

Surgical treatment of compensatory hyperhidrosis

Retrospective observational study

Mi Hyoung Moon, MD, PhD, Kwanyong Hyun, MD*, Jae Kil Park, MD, PhD, Jungsun Lee, RN

Abstract

Compensatory hyperhidrosis is a debilitating postoperative condition occurring in 30% to 90% of patients with primary hyperhidrosis. The most appropriate treatment for compensatory hyperhidrosis remains controversial.

Between January 2018 and December 2019, 44 patients with intractable compensatory hyperhidrosis underwent diffuse sympathicotomy (DS). In the early study periods, DS was performed sparsely (limited DS) to avoid possible adverse effects (right R5/7/9/11, left R5/6/8/10). In the late study periods, levels of surgical interruption were further modified to maximize sympatholytic effects (extended DS; bilateral R5/6/7/8/9/10/11). Patients were followed up for symptom resolution. For objective evidence of improved hyperhidrosis, thermographic images were taken for 7 patients.

Immediate resolution of compensatory hyperhidrosis was achieved in 81% of patients, as determined at the 1 to 2 week postoperative visit. With a median follow-up of 22.7 months, compensatory hyperhidrosis continued to be resolved in 46% (n=20). Logistic regression analysis showed that persistent resolution of compensatory hyperhidrosis was independently predicted by extended DS (odds ratio, 25.67, 95% CI, 1.78–1047.6; $P=.036$). The presence of gender, BMI, isolated compensatory hyperhidrosis, distribution of sweating, prior operation type, reoperation interval, and same-day lumbar sympathectomy failed to gain statistical significance on maintaining persistent resolution of compensatory hyperhidrosis. No patients experienced surgery-related side effects. Thermographic images obtained before/after surgery in 10 patients showed successful denervation and sweat diminishment.

This study shows the safeness and effectiveness of DS for treating compensatory hyperhidrosis, representing a new treatment option. Future research should be directed at confirming a promising result of extended DS with further follow-up.

Abbreviations: BMI = body mass index, DS = diffuse sympathicotomy, ETS = endoscopic thoracic sympathicotomy, HDSS = Hyperhidrosis Disease Severity Scale.

Keywords: compensatory hyperhidrosis, diffuse sympathicotomy, endoscopic thoracic sympathicotomy, infrared thermography

1. Introduction

Thoracic sympathetic surgery is an effective treatment for primary hyperhidrosis refractory to medical management.^[1,2] Since sympathetic surgery began to be conducted for primary hyperhidrosis, patients have frequently been encountered whose

hyperhidrosis is either incompletely controlled or complicated by reflex sweating at other body sites after the initial sympathetic surgery. Surgeons may be reluctant to offer further intervention to these patients because of a lack of experience with reoperative sympathetic surgery and inability to predict the efficacy of such procedures. This investigation reviewed our experience with reoperative sympathicotomy for patients with compensatory hyperhidrosis following initial sympathicotomy.

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2. Methods

2.1. Patients and data collection

From January 2018 to December 2019, endoscopic thoracic sympathicotomy (ETS) was conducted in 247 patients with primary, recurrent and/or compensatory hyperhidrosis. Among these patients, reoperative multilevel diffuse sympathicotomy (DS) was performed in 46 individuals who had developed severe compensatory hyperhidrosis over the chest, back, abdomen, and lower extremities after initial endoscopic thoracic sympathetic surgery. Indications for reoperation were disabling sweating for a long period of time, as defined by the need to change underwear more than twice a day. Demographic information, procedural details, and morbidities were extracted from inpatient and outpatient records. Two patients with loss of follow-up were excluded from our analysis. An informed consent was obtained and all procedure performed in the study involving human participants were in accordance with the ethical standards of The Catholic University of Korea Catholic Medical Center Institu-

tional Review Board (KC19RESI0542) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

The degree of sweating of each patient was assessed before and 1 to 2 weeks after DS. The severity was classified according to the Hyperhidrosis Disease Severity Scale (HDSS).^[3] In an attempt to assess the severity of compensatory hyperhidrosis, patients were asked whether they had to change clothes sometimes during the day because of excessive sweating. And then, patients were followed-up by telephone questionnaire regarding the effects of the surgery and postoperative complications. The resolution of compensatory hyperhidrosis after DS was defined when the HDSS score decreased from level 3 or 4 to level 1 or 2. For better understanding of the distribution of sweating, sweating areas were divided into 3 zones:

1. the upper zone, including the chest and mid-back;
2. the middle zone, including the abdomen, waist, groin, buttocks, and thighs; and
3. the lower zone, including the popliteus, calf, and sole.

An infrared thermography camera (FLIR T420, FLIR System, Inc. Sweden) was used for data visualization in recent 10 patients. The camera measures infrared radiation emitted by body areas and converts the energy detected into a temperature value.^[4] A thermal gradient was visualized on imaging, and areas of interest was interpreted for data extraction, to determine maximum, minimum, and mean body temperatures pre- and post-operatively. Since the pre- and post-operative background temperature differences was inevitable, the distribution of body temperature (the temperature differences in a designated area) was used as a surrogated marker of sympathetic denervation.

Statistical analysis included cross-tabulation and chi-square tests, implemented in the R computing environment (R Development Core Team, Austria, 2008). Univariate and multivariate regression analyses were performed using logistic regression model to determine the effect of variables on the presence of persistent sweating resolution. *P* values <.05 were considered statistically significant.

2.2. Surgical techniques

All reoperative sympathicotomy procedures were conducted under general anesthesia, with selective bronchial intubation using a double lumen endotracheal tube. Patients were in the lateral decubitus position with their arms extended. Starting on the left side, 2 5-mm thoracoscopic ports were placed and CO₂ gas insufflated into the thoracic cavity, with less than 8 mm Hg of pressure, to deflate the lung. Most patients had minimal pleural adhesions around sites of previous ETS. If there were extensive

pleural adhesions, a third 5-mm port was placed, to facilitate retraction of the lung. Sympathicotomy was performed by disconnecting the thoracic ganglia through the application of monopolar electrocoagulation on the sympathetic trunk, at the level of the superior margin of each rib. At the end of the procedure, pleural air was evacuated from the chest. Occasionally, the pleural drain was left in place for 12 to 14 hours, in patients with persistent air leakage from an injury to the visceral pleura. Almost all patients were admitted overnight, to monitor for side effects, and discharged the next morning.

Limited form of diffuse sympathicotomy (limited DS) was applied to the lower thoracic sympathetic chains on alternate levels, including R5, R7, R9, and R11 on the right and R5, R6, R8, and, R10 on the left to minimize unpredictable thoracic splanchnic interruptions. During the study period, we modified our surgical technique after 9 months surveillance of procedure-related side effects. Levels of interruption were expanded to maximize the sympatholytic effect by performing sympathicotomy on R5, R6, R7, R8, R9, R10, and R11 on both sides (extended DS) (Fig. 1). Upper thoracic sympathicotomy (R2, R3, or R4) was also performed when the patients had remaining primary hyperhidrosis on craniofacial or palmar area. Especially in the patients with pronounced plantar hyperhidrosis, cooperation with urology team was conducted by performing endoscopic lumbar L3 sympathectomy bilaterally.

3. Results

During a 24-month period, 44 patients (32 male, 12 female; median age, 33 years) were surgically treated for compensatory hyperhidrosis at our institution (Table 1). The severity of compensatory hyperhidrosis was severe (HDSS 3 or 4) in all patients, and frequently interfered with activities of daily life. As for the distribution of sweating area, the upper zone (chest and mid-back, n=42 (96%)) were the most common sites of compensatory hyperhidrosis. Seventeen patients (39%) had isolated compensatory hyperhidrosis and 27 patients (61%) had remaining primary hyperhidrosis on craniofacial/palmar/plantar area as well.

Previous ETS for primary hyperhidrosis was R2 sympathicotomy in 12 patients, R2+R3 sympathicotomy in 1, and R3 sympathicotomy in 23 patients. Among these patients, 2 had undergone additional sympathetic nerve reconstruction for compensatory hyperhidrosis, which had failed to achieve resolution of sweating. The median interval between the previous ETS and reoperative DS was 9.4 (range: 0.4–24.1) years. The outcomes of reoperative DS are presented in Table 1. Basically, DS was performed in all patients to treat compensatory hyperhidrosis, using limited DS in 29 and extended DS in

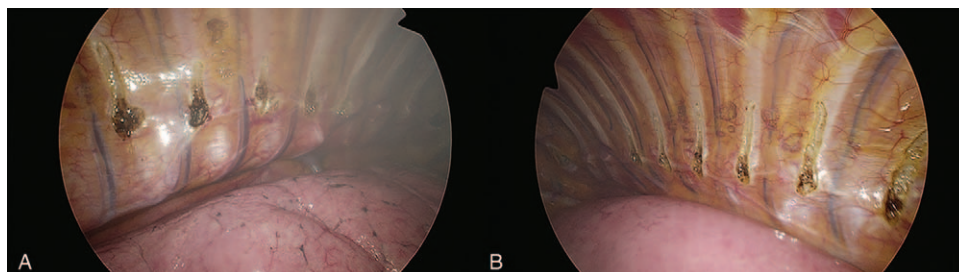


Figure 1. Thoracoscopic view of extended diffuse sympathicotomy (A) on the right side and (B) on the left side.

Table 1
Patient demographics and perioperative detail (n=44).

Variable	Result
Age, median years (range)	33 (18–64)
Sex, M/F	32/12
BMI, median kg/m ² (range)	24.8 (18–30)
Distribution of compensatory hyperhidrosis, n (%)	
Upper zone*	42 (96%)
Middle zone†	26 (59%)
Lower zone‡	22 (50%)
Gustatory	13 (30%)
Isolated compensatory hyperhidrosis, n (%)	17 (39%)
Combined compensatory hyperhidrosis, n (%)	27 (61%)
with palmar hyperhidrosis	11
with plantar hyperhidrosis	8
with axillary hyperhidrosis	5
with craniofacial hyperhidrosis	3
with facial blushing	4
Previous sympathetic surgery, n	
R2 and/or below (R2/R2+R3)	13 (12/1)
R3 and/or below (R3/R3+R4/R3+R5)	25 (23/1/1)
R4 and/or below (R4/R4+R5)	6 (4/2)
Mode of DS, n (%)	
limited DS (right R5/7/9/11, left R5/6/8/10)	29 (66%)
extended DS (both side R5–11)	15 (34%)
Combined Lumbar L3 Sympathectomy§, n (%)	7 (16%)
Operating time¶, median min (range)	50 (30–230)
Placement of pleural drainage, n (%)	7 (16%)
Hospital stay, median days (range)	1 (0–5)

* includes chest and midback.

† includes abdomen, waist, groin, buttock, and thigh.

‡ includes popliteus, calf, and sole.

§ performed as laparoscopic L3 sympathectomy.

¶ measured as bilateral procedure time.

DS = diffuse sympathectomy

15 patients. And notably, the same day co-operation (endoscopic L3 lumbar sympathectomy) with urology team was conducted in 7 patients with pronounced plantar hyperhidrosis. The average operation time was 50 minutes, excluding anesthesia induction and reversal time. No conversion to open technique was necessary, and there were no intraoperative complications including bleeding and bradycardia. At the end of the procedure, 7 patients were placed with Jackson-Pratt drainage or a chest tube, to prevent postoperative pneumothorax. The majority of patients were discharged on the first postoperative day (range, 0–5 days).

Ninety three percent (n=41) of patients returned for their outpatient assessment at postoperative week 1 to 2. At this visit, the rates of resolution of compensatory hyperhidrosis were 81% (33/41), defined as a reduction to class 1 or 2 symptoms on HDSS Scale (Table 2). Adverse events, such as sinus bradycardia, muscle weakness, diarrhea, and heartburn were not observed at this follow-up.

A total of 44 patients answered the questionnaire administered by telephone survey. Overall outcomes after surgery are summarized in Table 2. The median interval between reoperative DS and questionnaire was 22.7 (range, 7.9–28.5) months. Compensatory hyperhidrosis had continued to be resolved to class 1 or 2 symptoms on HDSS scale in 46% of patients (20/44); however, severe compensatory hyperhidrosis (HDSS 3 or 4) recurred in 54% (24/44). Compensatory hyperhidrosis was prominent on upper zone, resulting in upper zone only in 10

Table 2
Resolution of compensatory hyperhidrosis after DS.

Variable	Result
Immediate* resolution to HDSS‡ 1–2, n (%)	33/41 (81%)
Persistent† resolution to HDSS 1–2, n (%)	20/44 (46%)

* measured at postoperative week 1–2.

† median follow-up of 22.7 months

‡ HDSS 1 = my sweating is never noticeable and never interferes with my daily activities, HDSS 2 = my sweating is tolerable but sometimes interferes with my daily activities, HDSS 3 = my sweating is barely tolerable and frequently interferes with my daily activities, HDSS 4 = my sweating is intolerable and always interferes with my daily activities.

DS = diffuse sympathectomy, HDSS = Hyperhidrosis Disease Severity Scale.

patients (23%), upper and middle zone together in 12 (27%), and upper, middle, and lower zone together in 13 (30%) (Table 3). The rate of persistent resolution was lowest in patients with upper and lower zone compensatory hyperhidrosis (29%), and followed by upper, middle, and lower zone compensatory hyperhidrosis (33%). Table 4 showed individual patient outcomes by group (DS only vs DS with lumbar L3 sympathectomy, limited vs extended DS). Univariate logistic regression analysis for persistent resolution of compensatory hyperhidrosis showed a positive correlation with extended DS (P=.047). Age, gender, BMI, the presence of remaining primary hyperhidrosis, type of initial operation, reoperation interval, and same-day lumbar L3 sympathectomy were not associated with persistent resolution of compensatory hyperhidrosis. Multivariate logistic regression analysis again confirmed that extended DS independently predicted persistent resolution of compensatory hyperhidrosis (Table 5). Interestingly, zone of compensatory hyperhidrosis also gained significance on predicting persistent resolution in multivariate logistic regression analysis, showing that all zone involvement (upper, middle, and lower zone together) had lower odds (0.01) for persistent resolution compared to upper zone only involvement.

Objective proof of sympathetic denervation was obtained in 10 patients. Pre- and post-operative digital infrared thermographic imaging revealed thermal changes in chest and back areas (boxed area in Fig. 2). The body temperature was elevated and evenly distributed postoperatively showing smaller temperature differences in a designated area (Fig. 3). When we focused the area of interest to an area affected most severely with compensatory hyperhidrosis (dotted white circle in Fig. 2), the temperature differences were more prominent with an average temperature

Table 3
Distribution of compensatory hyperhidrosis.

Zone* of compensatory hyperhidrosis n=44	Postoperative persistent resolution n (%)	
upper zone only	10	7 (70%)
middle zone only	0	0
lower zone only	1	1 (100%)
upper and middle zone	12	5 (42%)
upper and lower zone	7	2 (29%)
middle and lower zone	1	1 (100%)
upper, middle and lower zone	13	4 (33%)

* Upper zone includes chest and midback. Middle zone includes abdomen, waist, groin, buttock, and thigh. Lower zone includes popliteus, calf, and sole.

Table 4
Persistent resolution of compensatory hyperhidrosis versus extent of operation.

	n	Compensatory hyperhidrosis		P value
		Persistent resolution to HDSS 1–2	No change of sweating (HDSS 3–4)	
Reoperative procedure				
DS only	37	17 (46%)	20 (54%)	1.00
DS with lumbar L3 sympathectomy	7	3 (43%)	4 (57%)	
Mode of DS				
limited DS*	29	10 (35%)	19 (65%)	.087
extended DS†	15	10 (67%)	5 (33%)	

* interruption level is right R5/7/9/11 and left R5/6/8/10.

† interruption level is both side R5–11

DS = diffuse sympathectomy, HDSS = Hyperhidrosis Disease Severity Scale.

increase being 1.2°C (chest), 2.2°C (back) in patient 1 and 3.0°C (chest), 2.3°C (back) in patient 2, respectively.

4. Discussion

The present study involved a cohort of patients with intractable compensatory hyperhidrosis treated using reoperative surgery. The preliminary results demonstrated that multilevel diffuse thoracic sympathectomy could manage the symptoms of compensatory hyperhidrosis per se. Even though the rate of persistent resolution of compensatory hyperhidrosis was 46%, the rarity of surgical intervention for intractable compensatory hyperhidrosis makes our findings valuable.

Compensatory hyperhidrosis is by far the most common and disagreeable complication of sympathetic surgery, producing subjective and objectively measurable increased sweating in body segments, usually just below the areas made dry by sympathectomy. The reported incidence varies considerably, with most

authors describing compensatory hyperhidrosis in 30% to 70% of their patients^[5–7]; however, Licht et al^[8] reported that 90% of patients included in their study had compensatory hyperhidrosis, and in 35% it was so severe that they often had to change clothes during the day. While more than a century has passed since the first report of compensatory hyperhidrosis,^[9] debate continues regarding the most effective approach to treat this condition. Medical and non-invasive therapy has gained in popularity for patients with mild compensatory hyperhidrosis (HDSS 1 or 2); however, adoption of such therapy as a mainstay treatment for patients with severe intractable compensatory hyperhidrosis (HDSS 3 or 4) has yet to be widely accepted.

The adoption of surgical intervention for treating compensatory hyperhidrosis has progressed slowly, mainly due to its uncertain outcomes and unpredictable side effects.^[10,11] To demonstrate the theoretical advantages of lower thoracic sympathectomy for the prevention of compensatory hyperhidrosis, Do et al^[11] analyzed the results of R2 sympathectomy

Table 5
Factors affecting persistent* resolution of compensatory hyperhidrosis.

Variable	Univariate logistic regression			Multiple logistic regression		
	Estimate	P value	Odds ratio	Estimate	P value	Odds ratio
Age, years	−0.002	.95	1.00	−0.0001	1.00	1.00
Sex	−0.69	.33	0.50	−0.53	.75	0.59
BMI	0.006	.95	1.01	0.02	.92	1.02
Isolated compensatory hyperhidrosis (vs combined compensatory hyperhidrosis)	0.49	.43	1.64	−0.32	.77	0.72
Initial operation (ref. = R2 and/or below)						
R3 and/or below	−0.73	.29	0.48	−1.65	.20	0.19
R4 and/or below	0.54	.60	1.71	3.11	.07	22.4
Zone† of compensatory hyperhidrosis (ref. = upper zone only)						
upper + middle zone	−1.18	.19	0.31	−2.94	.08	0.05
upper + lower zone	−1.76	.10	0.17	−0.99	.53	0.37
middle + lower zone	15.72	.99	> 100	15.36	.99	> 100
lower zone only	15.72	.99	> 100	18.53	.99	> 100
upper+middle+lower zone	−1.66	.07	0.19	−4.22	.02	0.01
Interval to reoperative DS, years	−0.04	.47	0.96	−0.01	.93	0.99
Extended DS‡ (vs limited DS§)	1.34	.047	3.80	3.24	.04	25.67
Lumbar L3 sympathectomy	−0.13	.88	0.88	0.88	.53	2.41

* Median follow-up of 22.7 months.

† Upper zone includes chest and midback. Middle zone includes abdomen, waist, groin, buttock, and thigh. Lower zone includes popliteus, calf, and sole.

‡ interruption level is right R5/7/9/11 and left R5/6/8/10.

§ interruption level is both side R5–11.

BMI = body mass index, DS = diffuse sympathectomy, REF = reference.

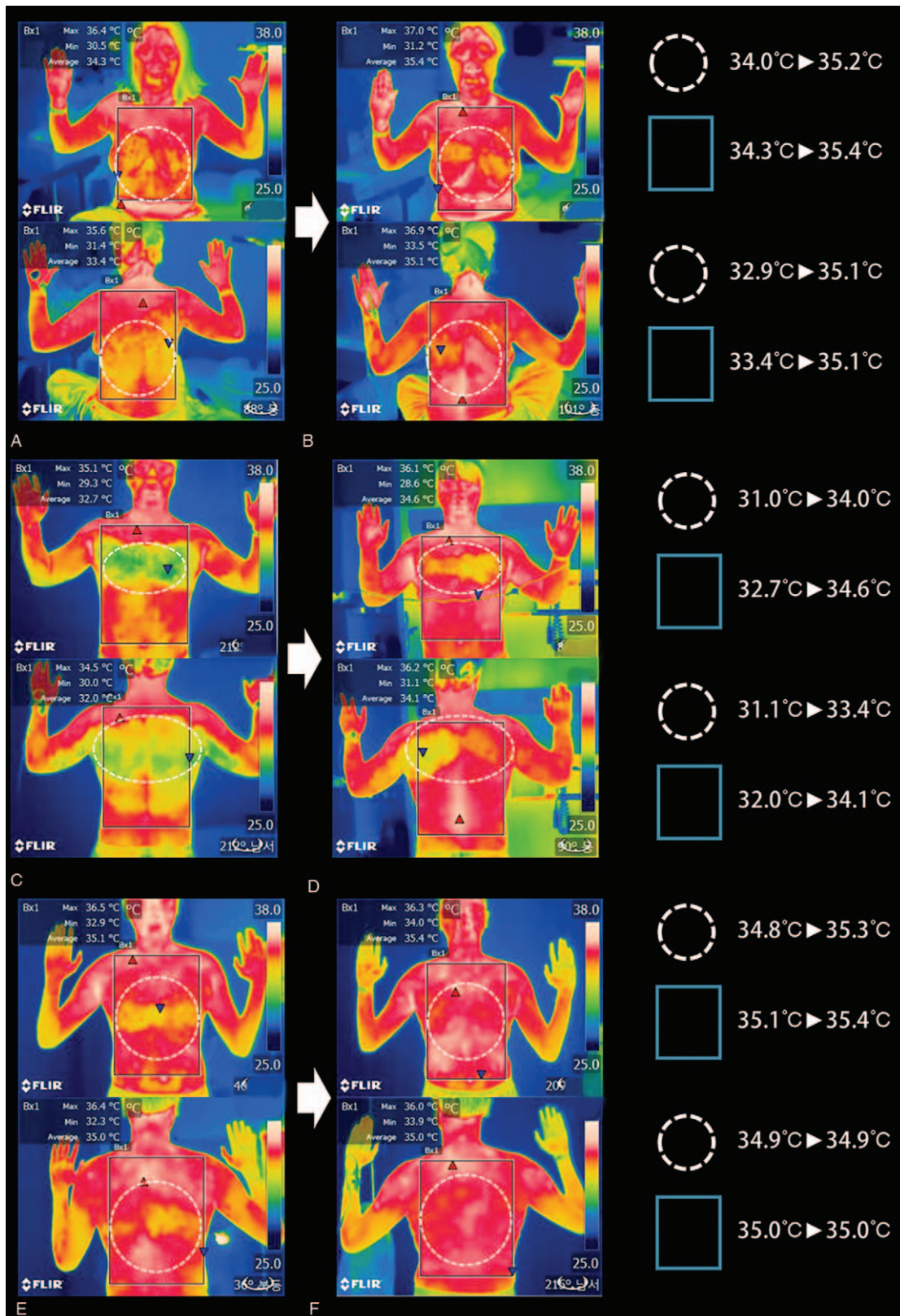


Figure 2. Digital infrared thermographic images obtained before (A, C, and E) and after (B, D, and F) surgery (diffuse sympathicotomy) in patient 1, 2, 3, respectively. Pre- and post-operative imaging show the thermal change in the chest and back. (Dotted white line shows focal area affected by compensatory hyperhidrosis. The boxed area is set for temperature change in the anterior chest and back area).

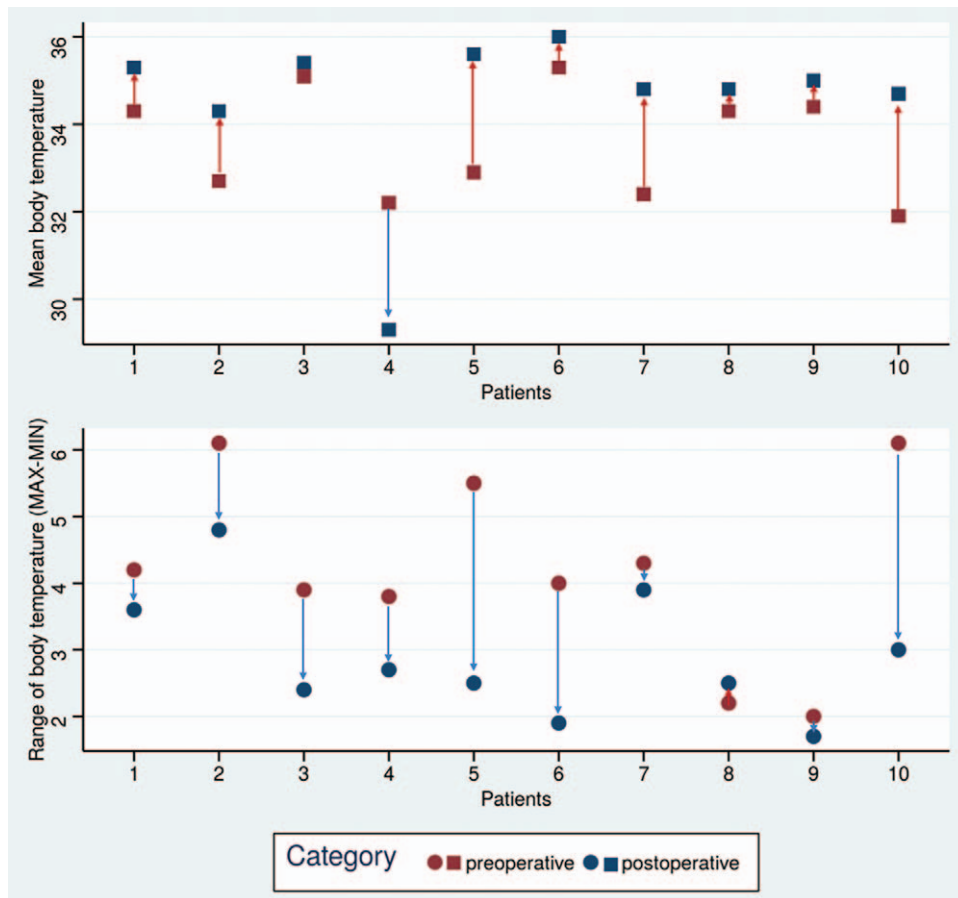


Figure 3. Body temperature of anterior chest before and after reoperative diffuse sympathicotomy. A. The plot shows preoperative (red square) and postoperative (blue square) mean body temperatures of each patient, showing a postoperative temperature increase in the affected skin area. B. The plot shows preoperative (red dot) and postoperative (blue dot) body temperature ranges in each patient, showing an even temperature distribution postoperatively in the affected skin area.

with 5th, 6th, and 7th sympathetic ablation for craniofacial hyperhidrosis. They did not find a significant preventive effect against compensatory hyperhidrosis, although the procedure could be performed safely and without any side effects. Interestingly, life-bothering compensatory hyperhidrosis was 22.2% in the study and limited to the mid-zone including abdomen, waist, groin, buttock, and thigh. Stefaniak et al^[10] also demonstrated procedural safety without any complications in performing R6–9 sympathetomy for compensatory hyperhidrosis. Though not yet presented as a data in this article, during the same study period as the present study, diffuse sympathicotomy was also safely performed in patients with primary hyperhidrosis to minimize a development of compensatory hyperhidrosis in our hyperhidrosis center (limited DS, 151 patients; extended DS, 92 patients).

Interestingly, sites affected by compensatory hyperhidrosis are generally thermoregulatory, nonglabrous skin regions of the trunk/back, buttocks, groin, and thighs that sweat normally before thoracic sympathicotomy. A plausible explanation is that normal thermoregulatory effectors become up-regulated as a mechanism of normal heat dissipation.^[12] Hence, we tried to abolish these reflex sweating responses by controlling the segmental origins of the sympathetic nervous system; however, the sympathetic dermatomes overlap each other and are difficult

to systematize. In general, the sympathetic supply involves a two-neuron pathway (preganglionic and postganglionic) from the spinal cord to the peripheral target tissues.^[13,14] The preganglionic fibers synapse with postganglionic cells in the paravertebral ganglion that lies at the same level, or pass through their segmental ganglion and run up or down to more distant paravertebral ganglia, where they terminate and synapse with postganglionic fibers.^[15] Thus, sympathetic supply to the head and neck has its origin from the nerve roots of T1–T5; the upper limb from roots T3–T6; the thorax from roots T3–T6; the abdomen from roots T7–T11 and the lower limbs from roots T10–L2 or L3. Based on this information, we started to use “limited DS” procedure for denervation in compensatory hyperhidrosis, which involved multiple bilateral sympathicotomy at the right R5, R7, R9, and R11 and left R5, R6, R8, and R10 levels. Notably, not all the levels in the right and left sides were interrupted surgically, in an attempt to prevent side effects. With time, and establishment of the safety of limited DS, we modified our mode of surgical intervention to interrupt all levels of sympathetic segments, in the form of “extended DS”, which theoretically allows complete sympathetic denervation of the trunk and abdomen.

Postoperative objective confirmation of successful outcome depends on monitoring responses to surgical denervation and

release of sympathetic tone, including assessment of skin temperature changes using digital infrared thermographic imaging. Previous studies used infrared thermography to confirm that skin blood circulation could be improved.^[16,17] Yamamoto et al^[18] reported successful denervation and sweat diminishment in patients with compensatory hyperhidrosis by the use of thermography. The changes in patterns of thermal histogram also correlated with sweat diminishment in our study. As shown in Figure 2, thermal imaging focused on areas affected with compensatory hyperhidrosis (dotted white circle) were green and yellow in preoperative imaging and became yellow and red on postoperative imaging. Importantly, our findings of postoperative body temperature increases and even temperature distribution in the anterior chest following diffuse sympathicotomy (Fig. 3) demonstrated successful denervation and sweat diminishment.

It must be emphasized that the present study is an initial presentation of a new concept for the treatment of compensatory hyperhidrosis and therefore has several shortcomings. The sample size was relatively small, and there was no randomization. In addition, for consistency, outcomes should be assessed by obtaining objective proof of sympathetic denervation and diminished sweating. For further and more reliable exploration of the subject, a study in a larger population is required, with longer follow-up, to determine the long-term effects of this new surgical modality.

Some questions remain unanswered; for example, how compensatory hyperhidrosis changes over time and whether it increases on concurrent lumbar sympathectomy. Using a unique series of reoperative patients we were able to demonstrate that immediate and early control of compensatory hyperhidrosis by diffuse sympathicotomy was successful in 81%. Nevertheless, in a long term follow-up, the rate of compensatory hyperhidrosis control had decreased to 46%, with severe compensatory hyperhidrosis recurring in 54% of patients. These findings could imply a failure of our surgical procedure; however, the results should be interpreted cautiously. As 66% (29/44) of patients underwent limited DS which interrupted sympathetic chains on alternate levels, some segment levels on sympathetic chains remained intact in these patients and the effect of sympathetic block over chest and abdomen area might be limited. Hence, the high incidence of recurrence of compensatory hyperhidrosis over time might be partly attributable to an incomplete sympathetic denervation technique used. On the contrary, extended DS involved all sympathetic segment levels bilaterally and represented a more comprehensive sympatholytic technique. The promising result of extended DS for controlling compensatory hyperhidrosis in the present study suggests that more cases of patients undergoing extended DS needs to be followed up and evaluated for the recurrence of compensatory hyperhidrosis.

5. Conclusion

In conclusion, there is currently no standard protocol for treatment of compensatory hyperhidrosis, because there is no consensus as to the best therapeutic modality. The results of this study are considered acceptable at present, given the lack of literature on this topic. Our data are promising, as they indicate that a reoperative diffuse sympathicotomy is a feasible treatment option with few adverse effects and extended form of diffuse sympathicotomy is better treatment option to control compensatory hyperhidrosis. Much more research is required to fully

understand and effectively treat this common and debilitating condition.

Author contributions

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