Augmented reality navigation to assist retrograde peroneal access for the endovascular treatment of critical limb ischemia

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ABSTRACT

Retrograde access is an alternative approach to endovascular intervention for critical limb ischemia but may be challenging in patients with poor below-knee vessel runoff. Here, we introduce an innovative technique based on an augmented reality navigation system to gain successful retrograde access to the peroneal artery of an 84-year-old woman with critical limb ischemia. Our result showed that this innovative technique had the potential advantage of influencing target vessel access selection with lower contrast material volume and radiation exposure compared with the conventional approach. More in-depth study is required to investigate the safety and efficacy of augmented reality-assisted vascular interventions. (J Vasc Surg Cases and Innovative Techniques 2019;5:518-20.)

Keywords: Retrograde access; Augmented reality; Critical limb ischemia; Endovascular

Although antegrade vessel access through either ipsilateral or contralateral puncture is a routinely used technique, retrograde access is often required to perform endovascular interventions for critical limb ischemia (CLI).[1] However, it may be challenging in some patients, particularly those with poor below-knee vessel runoff, even if it is guided by duplex ultrasound or fluoroscopy roadmap. Here we introduce an innovative technique based on an augmented reality (AR) navigation system to gain successful retrograde access to the peroneal artery for patients with CLI. The patient consented to publication.

CASE REPORT

The patient, an 84-year-old woman, presented with severe pain and ischemic symptoms in her right foot for 2 days. She had had claudication for 1 year but did not seek any medical treatment. On physical examination, she was found to have discoloration of the foot and absence of pulses in the popliteal artery and tibial arteries, consistent with CLI. Computed tomography angiography (CTA) revealed a high degree of stenosis of the distal superficial femoral artery and total occlusion of the popliteal artery. Her cardiovascular risk factors included hypertension, hyperlipidemia, and coronary artery disease.

The patient was brought to the operating room urgently for limb salvage. Antegrade access through the ipsilateral common femoral artery was established, and angiography confirmed total occlusion of the right popliteal artery and tibioperoneal trunk (Fig 1, *A* and *B*). After multiple failed attempts using a V-18 guidewire (Boston Scientific, Natick, Mass) and a TrailBlazer support catheter (Medtronic, Minneapolis, Minn) to cross the total occlusion, we proceeded with retrograde access to the tibial artery. The angiogram showed that the posterior tibial artery was stenotic distally (Fig 1, *C*); therefore, the peroneal artery was targeted, and the tibioperoneal occlusion was revascularized successfully (Fig 1, *D*).

For retrograde access, we used an AR navigation computer-assisted technique to guide access to the distal peroneal artery. The AR navigation system (Xiamen Minwei Limited Company, Xiamen, China) is made of three parts: three-dimensional reconstruction processing system, AR glasses, and interactive system. The working principle of the AR navigation system is described in Fig 2. Briefly, CTA is performed with four tracking makers attached to the lower extremity of the patient. The CTA data with Digital Imaging and Communications in Medicine format and the operator's command are input to the three-dimensional reconstruction processing system, which creates the recommended puncture path (site, depth, and angle of puncture) to the target vessel (Fig 3, *A* and *B*). The puncture path is then displayed on the AR glasses, on which the red dot represents the target vessel and the four yellow dots represent the four tracking markers attached to patient's leg, with green dots for the puncture needle (Fig 3, *C* and *D*). The information is further adjusted by the operator through the interactive system to

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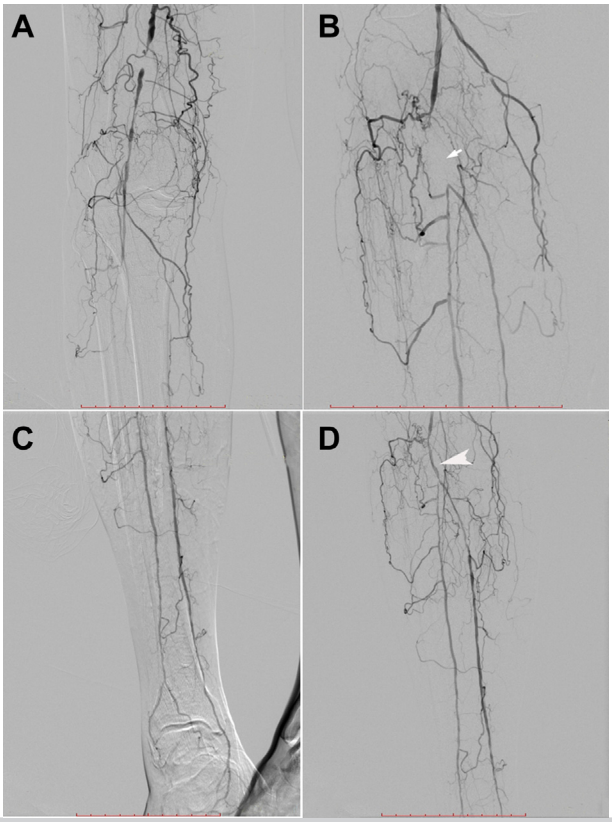

Fig 1. Revascularization of popliteal artery and tibioperoneal trunk in patient with critical limb ischemia (CLI). Total occlusion of the right popliteal artery **(A)** and tibioperoneal trunk (**B**; *arrow*) was confirmed by angiography. The runoff vessels showed the posterior tibial artery and peroneal artery, with stenosis in the distal posterior tibial artery **(C)**. Retrograde access to the peroneal artery was obtained, and the total occlusion of the tibioperoneal trunk was revascularized by balloon catheter of 2.5 mm in diameter (**D**; *arrowhead*).

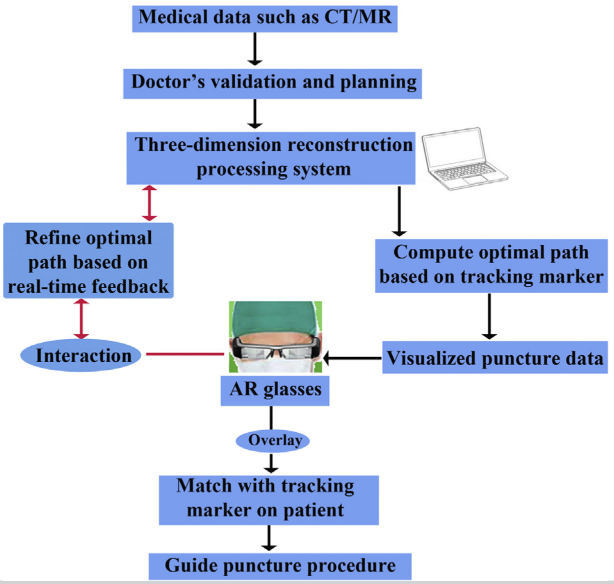

Fig 2. Schematic diagram of the working principle of the augmented reality (*AR*) navigation system. *CT,* Computed tomography; *MR,* magnetic resonance.

confirm overlapping of the yellow dots on the glasses with the four tracking markers on the surface of the patient's leg. The micropuncture needle is then aligned with the green dots and advanced along the blue track on the AR glasses toward the target vessel (red dot).

With use of this AR system, the access to the distal peroneal artery was established (Fig 3, *D*), and a V-18 guidewire successfully traversed the tibioperoneal occlusion. Subsequently, the patient was treated with balloon angioplasty using a 2.5- × 150-mm Pacific Plus angioplasty balloon (Medtronic Invatec, Frauenfeld, Switzerland; Fig 1, *D*). Hemostasis on the puncture site was achieved by manual compression. The patient had total resolution of her rest pain and was treated with antiplatelet medication.

DISCUSSION

Despite various retrograde techniques reported in the literature, a below-knee access might be challenging, especially in patients with CLI, because vessels are typically small and diseased.[2,3] Not infrequently, severe arterial spasm that necessitates the need for vasodilators, such as nitroglycerin or papaverine, can occur.[1,4] Not surprisingly, retrograde tibial or pedal access is reported to have lower technical success and primary patency rates compared with antegrade femoral access.[2,4] In some complicated CLI cases, the technical success rate was reported to be as low as 63.5%,[5] and devastating complications have been reported.[3,6] In addition, there is a steep learning curve for tibial and pedal access, and the technique subjects the operator to more radiation exposure because of proximity to the radiation source.[1,7] Precise visualization of the needle entry site and the needle trajectory can help minimize injury to the vessel and reduce radiation exposure of both patients and operators.

With the advancement of medical engineering, AR has been extensively used as a navigation tool. The intraoperative AR-assisted navigation system has been applied in various surgical procedures, such as percutaneous revascularization of coronary chronic total occlusion, transcatheter aortic valve implantation, perforator flap transplantation, plastic surgery, neurosurgery, maxillofacial surgery, and hepatopancreatobiliary surgery.[8-10] Its use in vascular interventions has not been described.

CONCLUSIONS

We reported a successful case of using an AR-assisted system in guiding accurate visualization of the target vessel by AR glasses. This case demonstrated the feasibility and safety of using a CTA-assisted AR-based

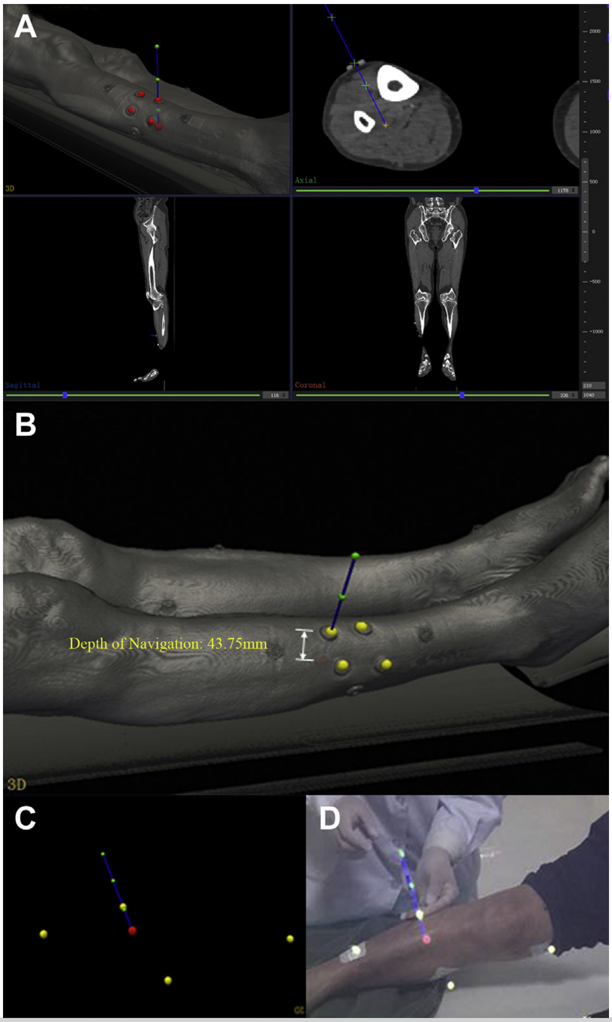

Fig 3. Retrograde access to the peroneal artery was guided by the augmented reality (AR) navigation system. The Digital Imaging and Communications in Medicine image data were input to the three-dimensional reconstruction processing system **(A)**, which created the puncture path with incorporation of cross-sectional, sagittal, and coronal images. The optimal path to the target vessel was shown on the computer with the given depth and puncture angle **(B)**. As shown in **(C)**, the *red dot* is the target vessel, and the four *yellow dots* represent four tracking markers attached to the patient's leg, with one of them set as the putative puncture site. The puncture path was then displayed on the AR glasses, and the operator adjusted the needle and aligned it with the *green dots* and the *blue route* toward the target vessel **(D)**. Note that the tracking markers on the leg overlapped the *yellow dots* displayed on the AR glasses.

navigation system for endovascular intervention. This technique did not interfere with the operator's routine activities in the catheterization procedure and has the potential to lower contrast material volume and radiation exposure.

Unlike with conventional endovascular approaches, there are important technical considerations. For example, it is empirical to maintain overlapping between the representative dots on the glasses and the real objective on the patient. The operator will need to become familiar with the technique and must adjust the needle trajectory to align with the puncture route shown on the glasses. Further improvement of this AR navigation system and more in-depth study are required to popularize AR-assisted vascular intervention.

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