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Augmented Reality–Supported Totally Thoracoscopic Epicardial Left Atrial Appendage Closure in a Patient With Liver Cirrhosis

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Introduction

Nonvalvular atrial fibrillation (AF) is a common cardiac arrhythmia leading to thromboembolic events. Stroke prevention with anticoagulation therapy or, if indicated, with percutaneous left atrial appendage closure (LAAC) is the appropriate management. Patients with liver cirrhosis present a high risk of hemorrhagic complications, and the use of oral anticoagulants may further exacerbate the risk of bleeding.[1] The combination of cirrhosis with AF is associated with significant mortality and morbidity rates ranging from 5% to 15%.[2] Stroke prevention through LAAC, avoiding the use of anticoagulation therapy, can be an effective and safer treatment in these patients.[3] This report documents the role of totally thoracoscopic LAAC in a patient with liver cirrhosis and AF in the setting of abnormal intracardiac anatomy, which made impossible percutaneous exclusion of the left atrial appendage (LAA). It is worth noting that percutaneous exclusion with devices necessitates about 45 days of anticoagulation therapy. Totally thoracoscopic LAAC was supported by augmented reality (AR) to integrate direct visualization of the LAA by the surgeon with an enhanced digital model of LAAC, which allowed identification of the optimal positioning of the port for the clip delivery system and the exact device landing zone (Supplemental Video).

Case Report

A 79-year-old female patient with liver cirrhosis was referred for LAAC due to persistent AF. The patient management was complicated by recurrent significant gastrointestinal bleeding due to the need for anticoagulation therapy. The thromboembolism score (CHA_2DS_2-VASc) and bleeding risk score (HAS-BLED) were >4 and 3, respectively. Echocardiography revealed a normal left ventricular ejection fraction and no significant valvular diseases. Several comorbidities including arterial hypertension, diabetes mellitus, dyslipidemia, obesity, and portal hypertension characterized the patient's medical history.

Percutaneous LAAC was attempted but unsuccessful due to the patient's agenesis of the inferior vena cava, which was an impediment for the delivery system to reach the right atrium via the femoral vein. The decision was then made for surgical exclusion of the LAA on the beating heart using a left-sided thoracoscopic approach. A longitudinal pericardial opening of 1.5 cm was made below the phrenic nerve toward the left pulmonary artery, just above the LAA, and a 35 mm AtriClip PRO2 epicardial device (AtriCure, Inc., Mason, OH, USA) was deployed parallel with the base of the LAA to allow complete exclusion of the appendage. Intraoperative transesophageal echocardiography confirmed the absence of LAA thrombi prior to LAAC and excluded any residual flow and stump after clip application. The postoperative course was uneventful.

Role of Augmented Reality

Computed tomography (CT) angiography imaging was conducted before LAAC to generate a digital model of the patient's LAA for enhanced visualization using AR in the operating room. Using the medical imaging software Mimics (Materialise, Leuven, Belgium), the rib cage, left ventricle, left atrium, and proximal aorta were reconstructed and depicted with different colors. In addition, a 3-dimensional model of the AtriClip PRO2 was generated based on the manufacturer's instructions for use. A computational simulation of the LAAC procedure was performed using finite-element analysis, as done in a similar study.[4] Subsequently, an animation of the LAAC simulation was integrated into Magic Leap AR glasses (Plantation, FL, USA) as used by the surgeon during the minimally invasive procedure. Figure 1a shows the digital heart anatomy superimposed onto the patient's body through manual overlay as seen by the surgeon wearing the AR tool in the operating room. The

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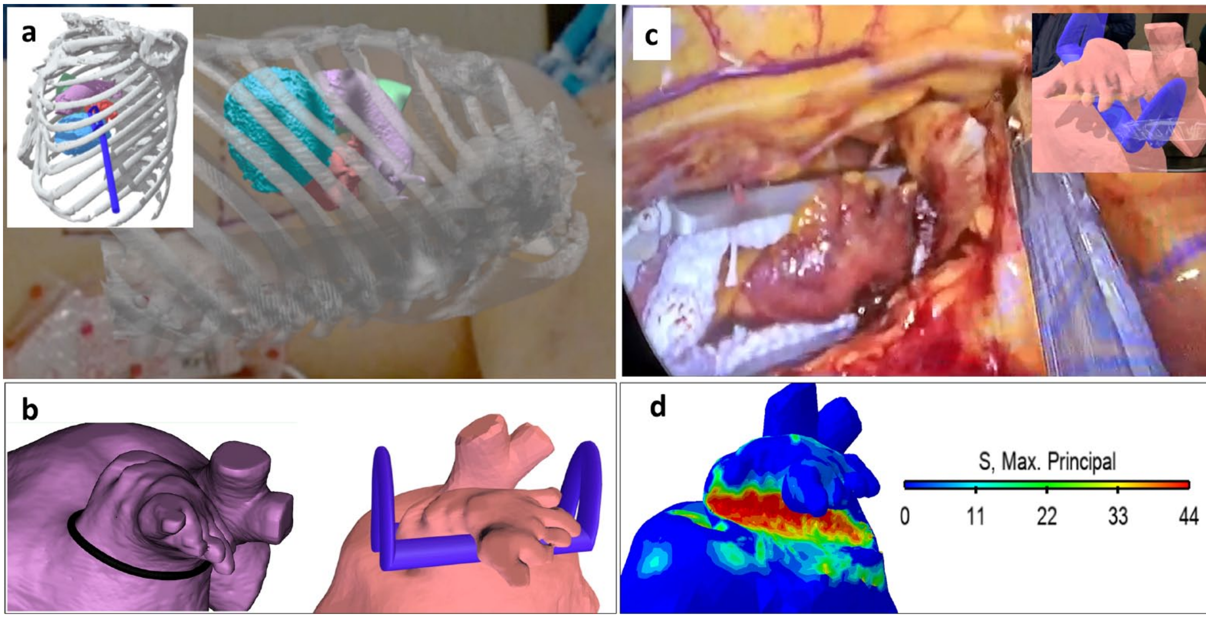

Fig. 1. (a) Surgeon view from the augmented reality glasses showing the digital heart model on patient body and a simulation of LAAC showing the entering of the rigid shaft from the fourth intercostal space. (b) AtriClip PRO (AtriCure, Mason, OH, USA) positioning before and after the final device delivery showing cauliflower-like LAA. (c) LAAC procedure performed by the surgeon. (d) Stress analysis showing the clipped tissue region likely undergoing remodeling. LAAC, left atrial appendage closure.

analysis of LAAC simulation highlighted the correct position of the port through the right fourth intercostal space to enable the rigid shaft to be well aligned with the base of LAA as compared with a port on the third intercostal space. The perimeter of the oval LAA ostium at the landing zone of the clipping device was predicted by simulation and visualized in the intraprocedural digital LAA model (Fig. 1b). This allowed us to optimize the LAAC procedure as shown in Figure 1c. Stress analysis also revealed the region of atrial remodeling likely occurring after LAAC (Fig. 1d).

Discussion

This case report describes the efficacy and safety of epicardial LAAC in a patient with nonvalvular AF and liver disease who was at high risk for bleeding. Surgical treatment was chosen due to the unfeasibility of percutaneous closure caused by anatomical constraints. For the first time, thoracoscopic LAA clipping was performed, supported by a digital heart model loaded into AR glasses, facilitating improved visualization of LAA. In addition, computer simulations were adopted to optimize the clipping procedure. Surgical planning of device delivery with AR and simulations provided an enhanced understanding of the position of the port for entering the rigid shaft through the intercostal space as well as the optimal landing zone of the clipping device, likely reducing residual flow and stump formation after LAAC.

Patients with liver cirrhosis and concurrent AF have typically been excluded from clinical trials evaluating the efficacy of endocardial and epicardial exclusions of the LAA to mitigate stroke risk. However, these patients can benefit from LAAC, as they are at increased risk for both acute ischemic stroke due to comorbidities and bleeding associated with oral anticoagulation therapy. A recent large population study demonstrated that cirrhosis patients who underwent endocardial LAA occlusion had similar rates of gastrointestinal bleeding as patients without cirrhosis.[5] In this article, we demonstrate that epicardial LAAC could represent an alternative strategy to anticoagulant therapy in patients with AF and concurrent chronic liver disease. The use of an augmented computer-based simulation of the clipping procedure, merging the digital model with the surgeon's view, clearly facilitated thoracoscopic LAAC compared with preprocedural planning using conventional 2-dimensional imaging. Therefore, we conclude that direct visualization of the LAA base using thoracoscopy can be complemented by AR-related digital visualization for a better positioning of the entering port for the device and identification of the device landing zone in patients undergoing LAAC. Future studies will aim to improve the positioning of the digital model on the heart anatomy and address image distortion caused by mechanical ventilation and discrepancies with preoperative CT imaging.

Declaration of Conflicting Interests

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Supplemental Material

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