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Anatomic analysis of computed tomography images obtained during fluoroscopic computed tomography-guided percutaneous lumbar sympathectomy

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Abstract
Purpose. The fluoroscopic computed tomography (CT)-guidance technique increases the accuracy and safety of needle placement for percutaneous lumbar sympathectomy. The aim of the present study was to provide anatomic data from CT images and to discuss the safest route for needle insertion.
Methods. We retrospectively analyzed CT images that were obtained from 25 patients (14 men, 11 women; 37–89 years of age [mean, 68.4 years]) during fluoroscopic CT-guided percutaneous lumbar sympathectomy. The anatomy around the inserted needle was measured and the correlations between patient characteristics and the procedure-related distances were assessed.
Results. The distance from the midline (spinous process) to the entry point and the depth to the target site correlated with body size, especially height and weight. The maximal distance from midline to the insertion point in the range of safe needle insertion at L2 was less than 7.0 cm in approximately 20% of the patients.
Conclusion. The present study was performed to determine the anatomic details required to guide safe percutaneous lumbar sympathectomy based on CT images. The use of CT guidance is recommended for lumbar sympathectomy, especially at the L2 spinal level.

Key words Computed tomography · Lumbar sympathectomy · Anatomy

Introduction

Severe peripheral vascular disease involving the lower limbs is resistant to various types of treatment. Although many patients require amputation, direct vascular surgery and peripheral vasodilators are sometimes effective. Lumbar sympathectomy is also effective for the palliation of severe peripheral vascular disease that is no longer suitable for arterial reconstruction [1–6]. In addition, lumbar sympathectomy may be beneficial for patients with chronic pain syndrome [5,6]. Lumbar sympathectomy is traditionally performed under laparotomy, or percutaneously using X-ray fluoroscopy. The classic technique using X-ray fluoroscopy, however, is difficult to perform in patients with a deformed lumbar spine or anatomic abnormalities [3,4]. Recently, minimally invasive, real-time imaging-guided percutaneous techniques under computed tomography (CT) fluoroscopy were added to the list of available treatment options for lumbar sympathectomy [1,4]. A new fluoroscopic CT-guidance technique increases the accuracy and safety of needle tip placement [1]. Although lumbar sympathectomy has been performed under CT guidance for 20 years, there has been no precise anatomic analysis of the safest route for needle insertion for percutaneous sympathectomy using CT images. The aim of the present study was to provide anatomic data from CT images obtained during fluoroscopic CT-guided percutaneous lumbar sympathectomy and to discuss the safest route for needle insertion.

Patients and methods

Patients

A total of 25 patients (14 men, 11 women; 37–89 years of age [mean, 68.4 years]) with peripheral arterial occlusive disease or chronic pain syndrome were treated using CT-guided percutaneous lumbar sympathectomy between January 2004 and October 2005. There were 11 patients with atherosclerosis obliterans, 7 with thromboangitis obliterans, 2 with collagen disease with peripheral vascular symptoms, and 5 with complex regional pain syndrome.

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Fluoroscopic CT-guided percutaneous lumbar sympathectomy technique

The patient was placed on the CT table in the prone position. A marking device made of X-ray opaque wires was attached to the patient's lower back. A scout view of the lumbar spine was used to determine the optimal level (L2 and L3) for sympathectomy. Computed tomography images (Hispeed Advantage SG; GE Medical System, Milwaukee, WI, USA or SOMATOM Volume Zoom; Siemens, Erlangen, Germany) were obtained at the L2 level, and the safest and shortest route to the target (between the anterior angle of the psoas muscle and the anterolateral plane of the vertebral body) was marked on the CT image. The insertion point was marked on the patient, using a marking device. Following sterilization and subcutaneous anesthesia with 0.5% lidocaine, a 22-gauge 140-mm needle (Hakko, Tokyo, Japan) was inserted at the marked point. The insertion angle of the needle was adjusted using a red-colored guiding laser conforming to the scanning slice in the CT gantry. The needle was advanced following a predesignated route under real-time CT-fluoroscopy. Care was taken to avoid injury to the kidney, vena cava, and ureter. When the needle tip was located at the target, a mixture of 0.7 ml saline with 0.3 ml contrast medium (Iomeron 350; Eisai, Tokyo, Japan) was injected through the needle. Based on CT fluoroscopic images, we were able to safely spread the agent using 0.5 to 1.0 ml diluted contrast medium. Lumbar sympathectomy using a chemical neurolytic agent requires the spreading of the agent into the retroperitoneal compartment surrounded by the anterior angle of the psoas muscle and the anterolateral plane of the vertebral body. It is important to ensure that the agent does not spread toward the ureter, backward into the psoas muscle, or into a vessel. If we suspected that the needle tip was located at an inappropriate site after injecting the contrast medium, the needle tip was moved under CT fluoroscopy observation and the proper spread of the contrast medium was verified. If the needle tip could not be placed at the appropriate site after several attempts, we abandoned the sympathectomy at that vertebral level. After ensuring that the contrast medium remained in the appropriate zone, 3 ml of 2% lidocaine was injected as a test block. The skin temperature was continuously monitored at two points (the calf and foot) in each lower extremity, using a precise skin thermometer (YSI Precision 4000A thermometer; Yellow Spring Instrument, Yellow Springs, OH, USA). Because the resolution of this thermometer is 0.01°C, very small changes in skin temperature can be detected. We judged the temperature rise by taking all factors (differences between right and left or before and after, and the change in room temperature) into consideration. In general, an increase of more than 0.5°C within 5 min was considered to indicate an effective block. After confirming the skin temperature rise in the lower extremities and a lack of complications, 3 ml of 7% phenol was injected to chemically degenerate the sympathetic trunk. Sympathectomy was then also performed at the L3 level using the same technique.

Image analysis methods

After obtaining approval from the ethics committee of our institution, written informed consent was obtained from the patients. We retrospectively analyzed CT images that were obtained from patients during fluoroscopic CT-guided percutaneous lumbar sympathectomy. Computed tomography images, including the craniocaudal midpoint of the vertebral column, were selected from each patient at the L2 and L3 spinal levels. According to the previous description, the target of the needle tip was determined to be the area between the anterior angle of the psoas muscle and the anterolateral plane of the vertebral body. The anatomy around the inserted needle was measured as follows (procedure-related distances; see Fig. 1). In Fig. 1, distance A is the distance from the innermost site available for puncture to the midpoint (spinous process); distance B is the distance from the outermost site available for puncture to the midpoint; distance C is the depth to the target when the puncture was made at the innermost point; and distance D is the depth to the target when the puncture was made at the outermost point.

Patient characteristics analyzed included age, sex, height, weight, and body mass index (BMI).

Statistical analysis

All data values are expressed as means ± SD. Comparison between groups with regard to sex was analyzed using Student's *t*-test. The correlations between patient characteristics and procedure-related distances (A–D) were assessed using Pearson's linear regression analysis. Differences with a P level of less than 0.05 were considered significant.

Results

The average duration of the fluoroscopy procedure in each patient was 150 s, and the duration of the total procedure was approximately 30 to 60 min.

Apparent beneficial effects, such as elevated skin temperature or decreased pain intensity, were observed in 20 patients (80%). There was no apparent effect in 5 patients (20%). None of the 25 patients suffered serious complications. Because we confirmed a skin tempera-

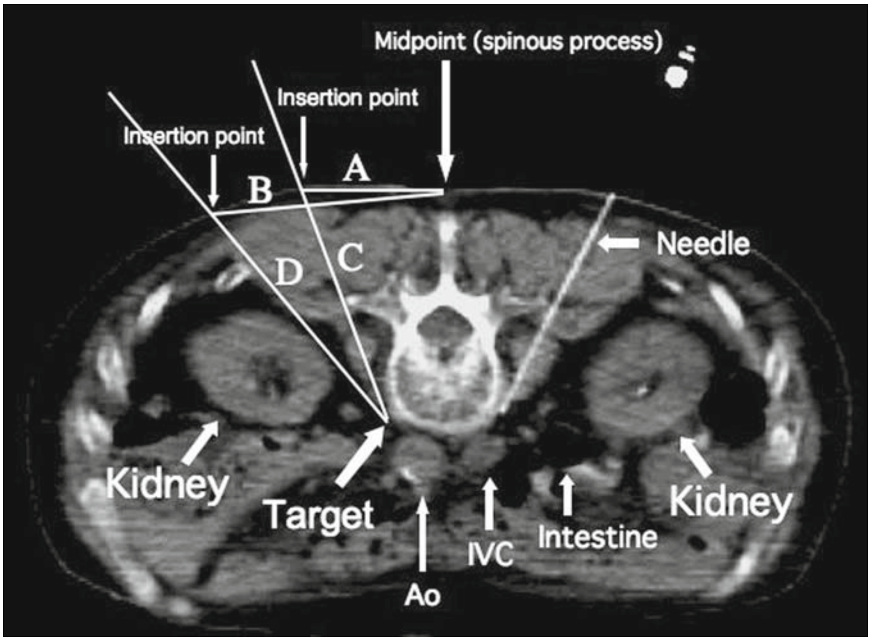

Fig. 1. The procedure-related distances (mm) were measured. *A*, Distance from the innermost site available for puncture to the midpoint (spinous process). *B*, Distance from the outermost site available for puncture to the midpoint. *C*, Depth to the target when the puncture is made at the innermost point. *D*, Depth to the target when the puncture is made at the outermost point. *Ao*, Aorta; IVC, inferior vena cava

Table 1. Patient characteristics

	Age (years)	Height (cm)	Weight (kg)	BMI
Male ($n = 14$)	73.2 ± 14.3*	155.1 ± 8.1*	49.8 ± 10.9	20.6 ± 2.7
Female ($n = 11$)	62.4 ± 9.7	148.1 ± 5.6	47.0 ± 9.5	21.4 ± 3.9
Total ($n = 25$)	68.4 ± 13.5	152.0 ± 7.8	48.6 ± 10.2	20.9 ± 3.2

* $P < 0.05$ compared with the female group
Data values are means ± SD
BMI, body mass index

ture rise in the lower extremities in all patients immediately after the procedure, the lumbar sympathetic ganglion sites determined were likely to have been exact. In our experience, there were no clinical changes due to complicated vascular conditions or pain mechanisms. A complete sympathectomy does not always result in a successful clinical outcome, especially in the case of severe peripheral vascular disease or intractable complex regional pain syndrome.

The patient characteristics are summarized in Table 1. Age and height were significantly greater in the men than in the women ($P < 0.05$).

Procedure-related distances at the L2 level

On the left side, distances C and D were significantly greater among men than among women ($P < 0.05$; data not shown).

Procedure-related distances at the L3 level

There were no significant differences in any distances between men and women (data not shown).

Correlation between patient characteristics and procedure-related distances

At the L2 level, patient height correlated significantly with all procedure-related distances, and especially with right-D, left-B, and left-D ($P < 0.001$). Also, patient weight correlated significantly with most of the procedure-related distances, and especially with right-B, right-D, and left-D ($P < 0.001$). Patient BMI correlated significantly with right-A, right-B, and left-D ($P < 0.05$).

At the L3 level, patient height correlated significantly with all procedure-related distances, and especially with right-D and left-C ($P < 0.001$). Patient weight correlated significantly with right-B, right-C, right-D, left-C, and left-D ($P < 0.001$), and with right A and left B ($P < 0.01$). Patient BMI correlated significantly with right-B, right-C, right-D, left-C, and left-D ($P < 0.05$).

Potential risk of kidney puncture

The distance from the outermost site available for puncture to the midpoint (distance B) at the L2 level was less than 70 mm in six patients (24%) on the right side and in five patients (20%) on the left side (Fig. 2). The CT image of a patient with a potential risk of kidney puncture during the needle placement is shown in Fig. 3.

Discussion

Lumbar sympathectomy, especially under X-ray fluoroscopy, can lead to complications, including lumbar nerve neuralgia; subarachnoid injection; and perforation of the aorta, inferior vena cava, bowel, lower pole of the kidney, and ureter. Injection into the psoas muscle may induce genitofemoral dysesthesia (5%–10% [6]) [1–3,6]. Furthermore, performing the procedure in a patient with anatomic abnormalities increases the incidence of complications [3,4]. To date, there has been no study to verify a lower rate of complications in percutaneous lumbar sympathectomy under CT fluoroscopy rather than X-ray fluoroscopy. Some complications in percutaneous lumbar sympathectomy may be due to the spread of the neurolytic agent rather than to misplaced needle insertion. Nevertheless, CT provides high-resolution images of the spread of the agent, which allows for easy identification of the differences in organ location.

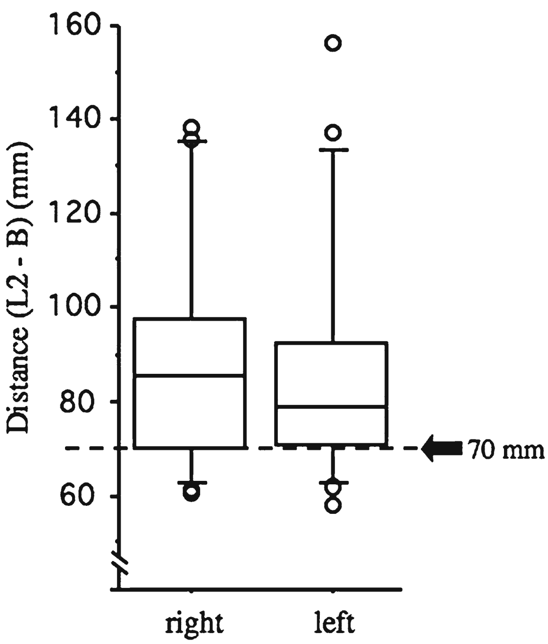

Fig. 2. The distances at the L2 level (*B*, the distance from the outermost site available for puncture to the midpoint). *Horizontal lines in boxes* indicate median and *horizontal bars* indicate 70 mm distance

Our study provides detailed anatomic and demographic data regarding safe insertion routes for percutaneous lumbar sympathectomy. The distance from the midline (spinous process) to the entry point and the depth to the target site correlated with body size, especially height and weight. These findings are consistent with textbook descriptions and are fundamental information for performing percutaneous lumbar sympathectomy, not only under CT guidance but also under classical X-ray fluoroscopy guidance [5,6]. In particular, the distance from the outermost site available for puncture to the midpoint (distance B) is an important measurement for decreasing the risk of organ puncture and increasing the success rate. Some of the four procedure-related distances we measured had different correlations with patient characteristics between the left and right sides. This finding may be due to differences in the position of abdominal organs, such as the liver, spleen, kidney, aorta, vena cava, and back muscles, between the right and left sides, but the precise reason for this difference remains unclear.

The maximal distance from midline to the insertion point in the range of safe needle insertion at L2 was less than 7.0 cm in approximately 20% of our patients. This finding indicates that the potential risk of kidney

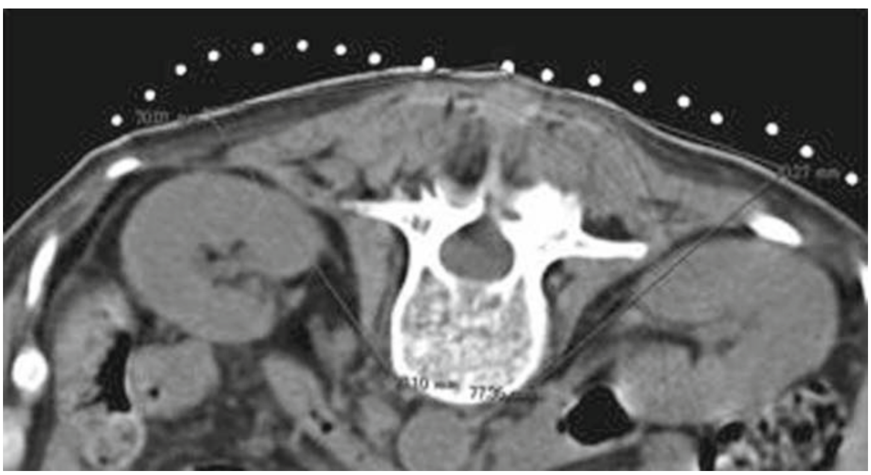

Fig. 3. Computed tomography (CT) image in a patient with potential risk of kidney perforation during the procedure

puncture is not low at the L2 vertebral level, when the needle is placed according to textbook descriptions [5,6]. In addition, ureter necrosis necessitating nephrectomy is reported to be a serious complication in chemically induced lumbar sympathectomy [7], suggesting that needle insertion at the L2 level should be performed carefully with consideration of the patient's body size. Thus, a CT-guided operation may be more suitable for percutaneous lumbar sympathectomy, because classical X-ray fluoroscopy does not show the kidney, ureter, muscles, and vessels.

If all available CT image data obtained from patients who did not receive percutaneous lumbar sympathectomy could be analyzed, the number of patients could be increased, leading to more detailed examination on a larger scale. Abdominal CT is usually taken with patients in the supine position, and the images of patients in the prone position are different from those of patients in the supine position, because the abdominal organs (such as inferior vena cava, aorta, kidney, and bowel) are pushed to the back and the abdominal circumference is deformed.

The findings on procedure-related distance and its correlation with patient characteristics do not seem to be so important for understanding patient anatomy, if we can perform percutaneous lumbar sympathectomy under fluoroscopic CT guidance. Performing the procedure under fluoroscopic CT guidance at institutions where there is no preinstalled CT fluoroscopy device, however, would obviously be difficult. Our results may also provide useful information for improving the procedure under conventional X-ray fluoroscopy. The demand for CT-guided interventions, such as biopsies and percutaneous radiofrequency ablation of tumors, is increasing, and many institutions are planning to install a CT device in their operating theaters. In the near future, CT-guided operative techniques, including nerve block, will become more common. If lumbar sympathectomy must be performed under X-ray fluoroscopy, we absolutely recommend obtaining an abdominal CT image in the prone position to plan the safest route before the procedure, especially at the L2 level in patients with anatomic anomaly or unusual body size.

The main purpose of the present study was to evaluate the safety range of the procedure-related needle insertion distances. The new fluoroscopic CT-guidance technique increases the accuracy and safety of needle tip placement. Successful sympathectomy requires the precise spreading of the neurolytic agent as well as precise location of the needle tip. Further evaluation including the spread of the agent and the effect of sympathectomy may be necessary to establish the optimal method for percutaneous lumbar sympathectomy. In addition, we did not measure more detailed anatomic data, such as abdominal circumference. More detailed data may enhance the value of the analysis.

In summary, in the present study we determined the anatomic details for safe percutaneous lumbar sympathectomy using CT images. The use of CT guidance is recommended for lumbar sympathectomy, especially at the L2 spinal level.

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