

# Association between incomplete surgical ligation of left atrial appendage and stroke and systemic embolization



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**BACKGROUND** Surgical exclusion of the left atrial appendage (LAA) can frequently yield incomplete closure.

**OBJECTIVE** We evaluated the ischemic stroke/systemic embolization (SSE) risk in patients with atrial fibrillation (AF) and complete LAA closure (cLAA) vs incompletely surgically ligated LAA (ISLL) and LAA stump after surgical suture ligation.

**METHODS** Seventy-two patients (CHA<sub>2</sub>DS<sub>2</sub>-VASc score  $4.1 \pm 1.9$ ) underwent surgical LAA ligation in conjunction with mitral valve/AF surgery and postoperative LAA evaluation using computerized tomographic angiography.

**RESULTS** Overall, cLAA was detected in 46 of 72 patients (64%), ISLL in 17 patients (24%), and LAA stump in 9 patients (12%). The incidences of oral anticoagulation (OAC) and recurrent AF were similar among the 3 groups during  $44 \pm 19$  months of follow-up. SSE occurred in 2% of patients with cLAA vs 24% with ISLL and 0% with LAA stump ( $P = .006$ ). None of the patients with SSE were receiving OAC, and all had recurrent AF during follow-up. Additionally, patients with SSE exhibited a significantly smaller ISLL neck diameter ( $2.8 \pm 1.0$  vs  $7.1 \pm 2.1$  mm;  $P = .002$ ). The annualized SSE risk was 1.9% (entire cohort), 6.5% (ISLL patients), 14.4% (ISLL patients not receiving OAC), and 19.0% (ISLL neck diameter  $\leq 5.0$  mm) per 100

patient-years of follow-up. The latter risk was nearly 5 times greater than predicted by conventional risk-stratification schemes. Moreover, ISLL emerged as an independent predictor of SSE in univariate analyses and as the sole predictor of SSE in a multivariate analysis.

**CONCLUSION** In patients with AF, ISLL is a predictor of SSE, independent of conventional risk stratification schemes. Consequently, OAC should be strongly considered in this high-risk cohort.

**KEYWORDS** Cardiac surgery; Incomplete closure; Left atrial appendage; Ligation; Stroke

**ABBREVIATIONS** AF = atrial fibrillation; CHADS<sub>2</sub> = Congestive heart failure, hypertension, age  $\geq 75$  years, diabetes and stroke; CHA<sub>2</sub>DS<sub>2</sub>-VASc = Congestive heart failure, hypertension, age  $\geq 75$  years, diabetes, stroke, vascular disease, age  $\geq 65$  years and sex category; cLAA = complete left atrial appendage closure; ISLL = incompletely surgically ligated left atrial appendage; LAA = left atrial appendage; OAC = oral anticoagulation; SSE = ischemic stroke and systemic embolization

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## Introduction

The left atrial appendage (LAA) is a common site of thrombus formation in patients with atrial fibrillation (AF).<sup>1</sup> As such, the practice guidelines recommend surgical LAA closure in patients with AF undergoing mitral valve or Maze surgery.<sup>2</sup> However, surgical LAA exclusion, particularly with suture ligation, can often yield incomplete LAA closure,<sup>3–6</sup> which may in turn be associated with increased

thromboembolic risk.<sup>3</sup> Incomplete surgical LAA closure can be further classified as incompletely surgically ligated LAA (ISLL) or LAA stump. In this study, we evaluated the risk of ischemic stroke and systemic embolization (SSE) in a contemporary cohort of patients with AF in the absence of rheumatic heart disease, in the setting of ISLL or LAA stump compared with complete LAA closure (cLAA), after surgical suture ligation performed in conjunction with mitral valve or AF surgery.

## Methods

### Study patients

Patients with nonrheumatic paroxysmal/persistent AF in the absence of mitral stenosis who underwent a first surgical

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LAA suture ligation concurrent with mitral valve or Maze surgery by 5 experienced operators (Mercy General Hospital, Sacramento, California) between January 1, 2008, and December 31, 2012, were enrolled. The surgical approach to LAA ligation consisted of an oversewing technique with a double-layer of running Prolene suture (Ethicon, Inc, Somerville, New Jersey).

### Computerized tomographic angiography

All patients underwent outpatient gated cardiac computerized tomographic (CT) angiography  $\geq 3$  months after surgery to evaluate the status of their LAA. Elective CT angiography for the purpose of this study was avoided within the first 3 months to allow sufficient recovery from the index surgery and to allow for delayed dehiscence of LAA suture ligation, but there was no “blinding period” with respect to detection of SSE in the postoperative follow-up period. Meanwhile, any opacification of the “residual” LAA (partial or complete) was classified as incomplete closure, whereas cLAA was defined as the absence of contrast flow into the presumed anatomic location of the LAA. Incompletely closed LAAs were further classified as (1) ISLL, characterized by the presence of a narrow, constricted LAA neck connecting the intact/nearly intact LAA to the left atrial cavity, or (2) LAA stump, which was defined by presence of a short residual LAA vestige measuring  $\geq 1.0$  cm in depth (Figure 1). Whenever present, the ISLL morphologies were further subclassified as “cactus,” “chicken wing,” “windsock,” or “cauliflower” based on previously reported LAA morphological criteria.<sup>7</sup> Finally, the overall dimensions and volumes of ISLLs and LAA stumps were also recorded. All examinations were carefully reviewed and interpreted by 2 designated, experienced radiologists blinded to the patients’ clinical histories and outcomes. Presence of recurrent AF after LAA ligation was also assessed by use of routine, in-office

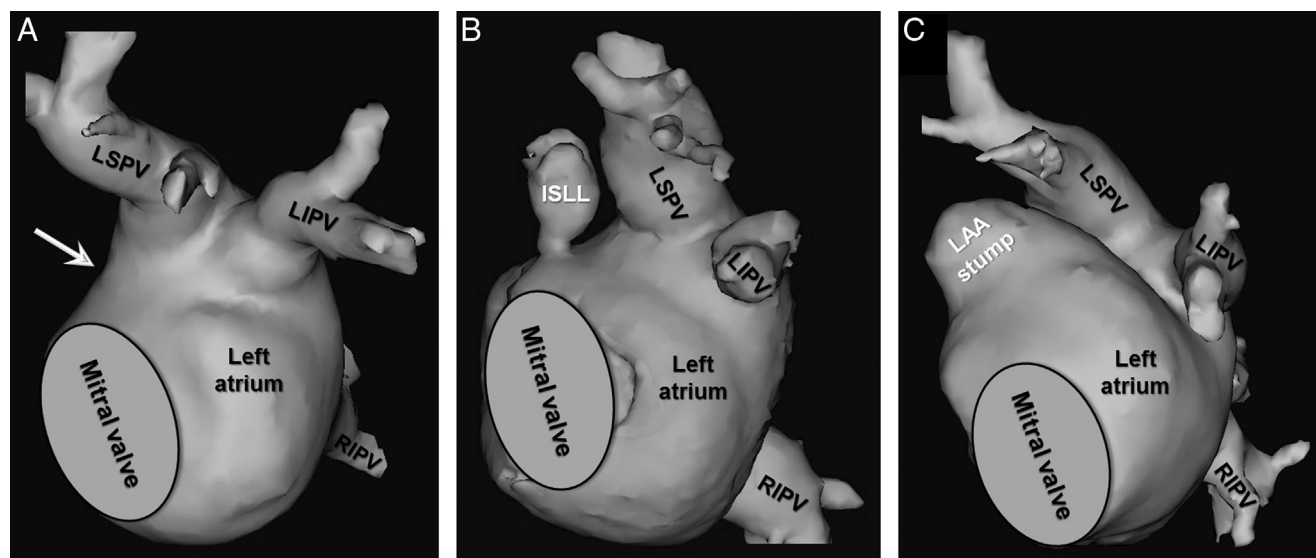
electrocardiograms and, whenever present, by use of routine cardiovascular implantable electronic device interrogations. All patients provided informed written consent for their participation in this study. Approval for this study was granted by our institutional review board (Dignity Health Institutional Review Board #14).

### Statistical analysis

Baseline patient demographics and procedural and clinical outcomes were compared among the groups. Continuous variables were analyzed with the 2-sample Student *t* test or Mann-Whitney test for parametric and nonparametric variables, respectively. The  $\chi^2$  or Fisher exact test was used for parametric or nonparametric categorical variables, respectively. Predictors of SSE as the primary outcome were discerned by univariable and multivariable regression modeling. The latter included all significant univariate predictors as well as clinically relevant variables, eliminating those that were correlated. This resulted in a parsimonious model after stepwise regression, providing odds ratios and 95% confidence intervals for statistically significant independent predictors of the primary outcome. Time-to-event analysis was performed via Kaplan-Meier curves, compared with log-rank and Wilcoxon tests. Additionally, the annualized risk of SSE was calculated for the entire cohort and various subgroups. Late follow-up was complete for 100% of patients at a mean of  $44 \pm 19$  months. For all analyses, *P* values were 2-sided, and *P* < .05 was considered significant. Analyses were conducted with SPSS version 20 (IBM SPSS Statistics, Chicago, Illinois).

### Results

Altogether, 72 patients participated in this study. CT angiography detected cLAA in 46 of 72 patients (64%),



**Figure 1** Computed tomography (CT) illustrations of complete left atrial appendage (LAA) closure (cLAA) vs incompletely surgically ligated LAA (ISLL) and LAA stump. Left atrial images segmented from cardiac CT angiograms illustrating cLAA (A), ISLL (B), and LAA stump (C) after prior surgical suture ligation at the time of cardiac surgery. In A, the arrow points to the presumed anatomic location of cLAA. LIPV = left inferior pulmonary vein; LSPV = left superior pulmonary vein; RIPV = right inferior pulmonary vein.

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