Clinical Article

Infrared Thermographic Findings of Peripheral Nerve Tumors: Report and Analysis of 5 Cases

Sang Hoon Lee, MD, Ho Yeol Zhang, MD

Department of Neurosurgery, National Health Insurance Service Ilsan Hospital and Yonsei University College of Medicine, Seoul, Korea

Objective: Infrared (IR) thermography studies about the peripheral nerve tumor are rare, despite of its useful visualizing function. We report the features of thermographic findings of peripheral nerve tumors.

Methods: From October 2013 to October 2014, five patients diagnosed with peripheral nerve tumor were enrolled in this study. Pathologic diagnoses of the tumors were one liposarcoma and four Schwannomas involved in peripheral nerves. Preoperative and postoperative thermography and thermography with compression test was performed.

Results: In the preoperative IR thermography, three cases showed the hyperthermic skin temperature and 2 cases showed non-specific result. In the study with compression test, 4 cases showed hypothermia and 1 cases showed hyperthermia. Postoperative IR thermography was performed in 2 cases. The result of 1 case showed normal skin temperature without neurologic deficit and the other case showed severe hypothermia with wrist drop.

Conclusion: IR thermography with and without nerve compression test of peripheral nerve tumor can visualize the thermal change of peripheral nerve tumor. However, we need more cases to find the exact findings and benefits of IR thermography for the peripheral nerve tumors.

Key Words: Infrared thermography · Peripheral nerve tumor · Schwannoma · Liposarcoma

INTRODUCTION

Infrared (IR) thermography is a very useful method to visualize the nerve dysfunctional status such as herniated lumbar disc, herniated cervical disc, whiplash injury, spinal cord tumor and so on[1,2]. The IR thermography has been used by many physicians as a good diagnostic method to explain spine disease easily. So far, relative enough data of IR thermography about degenerative spinal disease and spinal cord tumor have been collected. The data of the IR thermography about such spinal disease have been analyzed and organized consistently by members of The Korean Society of Thermology. As a result, the database of IR thermography about spinal disease is being built organically by them. In most literatures, patients diagnosed with peripheral nerve tumor are not common than we may think. Moreover IR thermography studies about the peripheral nerve tumor are very rare. This study is the pilot study to understand the general features of thermographic findings of peripheral nerve tumors.

Corresponding Author: **Zhang Ho Yeol**, MD, PhD
Department of Neurosurgery, National Health Insurance Service Ilsan Hospital, 100, Ilsan-ro, Ilsandong-gu, Goyang-si, Gyeonggi-do 10444, Korea
Tel: +82-31-900-0256, Fax: +82-31-900-0588
E-mail: hoyeolzhang@gmail.com

MATERIALS AND METHODS

From October 2013 to October 2014, the five patients diagnosed with the peripheral nerve tumors were enrolled in this study. All IR thermography was estimated on 2 points, the point of the side with mass and normal side. The difference of the two points was analyzed by assuming the temperature of the normal side with standard (the difference of the temperature: ΔT=temperature of the point of the side mass-that of the normal). In addition, the temperatures of the both distal points from the tumor and normal area according to dermatome were estimated. Preoperative IR thermography was performed in all 5 cases. In three cases (case 1, 4, 5), IR thermography with compression test was performed. In case 1, the mass was compressed for 1 minute (min) by the patient's finger. In case 4, researcher compressed the mass on patient's right axillar for 1 min. In case 5, the researcher compressed the mass for 1 min with a wood stick. After 1 minute compression, the IR thermography was performed

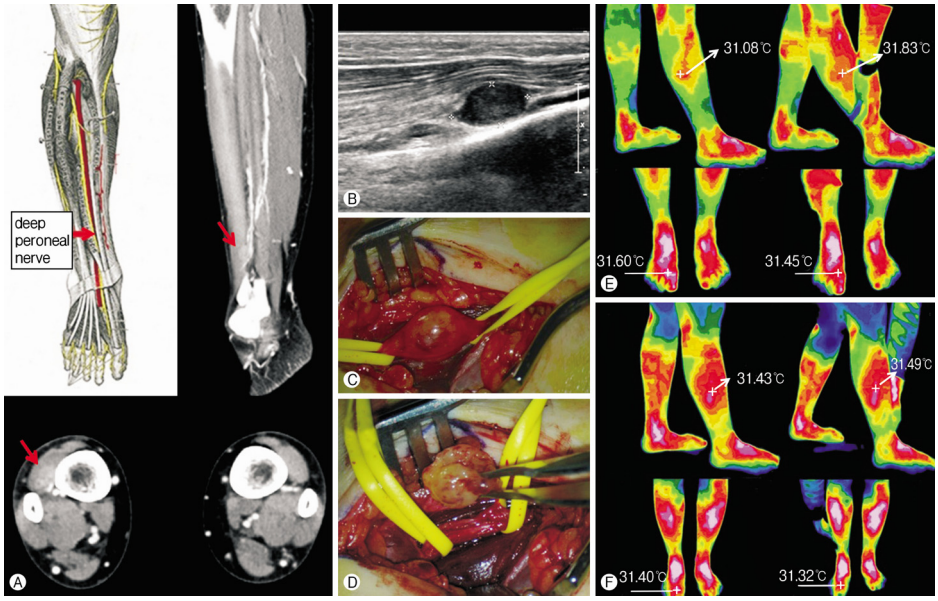

Fig. 1. (A) A mass in deep peroneal nerve is identified through MRI scan of the lower extremity. (B) The size of mass is measured through ultrasound (about 2×2 cm). (C) Gross identification, the mass shaped like a pigeon egg. (D) Excised tumor mass with preserving normal nerve. (E) Preoperative IR thermography with and without compression test. (F) Postoperative IR thermography with and without compression test.

Table 1. Infrared thermography Images show thermal changes in preoperative study (Pre-op) & postoperative study (Post-op) with compression (With comp.) & without compression (None comp.) of the mass.

	Pre-op		Post-op 1 month	
Measure (℃)	Fibular	dorsal	Fibular	dorsal
None comp.	31.08	31.60	31.43	31.40
With comp.	31.83	31.45	31.49	31.23
⊿T	0.75	0.15	0.06	0.08

on compressing the mass. In compression test, the temperature of the distal part of nerve distribution from the mass was considered significant value. Therefore, the effect of the temperature of the man's finger was not so serious condition in compression test. However, for smaller bias, we used the wood stick as nonconductor for compression test in case 5. Postoperative day (POD) 1 month, postoperative IR thermography of two cases were performed and analyzed. The temperature of the closed clinical laboratory room where IR thermographic studies were performed was maintained 22℃. Before the study, patients who underwent IR thermography took rest 30 min in the closed clinical laboratory room. In the absolute darkness, studies were progressed. The patients took off all clothes without minimal inner wears.

RESULTS

There were two males and three females. Their age was 47-66 years old. According to the involved nerves and pathologic diagnoses, the five patients were classed as follows. Case 1 was diagnosed with right deep peroneal nerve Schwannoma and case 2 was diagnosed with left L3 nerve in psoas muscle assumed Schwannoma (not operated). Case 3 underwent biopsy of left C7, C8 nerve root and was diagnosed with myxoid liposarcoma. Case 4 had right proximal upper arm mass assumed Schwannoma (not operated). Case 5 had left brachial plexus (radial nerve) Schwannoma and he underwent operational resection of the tumor (Table 2).

Case 1

fifty-two years old female patient had tenderness and a palpable mass on right tibia area. Through ultrasound and CT, it was revealed that the mass was located in deep peroneal nerve and it was about 2×2 cm sized (Fig. 1A and B). The mass like pigeon egg shape was removed without injury of normal deep peroneal nerve (Fig. 1C and D). The pathologic diagnosis of the mass was Schwannoma. Before the ope-

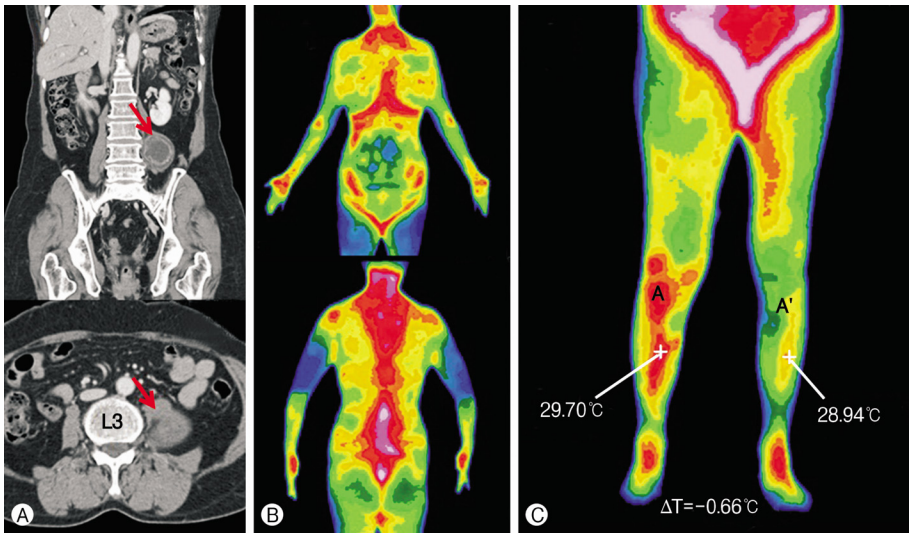

Fig. 2. (A) A mass in left psoas muscle on L3 level is identified through abdominal pelvic computerized tomography. (B) Isother- mia on skin of body. (C) Hypothermia on distal area according to dermatome of L3 nerve (ΔT= -0.66 ℃).

ration, the temperature was 31.08℃ at fibular area, 31.06℃ at dorsal area of the foot. When the palpable mass was compressed, the patient complained of nerve compression sign, severe pain on fibula (upward from mass to below the knee) and dorsal area of foot, especially on fibular area and big toe. At that time, a thermal change was found on IR thermography, 31.83℃ at fibular area, 31.45℃ at dorsal area of the foot: specifically, the temperature of the fibular area was elevated by 0.75℃ and dorsal area of the foot was decreased by 0.15℃. The IR thermography images show thermal changes in pre-operation (Pre-op) with compression & without compression of the mass (Fig. 1E and Table 1). After operation, IR thermography of both legs was performed at POD 1month. Temperature was 31.43℃ at fibular area, 31.40℃ at dorsal area on the foot. When the excision site was compressed, temperature was 31.49℃ at fibular area, 31.32℃ at dorsal area. There is no nerve compression sign and thermal elevation like pre-op status (Fig. 1F and Table 1).

Case 2

In sixty-four years old female patient, one thick walled cystic mass was incidentally found in posterior aspect of the left. psoas muscle through abdomen-pelvic CT study. The mass was located on left side L3 vertebral level. It was about 4.8×4.8 sized and round shaped (Fig. 2A). There was no degenerative lumbar disease such as herniated lumbar disc or lumbar stenosis (stenosis of foramen). The patient had undergone intermittent mild tingling pain of left lower extremity. The radiologic reading of the mass was Schwannoma (assumed benign mass). The direction of the treatment was decided to observation. In the IR thermography, there was no significant difference of the temperature of the body (Fig. 2B). However, there was hypothermia along the L3 dermatome of the left lower extremity. ΔT of the both lower extremities was -0.66℃ on pretibial (Fig. 2C).

Case 3

A fifty-five years old male patient had suffered from left arm tingling pain and weakness (motor grade III) for three months. In cervical spine MRI, enhanced mass was located in nerve root of the C7 and C8 (Fig. 3A). He underwent operation under intraoperative neuro-monitoring. The mass was gross totally removed and pathologic diagnosis was myxoid liposarcoma (Fig. 3B). In the preoperative IR thermography, hyperthermia was found around mass area (anterior neck and chest) and hypothermia on back area around mass and distal area of the both upper extremities. The difference of the temperature of anterior area around the mass was +0.19℃ and it of the back area was -0.9℃ (Fig. 3C and D). The temperature of the distal upper extremities were -0.53℃ (Fig. 3E). Because of more broad distribution of the local hyperthermia (not corresponded with dermatome), we assumed that the difference of the temperature on anterior area was not significant. Dermatomal hypothermias of the back area

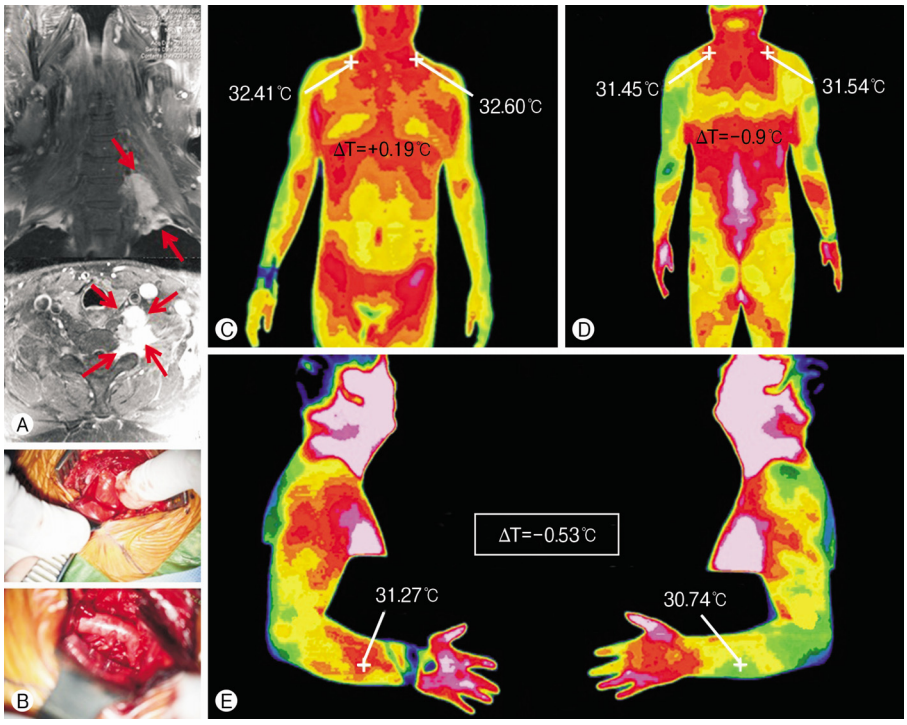

Fig. 3. (A) A mass is identified with irregular margin in left C7, 8 nerve roots trough cervical MRI scan with gadolinium enhan- cement. (B) Gross total removal of the mass without injury of normal nerve. (C) Broad distribution of hyperthermal area of the anterior body side, it is not significant sign. (D) Hypothermia of the on posterior body side (⊿T= -0.9℃). (E) Hypothermia of the distal area on the upper extremities according to C7, 8 dermatome (⊿T= -0.53℃).

and distal upper extremities were considered as significant results.

Case 4

A forty-seven years old female had palpable mass about 2.43×1.16×0.8 cm sized at right axillary area (Fig. 4A). She had no specific symptom and radiologists assumed that it was probable benign peripheral nerve sheath tumor. In the IR thermography, there was hypothermia around mass area (⊿T on both axillaries was -0.57℃) (Fig. 4B). Hyperthermia was on the proximal shoulder area (⊿T= +0.43℃) (Fig. 4C). Hypothermia was on the distal area, upper extremities, from the mass and the differences of the temperature were -0.19℃ and -0.28℃ (Fig. 4D and E). The IR thermography with compression test, there was hyperthermia on shoulder area (⊿T= +0.51℃) (Fig. 4F) and hypothermia was on the distal area from mass (⊿T were -0.34℃ and -0.83℃) (Fig. 4G and H). There was bigger difference of the temperature on the ventral portion of the distal area than dorsal portion of it.

Case 5

A sixty-six years old male patient had tingling pain around left axillary mass. The pain became severe and spread out left arm when the mass was compressed. We decided to remove the round shaped mass. The mass (2×2 cm sized on MRI) was gross totally removed preserving around normal nerve sheaths (Fig. 5A and B). The pathologic diagnosis was Schwannoma. In the preoperative IR thermography, there was hypothermia on distal area according to ulnar nerve (upper extremities). ⊿T on distal area were -0.37℃ at mid ulnar nerve area and -0.37℃ at distal ulnar area (around wrist) (Fig. 5C). In 8 day after surgery, the patient suffered from left wrist drop (motor grade I). In the IR thermography at that time, lower hypothermia was on the left wrist area. The temperature gap of the both wrists became increased (⊿T= -0.64℃) (Fig. 5D). After 1month, he recovered his left wrist drop (motor grade IV-V). The difference of the temperature on the both wrists became smaller (⊿T= -0.29℃). Moreover, the difference of the temperature on both distal areas (both

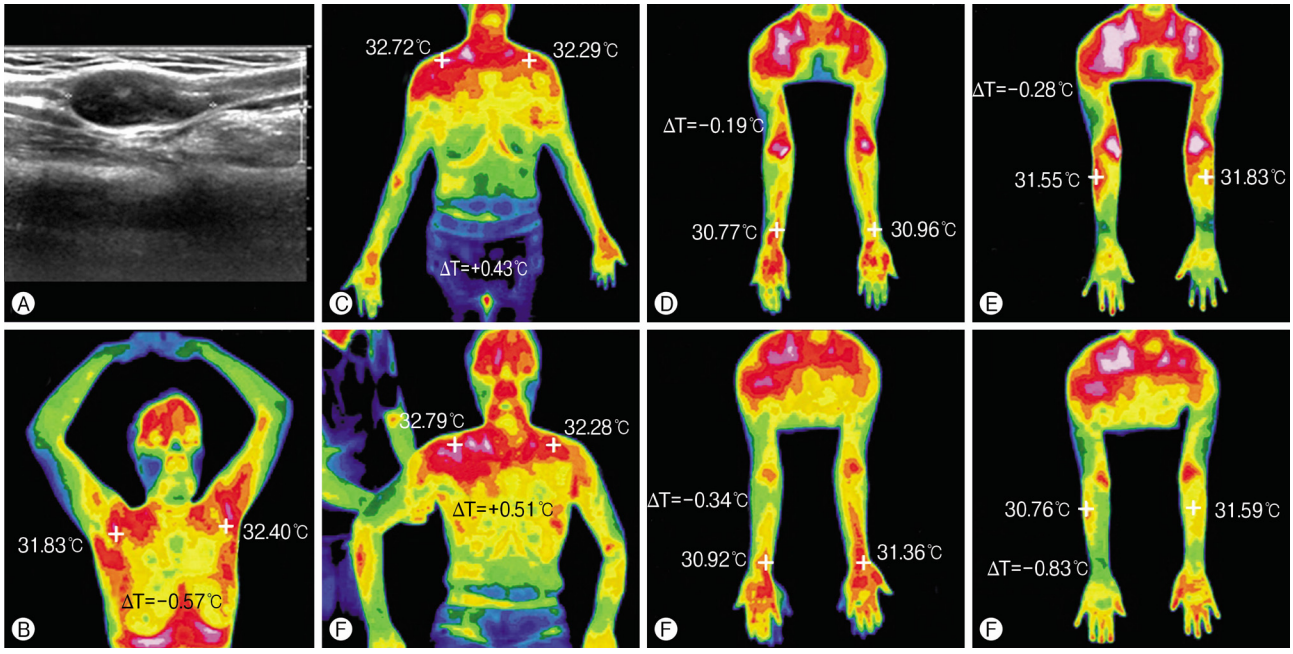

Fig. 4. (A) A mass is identified and the size of the mass is measured through ultrasound (about 2.43×1.16×0.8 cm). (B) Hypothermia around the mass in Rt. axillary. (C) Hyperthermia on the anterior body side without compression test (⊿T=0.43℃). (D) Hypothermia on distal area of upper extremity according to proximal ulnar nerve (⊿T= -0.19℃). (E) Hypothermia on distal area of wrist according to distal ulnar nerve (⊿T= -0.28℃). (F) With compression test, hyperthermia on the anterior body side (⊿T=0.51℃). (G) After compression test, hypothermia on distal area of upper extremity according to proximal ulnar nerve (⊿T= -0.34℃). (H) After compression test, hypothermia on distal area of wrist according to distal ulnar nerve (⊿T= -0.84℃).

Table 2. Results of Infrared thermography study in 5 cases. (TR: total resection, GR: gross total resection, Dx.: pathologic diagnosis, Cx.: complication, Schwann: Schwannoma, LPS: liposarcoma, upper: upper from lesion, lower: lower from lesion, distal: distal area from the mass according to dermatome of the involved nerve)

	Sex/ age	Lesion	Op.	Dx.	Pre-op △T(℃)	Pre-op △T(℃) With comp.	Post-op △T(℃)	Cx.
Case 1	F/52	Right. deep peroneal nerve	TR	Schwann.	upper: hyperthermia lower: hyperthermia	upper: hyperthermia lower: hyperthermia	Compression: upper: isothermia lower: isothermia	
Case 2	F/64	Left. psoas muscle		Schwann.	lesion: non specific distal: hypothermia			
Case 3	M/55	Left C7, 8 nerve root	GR	Myxoid Liposrcoma	lesion: isothermia distal: hypothermia			
Case 4	F/47	Right upper arm		Schwann	lesion: hyperthermia distal: hypothermia	lesion: isothermia distal: hypothermia		
Case 5	M/66	Left axillary	TR	Schwann.	lesion: hyperthermia distal: hypothermia	lesion: isothermia distal: hypothermia	POD8: hypothermia POD30: hypothermia Recover with Sx.	Wrist drop

upper extremities) became smaller too (⊿T= -0.18℃) (Fig. 5E). There were slight differences of the skin temperature between around the mass and opposite site (⊿T= -0.09℃) (Fig. 6A). In the preoperative IR thermography with compression test, the difference of the temperature around the mass and opposite site was slight too (⊿T= -0.01℃) (Fig. 6B). Otherwise, there was more decreased hypothermia on the distal area (according to ulnar nerve) with compression of the mass

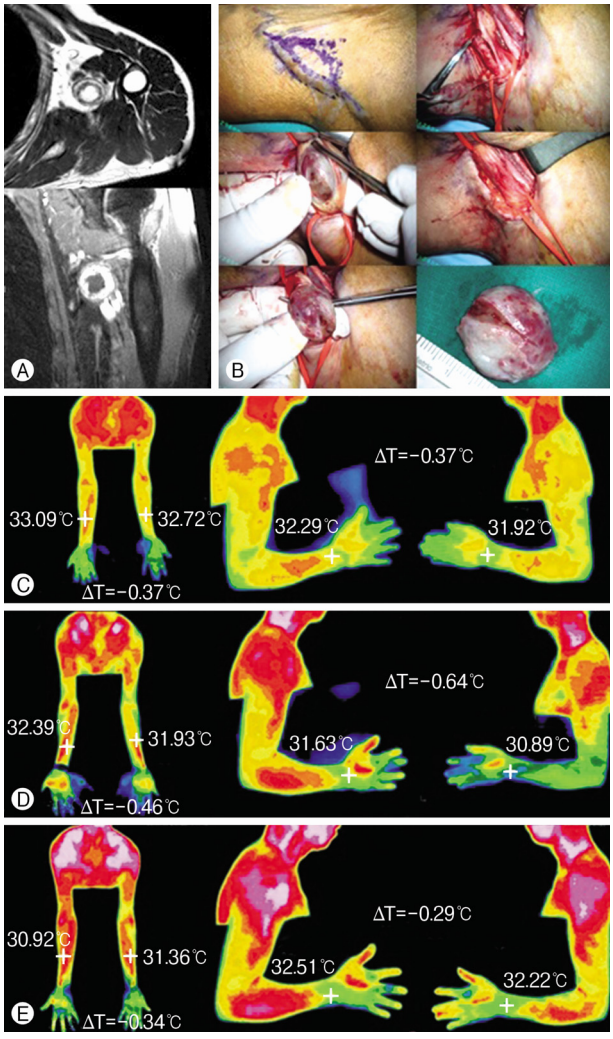

Fig. 5. (A) A mass with well divided margin is identified through MRI scan. (B) Surgical excision of the mass with preservation of around normal nerve tissue, round shape and 2×2 cm sized mass. (C) Preoperative IR thermography without compression test, Hy- pothermia on the distal area of the upper extremities and wrist (⊿T=-0.37℃). (D) Postoperative 8 day, hypothermia has thermal gap rises on the wrist with neurologic deficit (wrist drop) (⊿T= -0.64℃). (E) After 1 month, hypothermia has smaller ther- mal gap on upper arm and wrist (⊿T= -0.18℃ and ⊿T= -0.29℃).

and the temperature gap of distal area increased (⊿T= -0.17℃ → -0.27℃) (Fig. 6C and D).

The preoperative IR thermography was done all 5 cases. The skin temperatures around the peripheral nerve tumor origin were hyperthermia or wider warm area in 3 cases and there were non-specific findings in 2 cases. Dermatomes distal area from tumor lesion were hypothermia in 4 cases and hyperthermia in 1 case. In 3 cases, IR thermography with compression was performed at the tumor lesion. One case showed more hyperthermia around the tumor area and the dermatome distal from tumor area. 2 cases showed more hypothermia along dermatome distal from tumor area.

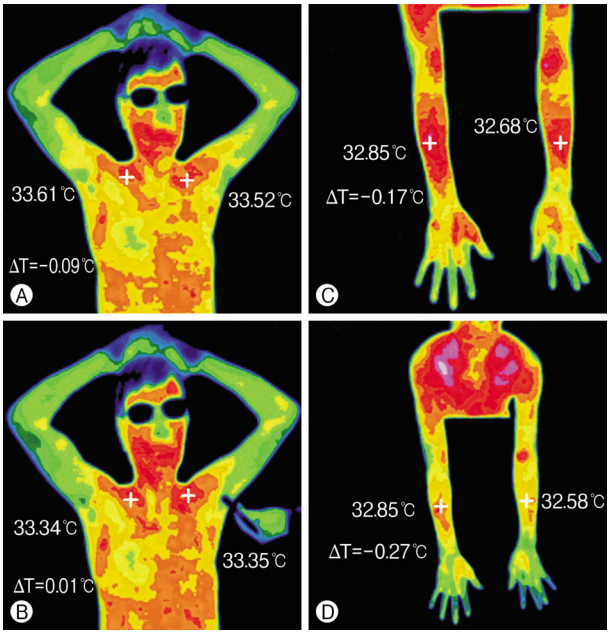

Fig. 6. (A) Preoperative IR themography without compression test, hypothermia on the area of the anterior body side (⊿T= -0.09°C). (B) Preoperative IR themography without compression test, hypothermia on the distal area of the dorsal side upper extremities (⊿T= -0.17°C). (C) With compression test, preopera- tive IR themography, isothermia on the area of the anterior body side (⊿T=0.01°C). (D) With compression test, preoperative IR themography, hypothermia on the distal area of the dorsal side upper extremities (⊿T= -0.27°C).

Postoperative IR thermography of one patient showed normal thermal difference around tumor and dermatome distal from tumor at compression test. Another one patient developed postoperative wrist drop was occurred. On postoperative 8th day, IR thermography showed severe hypothermia at palsy area and it was recovered near normal on postoperative 30th day with patient's symptom improvement (Table 2).

DISCUSSION

In IR thermography, the thermal difference of healthy body shows almost symmetric distribution[1,3]. However, in a patient with injury of some lesion, there is significant thermal difference[1]. In this idea about relationship pain and skin thermal difference, the IR thermography has been developed and used[1,4]. Wexler et al. first used thermography to evaluate

pain, there were cold areas on the affected side of the patients with traumatic cervical syndrome[1]. Moreover, abnormal skin surface temperature related to spinal problem was identified as hypothermia[4]. The studies involving IR thermography with neurology were performed a special form of neuropathic pain that develops after a minor trauma in extremities[1]. In 2002, Soldo-Butkovic et al. performed the characterization of thermal patterns in neurologically normal subjects and patients with affection of peripheral neural structures of the lumbosacral region[1,3]. The authors concluded that it can be a reliable sign of peripheral nervous system lesion at this specific localization[3,5]. They proposed that this diagnostic criterion can be introduced in the clinical practice[5,6].

The peripheral nerve sheath tumors (PNSTs) are a group of tumor that arise from not only peripheral nerves but also the various elements of nerve sheath (for example, Schwann cells and perineural fibroblasts)[7]. Nevertheless, PNSTs are rare (less than 1% of the neural tumor) and mostly benign[7,8]. The risk of developing a malignant PNST is estimated at 0.001% in the general population[6,7]. Because of the compression effect of the mass, some patients have pain around the mass or distal area according to involved nerve[9]. Therefore, total removal of the mass is recommended. However, there is often great difficulty in correctly delineating the tumor and healthy nerve structures[7,9]. The resection of a benign PNST and the preservation of unaffected nerve fascicles are of the utmost importance to maintaining neuromuscular function[9]. Therefore, preoperative nerve visualization and accurate planning of surgery and reconstruction are of utmost importance[8]. Recently, ultrasound and advanced MRI scan technologies are used for preoperative imaging[7,8,10].

Some authors reported that thermographic changes in patients with sensory-motor neuropathy are an early sign in the detection and prevention of risk of foot injury[3]. So, they suggested thermography usage as a method for diagnosis and dynamic evaluation of patients with peripheral sensory-motor polyneuropathy[3]. And the other authors (Gradl et al.) reported that thermography showed 58% of sensibility and 66% of specificity[3,11]. Again, thermography was used as a complementary tool for neural disorder diagnosis[3,4]. In case 5, there was neurologic deficit (wrist drop) and raised thermal gap (hypothermia). We assumed that the relation of neurologic injury and skin thermal change according to distributed distal nerve is very organized. Therefore, the IR thermography has a possibility to detect neural damages.

Liposarcoma (LPS) is the most common type of soft tissue sarcoma (STS) of the extremities in adult, accounting for 25 % of the STS[12]. The LPS subtypes vary widely in their histological appearance and biological behavior[12,13]. The World Health Organization (WHO) divides LPS into five distinct subtypes: atypical lipomatous tumour (ALT)/well-differentiated LPS, dedifferentiated LPS, myxoid LPS, pleomorphic LPS, and LPS not otherwise specified. The mainstay of treatment for extremity STS involves limb-sparing surgery[12,14]. However, adjunct radiation therapy has an increasingly important role in the treatment of STS[12,14]. In case 3, we performed grossly total removal of the mass, but we didn't perform the radiotherapy. Therefore, close follow up of the case 3 would be needed.

IR thermography of peripheral nerve tumor can visualize the thermal change along the involved nerve dermatome distally from tumor. The role of IR thermography is still limited as a diagnostic tool because it is doubtful that thermography is able to identify the entire characteristics of neurogenic dysfunction and disability. Nerve compression test can show more thermal difference than standard IR thermographic method. We need more data to analyze the exact visual findings and the benefits of IR thermography for the peripheral nerve tumors.

ACKNOWLEDGEMENT

I certify that this manuscript is an unique submission and is not being considered for publication with any other source in any medium. The authors have no conflict of interest to declare.

REFERENCES

1. Schmidt M, Kasprian G, Amann G, Duscher D, Aszmann OC. Diffusion tensor tractography for the surgical management of peripheral nerve sheath tumors. Neurosurg Focus 2015; 39:E17.
2. Cho YE, Kim YS, Chang HY. Clinical Efficacy of Digital Infrared Thermographic Imaging in Multiple Lumbar Disc Herniations. J Korean Neurosurg Soc 1998;27:237-45.
3. Neves EB, Vilaca-Alves J, Rosa C, Reis VM. Thermography in neurologic practice. Open Neurol J 2015;9:24-7.
4. Burke-Smith A, Collier J, Jones I. A comparison of non-invasive imaging modalities: Infrared thermography, spectrophotometric intracutaneous analysis and laser doppler imaging for the assessment of adult burns. Burns 2015; [in press].
5. Park JY, Hyun JK, Seo JB. The effectiveness of digital infrared thermographic imaging in patients with shoulder impingement syndrome. J Shoulder Elbow Surg 2007;16:548-54.
6. Onimaru R, Hida K, Takeda N. Three-dimensional conformal fractionated radiotherapy for spinal schwannoma with a paravertebral or an intraosseous component. Jpn J Radiol 2015 [in press].

7. Gosk J, Gutkowska O, Martynkiewicz J, Bąk M, Hałoń A. Schwannoma of the medial cutaneous nerve of the arm: A rare location with concomitant compression neuropathy of the ulnar nerve. Folia Neuropathol 2015;53:275-80.
8. Salunke AA, Chen Y, Tan JH. Intramuscular schwannoma: Clinical and magnetic resonance imaging features. Singapore Med J 2015;56:555-57.
9. Patel TD, Shaigany K, Fang CH, Park RC, Baredes S, Eloy JA. Comparative analysis of head and neck and non-head and neck malignant peripheral nerve sheath tumors. Otolaryngol Head Neck Surg. 2015 [in press].
10. Ali ZS, Pisapia JM, Ma TS, Zager EL, Heuer GG, Khoury V. Ultrasound evaluation of peripheral nerves. World Neurosurg. 2015 [in press].
11. Lee YS, Paeng SH, Farhadi HF, Lee WH, Kim ST, Lee KS. The effectiveness of infrared thermography in patients with whiplash injury. J Korean Neurosurg Soc 2015;57:283-88.
12. Wortman JR, Tirumani SH, Tirumani H, et al. Neoadjuvant radiation in primary extremity liposarcoma: Correlation of MRI features with histopathology. Eur Radiol. 2015 [in press].
13. Steinmann S, Gali-Muhtasib H, Huebner K, et al. Hsp90 inhibition by AUY922 as an effective treatment strategy against myxoid liposarcoma. Cancer Lett 2015;367:147-56.
14. Adamesteanu MO, Enache V, Zamfirescu D, Lascar I. Limb-sparing surgery as an alternative for limb amputation in an invasive myxoid liposarcoma-case report. J Med Life 2015; 8:218-25.