

# Clinical cases on detection of critical limb ischemia

May 2000



**Andreas Scheffler**

Department of Angiology  
Aggartalklinik  
Engelskirchen  
Germany

How relevant is transcutaneous measurements in the detection of critical limb ischemia? **Acutecaretesting.org** has asked a group of respected researchers and clinicians in the US and Europe to describe how they use transcutaneous measurements in their daily work.

## Case 1 - Investigating chronic foot wounds

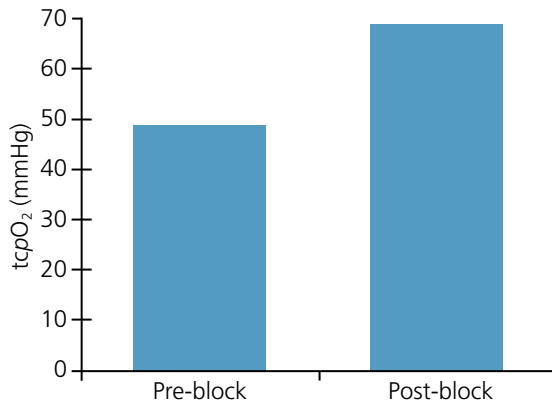
Tissue hypoxia is the most frequent, proximate cause of failure to heal. The most direct assessment is to measure transcutaneous  $pO_2$  ( $tcpO_2$ ). When done in conjunction with arterial oxygen tension,  $tcpO_2$  becomes more powerful because then the distinction between hypoxia due to vascular disease and hypoxia due to lung and heart diseases can be made. The  $tcpO_2$  response to oxygen breathing is the best known way to assess peripheral perfusion. When regional  $tcpO_2$  is measured in the vascular zones of the foot, distal obstruction can be inferred from the differences between the  $tcpO_2$  values and from the location of the ulcer.

## Clinical case

An 80-year-old woman suffered from a chronic, painful ulcer necrosis of the distal toes of one foot. There was no evidence of infection. There was no hair on the affected foot, which was cold and cyanotic. The skin was atrophic. No pulses were present, and this was confirmed with Doppler sonography. An arteriogram had been done at another institution, where the woman had been offered an amputation but she had declined all treatment options.

Transcutaneous oxygen measurements performed in the area of cyanosis revealed an unexpectedly high value, 35 mmHg, and a significant response to oxygen breathing. When the electrode was removed, the nurse noted a transient pinkish spot where it had been. The patient's foot became pinker after immersion in warm water. This led us to a diagnosis of vasospastic disease. She continued to decline all therapy, but after considerable

discussion, she agreed to a sympathetic neurolysis with injected alcohol and continuous warmth with a fur-lined boot.  $tcpO_2$  and its response to oxygen breathing improved immediately after the neurolysis (see diagram below). The pain disappeared by the next week. Within approx. four months, the necrotic distal toes separated, revealing full epithelization beneath. The foot remains cyanotic whenever it is removed from the boot, but the patient reports no pain.



This case illustrates a circumstance in which only the measurement of oxygen can tell the full story. Although the patient did have significant arterial disease, it was not sufficient to cause the necrosis. Vasospastic disorders often occur in conjunction with pain due to arterial disease.

Only the measurement of oxygen can tell the full story.

## Author

**Thomas K. Hunt**

Department of Surgery  
University of California  
San Francisco  
USA

## Case 2 - Management of venous ulcers

Once the etiology of a chronic wound such as a venous ulcer is determined, the therapeutic options for management essentially comprise suitable dressings and compression bandages. It is more difficult to deal with the reasons of the chronicity which range from edema to infection.  $tcpO_2$  measurements at 43-45 °C permit changes which are associated with healing to be reliably detected [1]. Low values of  $tcpO_2$  around non-healing wounds also indicate the need to reconsider therapeutic options.

### Clinical case

A 78-year-old woman suffered from intractable ulcers and grossly edematous legs. She had a large ulcer (> 75 cm<sup>2</sup>) in the region of the medial malleolus, which had failed to heal for 20 years. As her husband was dependent on her, she was reluctant to be hospitalized for any length of time. It was decided that she would be admitted for bed rest with leg elevation for 24 hours.



$tcpO_2$  was measured on the superior edge of a venous ulcer. Patient was supine at the time. Control values may be derived from measurements on the chest or on the ipsilateral forearm.

On admission, pulses were barely palpable because of swelling. ABI was > 0.7.  $tcpO_2$  at 43 °C on the superior edge of the ulcer was 11 mmHg. After 24 hours of leg elevation, her legs had been reduced significantly in size, the ulcer was drier, and  $tcpO_2$  had increased to 19 mmHg. After another 24 hours, she was discharged with heavy compression bandages and transferred to the care of community nurses who continued to bandage her legs and persuaded her to comply with the recommended afternoon bed rest with elevation. On healed skin, the  $tcpO_2$  value was 31 mmHg.

## References

1. Pekenmaki K, Kolari PJ and Kiistala U. Intermittent pneumatic compression for the treatment of post-thrombotic ulcers. *Clinical and Experimental Dermatology* 1987; 12: 350-53.

## Author

### Raj Mani

Department of Medical Physics and  
Medical Engineering  
Southampton General Hospital  
Southampton  
UK

## Case 3 - Detecting critical limb ischemia

In a patient presenting symptoms of peripheral vascular insufficiency, the assessment of the severity of the disease and of the need for invasive intervention (surgery or PTA) is usually made on the basis of a patient's clinical status and peripheral blood pressure parameters. Transcutaneous oxygen measurements ( $tcpO_2$ ) yield information about local skin microcirculation. Disturbed microcirculation is the ultimate cause of tissue loss. Hence, this technique is an excellent additional diagnostic tool, especially when the clinical symptoms are atypical or when diabetes, which can cause critical leg ischemia to exist without severely reduced ankle pressure, is present. It is easy to use and can be applied even after amputation of a toe, which prevents toe pressure measurements. Furthermore,  $tcpO_2$  measurements are useful for predicting the need for an imminent amputation and for assessing the wound healing potential in these patients.

### Clinical case

A 65-year-old woman suffered from a painless ulcer on the fifth toe. The ulcer had started as a blister 6 weeks earlier. She also suffered from mild claudication. She had had type II diabetes for 32 years, and had been insulin dependent for 20 years. Other risk factors present were hypertension and hyperlipidaemia. Medication:

Atenolol, Nifedipine, Atorvastatine, and Losartan/hydrochlorothiazide.

Physical examination showed a warm, reddish foot with a dry, peeling skin and an indolent, probably pressure-induced ulcer on the lateral side of the fifth toe, surrounded by erythema. No arterial ankle pulsations were palpable. Skin sensibility was reduced due to diabetic neuropathy.

The highest ankle Doppler blood pressure was 81 mmHg (ankle/brachial index [ABI]: 55 %), the systolic pressure of the left hallux was 32 mmHg.  $tcpO_2$ , as measured distally on the dorsum of the foot, was 5 mmHg. Subsequently, duplex ultrasound investigation of the aortoiliac tract showed no significant stenoses, whereas in the left common femoral artery a stenosis with a diameter reduction of more than 50 % was detected. Duplex scanning of the crural arteries showed an occlusion of the proximal anterior tibial artery, the dorsal pedal and the peroneal arteries. Only the posterior tibial artery was patent, albeit with several wall irregularities.

Although the ankle and the toe blood pressures were above the criteria for critical limb ischemia requiring invasive therapy (50 and 30 mmHg, respectively), the low  $tcpO_2$  indicated a threatened skin perfusion and a poor wound healing power. Hence, a percutaneous angioplasty of the common femoral artery was performed successfully. ABI was now 71 %, the toe pressure was 37 mmHg, and the  $tcpO_2$  was 33 mmHg.

One month later the  $tcpO_2$  had decreased to 7 mmHg, while the ABI and toe pressure were 51 % and 36 mmHg, respectively. Thus, an additional angioplasty of the distal popliteal and peroneal arteries was performed, yielding an ankle pressure of 123 mmHg (ABI: 78 %), and a toe pressure of 50 mmHg.  $tcpO_2$  also increased, but reached only 25 mmHg (in our clinic a value less than 30 mmHg is regarded as an indication of critical ischemia).

After a fortnight, the fifth toe had to be amputated because of poor wound healing. After another two weeks, the amputation wound was clean and healing.

Ankle pressure was 120 mmHg (ABI: 79 %), toe pressure 42 mmHg and  $tcpO_2$  41 mmHg. At the three-month follow-up visit the patient had a completely healed wound without complaints.

Ankle and toe pressures were now 129 and 55 mmHg, respectively (ABI: 100 %) and the  $tcpO_2$  was 54 mmHg. Half a year later the patient's condition was unchanged.

In summary, the treatment of this patient's ischemic ulcer was guided mainly by the  $tcpO_2$  findings, since the ankle pressure was probably affected by the presence of media sclerosis due to the diabetes, while the toe pressures were low, but not critically decreased. One can imagine that if the  $tcpO_2$  technique had not been applied as an additional tool to assess the presence of critical ischemia, there would have been a considerable risk that the treatment would have been delayed. Progression of the ischemia would then have resulted in extended tissue loss and/or an infection, which would have required more extensive surgery.

This patient's ischemic ulcer was guided mainly by the  $tcpO_2$  findings, since the ankle pressure was probably affected by the presence of media sclerosis due to the diabetes.

## Author

**Th. Dirk Th. Ubbink**

Academic Medical Centre  
Department of Vascular Surgery  
Amsterdam  
The Netherlands

## Case 4 - Determining amputation level

In selecting the optimal amputation level, the clinician must balance the necessity for primary wound healing against the need for retaining the maximum limb length. Indeed, the longer the limb is, the better the rehabilitation rate will be; and conversely, the more distal the amputation is, the greater the risk of wound healing failure will be. With clinical criteria, the typical failure rate of below-knee amputation ranges between 10 and

50 %, but the failure rate of too proximal amputations is ill-defined. On the other hand, a systematic literature analysis suggests that a transcutaneous  $pO_2$  measurement of 20 mmHg or more at the site of amputation predicts healing with 80 % accuracy [1].

## Clinical case

A 78-year-old man was admitted because of a chronic ulcer on his left foot. He had had the ulcer for more than 6 weeks, and there was no sign of improvement. Radiological examination showed osteitis of the fifth metatarsus. The patient had undergone amputation of the left great toe two years before due to an infected foot ulcer.

## Medical history

In his previous history, the following relevant events had been recorded:

- diabetes type II for more than 20 years, treated with insulin for the last 7 years
- coronary heart disease with CABG six years ago
- bilateral, invalidating intermittent claudication, leading to left femoropopliteal bypass five years ago and right femoropopliteal bypass four years ago
- cerebrovascular accident (regressive stroke) four years ago
- beside diabetes, cardiovascular risk factors included smoking (stopped 12 years ago), arterial hypertension, and hypercholesterolemia. Patient was on insulin, enalapril, simvastatine and low-dose aspirin.

Six weeks prior to the admission mentioned above, the patient had been treated for a foot ulcer and infectious cellulitis of the foot dorsum. The latter condition responded to antibiotic treatment, but the ulcer did not heal.

## The therapeutic options

Because of the absence of wound healing and the persistent osteitis, amputation was considered the

reasonable therapeutic option. One orthopedic surgeon suggested below-knee amputation while his colleague favored a more distal, transmetatarsal level. The first option would surely have been associated with a 25-50 % risk of ending in a wheelchair for this elderly patient, who was living alone.

Diabetic neuropathy was present, and pulses were not palpable below the knee. Ankle-brachial systolic pressure index was 1.6 (left) and 1.9 (right), suggesting vessel wall calcifications. Previous great toe amputation precluded systolic pressure measurement at this level. Arteriography disclosed an occluded left femoropopliteal bypass without the possibility of surgical repair due to poor runoff. Transcutaneous  $pO_2$  was measured on foot dorsum, calf and thigh levels to help us determine the amputation level. The values were 23, 42, and 51 mmHg, respectively.

### The therapeutic choice

Because  $tcpO_2$  was above 20 mmHg in spite of local edema which is known to reduce capillary density and consequently tissue oxygenation, ischemia was not considered the primary cause of the ulcer. Amputation level had to be decided according to other criteria. Accordingly, the more conservative option of transmetatarsal amputation was recommended.

Transcutaneous  $pO_2$  was measured on foot dorsum, calf and thigh levels to help us determine the amputation level.

### References

1. Wütschert, R.; Bounameaux, H.: "Determination of amputation level in ischemic limb: re-appraisal of the measurement of transcutaneous oxygen tension". *Diabetes Care* 1997; 20: 1315-18.

### Author

#### Henri Bounameaux

Division of Angiology and Hemostasis  
University Hospitals of Geneva  
Geneva  
Switzerland

## Case 5 - Surgical interventions, Patient selection and prediction of wound healing

Peripheral vascular disease (PVD) is associated with high morbidity and mortality, and annually it accounts for about 280 lower limb amputations per million U.S. diabetics. With non-diabetic patients, a history of tobacco abuse contributes to the development of PVD, which often results in critical limb ischemia. Non-invasive vascular tests like arterial Dopplers can provide an ankle/brachial index (ABI), which may be useful in diagnosing a severe disease. However, with patients with calcific vascular disease, ABIs are less reliable than transcutaneous oxygen measurements in screening for critical stenosis. With patients with limb threatening wounds, transcutaneous oxygen measurements can be used to select patients in need of vascular intervention, and to predict wound healing and success after intervention [1].

### Clinical case

A 54-year-old black woman suffered from ischemic rest pain and a necrotic lesion on the right lateral ankle. After débridement of the necrotic eschar, a tendon was found to be exposed.



### Medical history

- Coronary artery disease with angina
- Hypertension
- Lower extremity rest pain
- 30-year smoking history
- Necrotic right lower extremity ulceration
- Recent bilateral aortofemoral bypass

## Investigations

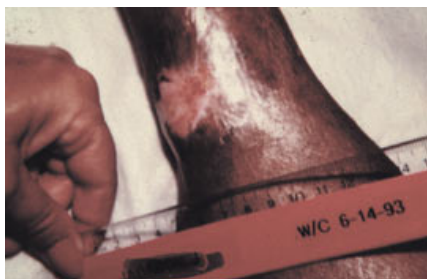
Initial transcutaneous oxygen measurements showed 2 mmHg values adjacent to the wound. Non-invasive arterial Dopplers were performed which revealed an ABI of 0.2. Angiograms revealed several areas of multifocal vascular disease, particularly of vessels below the knee.

## Therapeutic options

Due to the exposed tendon and wound ischemia, skin grafting was not an option for wound treatment, nor was extensive plastic surgery due to inadequate vascular supply. Revascularization was clearly necessary, but the patient had already undergone surgical revascularization and declined further surgical intervention.

## The therapeutic choice

Percutaneous transluminal angioplasty was performed on multiple occlusions with restoration of flow to vessels below the knee. Post procedure transcutaneous oxygen measurements improved to 46 mmHg. Because of the exposed tendon, the patient underwent 34 hyperbaric oxygen therapy treatments. Granulation tissue formed over the tendon and resulted in complete epithelialization. At the one-year follow-up, the patient had no recurrence of either ulceration or ischemic pain.



With patients with calcific vascular disease, ABIs are less reliable than transcutaneous oxygen measurements in screening for critical stenosis

## References

1. Hanna GP, Fujise K, Kjellgren O, Feld S, Fife C, Schroth G, Clanton T, Anderson V, Smalling R. Infrapopliteal interventions for limb salvage in diabetic patients: importance of aggressive interventional approach and role of transcutaneous oximetry. *J Am Coll Cardiol* 1997; 30: 664-69.

## Author

**Caroline E. Fife**

Anesthesia

University of Texas Health Science Center

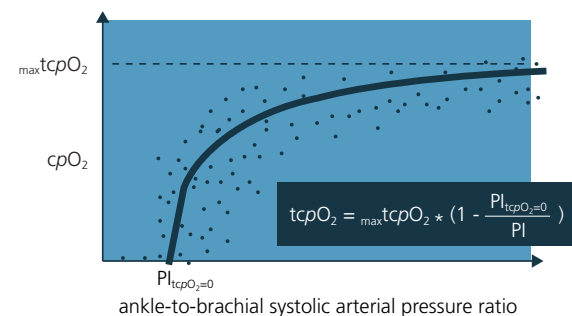
Director, Hermann Center for Wound Healing

Houston

USA

## Case 6 - Assessment of peripheral arterial occlusive disease

$tcpO_2$  serves as a noninvasive measure of microvascular skin perfusion in patients with peripheral arterial occlusive disease (PAOD). Because similar variations of low, medium, and high perfusion pressures correspond with large, moderate, and small changes of  $tcpO_2$ , respectively, values measured in healthy controls on asymptomatic patients and claudicants widely overlap. In contrast, severe PAOD reduces  $tcpO_2$  substantially. Lower limb  $tcpO_2$  values in adults normally exceed 40 mmHg in supine and 45 mmHg in dependent leg position.





Schematic drawing of the  $tcpO_2$  vs. flow circulatory hyperbola. The curve was fitted to original measurements obtained in PAOD patients at an electrode core temperature of 44 °C.

In patients with chronic ischemic rest pain or skin ulcerations, the method provides valuable diagnostic and prognostic information in addition to clinical findings and conventional hemodynamic techniques. To evaluate chronic critical limb ischemia  $tcpO_2$  measurements should be obtained in supine as well as dependent leg positions. Poor prognosis with regard to conservative treatment or amputation wound healing is typically associated with  $tcpO_2$  values below 10 and 45 mmHg in the horizontal and dependent leg positions, respectively. Because there may be considerable variation in forefoot  $tcpO_2$  measured on adjacent skin areas, the simultaneous usage of several electrodes offers the opportunity of detecting “islands of ischemia” more reliably.

### Clinical case

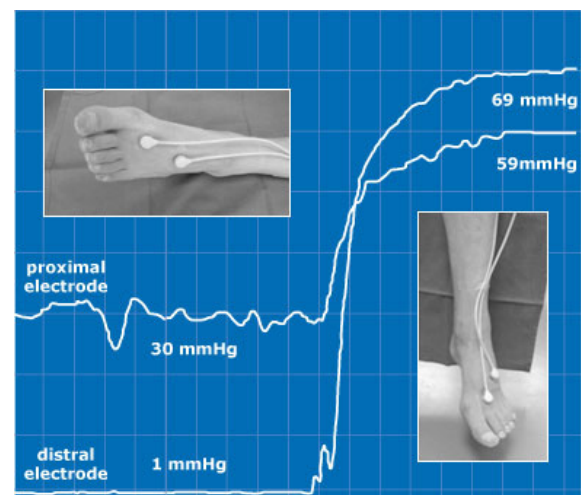
A 64-year-old man suffered from nocturnal rest pain in the left foot for more than two months. Major cardiovascular risk factors were cigarette smoking, dyslipoproteinemia, and arterial hypertension. Neither myocardial infarction nor cerebrovascular events had occurred so far. A peripheral arterial occlusive disease had been diagnosed ten years ago. Since that time angioplasties of pelvic and superficial femoral arteries were performed in either leg. A left femoral crural bypass graft, which was implanted due to acute ischemia two years ago, occluded a few months ago and all attempts of graft reconstruction failed.

On admission, clinical examination showed palpable pulses at the groin but not at the knee or ankle. Bruits were not found. Inspection of the foot and interdigital spaces excluded skin lesions. Sensoric and motoric functions of the toes were slightly diminished.

Conventional hemodynamic laboratory evaluation was difficult because no Doppler signal was found for noninvasive pressure measurement at neither the ankle

nor the dorsum of the foot. Mechanical oscillography revealed missing oscillations at the distal calf even at the lowest external pressure levels of 60 mmHg suggesting critical limb ischemia. Careful color-coded duplex sonography and intra-arterial angiography of the left leg arteries excluded any possibility of further catheter interventions or surgical reconstructions due to long proximal occlusions and multiple calf artery obstructions.

To assess the state of the forefoot skin microvascular blood supply, transcutaneous oxygen measurements were performed in supine and dependent leg position. Although supine  $tcpO_2$  values were below 10 mmHg (i.e. suggesting critical limb ischemia), they increased up to the lower normal range in response to limb lowering. This finding is not typical for critical limb ischemia and thus supported the clinical decision to attempt a four-week iloprost infusion therapy (1 ng•kg<sup>-1</sup>min<sup>-1</sup> over 6 hrs daily) accompanied by high doses of analgesics. At the end of this period, the patient's condition had significantly improved and he could be discharged without persistent nocturnal rest pain.



Original  $tcpO_2$  recording at the forefoot in supine and dependent leg position. Note the remarkable  $tcpO_2$  increase of the distal electrode signal from 1 to 69 mmHg in response to the positional maneuver.

This case demonstrates that  $tcpO_2$  can be used even in circumstances where conventional hemodynamic

evaluation is not feasible (e.g. missing Doppler flow signal – as was the case here, diabetic media sclerosis, etc.). Values should be obtained in supine as well as dependent leg position because only the combination of these results will yield reliable diagnostic and prognostic clinical information. Critical limb ischemia with poor prognosis should not be assumed if either supine  $tcpO_2$  values exceed 10 mmHg or dependent  $tcpO_2$  values exceed 45 mmHg.

$tcpO_2$  can be used even in circumstances where conventional hemodynamic evaluation is not feasible.