ALMAR hyperhidrosis is a common functional disorder among young Asians in subtropical areas. It is of unknown etiology and may cause professional, social, and emotional embarrassment. Experimental studies indicate that the T-2 ganglion plays a significant role in hyperhidrosis. Surgical intervention is currently accepted as appropriate management for curing or improving the intractable symptoms in the majority of patients. Among the available surgical modalities, endoscopic transaxillary T-2 sympathectomy has been widely recommended recently because it is less invasive and good illumination can be achieved under direct vision. However, this procedure includes the disadvantages of a narrow viewfield and poor orientation, which might lead to the most serious complications, such as hemorrhage, brachial plexus injury, pneumothorax, and Horner’s syndrome, in inexperienced hands. Therefore, some complicated intraoperative electrophysiological monitoring for verification of ganglion location is necessary. However, limited information is available concerning the anatomical method of localization. In this article, we will describe an alternative, simple, and reliable anatomical method to assist the beginner in identifying the T-2 ganglion more easily and correctly.

**Materials and Methods**

We totally dissected 17 adult cadavers, 16 male and one female, which had been prepared using a fixative solution for an anatomical dissection class held 1 year previously. We evacuated the sternum and intrathoracic contents, for example, the heart, lungs, and ascending aorta, to expose the posterior mediastinum. Three series of studies were performed. In the first part, we inserted the smallest rigid trocar (No. 16 French) alternately through the second, third, and fourth intercostal spaces (ICSs) along the anterior or middle axillary line via the second to fourth intercostal spaces to measure the aiming angles and intrathoracic depth needed. Second, the regional anatomical structures and their relationship to bilateral T-2 ganglia were delineated. It was discovered that the superior intercostal artery, a branch of the subclavian artery, was an accessible landmark. This small vessel existed in 87.5% of the cadavers studied. It consistently runs lateral to the parallel sympathetic chain at an average distance of 10 mm. Most important is that it can be easily distinguished where it runs across the inner part of the second rib. The authors emphasize that the superior intercostal artery should be a very beneficial landmark for surgical orientation.

**Key Words** • endoscopic transaxillary T-2 sympathectomy • palmar hyperhidrosis • superior intercostal artery • cadaver

![Schematic drawings depicting the method for measuring the angles and intrathoracic depth of the endoscope described in this study.](image)
Operative landmarks for T-2 ganglion

**Different Approach Level Versus Aiming Angle and Depth**

The human nipples are usually located at the fourth ICS just along the midclavicular line, so we could use them to localize the other ICSs very easily. The anterior or middle axillary line is a clear outer topographical landmark. Along the anterior axillary line from the second to the fourth ICS, the endoscope should aim medially in a caudal to cranial direction at a 40˚ to 60˚ angle (upward), and somewhat inferiorly in a ventral to dorsal direction at a 30˚ to 40˚ angle (downward), but at a 20˚ to 50˚ angle upward and a 10˚ to 20˚ angle downward along the middle axillary line (Table 1, Fig. 3 upper and center). We need the widest upward angle through the lowest (fourth) ICS level, but the downward angle is the narrowest. The length of intrathoracic endoscope needed is approximately 10 to 15 cm, with the length at the fourth ICS along the anterior axillary line the longest, but there is no significant difference on either side (Fig. 3 lower). In general, we need narrower upward and downward angles through the entry point at the middle axillary line, and the intrathoracic length is also relatively shorter compared to that at the anterior axillary line.

**The T-2 Ganglion Versus Surrounding Vessels and Ribs**

The sympathetic chain can be seen through the parietal pleura as a whitish cord that runs vertically over the neck of the ribs close to the costovertebral junction. The intercostal nerve and vessels always run beneath the lower margin of the corresponding rib and the sympathetic chain lies almost invariably immediately in front of them, but some intercostal veins may occasionally cross ahead of the chain. On the right side, the T-2 ganglion lies above the level of the azygos vein, which is located at the medial side of the sympathetic chain and drains into the superior vena cava. In the left thoracic cavity, the medial side contains the hemiazygos vein and the aorta, and the T-2 ganglion lies in the vicinity of the aortic arch. Around both
dome triangles are the subclavian arteries, with the heart located between these vital structures.

The operative approach is via the lateral aspect of the chest and aims superomedially (upward) to inferomedially (downward). Any injury to the midcentral vital structures such as the greater vessels and the heart should be avoided. For these reasons, we tried to find the landmark structures located at the near-lateral aspect of the sympathetic chain when a small vessel (approximately 2 mm in diameter) drew our attention. This superior intercostal artery is a branch of the subclavian artery and was found in 28 (87.5%) of 32 sides in the cadavers in our series; 15 (88.2%) of 17 in the right and 13 (86.7%) of 15 in the left side (Table 2). This artery always runs lateral to but not widely separated from the parallel sympathetic trunk (average distance 10 mm). Most importantly, it always travels in an inferolateral direction and can be visualized where it runs over the inner part of the second rib to end as the second intercostal artery (Fig. 2). It is a very helpful landmark for surgical orientation.

The T-1 ganglion is usually fused to the inferior cervical ganglion to constitute the stellate ganglion, whereas the main body of the T-2 ganglion is positioned fairly consistently at the second ICS distal to the corresponding intercostal nerve, but lies in a somewhat lower level very near the upper border of the third rib.7,13 We have classified the T-2 ganglion into three types according to its relationship to the trunk of the third rib (Fig. 4). In approximately 85% of cases, we can very easily recognize the T-2 ganglion just above the upper margin of this rib. However, it should be noted that in approximately 16% of the T-2 ganglia studied, 17.6% on the right and 13.3% on the left side, the main body is completely embedded in front of the third rib.

Clinical Application

Using our anatomical method for localization, the first author (T.S.M.C.) has operated on 73 consecutive patients in the past 2 years. There were 31 males (42.5%) and 42 females (57.5%) aged 15 to 44 years (mean age 24.5 years). Except in three cases with unilateral pleural ad-
hesion, we performed endoscopic T-2 sympathectomy on 143 hands. In 121 of the procedures (84.6%) we found the superior intercostal artery and used it as a landmark (Fig. 5). Three complications (2%) occurred, one mild hemorrhage and two pneumothorax with subcutaneous emphysema, but they resolved spontaneously without chest drains. We have achieved excellent relief of suffering without recurrence in 98% of the patients for whom follow-up evaluation was continued for at least 6 months (the longest 2 years) using a telephone questionnaire.

**Discussion**

The eccrine glands are located mainly over the palms, soles, and in the axillae. They are usually innervated by the sympathetic cholinergic fibers from T2–9. For palmar hyperhidrosis, the T-2 ganglion is a key object. The optimum level of sympathectomy is achieved by dividing the sympathetic chain immediately below the stellate and just above the T-3 ganglion. Because this disorder is a functional problem, the chosen treatment should be as safe, simple, and nontraumatic as possible. Of several surgical procedures, the endoscopic transaxillary transthoracic approach is currently recognized as an effective, simple, and minimally invasive procedure with low morbidity and excellent results. These patients usually require only a short hospitalization.

However, the orientation for endoscopic surgery is poor because of its narrow viewfield, so this technique involves a learning curve even for experienced surgeons. Also, numerous influential great vessels and major organs, such as the heart and lung, surround the operative area and they are vulnerable especially to an inexperienced hand. The most serious reported complications are hemothorax and Horner’s syndrome, which are caused by injury to greater vessels and stellate or T-1 ganglia, respectively. Furthermore, although the mechanism of recurrent sweating is unclear, improper identification of the target ganglion has been noted as one of the causes of failure of immediate symptomatic relief, whereas extensive resection distal to the T-4 ganglion will denervate the axilla and cause more severe compensatory hyperhidrosis.

Obviously, understanding the regional anatomy related to bilateral T-2 ganglia is a prerequisite for inexperienced practitioners; exact identification of the T-2 ganglion is the most important challenge for them.
By properly moving the endoscope, we can identify the magnified structures of the upper posterior mediastinum one by one as we gain familiarity with them. On reviewing the literature we found only two articles in which the methods of orientation using medial landmarks such as the aortic arch or the azygos vein are mentioned. Moreover, the sympathetic trunk is not readily visible intraoperatively in one-third of the cases. Given these ambiguous conditions, some surgeons locate the target by consulting surface landmarks such as the upper border of the sternum (which is the same as the T-2 body) and sternal angle (same as the T-5). Chest radiography may also be used. However, none of these maneuvers is really practical.

Because the upper sympathetic chain has influence on sudomotor function and temperature of the hands, some investigators advocate intraoperatively confirming the proper level of the sympathetic trunk with the aid of electrophysiological stimulation. At the correct gangoletic level, the threshold for piloerection, sudomotor response, and suppression of microcirculation of the ipsilateral fingers is minimal. As stimulus intensity is raised, piloerection increases gradually, whereas the microvascular flow decreases and persists throughout the period of stimulation. All the responses are present on the stimulated side only, thus this method is especially reliable when the sympathetic trunk is not clearly visible. The surgeon can locate the invisible target ganglia by gentle palpation with the electrode probe and then confirm them by the response to the electrical stimulation. However, this system is expensive and the whole procedure is so complicated, time-consuming, and technically difficult, that we need another more convenient tool like the method presented in this paper.

Although some use the laparoscope in most institutions have adopted the thoracoscope or urological endoscope with a working channel for applying a cautery probe so that only one stab wound is needed. The stab point in most published reports is via the second to fourth ICS along the anterior axillary line. However, because of the location of breast fat in females, we suggest a stab point along the middle axillary line to avoid injury to the adipose tissue and resulting hemorrhage. Furthermore, the human nipples are always located at the fourth ICS just along the midsclavicular line. For the above reasons, in our study we have established entry points at the second to fourth ICS and along the anterior or middle axillary lines alternately. First, we chose a suitable straight endoscope with an intrathoracic length of at least 15 cm. Thereafter, depending on the ICS level penetrated and its relationship to the anterior or middle axillary line, the aiming angles of the endoscope should be in the range of 20° to 60° upward, and 10° to 40° downward. The most important principle is the need for a larger upward superomedial angle but a smaller downward inferomedial angle at the lowest (fourth) intercostal level.

Some minor apical pneumothorax is intentionally created using a trocar just before the introduction of the thoracoscope. The surgeon should avoid using the vital structures on the medial aspect of the posterior mediastinum as a reference point. The venous system is generally more variable and is also not suitable as a landmark. Accordingly, it is advisable to search first for the superior intercostal artery to recognize the second rib (Fig. 5 upper right). Because we were operating in the vicinity of the sympathetic trunk, we could locate the third and fourth ribs and the intercostal nerves and vessels. Therefore, the target T-2 ganglion can be identified very easily, especially with the clear, magnified images of a video system.

Nine upper pairs of intercostal (T3–11) and one pair of subcostal arteries originate from the back of the thoracic descending aorta, whereas the first two intercostal arteries arise from the costocervical trunk of the subclavian artery. The former (T3–11) always run beneath the lower margin of the corresponding rib, whereas the latter two arteries (T1–2) go downward across the inner side of the first and second ribs. The first superior intercostal artery runs more medially near or even touching stellate and T-1 ganglia, which are always covered by subpleural fat and are not commonly visible (Fig. 5 upper right), but the second superior intercostal artery is clearly seen in almost 90% of cases, as our study indicates. Most important, this artery is located approximately 1 cm lateral to the sympathetic trunk, so it is an ideal landmark for orientation to the T-2 ganglion. Even in a situation with an obscure sympathetic trunk, we could identify the T-2 ganglion very easily by combining the palpation methods with use of an electrocautery probe.

There is another minimally invasive procedure for therapy of palmar hyperhidrosis, the percutaneous radiofrequency technique. Some advocate it as a simple method that can be performed while the patient is receiving local anesthesia. Based on our study, we do not believe that this procedure could locate the target ganglion accurately using only x-ray films, because at least 16% of the T-2 ganglia are embedded completely in front of the rib trunk. These Type III ganglia are absolutely impossible to reach via a dorsal approach. For Type II ganglia, the effect of coagulation should be inadequate except when using a larger electrical probe or higher current. Also, the intercostal nerve might be injured using these maneuvers, leading to intractable costal neuralgia postoperatively. Thus, this procedure should reasonably be expected to have the poorest and most unreliable operative outcome.

To confirm the effect of the sympathectomy, most institutions intraoperatively monitor the finger temperature and palmar skin perfusion of the patients. An elevation of at least 3°C in finger temperature after cautery has been adopted as an index of a successful operation. However, the thermoregulatory sweating mechanism of the hands is not completely understood. Thus it should not be considered a reliable parameter. In observations reported by Kao, et al, the temperatures of the patients’ fingers were elevated by 2°C just after the induction of anesthesia and before the sympathectomy. If we could identify the T-2 ganglion accurately based on anatomical landmarks, the intraoperative monitoring of finger temperature and tests of the electrophysiological response of sudomotor function would not be necessary.

Summary

In summary, we present an alternative anatomical method for exact localization of the T-2 ganglion intraoper-
Operative landmarks for T-2 ganglion

tively in endoscopic transaxillary sympathectomy. First, we measured the aiming angles and length of the operative endoscope needed for adult patients. Then we identified the superior intercostal artery, a branch of the subclavian artery, which our study also indicates, is a good, easy, fast, and reliable orienting landmark for the T-2 ganglion because it always runs lateral to but within only 1 cm of the parallel sympathetic chain. Most importantly, it runs visibly across the inner side of the second rib.

References

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