Letter to the Editor

A first attempt of inferior vena cava filter successfully guided by a mixed-reality system: a case report

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Pulmonary embolism (PE) is one of the fatal heart attacks, and lower limbs deep vein thrombosis (DVT) is the most common reason for PE. Inferior vena cava filter (IVCF) implantation is a most prevention for PE. But it may carry a high risk of injury because of the radiation and contrast agent. Patients with nephrotic syndrome (NS) or some other renal diseases may prone to thrombosis due to the excretion of protein C and protein S overmuch. So, it is necessary to develop a new therapy without contrast agent. Mixed-reality (MR) is a new technology as a guidance of inferior vena cava filter implantation exposed under no X-ray and required no contrast agent. We describe a case of old man with NS who can’t tolerate traditional interventional surgery to prevent the embolus from falling off. We performed IVCF implantation guided by MR system which was totally suitable for this patient.

The patient was a 65-year-old man with NS treated with losartan and Haikun Shenxi Capsule regularly for one year. A month ago, he underwent ultrasound for his right leg swelling and thrombosis was found from right external iliac vein to femoral vein. Then he received treatment with thrombolysis and anticoagulation for lower limb DVT without IVCF implantation due to renal insufficiency in the local hospital. But recently, the patient had recurrence of chest distress and dyspnea with oxygen desaturation. Physical examination showed roughly normal. ECG and Echocardiography didn’t show a manifestation of PE or right-ventricular failure. Blood levels of D-dimer were severe elevated. As the patient suffered from NS for one year, we also checked his renal function. Serum creatinine was 63.1 μmol/L but the glomerular filtration rate (eGFR) was just 50.96. Pulmonary artery computed tomography angiography (CTA) showed bilateral pulmonary filling defect and chest CT suggested pulmonary infarction in bilateral inferior lobe. An ultrasound of lower limb vein was reexamined and showed that the thrombosis was still there.

In summary, the patient had a history of DVT and thrombolysis treatment, high D-dimer and a typical change in pulmonary artery CTA. The diagnosis of PE was confirmed. So, anticoagulation therapy was continued. However, all the therapy did not work, and if we repeated thrombolysis could result in recurrence of PE. Inferior vena cava filter (IVCF) implantation is a most prevention for recurrence of PE. Though his renal insufficiency mattered, the management of PE was prioritized. But IVCF implantation with contrast agent injection of a patient with renal insufficient is at high risk. We hoped to find a method that can avoid the radiation and contrast agent to head-off risk of contrast-induced nephropathy (CIN) and even acute kidney injury (AKI). MR system can visualize human anatomy without the need for contrast agents. This technique requires only a small dose of contrast agent (about 10 mL) for preoperative CT examination to confirm the position of renal vein opening and no contrast agent during the surgery.

Before the operation, a CT three-dimensional (3D) reconstruction depend on DICOM data was performed to model the grid (STL) and then carry out the material setting including color assignments and transparency presets. And the data is output in v3d format (a data transmission format in Weizhuo Zhiyuan technology co., LTD, BeiJing) obtain holographic image data (Figure 1). Then we measured the length of the vascular centerline from the puncture point on...
the body surface to the preset position of the filter, set markers along the way and make a STL model, and push it to the mixed-reality display device (Figure 2).

During the operation, 3D holographic images of femoral vein, IVC and renal vein of the patient were presented in MR glasses worn by the operators through image fusion and spatial positioning. And the holographic 3D model was fused with the human body in the real surgery in equal proportions. The right femoral vein was punctured under local anesthesia and 6F vascular sheath was inserted. The operators turn on MR glasses, and inserted an elbow wire of temporary IVCF implant set (LifeTech Scientific Corporation) below the renal vein opening, then withdrew the 6F vascular sheath and expanded the skin with the lancet, and inserted the filter delivery sheath. According to the length of the sheath tube from the body surface puncture point into the vessel, the position of the sheath tube would display in real time in MR glasses. We sent the sheath tube to 1–2 cm below the renal vein opening and confirmed the position of the sheath tube was consistent with the preset position by ultrasound, then released the filter. After the removal of the sheath tube, the patient returned to the ward with no complaints of discomfort (Figure 3).

PE is one of the three most common cardiovascular diseases.[1] DVT is the main cause of PE. Thrombosis that forms in the veins of the lower extremities or the pelvis breaks off and blocks the pulmonary artery and its branches with venous reflux. For this case, the patient recurrent DVT and PE for his history of nephrotic syndrome (NS). As his renal impairment, protein C, protein S and some other procoagulant are excreted overmuch and increased the risk of DVT and PE. For patients with sufficient anticoagulation but recurrent PE, the implantation of IVCF is an important measure to prevent further PE.[2] The tradition IVCF implantation should be performed under X-ray. The position of the renal vein should be confirmed by cephalography of the IVCF and after the completion of placement, cephalography should be performed again. So 30–50 mL contrast agent is needed during the traditional surgery. CIN is one of the major complications of interventional surgery. In the general population, the incidence of CIN is about 2%. However, some studies have shown that renal impairment is the most important risk factor for CIN,[3,4] and the incidence of CIN increases to 14.8%–55% in patients with pre-contrast renal impairment.[4,5]
In this case, conventional surgical methods undoubtedly greatly increase the risk of CIN for the patient’s NS history. Therefore, the application of Mixed-Reality (MR) technology can guide the surgical operations without radiation and contrast agent, which not only avoids the risk of CIN in patients, but also reduces the radiation injury of the patient and surgeons. Although a CT 3D reconstruction with small dose of contrast agent had to be performed before the operation, the risk of CIN and AKI would be much decreased compared with the risks caused by traditional IVC filter implantation.

MR is a brand new digital holographic imaging technology, which generate virtual 3D models of patients’ imaging information and superimpose them on the real surgery of the operator to achieve the mixture of real human body and digital model, so as to visualize the human anatomical structure on the surface of human body.[6] The greatest advantage of this new technology is that it reduces the error between the actual structure and the operator’s range of vision.[7] Through 3D imaging of the interventional vessels, the authenticity and visual effects of the open surgery can still be achieved during the minimally invasive surgery. In addition, it can make surgeons clearer and more accurate about the interventional route and reduce the occurrence and risk of complications. At present, this technology has been effectively applied in surgery such as cancer operations and robot assisted surgery.[8,9] In the field of cardiovascular intervention, previous studies have shown that MR has good authenticity and reliability in the 3D imaging of subclavian vein.[10]

The successful implementation of this operation provides valuable evidences for the application of this technique in the cardiovascular field. In the future, MR is likely to be widely used in medical education, research, remote consultation and military medicine, promoting the development of medicine towards a more efficient and accurate direction.

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