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SURGICAL ENDOSCOPY
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The importance of classification in sympathetic surgery and a proposed mechanism for compensatory hyperhidrosis: experience with 464 cases

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Abstract
Background: Compensatory hyperhidrosis is the most troublesome side effect and the leading cause of regret with sympathetic surgery. A new classification is proposed to make the procedure more selective and to minimize the side effects and regret rate. Also, a proposed mechanism for compensatory hyperhidrosis is discussed.
Methods: Between January 2002 and July 2003, 464 patients with various sympathetic disorders underwent thoracoscopic sympathectomy/sympathicotomy (ETS) or sympathetic block by clipping (ESB) at various levels according to the authors' classification. The surgery was performed on an outpatient basis. The rates of success, compensatory hyperhidrosis, and regret were recorded.
Results: All the patients were followed up for 17 to 35 months. All excessive sweating was effectively stopped to varying degrees. The 25 patients with palmar hyperhidrosis who insisted on receiving ETS of T4 experienced no compensatory hyperhidrosis. Of the 54 patients with facial blushing who received ESB of T2, 23 experienced compensatory hyperhidrosis. Nine patients expressed regret and requested removal of the clips. Of the 33 patients with craniofacial hyperhidrosis who received ESB of T3, 9 experienced compensatory hyperhidrosis. Three expressed regret, and reverse procedures were performed. For 324 patients with palmar hyperhidrosis receiving ESB of T4, no compensatory hyperhidrosis was found. Only two expressed regret because of discomfort. No compensatory hyperhidrosis or regret was noted with 28 patients who received ESB of T5 for axillary sweating. There was no recurrence in the entire series.
Conclusions: Different procedures are recommended for different sympathetic disorders according to the classification. The higher the level of sympathetic ganglion blockade, the higher is the regret rate. Therefore, for T2 and T3 ganglion, endoscopic thoracic sympathetic block by the clipping method is strongly recommended because of its reversibility.

Key words: Classification — Compensatory hyperhidrosis — Sympathectomy

Although various methods of sympathetic surgery have been proposed [1, 5, 14, 16, 22], the endoscopic procedure currently remains the most popular and acceptable method. The reasons derive from its simplicity, safety, and efficacy [3, 9, 10]. Also, the endoscopic procedure is easy to learn and practice.

In addition to palmar hyperhidrosis, indications of sympathectomy have been extended to plantar hyperhidrosis [10], facial blushing, facial sweating [12], and the like. However, the side effects of sympathetic surgery have not been an item of concern as they should be, although they have been widely discussed in the literature. The most common and annoying side effect is compensatory hyperhidrosis, which often leads to regret in relation to the operation [11].

To reduce sweating substantially in the target area while simultaneously minimizing compensatory hyperhidrosis in the other "innocent areas," we classified different sympathetic disorders into different groups from concepts of segmental distributions of sympathetic innervations in the human body [21, 23]. Different sympathetic procedures for different sympathetic disorders were performed according to the new Lin-Telaranta classification (Table 1). This classification was first introduced in 2001 [12]. For this study, we modified it for better application in sympathetic surgery. The surgical outcomes and side effects in the entire series were

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Table 1. New Lin-Telaranta Classification (2004)

	Sympathetic disorders	Procedure
Group 1	Facial blushing	ESB_2
Group 2	Facial sweating, Facial sweating with blushing	ESB_3
Group 3	Palmar Hyperhidrosis	ESB_4
Group 4	Axillary sweating (Bromidrosis)	ESB_5

recorded and analyzed. Moreover, we advocate using the term "reflex sweating" instead of "compensatory hyperhidrosis." The reasons are listed in the Discussion section.

Materials and methods

For this study 464 patients (202 men and 262 women) with various sympathetic disorders who underwent sympathetic chain interruption at various levels according to the new Lin-Telaranta classification between January 2002 and July 2003 were retrospectively reviewed. They were divided into four groups according to different sympathetic disorders, for which different levels of ganglions were cut or blocked by a clipping method with Endoclips (Ethicon, Inc., Ohio, Cincinnati, USA). The differences between the original and the new classification are the addition of group 4 (Axillary Sweating) and a more disease-specific level of blockade.

A total of 25 patients (10 men and 15 women) with palmar hyperhidrosis were treated using T4 sympathectomy or sympathicotomy (ETS4). They insisted on receiving the cutting method after a detailed preoperative explanation. The only request of these patients was that a "dry hand" be maintained. All other possible side effects were of no concern. An important reason for their choice of ETS was that they had absolutely no desire to receive a second operation (reverse procedure) despite the possibility of severe side effects. That is, they were unlikely to express regret no matter how severe the compensatory hyperhidrosis proved to be. Nevertheless, we still explained the possible problems of compensatory hyperhidrosis and its irreversibility if the nerve was cut.

Consequently, 54 patients (23 men and 31 women) with facial blushing were treated using T2 sympathetic block by clipping (ESB2), and 33 patients (18 men and 15 women) with craniofacial sweating were treated by T3 sympathetic block (ESB3). A total of 324 patients (143 men and 181 women) with hyperhidrosis palmaris, with or without axillary sweating were treated by T4 sympathetic block (ESB4) (Fig. 1), whereas 28 patients (8 men and 20 women) with axillary sweating were treated by T5 sympathetic block (ESB5).

The surgery was performed for all the patients on an outpatient basis. They were followed up in the outpatient clinic once a week for the first month and by telephone questionnaire before the study was performed to investigate dryness of hands, severity of compensatory hyperhidrosis, recurrence, regret for the operation, complications (including wound infection, chest pain, and Horner's syndrome), and degree of satisfaction.

Operations

Endoscopic thoracic sympathetic block by clipping (ESB)

The ESB procedure was performed as previously described [8, 11]. With the patient under general anesthesia using single-lumen tracheal intubation, two 5-mm ports were inserted: one at the axilla and one in the midaxillary line at the level of the nipple. Through thoracoscopy (Karl Storz, Tuttlinten, Germany), the hooked diathermy probe was passed through the upper port. The pleura was opened along the sympathetic trunk. Endoclips were applied above and below the target ganglion. The ports were removed after the lung was fully expanded. No stitching was necessary.

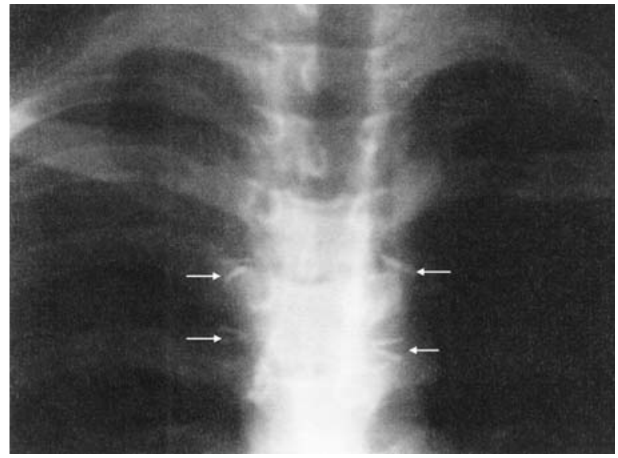

Fig. 1. A case of palmar hyperhidrosis with T4 clipping (*arrows*).

Reverse procedure (removal of clips)

The procedure for removal of the clips was the same as that for ESB, except that the clips previously applied were removed with endoforceps.

Endoscopic thoracic sympathicotomy or sympathectomy (ETS)

The ETS procedure was performed with the patient under general anesthesia, as with ESB. Either a two-port or single-port approach was used. The sympathetic trunk was cut with a diathermy probe at the upper and lower ends of the target ganglion. With ETS, the sympathetic ganglion is not removed in sympathicotomy as it is in sympathectomy. Both procedures produce the same surgical outcomes. The incision wounds were treated with the same procedure as used with ESB. Postoperative chest radiograph was routinely performed.

Results

No recurrence and no complications other than compensatory hyperhidrosis were encountered. Residual pneumothorax occurred in 5% of the cases. All subsided without intervention. The follow-up period ranged from 17 to 35 months. All excessive sweating was successfully stopped as the patients expected.

The definition of "regret" is primarily subjective. None of the 25 patients who received ETS4 experienced compensatory hyperhidrosis. The regret rate was zero because they were not likely to express regret (for the aforementioned reasons). With ESB2, all faces returned to fair complexion. Of the 23 patients (42.6%) who experienced compensatory hyperhidrosis, 9 (16.7%) expressed regret and underwent the reverse procedure, which involved removal of the clips because of severe compensatory hyperhidrosis over the abdomen, back, and both thighs.

With ESB3, minor facial sweating function was preserved, and nine compensatory hyperhidrosis cases (27.3%) were encountered. However, three of the nine patients (9.0%) still expressed regret, and the clips were removed for the same reasons. In the ESB4 group, the facial sweating function was almost completely preserved, and no compensatory hyperhidrosis was noted.

Table 2. Clinical Results under New Lin-Telaranta Classification

Procedures	ETS_4 $n = 25$	ESB_2 $n = 54$	ESB_3 $n = 33$	ESB_4 $n = 324$	ESB_5 $n = 28$
Male	10	23	18	143	8
Female	15	31	15	181	20
Compensatory hyperhidrosis	0	23 (42.6%)	9 (27.3%)	0	0
Regret Rates	0	9 (16.7%)	3 (9.0%)	2 (0.6%)	0
Total: 464					

Only two patients (0.6%) expressed regret because of discomfort. One of these patients received the reverse procedure.

In group 4 (ESB5), no compensatory hyperhidrosis or regret was encountered. All the patients were happy with the result. The aforementioned cases are summarized in Table 2.

The patients who underwent ESB4 (group 3) experienced only inoffensive sweating over the lower back or popliteal areas in hot weather (it did not happened in cold weather), which should be considered as a normal physiologic response to the environmental temperature.

A total of 13 patients received the reverse procedure in the current series. Ten patients recovered from compensatory hyperhidrosis and resumed their previous sweating condition within 2 months. One patient in the ESB4 group also recovered from the feelings of discomfort. One of the remaining two patients had partial reversal of compensatory hyperhidrosis, and the other had no improvement. The poor response after clip removal likely was attributable to the patients' late decision to receive the reverse procedure.

Discussion

The incidence of hyperhidrosis is high in Asia [4]. In Taiwan, where the climate is warm and humid [10], the problem is even more common. Its reported incidence among young people in Taiwan was found to be approximately 0.3% [7].

Excessive sweating causes considerable trouble in daily life, especially where electronic equipment has become indispensable. Also, the global warming makes the problem more severe. Many office workers are afflicted, even in air-conditioned environments. Furthermore, the psychological and social disturbances are rarely understood by outsiders. Currently, sympathetic surgery provides a permanent cure. However, the T2–T3 sympathectomy procedure, performed by most surgeons for palmar hyperhidrosis, is complicated, with a 30% to 75% rate of compensatory hyperhidrosis [6].

We advocate ESB4 for hand sweating because of its high success rate and effective reduction of the compensatory hyperhidrosis rate. We suggest using the term "reflex sweating" instead of "compensatory hyperhidrosis," which is a misused medical term. Changes in sweating patterns after sympathetic surgery may be attributable to a reflex response in the sweating center of the hypothalamus, and not at all to a compensatory mechanism.

First, different degrees of postoperative sweating have been found after different levels of sympathectomy. For example, severe reflex sweating is expected with the T2 procedure, whereas an unknown amount or no reflex sweating is found with the T4 procedure [2, 17]. Second, sweating problems can be induced after sympathetic surgery for nonsweating sympathetic disorders. The typical example is pure facial blushing. Severe reflex sweating often is induced after the T2 procedure. Third, in the current study of 18 cases with pure plantar hyperhidrosis, no change in sweating patterns was found after lumbar sympathectomy. That is, after the procedure, the soles became dry, but sweating did not change in other areas of the body. Fourth, the amount of increased sweating does not always correspond to the amount reduced after sympathetic procedures. The aforementioned findings support our philosophy that changes in sweating patterns are not compensatory, but are reflex responses activated in the hypothalamus.

Anatomically, the sympathetic nerves originate in the intermediolateral horns of the spinal cord, between segments T1 and L2. Each sympathetic pathway is composed of preganglionic and postganglionic neurons. The nerve fibers to the sweat gland are postganglionic fibers arising from the ganglion on the sympathetic trunks. These fibers reenter the corresponding spinal nerves along its grey ramus communicans. Also, they may go upward and downward in the sympathetic trunks before leaving and distributing to the sweat gland. Therefore, the distributions overlap, and are not necessarily to the same part of the body from the same spinal segments [19]. Moreover, visceral afferent fibers are accompanied by visceral efferent fibers. It has been demonstrated that the autonomic nervous system functions the same as the neuroendocrine system, through positive and negative feedback mechanisms [15]. Impulses initiated in the target organs (e.g., sweat glands) are transmitted as an afferent negative feedback signal to the central nervous system, from where the efferent positive feedback signals return to the target organs. We know that hyperhidrosis is induced centrally by mental stress or anxiety rather than by high temperature [18, 21]. These factors often trigger sweating centers located in the hypothalamus, releasing efferent signals, which are positive in a sympathetic tone to the target cells or organs (e.g., hands and feet). As with the neuroendocrine system, some sympathetic tones return from the target organs and then become afferent negative feedback signals to the hypothalamus (Fig. 2).

In clinical practice, ESB2 causes most severe compensatory hyperhidrosis. Less is caused by ESB3 [20],

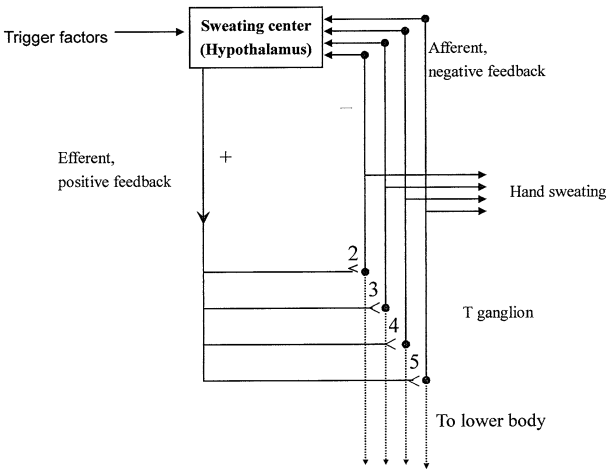

Fig. 2. Schematic diagram showing the mechanism of central sweating.

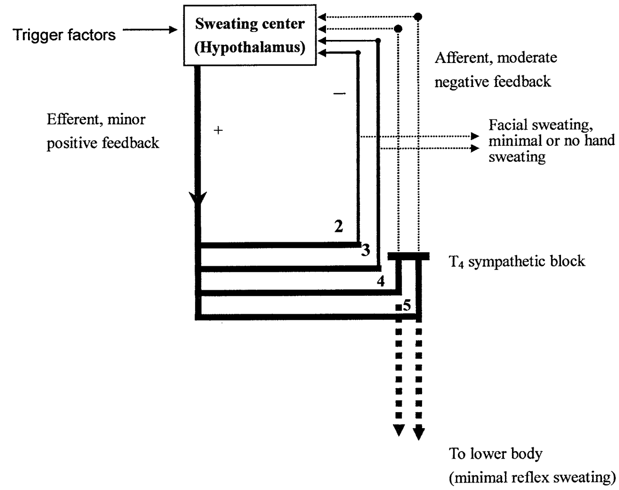

Fig. 4. Schematic diagram showing the proposed mechanism of reflex sweating with T4 sympathetic block.

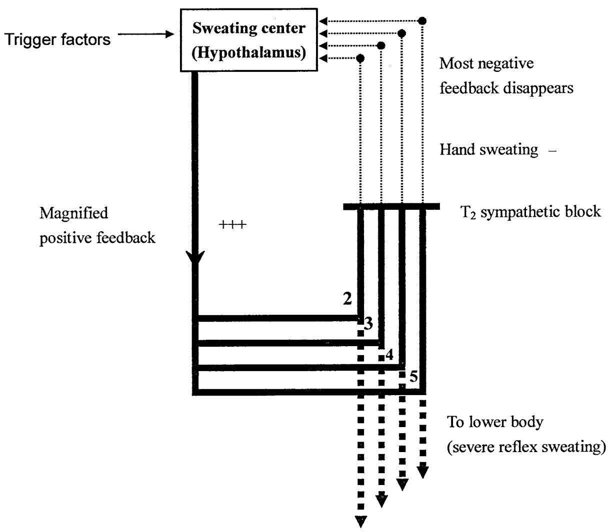

Fig. 3. Schematic diagram showing the proposed mechanism of reflex sweating with T2 sympathetic block.

and least by ESB4 [13]. Under the concept of a feedback mechanism, the T2 procedure stops most of the afferent negative feedback sympathetic signals (Fig. 3). Then a magnified efferent positive feedback signal is released from the sweating center, inducing severe sweating on the body or lower limbs. It never occurs on the upper body or face because the efferent sympathetic tone never reaches the hands or face again (due to blockage of the nerve). The same mechanism can be applied to T3, T4, and so on.

In contrast to the T2 block, whose afferent negative feedback signals are mostly destroyed, the T3 or T4 procedure preserves some negative feedback signals returning to the hypothalamus (Fig. 4, T4 interruption). As a result, the efferent positive feedback signals are weaker than those of the T2 block, which cause less sweating on the lower body. Preservation of different degrees of the facial sweating function after the T3 or T4 procedure supports our finding that some afferent negative sympathetic tones to the brain are present. Reflex sweating is a reflex response when afferent negative inhibitory sympathetic signals to the hypothalamus are depleted, and is not at all a compensatory mechanism. For this reason, the term "reflex sweating" is advocated. Similar to hyperhidrosis, reflex sweating is centrally (mentally) controlled rather than climate related. It occurs even in the cold weather. If postoperative sweating occurs only in a hot climate or during exercise, it should be considered as physiologic sweating although the sweating areas are changed after the sympathectomy.

We emphasize that the preceding statement proposes a mechanism in an attempt to explain the different results after different levels of sympathectomy observed in more than 1,000 cases of hyperhidrosis managed by surgery. The exact mechanism needs to be proved by further studies.

Because reflex sweating is annoying, some individuals regret the operation. The regret rate in our practice was about 3% the first year and up to 4.5% in the following 2 years of follow-up evaluation. No obvious increase in percentage was found afterward. With the use of ETS, the condition cannot be reversed. The only thing that can be done is to "wait for spontaneous subsidence." Several years ago, we developed the clipping method [11]. The main advantage of this method is its potential reversibility. The only drawback is another endoscopic procedure with anesthesia.

During the past few years, we have dedicated much time to finding the correct nerve level of interruption to prevent and control reflex sweating. After summarizing our previous results (before 2002) for different interdiction levels, we set up a new classification for the treatment of sympathetic disorders. The current series had surgery according to this classification. Most patients (85.7%) with regret were in groups 1 and 2. The higher the level of blockade, the higher is the expected regret rate. We therefore strongly recommend the clipping method as the unique choice for patients in groups 1 and 2. We conclude that satisfactory results can be obtained with the following suggestions: detailed preoperative explanation of the side effects and use of the clipping method for high-level procedures (groups 1 and 2).

The most ideal procedure, which remains our goal, is to stop the unwanted sweating without inducing reflex sweating. In the future, we will spend more time researching the single determinant sympathetic ganglion for each sympathetic disorder. In this series, T4 and T5 were the determinant ganglia of palmar hyperhidrosis and axillary sweating, respectively. When only the determinant ganglion is blocked, the result is more definite, and the side effects are reduced to a minimum. The majority of sympathectomy surgeons still believe that T2–T3 sympathectomy is associated with a desirable effect of stopping the hyperhidrosis in the palm, although reflex sweating may become a problem. To make progress, we must organize a prospective and multicenter study to prove that sympathectomy of T2–T3 is for facial sweating, T4 for palmar sweating, and T5 for axillary sweating.

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