DOI: 10.4149/BLL_2023_090

Bratisl Med J 2023; 124 (8)

578–582

CLINICAL STUDY

Infrared thermography as a complementary method when diagnosing birth-related brachial plexus injury

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ABSTRACT

OBJECTIVES: The main objective of this study was to determine whether infrared thermography could be used as an efficient technique to evaluate the impact of a birth-related brachial plexus injury on the temperature of the injured arm and whether it could be used as a complementary method when diagnosing this injury in clinical praxis.

BACKGROUND: Clinically, the brachial plexus injury is a peripheral paresis, which occurs when nerves that send signals from the spinal cord to the shoulder, arm, and hand are stretched or compressed. In principle, the brachial plexus injury, as a long-lasting injury, should be causing hypothermia of the injured arm.

METHODS: The usage of contactless infrared thermography could offer a “new view” of the diagnostic process in this case. The present study, therefore, describes a process of clinical infrared thermography examination of three patients of different age and presents results from those examinations.

RESULTS AND CONCLUSION: From our results, it can be confirmed that the birth-related brachial plexus injury affects the temperature of the affected arm, especially in the area of the cubital fossa, to an extent that the thermal camera is capable of detecting significant temperature differences between the healthy and injured arms *(Tab. 3, Fig. 7, Ref. 13)*. Text in PDF *www.elis.sk*

KEY WORDS: birth brachial plexus injury, upper type palsy, peripheral palsy, infrared thermography.

Introduction

The objective of this study was to state whether it can be useful and profitable to use infrared thermography as an additional diagnostic tool when diagnosing the birth-related brachial plexus injury. To find the answer to this enquiry, it was necessary to clarify whether there exists a relation between the temperature of the arm affected by the birth-related brachial plexus injury and the injury itself.

Birth-related brachial plexus injury

Brachial plexus injury is a peripheral paresis with an incidence that varies from one to two cases for every 1,000 births (1). It is caused during delivery and involves injury to any nerve of the brachial plexus during birth.

This complication varies from difficult cases (10–20 %) that must be treated with reconstructive surgery, to most common and manageable cases that rely on spontaneous recovery, which is usually referred to as conservative treatment (2, 3).

Regarding the statistical prevalence, the male gender and the right side of the body prevail slightly over other cases. Main risk factors are a large foetus (over 4,000 g) and pelvic position. Other factors that should be considered are maternal obesity and diabetes during pregnancy, use of birth pliers and prolonged second stage of labour. On the other hand, caesarean sections appear to be protective (2, 4).

Birth brachial plexus injuries can be divided into two groups, namely complete and incomplete types. The incomplete types are further classified as upper, lower, and total types. Upper-type palsy is known as Erb’s palsy involving C5 and C6 or C5, C6 and C7 roots. The typical arm position of the patient is extension in the elbow, pronation in the forearm, and flexion in the wrist called the “waiter’s tip” position. Lower type palsy is called Klumpke’s palsy, where paralysis is confined to the hand. Total-type palsy involves the whole plexus, where the limb is entirely flaccid. Upper-type palsy is the most common form, followed by total-type palsy (5). The current study focuses only on upper-type cases.

Recognition and determination of the severity of the injury is usually done by electromyography (EMG) examination. The EMG signal is a biomedical signal that measures electrical currents generated in muscles during their contraction, which represents neuromuscular activity. Hence, the EMG signal is a complicated signal controlled by the nervous system that depends on anatomical and physiological properties of muscles (6).

Infrared thermography for medical use

An infrared thermography camera is a device, which creates an image based on infrared radiation, which is otherwise not visible

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Acknowledgements: The study was supported by the Masaryk university grant MUNI/A/1416/2021 and MUNI/A/1390/2022.

to human eyes. The infrared part of the electromagnetic spectrum consists of heatwaves and heat is the primary imaging parameter for an infrared thermography camera. Using this device in medicine can bring new opportunities, as it is possible to measure and visualize temperature of the human body and its distribution.

Thermal imaging offers a great advantage of real-time two-dimensional temperature measurement. With modern technology, a single image may contain several thousand temperature points recorded in a fraction of a second. The human body is homeothermic, that is self-generating and regulates the essential levels of temperature for survival. The human skin behaves almost like a blackbody with an emissivity of 0.96–0.98, which is an important factor for the use of the infrared thermography camera (7).

The last twenty years can be considered the beginning of the "clinical era" which means that the thermal camera is becoming a practical diagnostic device with many applications used in hospitals all over the world. When considering the thermal imaging camera for visualization of a plexus brachialis injury, it is important to clarify some facts about muscle thermal activity.

Muscle action is the most important source of increased metabolic heat. Therefore, contracting muscles contribute to temperature distribution at the surface of the human body (8).

Long-lasting injuries appear on a thermogram as hypothermic areas caused by reduced muscle contraction, and therefore by reduced heat production. Similar areas of decreased temperature have been found adjacent to peripheral joints with a reduced range of motion due to inflammation or pain (4, 9).

As brachial plexus injury causes damage to the upper nerves it has a significant impact on the temperature of affected muscles due to their reduced metabolic activity (9).

Materials and methods

Contactless infrared thermography (IRT) measurement was performed in order to specify its benefit towards diagnosing brachial plexus injury. The IRT was performed prior to the standard EMG examination of the patients. The results of EMG measurement, performed to assess whether or not a patient suffers from brachial plexus injury were also used, yet in this case, for a qualitative comparison with IRT measurement results.

For IRT measurement, the Workswell WIC 640 (Workswell, Czech Republic) infrared camera with uncooled bolometric detector was used. Its resolution is up to 640x512 pixels and it has a thermal sensitivity of ≤ 30 mK (0.03 °C) and accuracy of ± 2 % or ± 2 °C, according to the manufacturer's indication. This thermal camera was quality-assured against a blackbody before use. The monitored area was scanned at constant room temperature (25 °C) and standard humidity (45–49 %). To keep the measurement conditions constant during the radiometric sequence recording, the windows and door were kept closed.

The infrared camera was used in a sequence-recording mode. It recorded a radiometric video with a recording frequency of 30 Hz (30 frames per seconds) so that the specific thermograms for analysis could be selected later. The emissivity was set to the value of 0.98 – standard human body emissivity (10). Postprocessing of the radiometric video and analysis of the thermograms were performed using CorePlayer software (Workswell, Czech Republic).

During the measurement, elder patients stayed in a straight standing position with arms loose along the body and were scanned from the frontal view. The smallest patient at 2 months of age was lying on his back and was also scanned from the frontal view. The regions of measurement interest were the arms and inner side of the elbow area (cubital fossa) of the patients. To be able to compare the results between the left and right arms, the patients were scanned by the infrared camera from a distance of 1 meter first, in order to capture both arms in the field of view. Later, both elbow joint areas (cubital fossa regions) were scanned separately and in a greater detail from a distance of 60 cm.

Patients´ specification

Measurements were performed on three male patients with upper-type palsy due to birth-related brachial plexus injury during their standard neurological examination. Patients differed in age as follows: 2 months (patient 1), 7 years (patient 2) and 10 years (patient 3). For patient 2, the difficulties associated with worsened hand-movements had become more significant over the past year before IRT and EMG measurement. Difficulties of patients 1 and 3 were of a standard nature with respect to brachial plexus injury.

The treatment of the elder patients (2 and 3) was only conservative, as their type of injury did not require a surgical solution. The treatment of patient 1 has not been specified yet, as he was too young at the time of the IRT examination, and the process of self-recovery can begin spontaneously at a later time.

Statistical evaluation

The data that were obtained from the detailed measurement of the surface temperature of cubital fossa regions were statistically evaluated using STATISTICA software (StatSoft CR s.r.o, Czech Republic). For graphical visualization of statistical data, box plots were used. The selected ROIs (regions of interest) that were evaluated consisted of up to 4,400 pixels (2,800 px for patient 1; 3,810 px for patient 2 and 4,400 px for patient 3). This means that the data for each statistic were obtained from at least 2,800 points of temperature measurement. The differences in data were tested for the statistical significance using the Mann-Whitney test at the significance level of $p = 0.05$. (Injured and healthy arms´ surface temperatures were always tested.) For each analysed area, the average, standard deviation, minimum and maximum temperature-corresponding values were determined.

Results

With validity for all three patients: EMG examination of the injured upper limb (the left one for patient 2 and the right one for patients 1 and 3) showed a normal finding in nerve conduction studies while the needle EMG examination from *musculus deltoideus* and *musculus biceps brachii* detected chronic reinnervation changes; however, acute axonal changes were not detected. In summary, EMG measurement confirmed a slightly reduced ability of muscle action caused by neuromuscular dam-

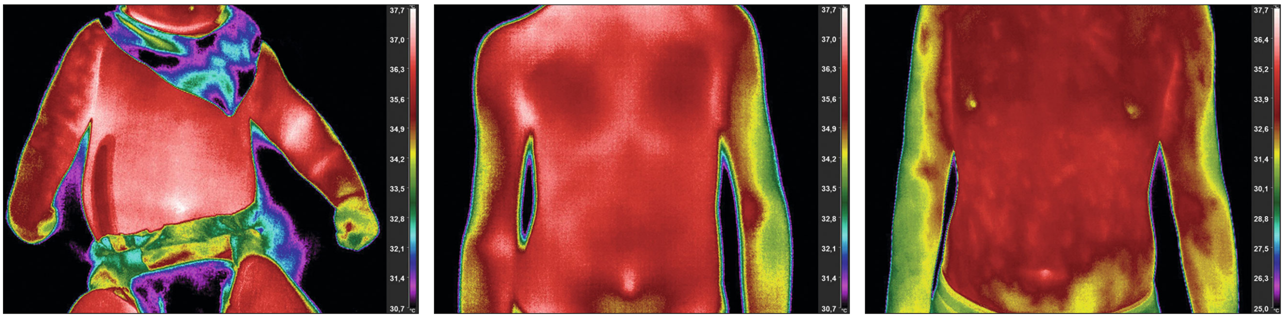

Fig. 1. Arms temperature distribution – patients with birth-related brachial plexus injury. (From the left: patients 1, 2 and 3).

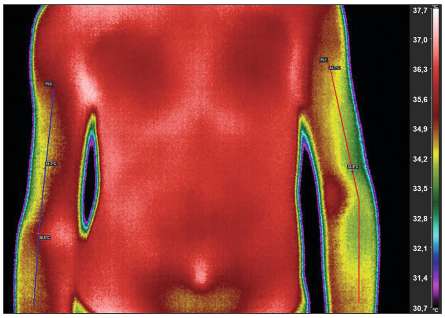

Fig. 2. Left and right arms´ temperature distribution. Measurement lines that correspond to the chart in Figure 3, are marked.

Tab. 1. Comparison of healthy and injured arms´ surface average temperatures. The measurement lines for patient 2, as for illustration, are marked in Figure 2.

	Healthy arm´s average temperature (°C)	Injured arm´s average temperature (°C)	Average difference in L. and R. temperatures
Patient 1	36.8	36.2	0.6
Patient 2	35.0	34.2	0.8
Patient 3	32.0	31.1	0.9

Tab. 2. Comparison of left and right arm average temperature in the cubital fossa area. Patient 2 ROIs, as for illustration, are marked in Figure 4.

	Healthy cubital fossa area´s average temperature (°C)	Injured cubital fossa area´s average temperature (°C)	Average difference in L. and R. areas´ temperatures
Patient 1	37.4	36.6	0.8
Patient 2	36.0	34.7	1.3
Patient 3	33.2	31.9	1.3

Tab. 3. Statistical evaluation of cubital fossa RIOs. Patient 2 ROIs, as for illustration, are marked in Figure 4.

	Healthy cubital fossa area			Injured cubital fossa area			M-W test
	S. D.	Max. (°C)	Min. (°C)	SD	Max. (°C)	Min. (°C)	
Patient 1	0.47	37.95	35.38	0.49	37.49	34.78	+
Patient 2	0.33	36.93	35.04	0.49	35.93	33.5	+
Patient 3	0.40	34.10	31.98	0.47	33.32	30.74	+

age in all three patients, only the severity was different for each of them.

The IRT measurement confirmed a reduced temperature of the affected limb. By comparing the temperatures of upper limbs, it can be said that the injured upper limb was colder than the other one, especially in the cubital fossa region, in all three cases.

The sample thermograms of patients are presented in Figure 1.

To be able to determine whether the injured arm is significantly colder, it is also important to perform a detailed quantitative temperature analysis to confirm the pathology. Figure 2 shows an illustration of the thermogram analysis of patient 2. It was confirmed that the temperature difference between left and right arms was existent.

In this case, the average temperature on the left (injured arm) measured line was rounded to 34.2 °C, which is 0.8 °C lower than the average temperature of the right (healthy arm) measured line, which was rounded to 35.0 °C. Anatomically, the measured line was positioned along the *musculus biceps brachii* and *musculus brachioradialis*.

Table 1 displays a summary of the left and right arms´ average temperature findings for all three patients. (For patients 1 and 3, the left arm was considered the healthy arm, while for patient 2, it was the right one.)

Another detailed thermal analysis was performed along the inside part of the cubital fossa region. For all three patients, the colder region was always located on the injured arm. In Figure 4, an example of measurement analysis on the cubital fossa (for patient 2) can be seen.

Tables 2 and 3 contain a summary of the statistical analysis of the cubital fossa region for all three patients. All measurements, which were performed on patients of different age, confirmed that the colder region was always located on the injured arm.

Figures 5 to 7 show box plots that correspond to the analysed areas of patients' cubital fossa. These graphs describe the thermal distribution difference in the cubital fossa regions of both arms, which was found to have statistically significant differences according to the Mann-Whitney test.

Discussion

Many studies that have been carried out on healthy subjects show only small differences in surface temperature between sym-

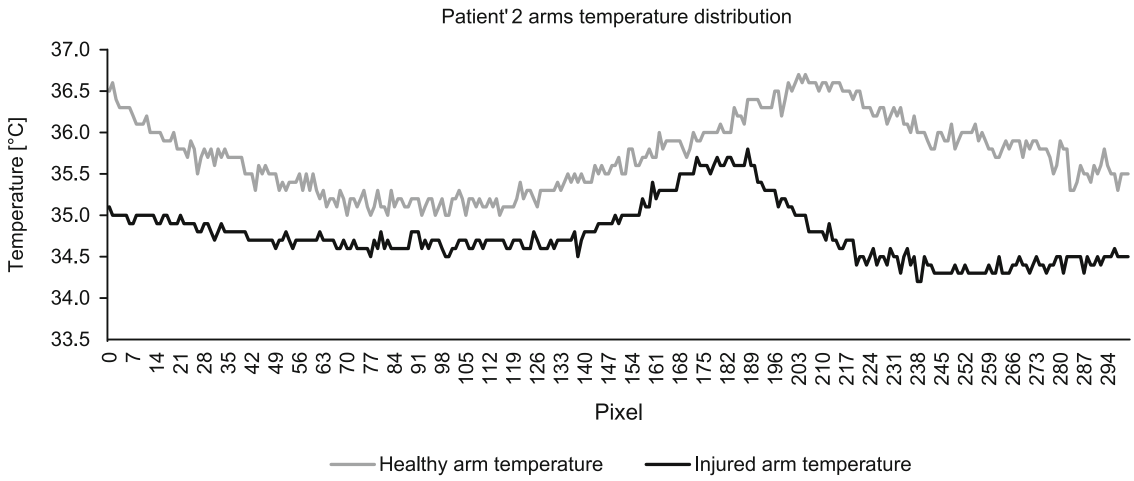

Fig. 3. Chart of the temperature distribution related to the measurement lines from Figure 2.

metrical body areas on the left and right sides when no pathology occurs. Usually, only 0.6–0.7 °C of thermal difference is considered healthy without any risk (11, 12). Any detected significant asymmetry of more than 0.7 °C can be defined as abnormal and may indicate a physiological or anatomical variance. Some types of tumours and other pathological conditions, especially inflammation, can lead to hyperthermia, while degeneration, reduced muscle activity, poor perfusion, and certain types of tumours may cause hypothermia (11).

From the results presented above, it follows that the average temperature differences between left and right (healthy and injured) arms are significant enough to confirm the presence of some pathology according to previous studies. The minimum average thermal difference between arms´ temperatures for all three patients was 0.6 °C. This number is set on the border of the significant value. An assessment aimed strictly only at the cubital fossa region yielded the minimum average thermal difference of 0.8 °C, which is significant enough.

Furthermore, the Mann-Whitney test also confirmed the existence of a statistically significant difference between injured and healthy arms´ temperatures in the cubital fossa regions. The fact that arm temperatures in the cubital fossa regions differ significantly ($p < 0.05$) means that the temperature of the injured arm must have been affected by birth-related brachial plexus injury.

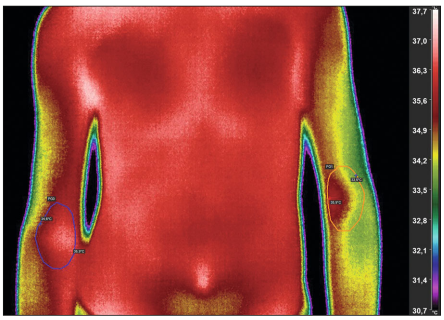

Fig. 4. The cubital fossa region IRT measurement. ROIs corresponds to the chart in Figure 6.

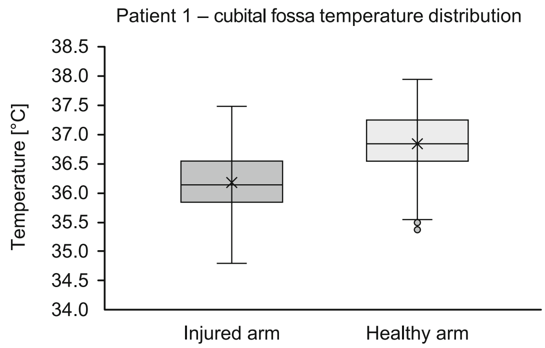

Fig. 5. Graphical representation of temperature distribution in the area of cubital fossa – patient 1.

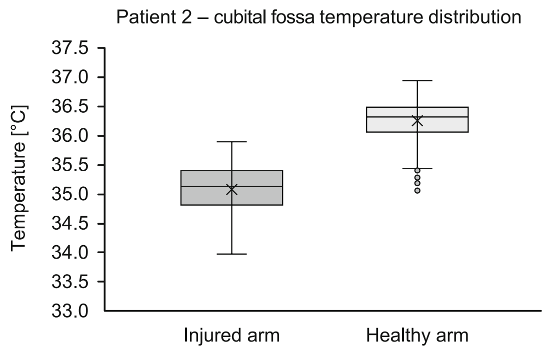

Fig. 6. Graphical representation of temperature distribution in the area of cubital fossa – patient 2.

Taking into account the results of the EMG examination, it can be said that the presence of birth-related brachial plexus injury affects the arms´ surface temperature, probably due to reduced muscle activity and perfusion of affected arms, as in the presented cases.

According to the results provided so far by this study, when using the IRT technique, it is possible to detect the birth-related

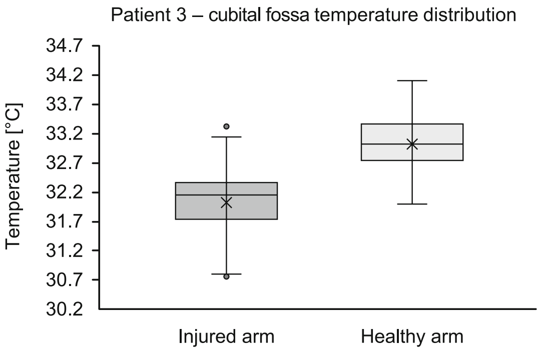

Fig. 7. Graphical representation of temperature distribution in the area of cubital fossa – patient 3.

brachial plexus and visualize it. The visualization of the injured area could also have a positive influence on the necessary rehabilitation process planning so that both physiotherapist and patient can see what needs to be emphasized during the rehabilitation process. This can be considered as an advantage of this additional diagnostic device to EMG.

The IRT measurement does not replace the EMG examination, but it can be helpful in locating the region of significant thermal difference when comparing the patient's arms. The IRT measurement should always be performed before the EMG is done since it is a non-invasive technique and it is a lot less stressful for children than EMG. The stress which occurs during EMG examination probably affects the body temperature (13), which would introduce bias into the IRT measurement results.

On the other hand, so far, only 3 male patients of different ages participated in the study due to the infrequent occurrence of the disease. This limited number causes some uncertainty and furthermore, it is not possible to claim with sureness that similar results are expected when diagnosing girls.

Furthermore, it must be mentioned that the examination in the case of the new-born, whose thermal difference between right and left arms was the lowest, was the most complicated due to difficulties associated with calming and positioning the patient.

In any case, this study presents primary outcomes that seem to be meaningful and can serve as a basis for further studies on this topic.

Conclusion

The main task of the study was to verify whether the thermographic measurement can be used as a reliable method to evaluate the temperature changes caused by a birth-related brachial plexus injury and whether it can serve as an additional method to help diagnose the birth-related brachial plexus injury in clinical praxis alongside the standard EMG examination.

These assignments have been answered successfully. Using the IRT technique during the neurological examination of the patients with birth-related brachial plexus injury provides additional information and visualizes its thermal impact. Also, it is a safe technique that tends to be convenient for being used in small children in particular.

Furthermore, taking into account the limited number of patients, it was verified that brachial plexus injury causes a decrease in the arm´s surface temperature. What is more, the temperature difference of the measured areas (i.e, of arms with an emphasis on the cubital fossa region) was significant enough to confirm the presence of pathology in all cases.

Finally, as hypothermia of the injured arms was detected in all cases, it can be concluded that all three patients suffered from reduced muscle activity due to birth-related brachial plexus injury, which was also confirmed by EMG examination.

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Received February 3, 2023.
Accepted March 7, 2023.