Long-term Assessment of Percutaneous Stereotactic Thermocoagulation of Upper Thoracic Ganglionectomy and Sympathectomy for Palmar and Craniofacial Hyperhidrosis in 1742 Cases

King-Shun Chuang, M.D.

Division of Neurosurgery, Foo-Yin Technological University Hospital, Ping-Tung Hsien, and Laboratory of Neuroscience, National Defense Medical Center, Taipei, Taiwan, Republic of China

Jiang-Chuan Liu, D.D.S., Ph.D.

Department of Biology and Anatomy, National Defense Medical Center, Taipei, Taiwan, Republic of China

Reprint requests:
King-Shun Chuang, M.D., Division of Neurosurgery, Foo-Yin Technological University Hospital, 5, Chung-San Road, Tung-Kang, Ping-Tung Hsien, Taiwan, Republic of China (928).
Email: Kingsman@mail.educities.edu.tw

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OBJECTIVE: We sought to determine the long-term outcome of percutaneous stereotactic thermocoagulation for upper thoracic ganglionectomy and sympathectomy in patients with palmar and craniofacial hyperhidrosis with the use of a three-dimensional system of coordinates for the location of the T2 and T3 ganglia on the basis of the findings in a cadaveric study.

METHODS: From November 1986 to May 1998, upper thoracic ganglionectomy and sympathectomy with the use of percutaneous stereotactic thermocoagulation were performed in 1688 patients with palmar hyperhidrosis and 54 patients with craniofacial hyperhidrosis as outpatient surgical procedures based on a three-dimensional coordinate system for determining the location of the thermocoagulation point, which was developed by the authors in a cadaveric study. The technique requires only local anesthesia.

RESULTS: After initial thermocoagulation, sweating stopped in 3465 (99.5%) of 3484 sides. Hyperhidrosis recurred within 2 to 59 months of treatment in 268 procedures. All patients in whom hyperhidrosis recurred were retreated successfully, resulting in a final success rate of 99.9%. Complications of treatment included pneumothorax in seven procedures (0.2%) and partial Horner's syndrome in five procedures (0.15%). Decreased plantar sweating was noted during follow-up in 92% of patients.

CONCLUSION: The results of this study indicate that upper thoracic ganglionectomy and sympathectomy performed with the use of percutaneous thermocoagulation are a very effective treatment for palmar and craniofacial hyperhidrosis that provides excellent immediate and long-term results as well as a low complication rate. The method is also effective as a retreatment for recurrences. Our data also suggest that performing ganglionectomy and sympathectomy in both T2 and T3 is unnecessary, because the procedure had equal long-term effectiveness when performed in T2 alone.

KEY WORDS: Craniofacial hyperhidrosis, Palmar hyperhidrosis, Percutaneous thermocoagulation, Thoracic ganglionectomy, Thoracic sympathectomy

P almar hyperhidrosis and craniofacial hyperhidrosis are common problems in young people in Taiwan. Shih and Wang (44) reported a 3.8% incidence of palmar hyperhidrosis in Taiwan. Although the incidence of craniofacial hyperhidrosis is much lower than that of palmar hyperhidrosis, its prevalence in Taiwan has not been reported. In November 1986, we began using a new stereotactic technique for percutaneous thermocoagulation in upper thoracic ganglionectomy and sympathectomy for patients with palmar hyperhidrosis (14). During the 11-year, 7-month period from November 1986 to May 1998, we used this method to treat 1688 patients with palmar hyperhidrosis and 54 patients with craniofacial hyperhidrosis. This report describes the success rate and side effects immediately after treatment in these 1742

patients and the success rate of retreatment in patients who experienced relapse during long-term follow-up ranging from 1 to 8 years (mean follow-up, 3 yr, 3 mo). As we gained experience with the procedure, the technique was modified from our original procedure by broadening the diameter of the thermocoagulation probe from 0.9 to 1.6 mm and by lengthening the probe tip from 10 to 16 mm, with the intention of decreasing the time required to perform thermocoagulation. In addition, the procedure was modified after November 1988 so that we performed only T2 ganglionectomy and sympathectomy instead of T2–T3 ganglionectomy and sympathectomy as in the original procedure. These modifications resulted in a shortening of the thermocoagulation time from an average of 150 minutes in the original procedure to 15 minutes in the final version of the modified procedure. The procedure immediately stopped palmar and craniofacial hyperhidrosis, with excellent outcomes observed during long-term follow-up.

PATIENTS AND METHODS

From November 1986 to May 1998 in the Tri-Service General Hospital and the Chuang King-Shun Neurosurgical Clinic, 1688 patients with palmar hyperhidrosis and 54 patients with craniofacial hyperhidrosis were treated with stereotactic percutaneous thermocoagulation of the upper thoracic sympathetic ganglia. Their demographic characteristics are summarized in *Table 1*. The indications for treatment were job-related inconvenience (e.g., writing, painting, fine manual work), inconvenience in practical daily tasks (e.g., loose grip of objects, transfer of sweat from the hand to objects), psychological disturbance associated with the condition (e.g., sense of inferiority or embarrassment), or ineffective results of prior nonsurgical treatment.

The procedure was performed as described in our original technical report (14), with minor modifications based on cumulative experience obtained during the course of the series. A near lateral x-ray was collected for measurement of the median sagittal depth of the ganglion from the skin above the spinous process for use in determining stereotactic parameters for the procedure on the basis of our previously established coordinate system. Because we found that interference from the bones of the shoulder with the T2–T3 spinal area occurs on a near lateral x-ray obtained with the patient standing in the

TABLE 1. Physical characteristics of the 1742 patients in the three treatment groups

Group	No. of patients (male)	Age range (yr)	Mean age (yr)
Group 1	38 (27)	15–38	22
Group 2	198 (131)	13–58	25
Group 3	1506 (931)	5–71	24

anatomic position, the patient was instructed to place the right hand behind the head and to rotate the right shoulder medially, without rotating the trunk, and also to place the left hand behind the back and rotate the left shoulder laterally without rotating the trunk. Imaging the patient in this position avoided the interference of the bones of the left and right shoulder with the T2–T3 area on the x-ray. The radiologist monitored the lateral positioning of the patient so that the spine and rib cage remained unaffected by the changed position of the shoulders. A 10-cm small stainless steel rod was placed along the skin above the spinous process from C7 to T5, and the radiographic depth of thermocoagulation was measured from the x-ray and used in our previously established coordinate system to determine the position of the percutaneous point and a depth parameter for use with the stereotactic system. The angle of entry of the probe was preestablished for all patients on the basis of our previously reported system, with 11.2 degrees for T2 and 10.5 degrees for T3. The procedures were performed with the patient under local anesthesia with 2% xylocaine solution and a mild systemic analgesic. The thumb skin temperature increased progressively when the area surrounding the ganglion was successfully infiltrated by the xylocaine solution. After 10 minutes, a No. 16 lumbar puncture needle was inserted at the percutaneous point to the target (i.e., the lateral margin of the middle portion of the T2 ganglion) with the help of a stereotactic frame that we designed and with the use of the predetermined angle and calculated depth parameter (14). The position of the thermocoagulation point was checked by fluoroscopy.

Group 1 patients were treated at both T2 and T3 with the use of a thermocoagulation probe tip measuring 0.9 mm in diameter and 10 mm in length. Twenty lesions were applied to the bilateral T2 and T3 sympathetic ganglia (six lesions for each T2 ganglion and four lesions for each T3 ganglion) with the use of the method described in our previous report (14). The radiographic depth of the T2 or T3 ganglion in the medial sagittal plane was measured on the basis of the near lateral x-ray from the midpoint between T2 and T3 or T3 and T4 rib heads to the 10-cm stainless rod placed on the spinous process. Stereotactic parameters used in the procedure were determined on the basis of this measurement.

In Group 2, a single thermocoagulation was performed with the use of a probe tip measuring 1.6 mm in diameter and 16 mm in length. The depth of the T2 or T3 sympathetic ganglion was measured from the ventral margin of the T2 or T3 rib head to a 10-cm stainless rod.

In Group 3, a single thermocoagulation was performed with the use of a probe tip measuring 1.6 mm in diameter and 16 mm in length. Only the T2 level was treated, however. As in Group 2, the distance from the ventral part of the second rib head to the skin was measured from the x-ray to determine the depth of the probe for thermocoagulation (*Fig. 1*). Adding 1.0 cm to the true depth modified the actual application depth. A No. 16 liver puncture needle was used to puncture the skin and subcutaneous tissue. Each ganglion was thermocoagulated at 85 to 90°C for 5 minutes with the use of a radiofre-
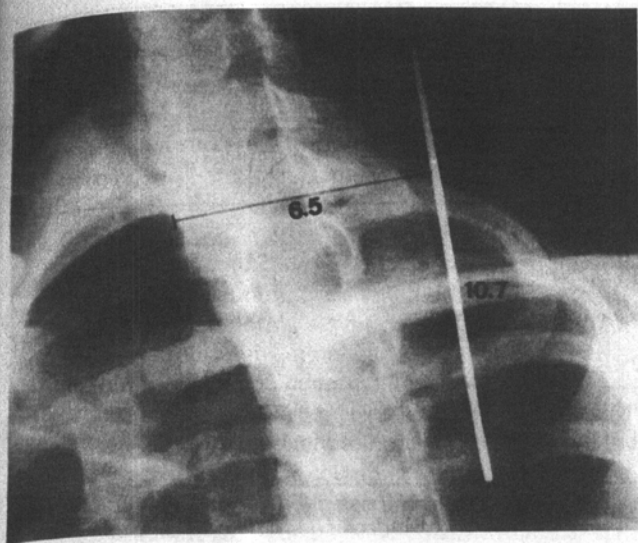
FIGURE 1. *Radiographic image showing a near lateral view from C7 to T5 along with a 10-cm small stainless steel rod. One line between the ventral aspect of the second rib head was drawn toward the rod forming a right angle with the small rod. The radiographic depth of the ganglion was calculated from the rib head to the skin of the patient at the location of the bar measuring from the x-ray. This depth was used in the calculation of parameters used in performing the stereotactic procedure.*

quency lesion generator (Radionics Model RFG-5; Radionics, Inc., Burlington, MA). A single lesion (*Fig.* 2) was made on each of the bilateral T2 ganglia in Group 3 (one lesion for each T2 ganglion and one lesion for each T3 ganglion in Group 2). The cessation of palmar or craniofacial sweating was indicated if the thumb skin temperature remained persistently higher than 35°C for 15 minutes. Otherwise, if the thumb skin temperature remained persistently lower than 35°C, additional lesioning was made 5 mm laterally and 3 mm medially from the initial lesioning site. Patients were followed for recurrence for 1 to 8 years, and retreatment was administered for recurrences.

RESULTS

Group 1 included 38 patients (76 hands) with hyperhidrosis. After initial thermocoagulation, 71 (93.4%) of these hands stopped sweating immediately (*Table* 2). Three hands in Group 1 had false-positive results on sweating and did not show improvement on the day after treatment. Temperature in both hands in another patient in Group 1 did not increase above 35°C, and dorsal sympathectomy was immediately performed after postoperative consultation. At 44 to 54 months of follow-up (three patients were lost to follow-up), 62 (91.2%) of 68 hands in Group 1 had not relapsed, and 6 hands had relapsed but were cured after retreatment. The final success rate was 97.1% (68 of 70 hands). Pneumothorax occurred in one patient and was resolved within 30 minutes after completion of the procedure. The average operative time was 150 minutes.

Group 2 included 192 patients with palmar hyperhidrosis and 6 patients with craniofacial hyperhidrosis (*Table* 2). After initial thermocoagulation, 388 sides (98%) stopped sweating immediately, 7 sides were false-positive for the cessation of sweating, and 1 side could not be thermocoagulated because the intercostal space was too narrow to allow the passage of the thermocoagulation probe. At follow-up ranging from 29 to 45 months (seven patients were lost to follow-up), 349 (91.4%) of 382 hands had not relapsed, 23 hands had relapsed once, and 2 hands had relapsed a second time. The 25 hands that had relapsed stopped sweating after rethermocoagulation. The final success rate was 99.7% (381 of 382 hands). One patient developed pneumothorax, which was resolved within 30 minutes postoperatively. The average operative time was 39 minutes.

FIGURE 2. *Radiographic image showing an anteroposterior view of the location of the thermocoagulation probe tip in the right T2 ganglion.*

Group 3 included 1458 patients with palmar hyperhidrosis and 48 patients with craniofacial hyperhidrosis (*Table* 2). After initial thermocoagulation, 3006 sides (99.8%) stopped sweating, and 6 sides were false-positive for the cessation of sweating. After follow-up ranging from 1 to 8 years, 2735 (92%) of 2972 sides had not relapsed, 228 sides had relapsed once, 8 sides had relapsed twice, and 1 side had relapsed three times. Twenty patients were lost to follow-up, 1 patient refused retreatment, and the remaining 237 sides did not relapse after rethermocoagulation. The final success rate was 99.9% (2971 of 2972 sides). There were five sides with pneumothorax and five sides with partial Horner's syndrome. We collected data regarding the accuracy of localization of the thermocoagulation probe tip for 100 sides in 50 patients. There were 95 sides (95%) with complete thermocoagulation at the first localization, four sides (4%) with complete thermocoagulation that needed a second treatment, and one (1%) side that needed three retreatments. The average time operative time was 15 minutes.

As shown in *Table* 2, among the 1742 patients (3484 sides) with palmar and craniofacial hyperhidrosis, 3465 sides (99.5%) stopped sweating after the first thermocoagulation. At follow-up ranging from 1 to 8 years, 3156 (92.2%) of 3424 sides had not relapsed and 30 patients were lost to follow-up. During the same follow-up period, however, 257 sides had relapsed once, 10 sides had relapsed twice, and only 1 side had relapsed three times. The time of relapse ranged from 2 to 59 months. None of the 268 sides had relapsed after one to three repeated thermocoagulations. The final success rate was 99.9% (3420 of 3424 sides). The complications were pneumothorax in seven sides (0.2%) and partial Horner's syndrome in five sides (0.15%). We recorded no deaths, coma, hemothorax, wound infection, or muscle atrophy. The average operative time, in-

TABLE 2. Effects of stereotactic percutaneous thermocoagulation of upper thoracic ganglia for palmar or craniofacial hyperhidrosis in 1742 consecutive patients in three groups

Group	No. of sides (no. of patients)	No. of sides cured (%)			Complications		Average operative time (min)
		First thermocoagulation	Follow-up (range, 1–8 yr)	Repeat coagulation	Pneumothorax	Partial Horner's syndrome	
Group 1[a]	76 (38)	71 (93.4%)	62 (91.2%)	68 (97.1%)	1	0	150
Group 2[a]	396 (198)	388 (98%)	349 (91.4%)	381 (99.7%)	1	0	39
Group 3[b]	3012 (1506)	3006 (99.8%)	2735 (92%)	2971 (99.9%)	5	5	15
Total	3484 (1742)	3465 (99.5%)	3156 (92.2%)	3420 (99.9%)	7	5	

[a] Thermocoagulation of T2 and T3 ganglia and sympathetic trunk. Diameter of thermocoagulation probe tip, 0.9 mm in Group 1 and 1.6 mm in Group 2.
[b] Thermocoagulation of T2 ganglion and trunk only. Diameter of probe tip, 1.6 mm.

cluding the entire process of setting up the probe and localization, heat-up and thermocoagulation, and removal of the thermocoagulation probe required from 55 minutes to 7 hours, 48 minutes in Group 1 patients, with an average operative time of 150 minutes (Table 2). The operative time for Group 2 ranged from 23 minutes to 1 hour, 55 minutes, with an average of 39 minutes; the operative time in Group 3 ranged from 12 minutes to 1 hour, 50 minutes, with an average of 15 minutes.

Before treatment, simultaneous palmar and plantar sweating was present in 82% of patients, plantar sweating occurred after palmar sweating in 10%, palmar and plantar sweating occurred at different times in 7%, and palmar sweating occurred after plantar sweating in 1%. After treatment, 24% of patients had dramatic improvement in plantar hyperhidrosis, 68% patients had decreased plantar hyperhidrosis, and only 8% of patients had no improvement or a slight increase in plantar hyperhidrosis.

The reasons for seeking treatment included job-related inconvenience (e.g., writing, painting, fine manual work) in 514 cases (29.5%), inconvenience in practical daily tasks (e.g., loose grip of objects) in 263 cases (15.1%), psychological hindrance (e.g., sense of inferiority or embarrassment) in 36 cases (2%), disturbances at job, in practical daily tasks, and in psychology in 539 cases (30.9%), disturbances at job and in practical daily tasks in 251 cases (14.4%), disturbances at job and in psychology in 74 cases (4.2%), and psychological disturbances as well as in practical daily tasks in 65 cases (3.7%). Patients with hyperhidrosis had previously tried nonsurgical treatments, which turned out to be ineffective in 417 (23.9%) of 1742 patients. These treatments included Chinese herbal medicine in 194 patients, drionic in 45 patients, acupuncture and moxibustion in 51 patients, sympatholytic medication in 42 patients, religious intervention in 5 patients, and more than two kinds of treatments in 47 patients.

DISCUSSION

Our previous study indicated that the T2 sympathetic ganglion determines palm skin temperature in patients with es-

sential palmar hyperhidrosis (44). The facial innervation ascending from the T2 ganglion may be responsible for the effectiveness of T2 lesioning in patients with facial hyperhidrosis. In 1988, we first reported a new stereotactic procedure for percutaneous thermocoagulation upper thoracic ganglionectomy in 10 cases of palmar hyperhidrosis (14). In their comments in our previous article (14), Wilkinson and Hardy (50a) warned of the potential for recurrent symptoms either immediately or in a delayed fashion after extended assessment. In comments in the article by Yarzebski and Wilkinson (51), Rengachary (40a) stated that the question whether the patients' outcomes were comparable to those reported by Kux (31) could be determined only after a large number of patients had been treated with the use of newly acquired anatomic knowledge.

During an 11-year, 7-month period, we performed thermocoagulation upper thoracic ganglionectomy and subsequently evaluated outcomes in 1742 patients with hyperhidrosis. The immediate success rate for the initial treatment was 99.5%. This success rate is similar to the results in 1152 cases reported by Rex et al. (41). Although we did not achieve the 100% immediate success rate reported in several previous studies (13, 19, 21, 36, 40), our immediate success rate is still higher than the rates reported in most previous series (9, 11, 16, 17, 22, 23, 25, 27, 32, 37, 38, 45, 46, 50, 53). During a follow-up period of 1 to 8 years (mean, 3 yr, 3 mo), 268 sides (7.8%) relapsed. This recurrence rate is higher than the relapse rate reported in most studies in which other treatment methods were used (3, 21–23, 25, 36, 40, 45) but lower than the rates described in several other reports (12, 34, 53). The recurrence in all 268 sides in our series was immediately cured after rethermocoagulation. The modifications that we made to our original technique, including the use of an increased probe diameter and the performance of ganglionectomy and sympathectomy on T2 only (instead of T2 and T3), were as safe and effective as the original technique but decreased the operative time. Relapses occurred from 2 to 59 months after thermocoagulation, probably because of the regeneration of sympathetic nerves (4, 6, 8).

After the initial thermocoagulation or repeated thermocoagulations, all patients with hyperhidrosis stopped sweating, which confirms the effectiveness of our previously reported method. The final cure rate in this study was 99.9%, which is similar to the final success rate that Rex et al. reported in 1152 cases (41). Our final cure rate is higher than that described in reports in which other methods were used (4, 8, 9, 16, 31, 37–39, 46–50, 53).

In this study, only 7 (0.2%) of 3484 procedures resulted in the complication of pneumothorax, and 5 sides (0.15%) developed transient partial Horner's syndrome. The frequency of postoperative complications in our series was lower than that reported in studies in which other methods were used (1, 3, 4, 8, 12, 16–20, 22, 24–26, 30, 32, 33, 36, 38–42, 44, 45, 48, 50, 53). Seven patients developed pneumothorax as a result of the procedure, which presented as coughing during local anesthesia, indicating that the anesthetic needle had injured the lung. During local anesthesia, patients were asked to take a light breath and to tell the doctor if they felt like coughing. We immediately elevated the anesthetic needle by approximately 1.5 cm when signs of pneumothorax (i.e., coughing, sensation of a need to cough) were suspected or were reported by the patient. The rate of postoperative pneumothorax using our technique was lower than in previous studies in which endoscopic thoracic sympathectomy was performed (1, 8, 12, 16, 17, 20, 22, 24–26, 30, 32, 33, 36, 38–41, 45).

Partial Horner's syndrome developed in five of our patients, possibly in part because the patients' partial ciliospinal fiber extended downward in front of the T2 ganglion (1, 18). All of these patients returned to normal within 6 months. None of the previously reported postoperative complications occurred in our series, including persistent Horner's syndrome (3, 6, 15, 22, 25, 45), hemothorax (11, 18, 22, 36), chylothorax (3, 6, 18, 33), pleural effusion (3, 4, 6, 25, 39), intercostal arterial bleeding (31, 44), wound infection (22, 25, 36, 38, 40, 44), wound hemorrhage (46), poor wound bleeding (11, 20, 29, 45), pneumonia (11, 25, 38), brachial plexus injury (3, 4, 6, 40), death (18), subclavian artery injury (3, 10, 18, 25, 40), hemopneumothorax (40), severe air embolism (33), hypoxia (24), cardiac arrest (35), atelectasis (25), cerebral damage (10), and hypertrophic operative scar (38).

It is well established that compensatory hyperhidrosis often occurs after thoracic sympathectomy (2, 3, 13, 49). We did not attempt to assess the extent of compensatory hyperhidrosis in the present study, however, because this was not our original purpose for the study, and an adequate analysis would have required additional planning and follow-up that would have exceeded the scope of this already lengthy study. On the basis of patient report, however, we have no reason to suspect that there was other than a very low incidence of compensatory hyperhidrosis in our series of patients.

The success rate of 99.5% in Group 3 despite the use of only T2 ganglionectomy and sympathectomy supports previous observations that the T2 ganglion is the key ganglion that mediates the sympathetic efferents to the upper extremity with special reference to the perspiration of the palms (43, 44).

In our previous study, we found that the preganglionic neurons for the upper extremities and the face are located in C8–T5 but are concentrated at T1–T3 (52). Other previous studies (12, 26, 27, 40, 41) that used T2 sympathectomy alone also were successful, however. Thus, we sought to investigate the efficacy of thermocoagulation at T2–T3 and at T2 only. In our series, the clinical outcomes indicate that the probe was successfully localized on the first attempt in 95% of patients, whereas 4% of patients required a second localization and 1% required three localizations.

In our series, 54 patients with craniofacial hyperhidrosis were treated with T2 ganglionectomy and sympathectomy. Hyperhidrosis stopped immediately in all 54 of these patients. These results support previous findings that the T2 ganglion is the key ganglion that controls the palm and craniofacial areas (5, 19, 28, 41).

In the first 487 cases in our series, we injected a local anesthetic agent, xylocaine, around the T2 ganglion, and thermocoagulation was started 10 minutes later. After the procedure, if the temperature of the thumb remained above 35°C for a period of 10 minutes, the patient's hyperhidrosis was considered cured. Because xylocaine probably affected the T2 ganglion and trunk to an extent that might have produced a chemical sympathectomy and ganglionectomy, however, false-positive results were likely. To avoid such a potential for false-positive results in subsequent cases, the procedure was changed so that after the injection of xylocaine, if the temperature of the thumb was higher than 35°C, we waited until the temperature remained below 34°C before performing thermocoagulation. If thermocoagulation was completed and the temperature of the thumb ascended higher than 35°C for 15 minutes, the thermocoagulation procedure was considered successful. After this modification of our method, the success rate of thermocoagulation was 100%.

Most patients with palmar hyperhidrosis also have sole hyperhidrosis (4–6, 12, 13, 16, 25, 36, 38, 40, 44), which is problematic. The L2 and L3 ganglia control the plantars. These two ganglia also control sexual function. Therefore, if these two ganglia are destroyed, sexual dysfunction will result (7). After we used our technique for the control of palmar and craniofacial hyperhidrosis, however, we found that 24% of plantar hyperhidrosis improved dramatically, 68% of plantar hyperhidrosis improved partially, and only 8% plantar hyperhidrosis did not improve or became worse. Thus, a dramatic or partial improvement was achieved in 92% of patients. This result is similar to the success rate of Lin et al. (36) and Cloward (15) but still higher than the 23.3 to 44% rate of improvement reported in other studies (3, 5, 12, 23).

In conclusion, we had an initial success rate of 99.5% in this series of 1742 hyperhidrotic patients with the use of our technique of ganglionectomy and sympathectomy. During a long-term follow-up assessment ranging from 1 to 8 years, recurrence developed in 268 sides, and retreatment was successful in all of these sides. The final success rate was 99.9%. The postoperative complication rates of 0.2% for pneumothorax and 0.15% for partial Horner's syndrome are very low. Be-

cause we administered only local anesthesia, there were no contraindications for this treatment. The procedure, which involves the placement of a thermocoagulation probe into the patient's skin through to the T2 ganglion and trunk, can be performed as an outpatient procedure and does not result in the development of scars. After the procedure, the patient feels little pain. The findings of this study indicate that despite the learning curve involved, dorsal percutaneous stereotactic thermocoagulation in T2 ganglionectomy and sympathectomy is associated with few complications and a high success rate and should therefore be considered an attractive first-line alternative in the management of severe hyperhidrosis.

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Acknowledgment

COMMENTS

The authors present their significant and extensive experience with percutaneous radiofrequency thoracic ganglionectomy for hyperhidrosis during an approximately 11-year period. This article follows their 1988 report of the technical aspects of the approach and their experience up to that time in 10 patients. As predicted, with experience, their learning curve has helped them to refine the technical aspects of the procedure, resulting in shorter operative time and a low rate of recurrence of hyperhidrosis. As one might also predict, complications do occur with this procedure, albeit at a relatively low incidence. This article should be read as a case series (e.g., Class III evidence) exemplifying the excellent results that can be obtained with the use of percutaneous sympathectomy for hyperhidrosis. This condition is one that not many neurosurgeons treat. As these authors demonstrate, however, neurosurgeons can make an important contribution in the treatment of patients with this disabling condition.

Kim J. Burchiel
Portland, Oregon

The authors share their vast experience with the development of a percutaneous technique for the treatment of patients with palmar and craniofacial hyperhidrosis, which is also often incidentally helpful for the treatment of plantar hyperhidrosis. Their success rate is impressive, and the procedure might be considered by neurosurgeons treating this malady.

Perhaps as important as the report itself is the description of how their technique evolved in three stages. Although the protocol that they originally devised was successful, they sought ways to improve their results as well as ways to simplify and shorten the procedure. Rather than incorporate frequent and uncontrolled changes, they remained with each protocol long enough to evaluate it. In doing so, the technique became shorter, simpler, and more refined.

This approach also illustrates how procedures become progressively less invasive. Upper thoracic sympathetic ganglionectomy originally involved a thoracotomy, then partial rib resection, then endoscopy (ordinarily with induced controlled pneumothorax), and now percutaneous sympathectomy. The authors follow the dictum of stereotactic surgery, "Never do with a knife what you can do with a needle!"

Philip L. Gildenberg
Houston, Texas

The authors have gained huge experience in performing stereotactic thermocoagulation of the second thoracic sympathetic ganglion for palmar hyperhidrosis as well as less but still significant experience in treating patients with craniofacial hyperhidrosis. After performing 3484 coagulations, only 278 of their patients had recurrence of symptoms. These relatively few patients were usually helped by repeat thermocoagulation. The complication rates for pneumothorax and Horner's syndrome were quite low. The probe tip diameter was increased from 0.9 to 1.6 mm and lengthened from 10 to 16 mm to help shorten the thermocoagulation time. A stereotactic frame and fluoroscopic guidance were used. Thumb skin temperature was monitored closely.

These disorders are much more common in Asian countries, especially Taiwan and the People's Republic of China, than in North America. Chuang and Liu have written extensively about these patients and procedures previously. Nonetheless, this article is of some value and interest in the United States and Canada. I am surprised that no cases of clinically obvious secondary hyperhidrosis are reported here. This presentation has been reported extensively in other series. In my experience, such a side effect is quite bothersome in some cases, to the extent that patients emphatically state that they wish they had never had such a procedure. This comment should not detract from the value of this report of a very large surgical experience, however.

David G. Kline
New Orleans, Louisiana

In 1983, I first described my technique of percutaneous radiofrequency thoracic sympathectomy (1), which these authors began using 3 years later in their "Group 1" patients. I am pleased that they have modified and improved that technique, which is a healthy development for the neurosurgical profession. Their modification has greatly reduced the time necessary for this procedure. In addition, their overall results are excellent. Even though many of their patients required reoperation, their study documents the ease and efficacy of reoperation with the use of this technique and shows that persistence is worthwhile. It is noteworthy that some of their