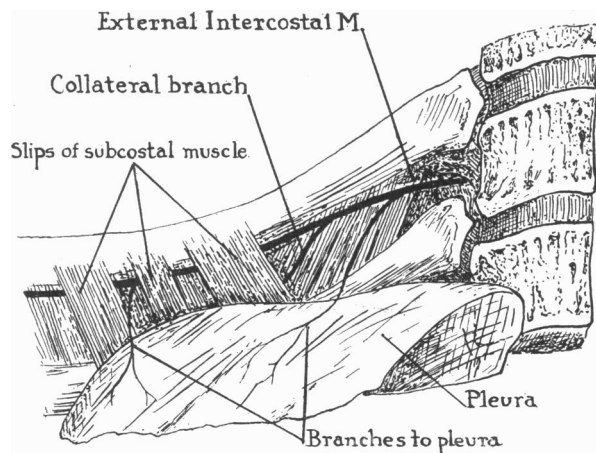

Fig. 9. From a dissection by Dr E. P. Stibbe. The vertebral end of a lower right intercostal space viewed from the front. The pleura has been turned down and the posterior intercostal membrane removed. The main intercostal is seen to give off a collateral branch and branches to the pleura.

The twelfth thoracic nerve passes entirely in front of the rectus muscle; the upper branch ends in skin, the lower is distributed to the Pyramidalis muscle and the skin.

SUMMARY

1. The muscles of the chest wall are four in number in each space: external intercostal, internal intercostal, intracostal and subcostal from without inwards. The subcostal muscle is variable in its extent, the others constant in each space.

2. The intercostal nerves and vessels are confined to the plane between the internal intercostal and intracostal muscles.

3. Each intercostal nerve divides at the back of the space into a series of branches:

(*a*) The "main" nerve, is prolonged as the anterior cutaneous branch.

(*b*) The lateral cutaneous.

(*c*) The collateral branch, either rejoins the anterior cutaneous branch nerve, or ends independently as a second anterior cutaneous branch.

4. The lower intercostal nerves form an elaborate plexus in the abdominal wall. Each muscle and skin "segment" receives branches from at least two and more commonly three spinal nerves.

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