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ИНФРАЧЕРВЕНА ТЕРМОГРАФИЯ КАТО ДИАГНОСТИЧЕН МЕТОД ПРИ ОСТРА ИСХЕМИЯ НА ДОЛЕН КРАЙНИК

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INFRARED THERMOGRAPHY IMAGING AS A DIAGNOSTIC TOOL IN THE CASE OF ACUTE LOWER LIMB ISCHEMIA

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Abstract. Atherosclerosis is the major cause of cardiovascular diseases (CVD) in the world. It is a multifocal disease that leads to plaque formation and subsequent ischemia in the arteries of the body. Atherosclerotic obstructive peripheral artery disease causes disturbance of blood delivery to the tissues, which can be translated as temperature decrease on the skin surface, making surface temperature an important indicator of vascular health. Even though there are many classical diagnostic tools for assessing patients with peripheral vascular dysfunction, they have many limitations. On the other hand, infrared thermography imaging presents a noninvasive, relatively cheap, quick and reliable method that does not require direct doctor-to-patient contact. It provides a real time screening information of the tissue perfusion, based on the skin surface temperature. In this article, we present a case of a patient with type B aortic dissection, treated with an endovascular approach. A postprocedural closure device complication led to an acute left lower limb ischemia during the night, which was promptly diagnosed with the help of an onsite high-resolution infrared thermography optimized by specialized AI based software performed by the physician on duty followed by remote evaluation by the operator. The obstruction was treated immediately with successful endovascular recanalization and flow restoration and again evaluated with the thermographic camera confirming excellent tissue vascular result. Infrared thermography imaging can be a time-saving method for physicians, while being a very convenient method for the patient and that is why we advocate on the usage of specialized software supported high resolution thermography imaging as a supplementary diagnostic modality for patients with peripheral artery disease.

Key words: ischemia, peripheral artery disease, atherosclerosis, endovascular, infrared, thermography, camera, imaging

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Резюме. Атеросклерозата е основната причина за сърдечно-съдовите заболявания (ССЗ) в света. Тя е мултифокално заболяване, водещо до образуване на плаки и последваща исхемия в артериите на тялото. Периферната артериална болест води до нарушение в кръвоснабдяването на тъканите, което води до температурни колебания на повърхността на кожата. Това превръща температурата във важен показател за здравето. Въпреки че съществуват много класически диагностични инструменти за оценка на пациенти с периферна съдова дисфункция, те имат редица ограничения. От друга страна, инфрачервената термография представлява неинвазивен, сравнително евтин, бърз и надежден метод, който не включва пряк контакт на лекаря с пациента. Той осигурява скринингова информация за тъканната перфузия в реално време въз основа на температурата на повърхността на кожата. В тази статия представяме случай на пациент с дисекация на аортата тип B, лекуван чрез ендоваскуларен подход. Постпроцедурно усложнение на устройството за затваряне довежда до остра исхемия на левия долен крайник през нощта, която е своевременно диагностицирана с помощта на смартфон-монтирана инфрачервена термография, оптимизирана от специализиран AI софтуер, извършена от дежурния лекар и оценена от оператора. Обструкцията беше незабавно третирана с успешно възстановяване на кръвотока и отново оценена с термографската камера. Инфрачервената термография може да бъде метод, който спестява време на лекарите, като същевременно е много удобен за пациента, и затова ние съветваме да бъде използван като допълнителен диагностичен метод при пациенти с периферна артериална болест.

Ключови думи: исхемия, периферна артериална болест, атеросклероза, ендоваскуларно, инфрачервена, термография, камера, изображение

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Introduction

Every year more than 17 million lives are claimed by the global burden of heart diseases and stroke. The major cause of cardiovascular diseases (CVD) is atherosclerosis. Atherosclerosis is a multifocal disease, and most patients have more than one atherosclerotic plaque in different artery trees (coronary artery disease, peripheral artery disease, carotid artery plaques). Major risk factors for developing atherosclerosis and subsequent CVD are hypertension, dyslipidemia, diabetes mellitus, smoking, obesity, and the lack of physical activity. Lipid metabolism is a key part in the process of atherosclerosis. High-density lipoprotein (HDL) role is to uptake the cholesterol from the peripheral tissue and deliver it to the liver. This antiatherogenic mechanism of HDL is preventing the stenosis of blood vessels, by removing the excess cholesterol. This mechanism is specifically important for preventing peripheral atherosclerosis [1]. In the recent observational studies conducted by investigators, is suggested that little progress is made in the field of evidence-based management of vascular dysfunction [2]. It seems like the management of vascular diseases is more or less limited to the therapeutic interventions for modifiable risk factors. According to Doctor Jay Cohn and Dr. Daniel Duprez of the University of Minnesota a simple screening test for the early identification of vascular diseases is needed and more work should be directed in this field [2, 3]. In vascular dysfunction, there is a disturbance of blood delivery to the tissues, which causes a temperature variation on the skin surface, making temperature an important indicator of vascular health. Diagnosis of atherosclerotic plaque and peripheral vascular dysfunction can be made via ultrasound doppler (UD). Accurate measurements with UD are possible only if the blood vessel and its flow are well visualized and measured by the technician, so the method is more or less operator dependent [1]. Infrared thermography (IT) is a noninvasive, real-time diagnostic method that requires no direct contact with the patient and has a broad spectrum of applications. IT captures the natural infrared radiation (IR) energy from the human body, which in turn generates a thermographic image to allow tissue perfusion analysis. IT is fast, prompt and cost-effective method, since it uses a miniature infrared thermographic camera, which can be attached to a smartphone. In this article, we present a case of acute lower limb ischemia diagnosed via a smartphone-attached thermography camera [4, 5].

Case report

A 53-year-old male patient presented to the emergency department (ED) of our hospital with complaints of sudden back and abdominal pain, accompanied by nausea without vomiting and severe pain on both legs, more pronounced on the left side. On first examination, the patient was well built, with normal skin texture. He was hemodynamically stable with elevated blood pressure – 166/95 mm Hg, without a significant difference in both arms. His heart rate was 81 bpm and bilaterally symmetrical. The peripheral pulsations from both femoral arteries were missing. The ECG was normal with evidence of left anterior hemiblock. There were no heart murmurs on auscultation. The respiratory system was normal, with clear breath sounds. Our patient's past medical history was scarce with long-term arterial hypertension and dyslipidemia without any clear medical control. From the initial echocardiography, we detected a severe left ventricular hypertrophy and moderate aortic insufficiency. Because of acute aortic syndrome suspicion, a computer tomography angiography (CTA) scan was performed and revealed an aortic dissection (AD) of DeBakey Type III (Stanford B) with full obliteration of distal part of the abdominal aorta (Figure 1). A multidisciplinary heart and vascular team discussion was held. Due to the underlying life-threatening emergency condition, complicated by visceral and peripheral ischemia endovascular strategy was chosen.

The procedure was performed totally with the help of percutaneous intervention under a deep awake sedation, local anesthesia with three vascular access sites: 20-Fr left femoral access, 6-Fr right femoral access and 5-Fr left radial access for angiographic Pigtail catheter insertion. We placed a stiff guidewire retrogradely in the ascending aorta and implanted Valiant thoracic 36/219 mm stent-graft (Medtronic, Santa Rosa, Calif), Valiant thoracic 32/192 mm stent-graft and Sinus XL 32/100 mm (Optimed, Ettlingen, Germany) with fully isolated false lumen and successfully restored blood flow (Figure 2). During the postprocedural night, six hours after closing the 20-Fr left femoral access site with Manta closure device (Teleflex, PA, USA), the patient developed clinical symptoms of acute left lower limb ischemia (Figure 3). Based on our positive clinical experience with high resolution infrared thermography supported by specialized artificial intelligence-based software, the team on duty performed immediate bedside infrared thermography registration showing dramatic lack of tissue perfusion on the left leg. The pictures were immediately remotely evaluated by the main operator and suspicion for acute left common femoral artery thrombosis was reinforced. The patient was transferred to the cath lab for immediate intervention. From a contralateral 6-Fr crossover access we confirmed the suspicion of acute thrombosis of the left common femoral artery on the level of the Manta closure device. With the support of a 0.018"TrailBlazer™ support catheter (Medtronic) and a hydrophilic .018" angled Radifocus (Terumo) wire we managed to go through the occlusion. A series of balloon pre-dilatations were conducted with 6,0/60 mm, 7,0/60 mm and 8,0/60 mm balloons, after that we implanted an Everflex stent 8.0mm/100 mm (Medtronic, USA) with successful restoration of the blood flow (Figure 4). We took a series of thermographic images of the patient's limbs, before and after the Everflex stent implantation with clear evidences of diminished blood flow to the left leg and a corresponding change in the surface skin temperature from the TI. After the stent implantation, the TI showed higher surface skin temperature, which in turn correlates with the restored blood flow (Figure 5, Figure 6). The patient was hemodynamically stable, after the procedure, with no further access site complications. His antihypertensive therapy was optimized and on the fifth post-procedural day he was discharged from the hospital.

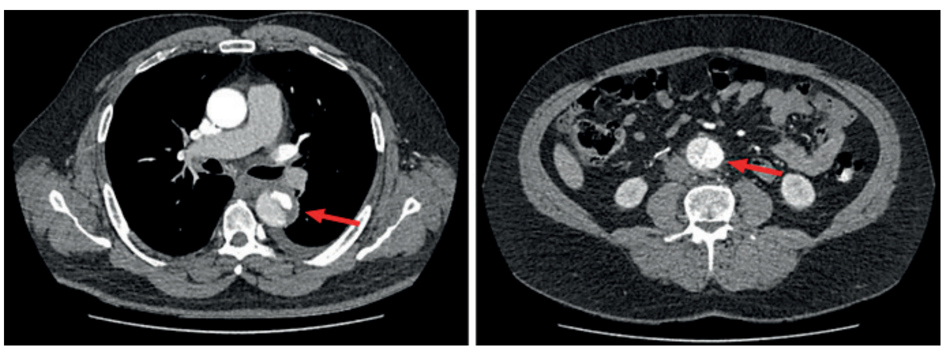

Fig. 1. Initial CTA scan images showing the aortic dissection (Stanford type B) at two different levels

Fig. 2. Aortography demonstrating the fully restored blood flow into the true lumen of the aorta

Fig. 3. Crossover access angiography showing complete obstruction of the common left femoral artery at the level of the implanted Manta closure device

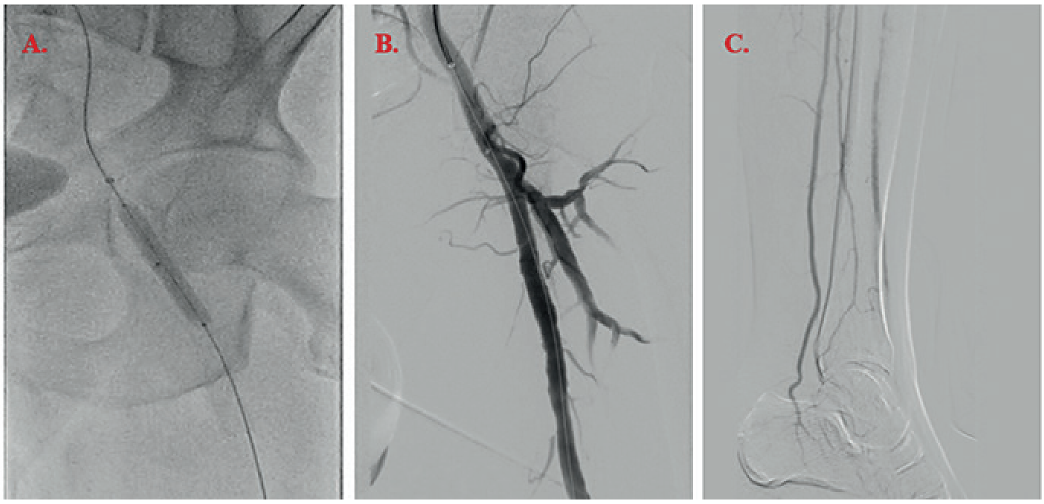

Fig. 4. A – Balloon dilatation after crossing beyond the obstruction. **B** – Angiography showing the successfully treated complication after the implantation of the Everflex stent 8.0/100 mm (Medtronic, USA). **C** – Angiography of the distal left limb arteries demonstrating the restored blood flow in the left lower leg

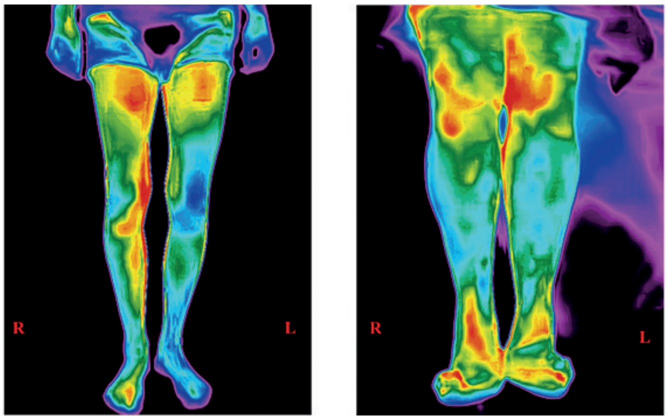

Fig. 5. Infrared TI before and after the emergent procedure. Left one – before, showing asymmetry in the thermographic images suggesting left leg ischemia; right one – showing full infrared thermography equalization, speaking about perfusion restoration after the recanalization

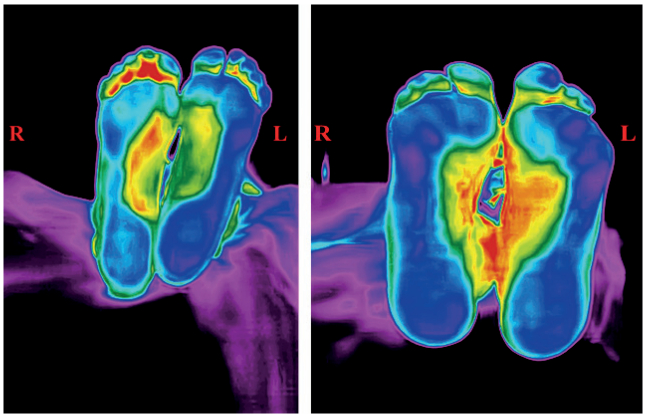

Fig. 6. Infrared TI demonstrating the surface skin temperature differences in the right and left leg, On the left image efore the stent implantation in the obstructed femoral artery showing significantly reduced temperature (hence blood flow) in the left foot and in the right image restored foot skin temperature t(hence restored blood flow suggested by the thermographic images) after the recanalization procedure

Discussion

Thermography imaging can be used for the detection of peripheral ischemia and for the evaluation of the treatment effect of percutaneous transluminal angioplasty (PTA). Peripheral ischemia leads to impaired blood flow into the limbs, and therefore the skin temperature in the affected limb is lower, well known by the clinical experience. We must bear in mind that infrared thermography imaging evaluates the surface temperature, not the internal. Surface temperature correlates with the blood flow in the arterial system and despite the fact that TI is a noninvasive method, it is reliable for diagnosis. A study by Staffa et al., evaluated the possible use of infrared thermography as a supplementary method to the ankle-brachial index used in assessing the treatment effect of PTA. They found a significant temperature difference between treated and nontreated limbs with a p value = .0035 [6]. Even though the temperature correlated with the ankle-brachial index (ABI), it is still questionable whether the observed change in the skin temperature may have been caused by some other reactions of the organism - increased temperature as a result of an inflammatory reaction or the activity/inactivity of the limb in the last couple of hours. We argue that because there are no studies to back up these claims, we can rule them out. Despite that, in order to maximize the accuracy of the TI, the imaging should be taken in the same position of the patient (horizontal/vertical) and after a fixed time of inactivity and same surrounding ambiental temperature. Because a low background temperature is important for sharper thermal images, we recommend taking the images in a room temperature environment. The sensitivity of the thermal imaging could be diminished if we take the images in a warm environment, because of the reduced temperature gradient. Another study conducted by Sturgeon et al., followed forty patients treated with PTA for stenotic or occlusive lower limb arterial disease. TI and other classic physiological tests (ankle brachial pressure index, toe pressure index, pulsatility index, and spectral waveforms) were performed at two separate time points after intervention – firstly 48 hours after the procedure and then 6-8 weeks later [7]. A significant increase in the temperature of the treated limbs after revascularization was observed, while no change was detected in the untreated limbs. Interestingly enough, the other physiological tools were useful in only 10 of the 40 patients. These results clearly present the limitations of the standard physiological methods used for the evaluation of lower limb arterial diseases. These limitations can be related to very calcify arterial vessels, patients with end stage renal disease, diabetes, and extreme age. TI not only proves to be a reliable tool for detecting limb arterial disease, but it shows a better result than the standard diagnostic tools [8].

TI has a number of advantages over the standard diagnostic tools used for peripheral artery disease. Not only, TI shows better results and higher feasibility, but the testing does not require any direct contact with the patient's skin, making it highly acceptable and safe for both sides. The technique can be repeated as many times as needed, without causing any discomfort or pain to the patient. The lack of direct contact with the skin has a significant advantage, particularly in the context of infection control. A large part of the patients with peripheral artery disease, have diabetes, kidney diseases, and are elderly and the infection control should be very strict [7, 8]. All of the clinical advantages of the TI come with the positives of the low price of the thermal camera. It is a simple, effective, and inexpensive tool in accessing cutaneous temperature as an indirect measurement of tissue perfusion. Keeping that in mind, it is important to mention that TI could find application in some rural regions. Even though, the diagnostic process of ischemia is mainly clinical, TI could be used as a diagnostic method in remote areas, where there is a lack of trained medical staff. Researchers report the effectiveness of TI for the differentiation of melanoma from benign cutaneous pigmented lesions [9]. This modality is found to be effective as a breast cancer screening tool and in detecting vascular tumors such as cutaneous hemangiomas and arteriovenous malformations and even in the follow up periods of arteritis [10-12]. In our case, we use a smartphone-mounted infrared thermographic camera. The thermographic sensors in these types of cameras can capture long-wave (8-14 mm) infrared light energy and has an effective working temperature range of 32°F to 212°F. Since, it contains both thermal and digital camera, the images are taken separately and then merged into one. In order to optimize the imaging quality, we suggest taking the picture at a distance of 60-70 cm from the patient. As shown from the case we presented, the infrared thermographic camera helped us to prove the acute ischemia and to visually demonstrate and evaluate the treatment effect of PTA.

Conclusion

The smartphone-based infrared TI is noninvasive, relatively cheap, quick, and reliable method that does not involve direct patient contact. It provides a real time screening information of the tissue perfusion, based on the skin surface temperature. Taking into account all the studies conducted and our team's experience we advocate on the usage of TI as a supplementary diagnostic modality for patients with peripheral artery disease. Infrared TI can be a time-saving method for physicians, while being a very convenient method for the patient. This technology holds promise in the future diagnostic process of patients with peripheral artery disease.

No conflict of interest was declared

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