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# Usefulness of galvanic skin reflex monitor in CT-guided thoracic sympathetic blockade for palmar hyperhidrosis

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**Abstract**
Computed tomography (CT)-guided thoracic sympathetic blockade with ethanol was performed while monitoring sympathetic nerve activity, with an alternating current (AC) galvanic skin reflex (GSR) monitor, in a patient with palmar hyperhidrosis in whom endoscopic thoracic sympathectomy was impossible because of pleural adhesion. Sweating was suppressed after the thoracic sympathetic blockade, and the monitor showed a significant increase in skin resistance. The effect of sympathetic blockade could be evaluated directly and in real time using a GSR monitor.

**Key words** Hyperhidrosis · Endoscopic thoracic sympathectomy · Pleural adhesion · CT-guided thoracic sympathetic blockade · Galvanic skin resistance

## Introduction

Endoscopic thoracic sympathectomy (ETS) [1,2] and thoracic sympathetic blockade, using drugs including phenol and alcohol, are techniques employed to treat blood flow obstruction of the fingers in Buerger's disease hyperhidrosis and intractable thoracic pain [3–5]. However, if there is pleural adhesion, it is difficult to monitor the internal environment. Thus, these blockade approaches are anatomically difficult to perform and their effects are uncertain. At our facility, computed tomography (CT)-guided blockade has been employed to perform more accurate sympathetic blockade. Several investigators, including Schneider et al. [4], have reported the usefulness of this technique. In cases of pleural adhesion, it is necessary to confirm the accuracy of the blockade; changes in heart rate [6], thermographic skin temperature [7], and skin sympathetic response (SSR) [8] have been used as indicators. However, few reports have described direct and real-time monitoring.

Previously, we reported a monitoring technique whose main principle was the galvanic skin reflex (GSR) [9]. The sympathetic nerve activity after ETS in a patient with hyperhidrosis was analyzed in real time. The GSR, a phenomenon based on the fact that skin resistance decreases after pain, was first described by Féré [10]. The GSR is reported to be influenced by intrinsic mental changes as well as by extrinsic stimuli, and it has been mainly used in the fields of psychology and psychiatry. It is suggested that changes in resistance can be used as an indicator of sympathetic nerve activity [11], and the usefulness of the GSR has recently been studied by anesthesiologists [12,13]. However, it is unclear whether the GSR could be an indicator to assess treatment, including sympathetic blockade, in the pain clinic, and this has not been investigated sufficiently. In the present study, we performed CT-guided thoracic sympathetic blockade while monitoring sympathetic nerve activity. To do this, an alternating current (AC) skin resistance measurement device (a GSR monitor) was used in a patient with palmar hyperhidrosis (in whom ETS was unable to be applied because of pleural adhesion), with a favorable outcome.

## Case report

The subject was a 62-year-old man with left palmar hyperhidrosis from whom informed consent for the procedure was obtained. The study was approved by the Institutional Review Board of Tokyo Medical University.

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In July 1998, he had received ETS; however, it was applied only to the right lung because of severe adhesion of the left lung. He had previously been treated with aluminum chloride, but this had only a temporary effect. Because sweating of the left hand persisted afterwards, he was admitted for thoracic sympathetic blockade. After the blockade, he was discharged from hospital without any postoperative complication, 3 days after admission.

## Methods and results

### *Thoracic sympathetic blockade*

We placed the patient in the right lateral position. Tomograms from the first to the fourth thoracic vertebrae had been taken at 1-cm intervals. As shown in Fig. 1B*a*, we selected a compartment of the anterior part of the rib head surrounded by the vertebral body and outer surface of the pleura, which is optimal for the insertion of a nerve block needle, and we determined the puncture points for performing sympathetic blockade at the level of the second and third thoracic vertebrae. The distance and depth from the first puncture point (second thoracic vertebral level) to the outer surface of the vertebral body were 2.1 cm and 6.8 cm, respectively; and those from the second puncture point (third thoracic vertebral level) were 4.5 cm and 7.0 cm, respectively (Fig. 1A,C). A nerve block needle (22 G × 8 cm) was inserted at each puncture point. After the needle had contacted the transverse process of the second thoracic vertebra (or third rib), computed tomography (CT) was performed to confirm the direction of the needle. Then the needle was slid into the inferior margin, and CT was then performed to measure the distance to the compartment again. The needle was advanced to the anterior part of the rib head (or anterior part of the rib; Fig. 1A). After confirming the absence of blood reflux, 3 ml of a solution, consisting of iohexol (300 mg·ml$^{-1}$), as a contrast medium and 1% lidocaine, as a local anesthetic, at a ratio of 4:1, was

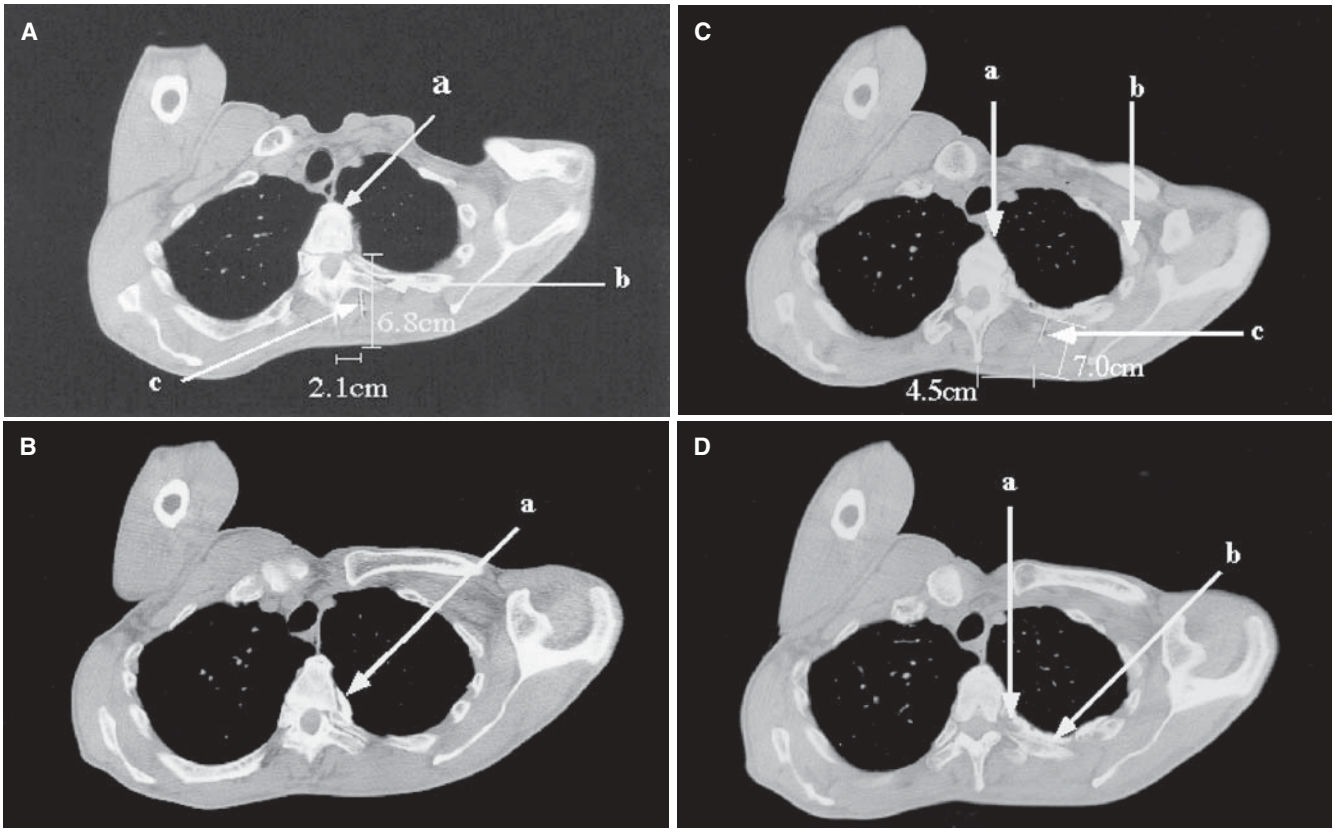


**Fig. 1A–D.** Procedures for computed tomography (CT)-guided thoracic sympathetic blockade. **A** A needle was inserted until it touched the transverse process. *a*, Second thoracic vertebral body; *b*, transverse process; *c*, nerve block needle. **B** Distribution of contrast medium in compartment (*a*). **C** Advance of needle into compartment. *a*, Third thoracic vertebral body; *b*, third rib; *c*, nerve block needle. **D** Distribution of contrast medium in compartment. *a*, Distribution of contrast medium; *b*, suspected region of adhesion

injected. After confirming that the solution was distributed in the compartment, 3 ml of pure ethanol was injected at each puncture point (Fig. 1B,D).

*Changes in palmar temperature and weight of sweat*

Before the thoracic sympathetic blockade, the palmar skin temperature and weight of sweat in the blocked hand (the left) were 31.3°C and 0.78 g, respectively, and those in the nonblocked hand (the right) were 34.5°C and less than 0.01 g, respectively. After the thoracic sympathetic blockade, the palmar skin temperature in the blocked and nonblocked hands was 34.6°C and 34.7°C, respectively; and the weight of sweat was not measurable (less than 0.01 g) in either hand.

*GSR monitoring*

Skin resistance was measured with a GSR monitor (Diamedical, Tokyo, Japan) using two pairs of Ag-AgCl ECG electrodes placed approximately 1 cm apart on each palm. Using this GSR monitor (Fig. 2), it was possible to measure the real skin resistance without contact resistance between the electrodes and skin. A sine wave current (maximum, 510 μA, 10-ms duration, and 10-Hz to 30-kHz frequency) was applied to two electrodes (E1 and E4). E2 and E3 were for measurement of the voltage drop due to the skin resistance (Rx). The voltage drop between E2 and E3 (Rx × Current(i)) was measured using an amplifier with high input impedance, which made electrode resistances (see Fig. 2) negligible. The unstable direct current due to electrode displacement was eliminated with a capacitance circuit. The Rx was amplified, rectified, and displayed in kΩ (range, 0-200 kΩ).

Before sympathetic blockade of the second and third thoracic vertebrae, the palmar skin resistance was 41.3 kΩ in the blocked hand, and 128.4 kΩ in the nonblocked hand. The palmar skin resistance at 2 days and at 1 month after the thoracic sympathetic blockade was 129.5 and 128.1 kΩ, respectively, in the blocked hand; and 128.5 and 132.5 kΩ, respectively, in the nonblocked hand.

*SSR and thermography*

The patient sat comfortably in a semi-recumbent position in a semi-darkened room, and the temperature of the room was maintained above 25.0°C. SSR was amplified and recorded through a restricted filter setting of 1 to 3 kHz (analysis time, 5 or 10 s) using a SYNAX2100 apparatus (NEC, Tokyo, Japan). A magnetic stimulator (SMN-1100; Nihon Kohden, Tokyo, Japan), consisting of a capacitor and a flat round coil with an inner diameter of 10.4 cm and an outer diameter of 17.3 cm, was used [14]. As shown in Fig. 3A, following a single

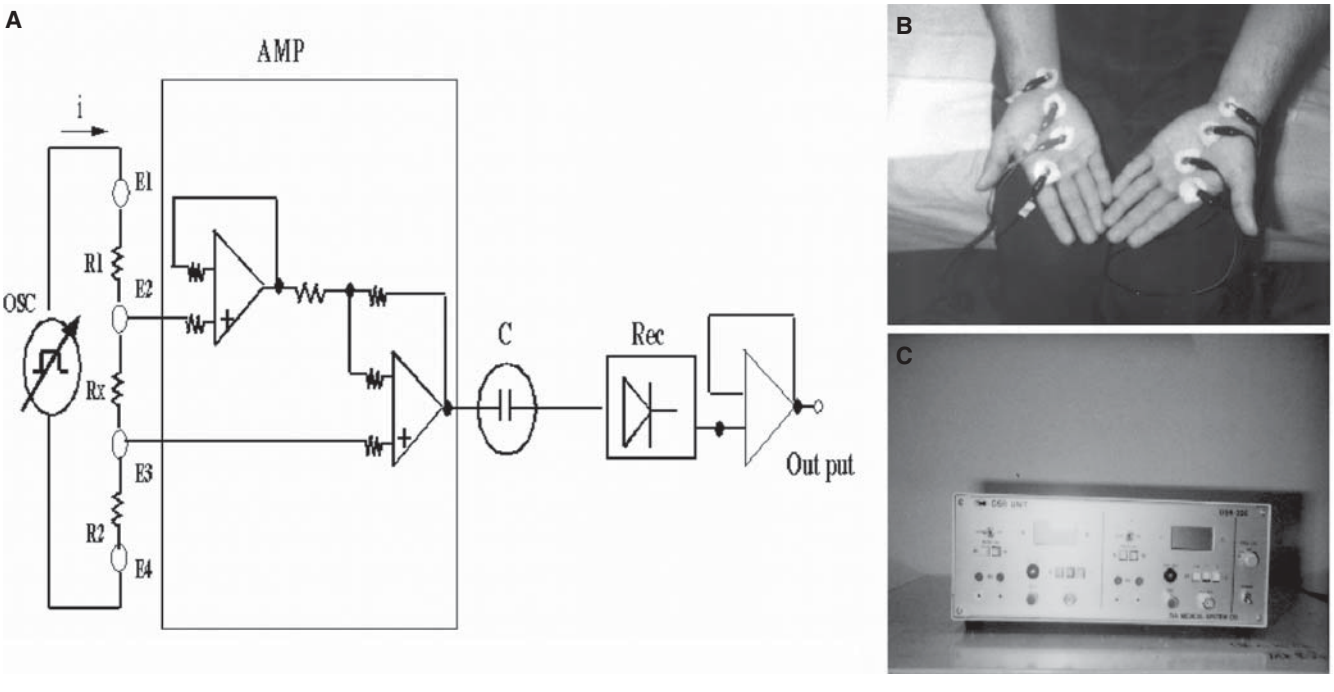


**Fig. 2.** **A** Schematic diagram of galvanic skin reflex (GSR) monitor. *E1 and E2*, Electrodes for current application; *E3 and E4*, electrodes for measurement of skin resistance; *Rx*, skin resistance that reflect between each electrode and skin; *R1 and R2*, skin resistance between E1 and E2, and E3 and E4, respectively; *C*, capacitance; *AMP*, amplifier; *i*, alternating current (<510 μA); *OSC*, oscillator; *Rec*, rectifier. **B** Electrode placement. **C** Photograph of GSR monitor

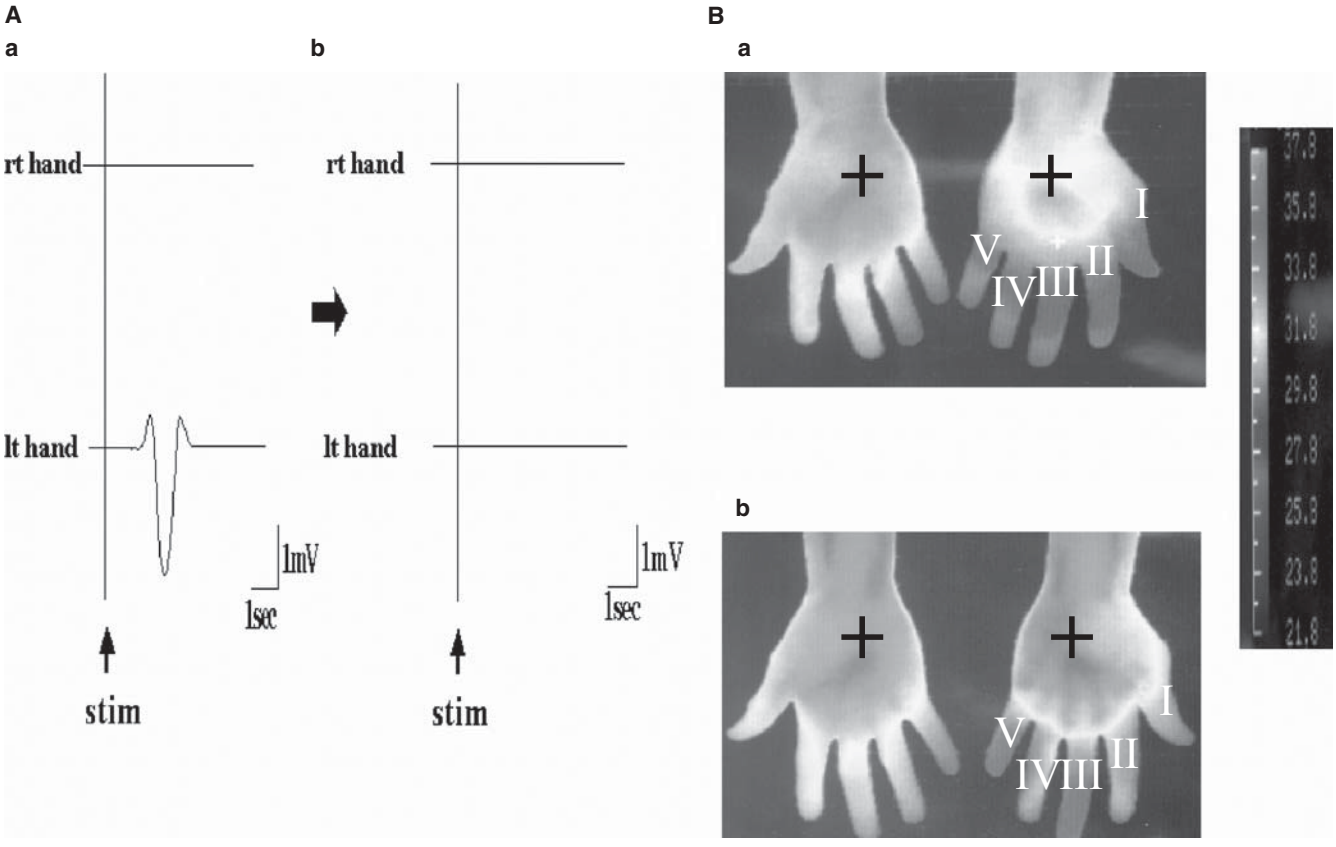


**Fig. 3A,B.** Evaluation of efficacy of thoracic sympathetic blockade. **A** Change of skin sympathetic response (SSR) and **B** thermographical change. **A** *a*, Before thoracic sympathetic blockade and *b*, 2 days and 1 month after thoracic sympathetic blockade. Note that the left (*Lt*) hand showed SSR before thoracic sympathetic blockade, but the waveforms disappeared after the blockade. *stim*, stimulation **B** *a*, Before thoracic sympathetic blockade and *b*, 1 month after thoracic sympathetic blockade. Increased temperature in the affected hand (29.8°C) was observed on the thermogram compared to the temperature before thoracic sympathetic blockade (24.5°C), which indicated that the effect of the thoracic sympathetic blockade persisted

magnetic stimulation, SSR was recorded in both palms simultaneously. Before, and at 2 days, and 1 month after the thoracic sympathetic blockade, SSR was evoked. SSR could be delivered from the left hand before the thoracic sympathetic blockade, but the waveforms had disappeared 2 days after blockade. The disappearance of waveforms persisted for 1 month after the blockade.

The effectiveness of the blockade was also assessed on the basis of images obtained with a thermovisual camera (Thermo Tracer TH5102; NEC Sanei, Tokyo, Japan), and on the basis of the temperatures of the upper extremities before, and at 3 days, and 1 month after performing the blockade. Differences in the mean image before blockade from those after blockade were investigated. Increased temperature in the affected hand was observed on thermography 1 month after the blockade, which indicated that the effect of the thoracic sympathetic blockade had persisted. Before the thoracic sympathetic blockade, the average fingertip (digits I to V) temperature was 24.5°C, and after the blockade it had increased to 29.8°C (Fig. 3B*a*,*b*).

## Discussion

Skin resistance increased immediately after the thoracic sympathetic blockade, it remained higher at 1 month after the blockade, reflecting the effect of the sympathetic blockade. In addition, the disappearance of SSR, decrease of sweating, and increase of palmar temperature on the thermogram supported the results obtained through the GSR monitor. Ordinarily, core temperature instruments and thermography are powerful tools to evaluate the effect of sympathetic blockade. Their disadvantages are that they are very expensive and they need time to stabilize at room temperature. In particular, the instrument used for thermography is sometimes very large and difficult to carry. However, our GSR monitor costs 10% to 30% of the cost of core tempera-

ture instruments and thermography equipment, and it is easy to carry.

GSR monitoring is a simple and easy method for assessing the function of the sweat glands [15], and it can be used to assess the degree of denervation and sympathetic nerve activity in patients with degenerative diseases [16]. The changes in skin resistance due to galvanic stimulation correlate with changes in sympathetic nerve activity. The GSR is reported to be a reflex from the corticocerebral motor area and hypothalamus as centers, through sympathetic nerves as the efferent nerve pathway, and sweat glands as the effector. Some investigators consider the GSR to be the same phenomenon as the SSR [17]. The SSR is assessed based on the electric potential that records the somato-autonomic reflex induced by afferent galvanic stimulation, originating from the skin and sweat glands, and monitoring of the SSR was reported by Shahani et al. [18] as a noninvasive method for evaluating sympathetic nerve function. Although real-time measurement is possible for the SSR, it has a disadvantage in that, unlike the GSR, the SSR cannot easily or consecutively detect changes in sympathetic nerve activity.

The main principle of our GSR monitor is the electrode method. Using this GSR monitor, it is possible to measure the apparent changes in skin resistance by passing a weak current, not exceeding 510 μA, to a pair of electrodes applied to the palm, the region of sweating associated with mental activity. It is difficult to measure the true skin resistance (Rx) alone using direct current (DC) because such measurements simultaneously measure the capacitance component, electrode resistance, and contact resistance in addition to the skin resistance, due to the complex impedance component present in the living body. In the newly developed skin resistance measurement device (consisting of four electrodes) used in the present study, measurements were made with AC. The reason for this is that AC current is composed of positive and negative current components, which offset the electrode polarization (battery-forming effect due to the charge by the current), electrode resistance, and contact resistance, thus making precise measurements of skin resistance possible. The GSR monitor calculates and presents skin resistance based on the output voltage of an amplifier induced by passing a constant AC current from a oscillator for measuring resistance. The frequencies of AC current used in the current study ranged from 10 Hz to 30 kHz [9], and skin resistance varied from 0 kΩ to 2 MΩ. The electrical characteristics of the human body mean that the body can be treated as a conductor in the low-frequency band. The current is characterized by the flow in the intercellular fluid, avoiding the cell membrane, which has high impedance, and conductivity is extremely low in the epidermis, as it has little extracellular fluid. When voltage is applied through the epidermis, the current flowing into a living body decreases. At the frequency band used in the present study, most of the current would flow in the epidermis, which would reflect the resistance of the surface of the skin [9].

The GSR monitor has not been used in the field of pain management because previous models were large and the procedure was complicated. Recently, several trial models have been put on the market, but the ability of the apparatus to accurately measure changes in resistance is still low. In our patient, skin resistance increased significantly after thoracic sympathetic blockade with alcohol compared with that before blockade. The suppression of sweating due to sympathetic blockade may have affected the skin resistance. In conventional skin resistance measurements, because a two-electrode method is applied, contact resistance may be included. In the present study, an impedance measurement device, employing a four-electrode method, was developed to minimize the influence of contact resistance and to detect changes in skin resistance more accurately. Using our GSR monitor, the effect of sympathetic blockade could be evaluated in real time through the analysis of skin resistance changes, and this might be a useful method for diagnosing and treating diseases in the field of pain management.

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