

CONTRIBUTION OF TRANSCUTANEOUS OXYMETRY IN DIABETIC FOOT SYNDROME

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Four major complications are participating in tissue damage in diabetic foot syndrome – diabetic angiopathy, neuropathy, osteoarthropathy and inflammation. Low ankle-brachial pressure index (ABI) is a well-known indicator for ischemia of lower limbs, but in patients with diabetes mellitus is common also a high ABI (over 1.3) as reliable predictor of the presence of arterial calcification – medial calcinosis. Aim of the study is to determine the degree of ischemia using transcutaneous oximetry in patients with diabetic foot syndrome - with clinical manifestations of peripheral arterial occlusive disease (PAOD) and medial calcinosis. We investigated three groups: first consisted of 46 members in IInd stage of PAOD according to Fontaine classification, in second group were 30 members in IIIrd stage of PAOD and third had 29 members in IVth stage of PAOD. The ABI was determined with Doppler ultrasound examination. Transcutaneous oxygen tension (TcPO₂) was measured with Oxykapnomonitor Hellige SMK Germany equipment with sensing probe – transoxide. Resting values of TcPO₂ were obtained in lying patient on the foot in first metatarsal space. Subsequently leg was passively elevated into 30 degree angle for 3 minutes and then reimposed into primary position. One minute exercise – plantar and dorsal feet flexion was performed and after the TcPO₂ values stabilization the patient hung his shin from the edge of the bed touching the floor. TcPO₂ values were continuously recorded by analog waveform. In more severe stages of PAOD according to Fontaine stage III and IV we detected lower levels of TcPO₂ under basal resting conditions: 20 respectively 5 mmHg. Patients with IInd stage of PAOD had basal TcPO₂ values of 40 mmHg. Conclusions of the study are: TcPO₂ values are not affected by the presence of medial calcinosis and sothis method is particularly beneficial in patients where Doppler ultrasound examination shows artificial high pressure values on lower limbs. In the third and fourth stage of PAOD passive leg elevation is as effective in determination of ischemia as working test.

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Introduction

Diabetic foot syndrome is defined by WHO (1999) as the foot of diabetic patient that has the potential risk of pathologic consequences including infection, ulceration and destruction of deep tissues associated with neurologic abnormalities, various degrees of peripheral vascular disease and metabolic complications of diabetes in the lower limb. This pathologic condition under certain circumstances can

lead to a breakdown of tissue structures, represented by cutaneous or osteoarticular lesions. The state is hence characterized by a chronic non-healing ulcers of skin often complicated with infection and may lead to a tissue necrosis and surgical amputation.

Four major complications are participating in tissue damage in diabetic foot syndrome:

- diabetic angiopathy (macroangiopathy and microangiopathy),
- diabetic neuropathy,
- diabetic osteoarthropathy,
- infectious (inflammatory) complications.

The main factors that contribute to the development of diabetic foot are diabetic neuropathy (distal symmetric sensorimotor neuropathy, autonomic neuropathy) as well as the consequences of peripheral arterial disease.

Atherosclerosis is a complex systemic, generalized obliterating arterial disease which leads to various combination of changes in the arterial intima consisting of focal accumulation of lipids, blood and blood products, connective tissue and calcium deposits. Violation of the integrity of atherosclerotic plaque by fissure, disruption or rupture of fibrous cap leads to the formation of unstable plaque with thrombus, which causes vasoconstriction with varying degree of dynamic arterial obstruction.

A high ankle-brachial pressure index (over 1.3) is a reliable predictor of the presence of arterial calcification (medial calcinosis) that reduces the elasticity of the affected blood vessels with subsequent hemodynamic consequences. The incidence of arterial calcification increases with age and the presence of other associated diseases (diabetes mellitus, chronic kidney disease, hyperparathyreosis, chronic inflammatory disease, rare genetic diseases as Keutel syndrome).

The aim of our study was to determine the degree of ischemia using transcutaneous oximetry in patients with diabetic foot with clinical manifestations of peripheral arterial occlusive disease (PAOD) and medial calcinosis as well as to determine the contribution of functional tests in the diagnostic process.

Materials and methods

Patients were divided into three groups according to history, physical examination, determination of vibration sensation, tactile sensitivity and Doppler ultrasound examination.

Group 1 consisted of 46 members in 2nd stage of PAOD according to Fontaine classification. In group 2 there were 30 members in 3rd stage of PAOD. Group 3 had 29 members in 4th stage of PAOD.

The ankle-brachial pressure index was determined with Doppler ultrasound examination. Vibration sensation was examined with the use of tuning fork or biothesiometer, tactile sensitivity with the use of Semmes-Weinstein monofilament. Patellar and Achilles tendon reflexes were examined, as well.

Transcutaneous oxygen tension (TcPO₂) resting values were obtained in lying patient on the foot in first metatarsal space. Subsequently leg was passively elevated into 30 degree angle for 3 minutes and then re-imposed into primary position. After TcPO₂ values stabilization patients began one minute exercise - plantar and dorsal feet flexion (30 times per minute). After exercise patient remained in the supine position waiting again for TcPO₂ values stabilization. Then the patient hung his shin from the edge of the bed touching the floor. TcPO₂ values were continuously recorded by an analog waveform. The beginning and the end of the test was noted by a gage.

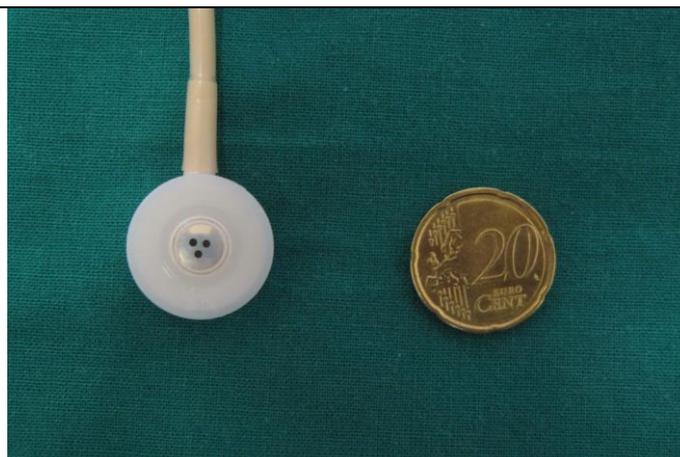
Figure 1 shows Oxykapnomonitor Hellige SMK 365, Germany and figure 2 shows Sensing probe – Transoxode.

Figure 1: Oxykapnomonitor Hellige SMK.



Source: Authors

Figure 2: Sensing probe – Transoxode in diameter comparison with 20-cent coin.



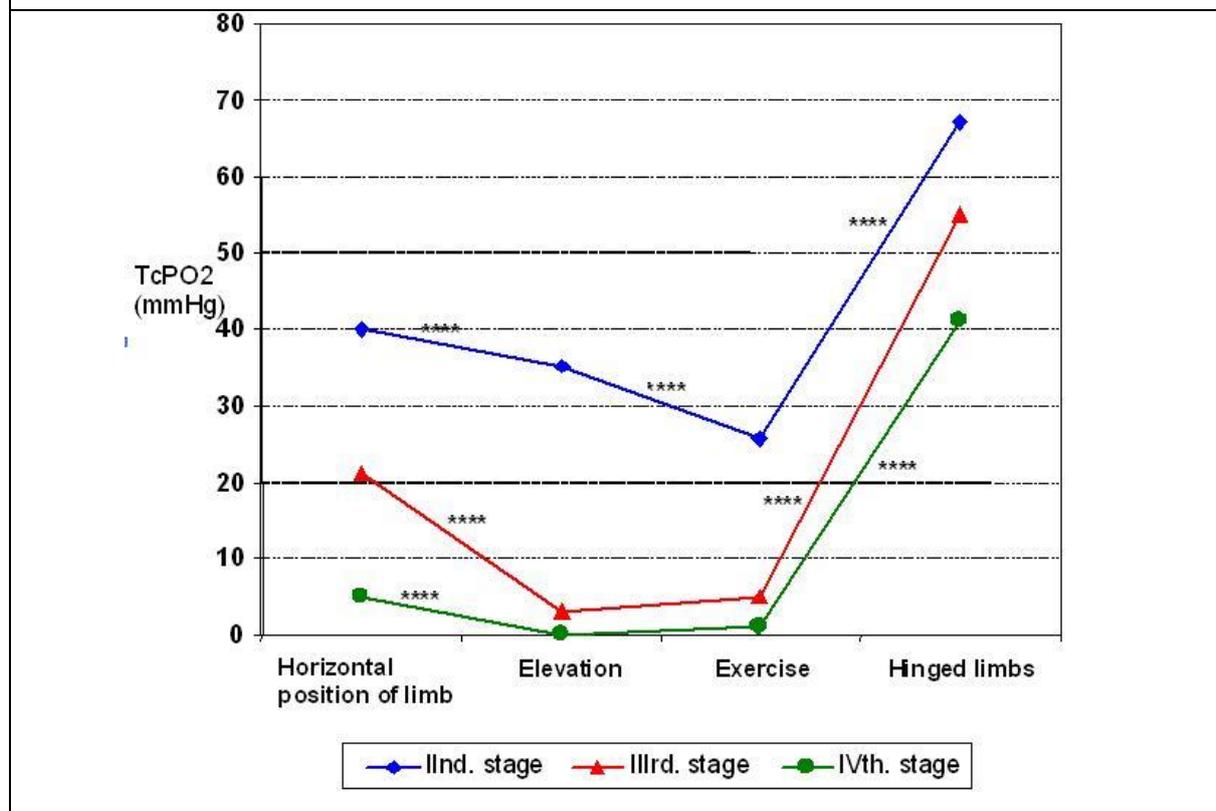
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Stabilized values of TcPO₂ before elevation of leg and after functional test were used for statistical evaluation.

Results

Determination of TcPO₂ value is a valuable indicator of the degree of limb ischemia. In more severe stages of peripheral arterial obliterative disease according to Fontaine (III, IV), we detected lower levels of TcPO₂ under basal resting conditions (20 respectively 5 mmHg). Patients with intermittent claudication (Fontaine II) had signs of ischaemia usually only during functional tests (24 mmHg during exercise). Figure 3 shows the comparison of TcPO₂ medians in functional tests for each PAOD stage and Figure 4 shows comparison between each PAOD stage. Statistical significance of $p < 0.001$ is marked with asterisk.

Figure 3: Changing of TcPO₂ during the functional tests of lower limbs



Source: Authors

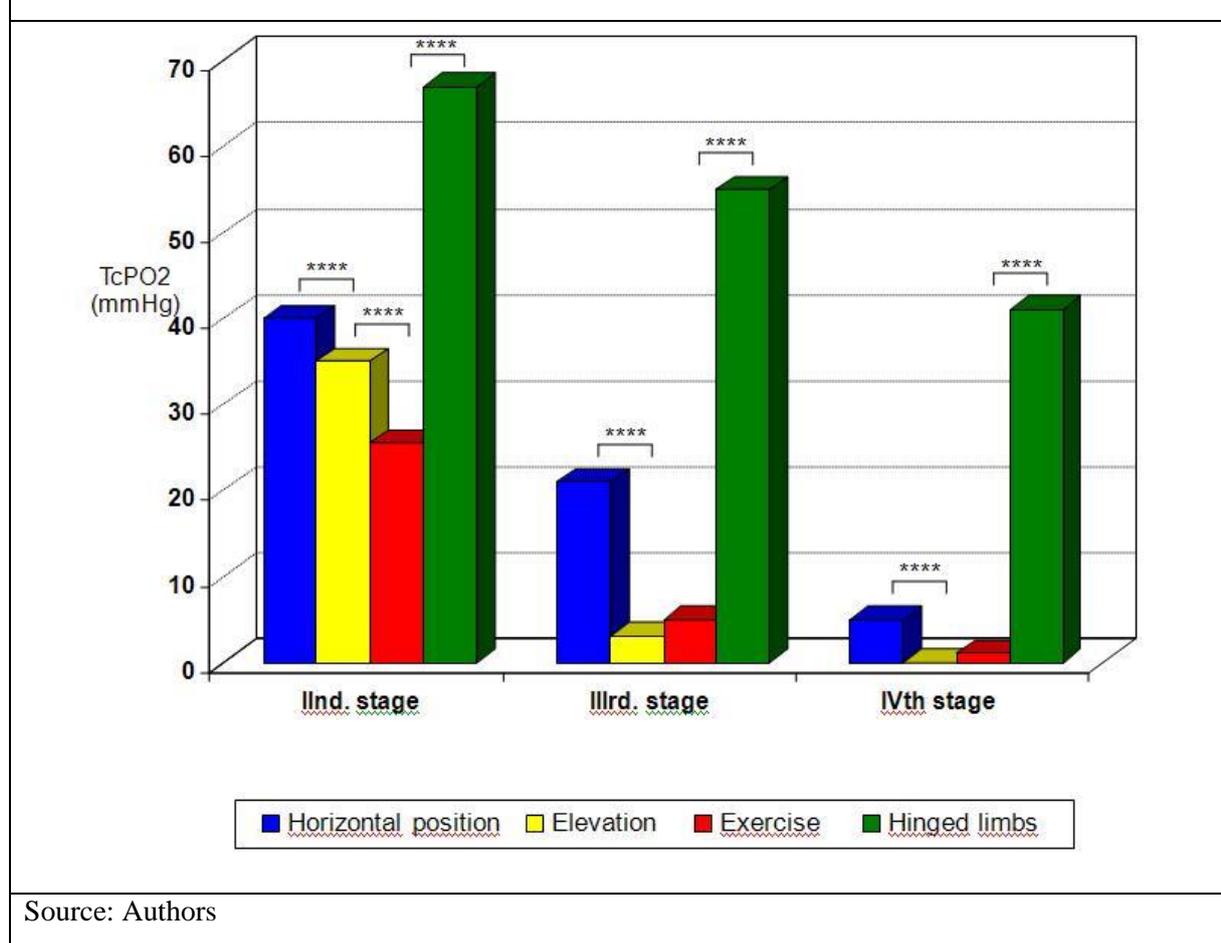
Discussion

The transcutaneous oxygen tension value is a good indicator of the degree of limb ischemia. In more severe stages of PAOD TcPO₂ values are already low in basal, resting condition in supine patient. Patients with claudication in comparison with healthy subject have lower TcPO₂ only during functional tests (elevation of leg, exercise) (Meluzínová, 2007, Ruzička, 2003, McGee, 1998, Got, 1998).

In our study TcPO₂ values correlated with the clinical stage of PAOD. The baseline of TcPO₂ differentiated the severity of ischemia in the horizontal position of limb. However, some patients may not have TcPO₂ baseline reduced compared to healthy subjects. Several authors confirmed that

collateral circulation under resting conditions can compensate the deterioration of blood flow in lower limbs in the case of stenosis or obstruction of the great vessels (Ballard, 1995).

Figure 4: Comparison of TcPO₂ changes during functional tests for each PAOD stage



Medial calcinosis is a marker of cardiovascular complications including increased cardiac mortality and increased risk of amputation (Sadr, 2008, Allison, 2008, Silvestro, 2006). Tracking changes in TcPO₂ during passive elevation provides valuable information about the degree of ischemia in affected limb. In our study elevation of the lower extremities caused significant decrease in median values of TcPO₂ in all groups but patients in the third and fourth stage of PAOD had severe limb ischemia. The exercise test (plantar and dorsal flexion in the ankle) induced severe degree of ischemia in these groups, as well. After hanging the leg over the bed to the floor an increase of TcPO₂ values were recorded in all three groups. However, people in the fourth stage of PAOD had the lowest values of TcPO₂.

Metabolic control of diabetes is a key factor in the development of chronic complications. Diabetes accelerates atherogenesis and increases the risk of thrombosis. In addition to diabetes itself, there are many other risk factors whose effects are multiplied. Macro- and microcirculatory conditions are adversely affected by the changes in coagulation. Various hematologic dyscrasias may also be involved in the deterioration of microcirculation. Hyperglycemia also induces a change of rheological properties of blood (Rathur, 2007). An important factor is the age but in our study particular groups did not differ in median age.

Transcutaneous oximetry is a noninvasive test that directly measures the oxygen level of tissue beneath the skin. Because oxygen is carried to tissues by blood flow in the arteries, TcPO₂ is an indirect measure of blood flow. Severe atherosclerosis in the extremities can block blood and oxygen flow and cause walking discomfort, gangrene and after all also limb loss (Hanna, 1997, Diamantopoulos, 1998). The important role of microcirculation in the pathophysiology and symptoms of peripheral obliterative disease has been progressively emphasized during the past decades. (Štrbová, 2009) Different non-invasive methods, such as capillaroscopy, laser Doppler fluxmetry and transcutaneous measurement of oxygen tension have been introduced. In critical limb ischemia, more advanced cutaneous microcirculatory deterioration has been clarified, with a more severely reduced TcPO₂ in the diseased legs. Our data clearly documented that with the progression of PAOD the values of TcPO₂ decrease.

Conclusion

1. As TcPO₂ values are not affected by the presence of medial calcinosis this method is particularly beneficial in patients where Doppler ultrasound examination shows artificial high pressure values on lower limbs.
2. In the third and fourth stage of peripheral artery occlusive disease passive leg elevation is as effective in determination of ischemia as working test - dorsal and plantar flexion of foot. In the case of impossibility of carrying out the work test passive elevation of extremities is an alternative solution.

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