Target region oxygenation-based endovascular treatment in a chronic limb-threatening ischemia patient with multifocal arterial diseases

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ABSTRACT

Patients with chronic limb-threatening ischemia often have multiple segmental diseases requiring revascularization. However, there is no defined milestone to indicate sufficient endovascular treatment (EVT). Using multiple near-infrared spectroscopic oximeters, we intraoperatively monitored regional tissue oxygen saturation (rSO2) to perform target region oxygenation-based EVT for a patient with chronic limb-threatening ischemia. Stent placement at the superficial femoral artery and angioplasty of the tibioperoneal trunk enabled rSO2 in the target ischemic regions (dorsal foot and heel) to be >50% for ulcer healing. We herein describe target region oxygenation-based EVT with rSO2 monitoring as an effective strategy for performing the minimum requisite procedures. (J Vasc Surg Cases and Innovative Techniques 2020;6:228-32.)

Keywords: Endovascular treatment; Regional oxygen saturation monitoring; Near-infrared spectroscopic oximeter; Chronic limb-threatening ischemia; Foot ulcer

Patients with chronic limb-threatening ischemia (CLTI) secondary to peripheral artery disease (PAD) often require multiple revascularizations. Currently, no definite intraoperative characteristic exists for the extent of revascularization required for ulcer healing during endovascular treatment (EVT).

It is important to increase perfusion and regional oxygenation saturation (rSO2) by revascularization for ischemic wound healing. However, these are rarely monitored during the revascularization procedure because of lack of reliable measuring devices. Near-infrared spectroscopy devices noninvasively measure rSO2, which is the oxygenated hemoglobin/total hemoglobin ratio; they have not been used during EVT except in a few studies.

We previously reported the utility of a newly invented finger-mounted tissue oximeter (Toccare; Astem Co, Ltd, Kawasaki, Japan) designed to measure rSO2 up to a depth of 5 mm below the probe for evaluating perfusion at the toe and dorsal foot of PAD patients. We routinely use the device in an office setting in daily practice. Here, we present a case in which rSO2 was continuously monitored as a milestone using multiple oximeters at the target regions during EVT. This concept, which we named target region oxygenation-based EVT (TOE), was applied in a patient with CLTI. Written informed consent was obtained from the patient for the publication of this case report and accompanying images.

CASE REPORT

A 71-year-old man was admitted with a 4-month history of painful ulcers in the left second toe and heel (Fig 1, A and B). He had diabetes and was undergoing hemodialysis. The right ankle-brachial index was 0.35, and the transcutaneous oxygen tension (TcPO2) at the right dorsal foot was 8 mm Hg. Given the limb-threatening situation due to ischemia, EVT was planned to revascularize the ischemic regions (toe and heel). Before the start of EVT, three oximeter sensor probes were placed at the selected target oxygenation regions: ankle, dorsal, and plantar regions (Fig 1, C). They were a finger-mounted type of sensor attached with adhesive tape. Angiography (Fig 2, A) revealed multiple stenotic lesions, including lesions in the proximal superficial femoral artery (SFA, target lesion #1; Fig 2, B), popliteal artery (target lesion #2; Fig 2, C), tibioperoneal trunk (TPT, target lesion #3; Fig 2, D), and anterior tibial artery (target lesion #4; Fig 2, D). The pedal arch was scarcely visible.

To revascularize the four target lesions (Fig 2, B-D), EVT was performed as follows: a 6F retrograde puncture was made in the right common femoral artery, a 6F 45-cm Destination guiding sheath (Terumo, Tokyo, Japan) was passed into the left common femoral artery, and revascularization was performed from the proximal regions. The rSO2 was recorded every 5 minutes after each procedure. The TOE end point was rSO2 >50%. Proximal SFA angioplasty was followed by stent placement (6 × 60-mm SMART; Cordis, Bridgewater, NJ; Fig 2, E and F) because...
the lesion was severely calcified. Next, angioplasty of the proximal popliteal lesion (Fig 2, C) was successfully performed with a \( \frac{5}{4} \times 40 \)-mm Armada balloon (Abbott Vascular, Abbott Park, Ill; Fig 2, G and H). After that, we performed angioplasty of the TPT with a \( \frac{3}{4} \times 20 \)-mm Coyote balloon (Boston Scientific, Marlborough, Mass; Fig 2, I and J). Although the SFA angioplasty increased \( rSO_2 \) from 55% to 61% in the ankle (Fig 3), \( rSO_2 \) did not show any significant increase after the SFA stent placement and midpopliteal artery angioplasty at either the dorsal foot or the plantar region (Fig 3). After successful EVT at the TPT stenosis, \( rSO_2 \) at both dorsal foot and plantar regions finally increased to >50% (Fig 3). At that point, we ended EVT, leaving stenosis at the proximal anterior tibial artery, fibular artery, and pedal arch. The patient had an uneventful postoperative course. On postoperative day 1, \( rSO_2 \) values of the dorsal foot and plantar regions were elevated to 53%. The patient’s pain was alleviated, and he was discharged on the same day. Two months after EVT, the TcPO2 at the left dorsal foot was 48 mm Hg, and the ulcers in both the second toe and heel of the patient were completely healed.
DISCUSSION

The number of PAD patients has exceeded 200 million globally." The number of CLTI patients has increased because of the growing incidence of diabetes and renal insufficiency. In the United States, there are about 3500 new cases of CLTI annually. Recently, advancement in EVT has enabled revascularization of high-risk patients with complex arterial diseases. However, devices such as balloons and stents mainly focus not on the rate of wound healing but on target lesion revascularization as the successful end point for the devices in numerous clinical trials after recanalization of a single arterial lesion. The prognosis of the ischemic ulcer after EVT depends on the cumulative effect of multiple procedures, particularly patent pedal arch, which seems to be a key factor for wound healing." However, the EVT parameter that facilitates ulcer healing has not yet been identified.

As PAD patients are usually frail and cannot tolerate lengthy procedures, EVT has been considered to be the first choice for such patients rather than open bypass/
revascularization. However, PAD patients often have kidney dysfunction; thus, contrast medium should be used minimally, with either a more dilute contrast medium or a small volume. Hence, only the necessary revascularization procedure for ulcer healing should be performed. According to our previous study, rSO2 > 50% is almost equivalent to skin perfusion pressure > 50 mm Hg or TcPO2 > 50 mm Hg, which is considered adequate for ulcer healing. Furthermore, our retrospective study indicated that all patients with critical limb ischemia who underwent EVT with rSO2 > 50% in the dorsal foot on postoperative day 1 showed improved ulcer healing.

Therefore, we aimed to perfuse the target region up to rSO2 > 50%. This would save time and costs. In the case that rSO2 > 50% is not achieved, other EVT strategies or vascular reconstruction procedures, such as bypass surgery, should be considered. The oximeter used to perform TOE in this study was efficient. Unlike an ankle-brachial index, skin perfusion pressure, or TcPO2 that consume time and lack data reliability, the newly invented oximeter can measure rSO2 within seconds and can be used for real-time monitoring. Although the rSO2 was monitored continuously, its measurements were recorded every 5 minutes after each EVT procedure because it took a few minutes for the value to stabilize.

There is also a possibility of vasospasm or embolism, which may decrease the rSO2; this decrease may be resolved after the procedure. The oximeter can reflect the dermal or subdermal tissue oxygenation. Unlike with our oximeter measuring rSO2 up to a depth of 5 mm below the probe, depth exceeding 15 to 20 mm in conventional near-infrared spectroscopy devices may affect the rSO2 values because of the thin subdermal layer of the foot and may influence the outcome of ulcer healing. With multiple oximeters and the concept of the TOE, we may be able to perform EVT to the extent necessary for individual CLTI patients. However, it may be better to place the sensor probe at the site of one of the ulcerations on the toe or on the surface of open ulcers directly rather than on the dorsal foot, especially when the pedal arch is absent.

CONCLUSIONS

With multiple oximeters and the concept of TOE, it is feasible to monitor the effect of each EVA procedure on tissue perfusion. TOE may become a standard strategy to perform EVT; however, further studies are needed to identify the suitable location for sensor probes for monitoring the rSO2 and its threshold levels for wound healing.

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