The pathophysiologic role of the left atrial appendage (LAA) in thromboembolic disease and as the primary source for cardioembolic events in patients with atrial fibrillation (AF) has been recognized since the 1950s. This has led to the development of percutaneous approaches to exclude LAA, including LAA ligation with the LARIAT suture delivery device (SentreHEART, Inc, Redwood City, CA). However, the anatomic consequences of percutaneous LAA ligation are unknown. This report describes LAA gross anatomy and histological consequences of LAA ligation from 2 patients.

Case 1
A 63-year-old man with a history of persistent AF on chronic warfarin oral anticoagulation was referred for LAA exclusion after severe gastrointestinal bleeding and history of falling resulting in a hip fracture. His past medical history included hypertension, diabetes mellitus, previous myocardial infarctions, congestive heart failure, end-stage renal disease on hemodialysis, peripheral vascular disease, status post- femoral popliteal bypass surgery, and hip fracture. The patient had a CHADS2 score of 3, CHADS-Vasc score of 4, and a HAS-Bleed score of 4.

The patient underwent an uncomplicated closed-chested LAA ligation with the LARIAT suture delivery device. LAA closure was confirmed with transesophageal echocardiography (TEE) and contrast fluoroscopy acutely (Figure 1). The patient did well post-LAA closure and was on no antiplatelet or antithrombin medications. A follow-up TEE performed at 8 months revealed a closed LAA with no leaks. Eleven months after his LAA ligation, the patient was admitted to the hospital with pneumonia and volume-overloaded congestive heart failure. During dialysis, the patient had a ventricular fibrillation arrest. Cardiac resuscitation was initiated but was unsuccessful and the patient died. An autopsy was performed. Gross anatomy of LAA demonstrated an atretic LAA that was adhered to the epicardial surface of the left atrium (LA; Figure 1D). The endocardial surface of LA had a smooth surface with no visual evidence of LA to LAA communication (Figure 1F). Histology revealed that the majority of LAA muscle was replaced by scar tissue at the apex and endocardial aspect of LAA with severe fibrosis throughout the epicardial aspect of LAA (Figure 1G). There was evidence of remnant thrombus formation within the obliterated cavity of LAA (Figure 1H).

Case 2
A 60-year-old man with idiopathic cardiomyopathy and persistent AF was referred for LAA exclusion due to warfarin intolerance, traumatic falls, and a labile international normalized ratio. His past medical history is significant for hypertension, diabetes mellitus type 2, left ventricle dysfunction (left ventricular ejection fraction of 30%), mitral regurgitation, heart failure (New York Heart Association class III), and renal insufficiency. The patient has a CHADS2 score of 3, CHADS-Vasc score of 4, and a HAS-Bleed score of 4.

The patient underwent an uncomplicated closed-chested LAA ligation with the LARIAT suture delivery device. LAA closure was confirmed with TEE and contrast fluoroscopy acutely (Figure 2). The patient did well post-LAA closure and was on no antiplatelet or oral anticoagulation therapy. Follow-up TEE with color flow Doppler was performed at 1 day, 1 month, 3 months, and 1 year revealed a closed LAA with no leaks. The patient’s cardiomyopathy continued to worsen despite optimal medical heart failure management. The patient underwent heart transplantation 1 year and 11 months after his LAA ligation procedure. During explantation of the heart, the examination of pericardial cavity did not reveal any adhesions. The suture was still present at the neck of LAA, and the LAA was atrophied. The endocardial surface of LA was smooth with no evidence of LA to LAA communication (Figure 2E). Histology demonstrated a small residual LAA lumen with fibrosis and scarring present throughout the wall of the LAA (2F) and fibrotic scarred tissue at the site of suture ligation with endothelialization of the atrial surface (Figure 2F and 2G).

Discussion
The LARIAT procedure is a percutaneous adaptation of the surgical exclusion of LAA with a suture. The suture material delivered by the LARIAT snare is identical to the suture material...
used during open-heart surgery to exclude LAA; and it is similarly positioned at the base of LAA. A single-center observational study has demonstrated the efficacy of LAA closure by delivering a suture around the base of LAA by the LARIAT device. Although there has been no prospective randomized study to determine stroke reduction with the LARIAT device, the procedure is used as an alternative to open-heart surgery in patients with AF at high risk of embolic stroke who have contraindications or intolerances to oral anticoagulation therapy. Both patients had contraindications or intolerances to long-term anticoagulation therapy. At the time of each patient’s procedure, newer oral anticoagulants were not available in Poland, nor rivaroxaban or apixaban was available in the United States. Each patient was offered options of surgical exclusion, referral to a center implanting the Watchman device, or LAA ligation with the LARIAT device. Both patients chose LAA ligation with the LARIAT device.

This case report demonstrates that percutaneous suture ligation of LAA resulted in extensive inflammation of LAA leading to fibrosis, scarring, and permanent closure of LAA. These findings also suggest that TEE demonstration of the absence of color Doppler flow is a reasonable assessment of permanent successful LAA closure. The cases presented are consistent with preclinical studies of LAA ligation with the LARIAT device, in which there was atrophy of LAA and complete endothelialization of the endocardial surface at suture site. The profound inflammatory response that occurred throughout LAA and at the site of closure undoubtedly contributes to observed events such as pericarditis and Dressler syndrome. It is noteworthy that inflammation and scarring can also involve the LA (Figure 2). Acute inflammation within the LA could lead to endothelial dysfunction and attraction of platelet adhesion, thus giving rise to thrombus formation.

These findings support the consideration of prophylactic use of anti-inflammatory agents such as cholechicine and nonsteroidal to prevent pericarditis and Dressler syndrome. Although thrombus formation seems to occur infrequently, one possible mechanism contributing to thrombus formation may result from endothelial injury leading to platelet accumulation. A short-term antithrombotic therapy such as aspirin or aspirin and clopidogrel should be considered until a follow-up TEE demonstrates a closed LAA with no thrombus. Additional investigation of the incidence of thrombus formation post-LAA ligation is warranted.

**Disclosures**

Dr Lee is a consultant and equity holder in SentreHEART, Inc. The other authors have no conflicts to report.

**References**

Figure 1. Anatomy and histology of case 1. Prescreening CT angiography reveals that the left atrial appendage (LAA) is a single lobe with a width of 3.4 cm (green line in A). Transesophageal echocardiography imaging of the left atrium (LA) and LAA at baseline (B) and 8 mo after LAA ligation reveals an excluded LAA with no color Doppler flow (C). Gross inspection of the atretic LAA adhered to the epicardial surface of the LA (D, bar, 0.5 cm). Lifting of LAA reveals strands of adhesion between the epicardial surface of LA and LAA (E). The pericardium was not adhered to the LAA. The endocardial surface of LA is smooth with no apparent opening to the LAA (F). The arrow designates the site of closure of LAA. Hematoxylin and eosin staining of a cross-section of atrophied LAA reveals extensive scarring with a remnant LAA cavity (G; low power, ×12.5). High magnification of LAA reveals diffuse degeneration of LAA muscle cells, inflammation, and scarring (H; high power, ×200). I. Inflammation and fibrosis seen within the epicardium of LAA. LUPV indicates left upper pulmonary vein; and PA, pulmonary artery.
Figure 2. Anatomy and histology of case 2. Prescreening CT angiography reveals that the left atrial appendage (LAA) is a single lobe with a length of 3.5 cm (green line in A and B). Transesophageal echocardiography (TEE) at 1 mo post-LAA ligation demonstrates an excluded LAA (C) with no evidence of color flow Doppler (D). TEE findings correlate with the gross examination of LAA that reveals a remnant LAA with complete closure at ligation site (E). Mason trichrome staining demonstrates extensive scarring (dark blue) within the LAA and suture site that extends into the left atrium (F and G). H, Hematoxylin and eosin staining.
Anatomic Analysis of the Left Atrial Appendage After Closure With the LARIAT Device
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