Feasibility and safety of a percutaneous and non-fluoroscopic procedure for left atrial appendage closure in patients for whom fluoroscopy presents risk: a cohort study

Mengxuan Zou[1,2,3,4#], Donglin Zhuang[2,3,4,5#], Horst Sievert[6], Yat-Yin Lam[7], Guangzhi Zhao[2,3,4,5], Wenbin Ouyang[2,3,4,5], Fengwen Zhang[2,3,4,5], Fang Fang[2,3,4,5], Deyuan Zhang[8], Anning Li[8], Xiangbin Pan[2,3,4,5]

[1]Department of Congenital Heart Disease, National Center for Cardiovascular Disease, China and Fuwai Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, China; [2]National Health Commission Key Laboratory of Cardiovascular Regeneration Medicine, Beijing, China; [3]Key Laboratory of Innovative Cardiovascular Devices, Chinese Academy of Medical Sciences, Beijing, China; [4]National Clinical Research Center for Cardiovascular Diseases, Fuwai Hospital, Chinese Academy of Medical Sciences, Beijing, China; [5]Department of Structural Heart Disease, National Center for Cardiovascular Disease, China and Fuwai Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, China; [6]Department of Cardiology and Vascular Medicine, Cardiovascular Center, Frankfurt, Germany; [7]Division of Cardiology, Department of Medicine and Therapeutics, Prince of Wales Hospital, The Chinese University of Hong Kong, Hong Kong, China; [8]LifeTech Scientific Corporation, Shenzhen, China

Contributions: (I) Conception and design: All authors; (II) Administrative support: X Pan; (III) Provision of study materials or patients: X Pan, G Zhao, W Ouyang, F Zhang, F Fang; (IV) Collection and assembly of data: M Zou, D Zhuang; (V) Data analysis and interpretation: M Zou, D Zhuang; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

[#]These authors contributed equally to this work.

Correspondence to: Xiangbin Pan, MD. National Health Commission Key Laboratory of Cardiovascular Regeneration Medicine, Beijing, China; Key Laboratory of Innovative Cardiovascular Devices, Chinese Academy of Medical Sciences, Beijing, China; National Clinical Research Center for Cardiovascular Diseases, Fuwai Hospital, Chinese Academy of Medical Sciences, Beijing, China; Department of Structural Heart Disease, National Center for Cardiovascular Disease, China and Fuwai Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, No. 167 North Lishi Road, Xicheng District, Beijing 100037, China. Email: panxiangbin@fuwaihospital.org.

Background: Most patients undergoing left atrial appendage closure (LAAC) are older adult individuals with atrial fibrillation (AF) and many comorbidities, which may elevate the risk for complications associated with contrast agents with the fluoroscopic image-guided procedure. This retrospective cohort study of patients with AF at high risk for use of contrast agents compared the feasibility and safety of LAAC using percutaneous and non-fluoroscopic procedure with transesophageal echocardiography (TEE) as the only image guidance relative to those under fluoroscopic image guidance.

Methods: In this retrospective study, we enrolled 126 patients with AF who underwent LAAC from September 2017 to December 2020. Patients were divided into 2 groups based on the imaging guidance modality: a TEE group (n=32) and a fluoroscopic group (n=94). We analyzed the differences in complete closure rates and device- and procedure-related complications between the 2 groups. Continuous variables were assessed using the Student *t*-test or Mann-Whitney test, while categorical variables were evaluated using Pearson chi-squared test or Fisher exact test. Propensity-score matching was used to adjust for baseline differences.

Results: Propensity-score matching yielded 25 pairs of patients with similarly distributed age (72.9±6.9 *vs.* 73.1±4.9 years; P=0.925), gender (10:15 *vs.* 11:14; P>0.99), weight (68.3±11.2 *vs.* 68.1±12.3 kg; P=0.948), and alanine aminotransferase level (20.0±9.8 *vs.* 22.5±14.2 U/L; P=0.482). The LAA was successfully occluded in all patients, and the TEE group showed similar results to the fluoroscopic group in terms of success rate (100% *vs.* 100%; P>0.99) and hospitalization duration [5.0 (IQ1–IQ3: 3.0–7.0) *vs.* 5.0 (IQ1–IQ3: 3.0–6.0) days;

P=0.498]. The groups also demonstrated comparable complication rates, with 1 (4.2%) case of pericardial effusion and 1 (4.2%) case of residual shunt in the TEE group, and 5 (20%) cases of residual shunt, 1 (4.2%) case of pericardial effusion, 1 (4.2%) case of myocardial infarction, and 1 (4.2%) case of access-related complications in the fluoroscopic group. There were no deaths. The overall incidence rate of procedure-related complications (6.2% *vs.* 18.1%, P=0.153) at mean 22.2±4.5 months follow-up between the 2 groups was similar.

Conclusions: In patients with AF of high risk for use of contrast agents, LAAC under non-fluoroscopic guidance appears feasible and safe with similar outcomes to that under fluoroscopic guidance.

Keywords: Echocardiography; atrial fibrillation (AF); chronic kidney disease; left atrial appendage (LAA)

Introduction

Patients with atrial fibrillation (AF), the most common type of arrhythmia (1,2), are at a 5-fold risk of secondary stroke due to thromboembolism. Oral anticoagulation decreases stroke risk but increases bleeding risk (3,4). Thrombus formation in patients with AF most likely occurs in the left atrial appendage (LAA) (5). For 90% of the affected patients, LAA closure (LAAC) effectively reduces the risk of thromboembolism and stroke with a similar effect to that of warfarin (3,6-8), which renders it a better choice for patients at high-risk of bleeding, especially from intracranial hemorrhage. However, traditional fluoroscopic-guided LAAC involves the use of contrast agents which increases the potential risk iatrogenic damage (5,9). Among older adult patients with comorbidities, the incidence of abnormal renal function is 15.6% (10,11) while the occurrence of contrast-agent allergy is 2–3% (12), which increases the risk of using contrast agents. Avoiding the use of potentially nephrotoxic drugs [such as contrast agents, angiotensin-converting enzyme (ACE) inhibitors, and angiotensin receptor blockers (ARBs)] around the time of cardiac surgery is the better choice for these patients (13). We hypothesized that transesophageal echocardiography (TEE) is applicable for this specific population of patients and has comparable feasibility and safety to fluoroscopic guidance when used as the sole image-guidance method. Therefore, we retrospectively compared the short-term outcomes of LAAC under TEE with those under fluoroscopic image guidance. We present this article in accordance with the STROBE reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-23-169/rc).

Methods

Study participants

From September 2017 to December 2020, this single-center cohort study retrospectively included 126 consecutive patients with AF who underwent LAAC. The treatment principles for all patients followed the 2014 American College of Cardiology/American Heart Association (ACC/AHA) guidelines (3), the 2014 European Heart Rhythm Association/European Association of Percutaneous Cardiovascular Interventions (EHRA/EAPCI) expert consensus (14), and the 2016 European guidelines for AF management (10,15). Treatment inclusion criteria for our center were as follows: age >18 years; with AF: persistent AF (lasting >3 months), long-standing persistent AF (lasting >1 year), or permanent AF; CHA_2DS_2-VASc [congestive heart failure, hypertension, age ≥75 years (doubled); diabetes mellitus prior to stroke or transient ischemic attack (doubled), vascular disease, age 65 to 74 years, and sex category] score ≥2 points; HAS-BLED (hypertension, abnormal renal/liver dysfunction, stroke, bleeding history, elderly, drugs) score ≥3 points; and on long-term clopidogrel and aspirin, with contraindication to oral anticoagulation or inability to use it for a prolonged period, or at high risk for contrast agents use, such as that associated with IV chronic kidney disease or allergy to contrast agents. The exclusion criteria were the following: (I) AF combined with moderate/severe mitral stenosis, (II) AF combined with other disease requiring surgery, (III) New York Heart Association Classification of Heart Failure (NYHA class) III–IV, (IV) acute myocardial infarction or unstable angina

pectoris, (V) and stroke or transient ischemic attack within 30 days. Patients with an estimated glomerular filtration rate (eGFR) of less than 60 mL/min were considered to have renal insufficiency, which was equivalent to stage 3 or higher chronic kidney disease. Due to the difference of baseline level between patients who underwent LAAC in TEE image guidance and in fluoroscopic image guidance, a 1:1 propensity-score match analysis was performed based on age, gender, weight, and alanine aminotransferase (ALT) level to minimize preoperative differences. This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and was approved by the Ethics Committee of Fuwai Hospital of The Chinese Academy of Medical Sciences (No. 2018-9). Written informed consent was obtained from all patients enrolled in both groups. The number of cases encountered during the study period determined the sample size.

Preprocedural imaging of TEE guidance

For this study, the choice of an occluder was based on TEE instead of contrast; we formulated a selection scheme for the LAmbre occluder (LifeTech Scientific, Shenzhen, China), Amplatzer Cardiac Plug (ACP) occluder (Abbott Vascular, Santa Clara, CA, USA), and WATCHMAN occluder (Boston Scientific, Natick, MA, USA) under TEE guidance with TEE measurements (*Figure 1A*). First, the LAA orifice was defined as the plane connecting the pulmonary vein (PV) ridge superiorly to the inferior junction of the left atrium and the LAA at the level of the circumflex artery (16). The size and depth of the LAA were preoperatively measured with the 0°, 45°, 90°, and 135° views using TEE (*Figure 1B,1C*). The size of the WATCHMAN occluder was chosen to be 4–6 mm larger than the length of LAA orifice. The midpoint of the LAA orifice was marked as point A. TEE was performed to measure the distance between the left lower PV (D1) and the mitral annulus (D2) to point A. D1 or D2 (the shorter distance) was multiplied by 2, yielding the maximum diameter of the cover disc of the device (LAmbre or ACP) to be used. The LAA landing zone was defined as the area about 1.5 cm from point A, where a potential LAA device could be seated comfortably and safely within the confines of the body of the appendage. Passing through point A, a perpendicular line through the LAA orifice was made, and the diameter of the LAA was measured at a distance of 1.5 cm (D3) from point A. The diameter of the landing umbrella of the occluder (LAmbre or ACP) was chosen to be 6–8 mm larger than D3 (*Figure 1D,1E*).

If the selected landing umbrella was too large, the occluder would be stretched and the cover disc would not cover the LAA orifice successfully (*Figure 1F*). The occluder size was selected based on the results of the above-described measurements.

Procedures

Supine and routine tracheal intubation with general anesthesia was completed. The position at which the top one-third of the landing umbrella was deployed out of the delivery sheath was indicated by the marking on the delivery cable (*Figure 1G*). The right femoral vein was punctured, and the distance between the right third intercostal parasternal space and the puncture site was measured as the working distance to control the catheter insertion length. A 9F sheath was introduced through which an SL1 atrial septum catheter (St. Jude) and a guidewire were advanced under TEE guidance into the right atrium through the inferior vena cava; the guidewire then was withdrawn. A transseptal needle was inserted through the catheter (*Figure 1H*), which was positioned at the posterior and inferior parts of the atrial septum toward the LAA under TEE guidance using apical 4-chamber and parasternal short-axis views. The transseptal needle was passed through the atrial septum. The catheter was advanced into the left atrium, and the transseptal needle was withdrawn (*Figure 1I*). Heparin (80–100 U/kg) was injected to maintain the activated clotting time (ACT) to between 200 and 300 seconds. The guidewire was inserted into the left atrium, the SL1 catheter was withdrawn, and the distance that the SL1 catheter had been inserted was measured. The delivery system was inserted into the left atrium along the guidewire according to the latter's distance. The guidewire and the inner core were withdrawn while the delivery sheath was maintained in the left atrium. If the patient had an atrial septal defect, the delivery system was directly delivered to the left atrium through the defect. This was performed carefully under TEE guidance to avoid the guidewire entering the pulmonary veins. The pigtail catheter was placed into the LAA, and the delivery system was inserted into the LAA along the pigtail catheter (*Figure 1J*). The LAA occluder (LAmbre or ACP) was inserted along the delivery sheath. The top one-third of the landing umbrella was deployed out of the delivery sheath (*Figure 1K*) according to the marker on the cable, and the delivery sheath was advanced or pulled to ensure that the top of the landing umbrella reached the landing zone. When the WATCHMAN occluder was
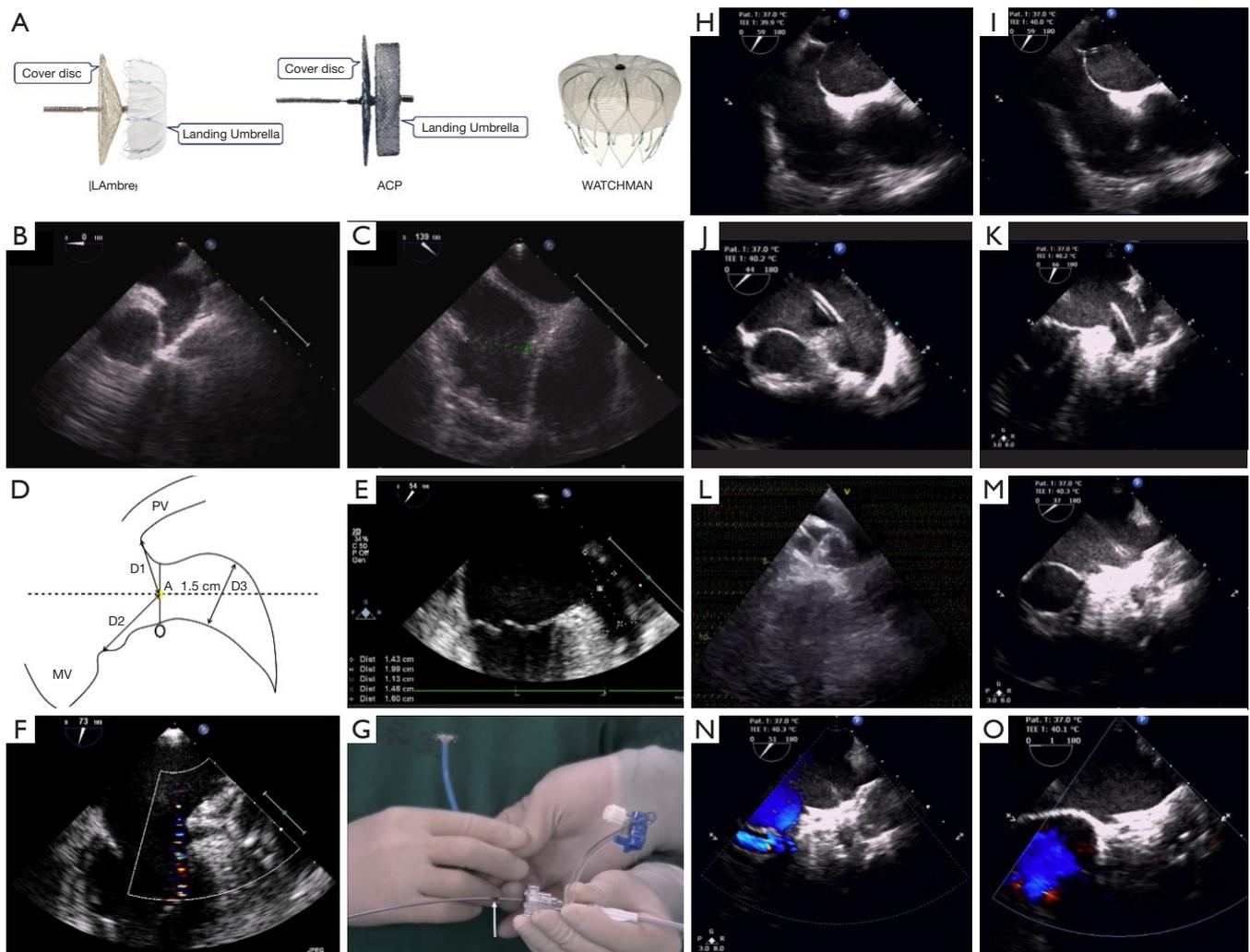
Figure 1 Structure of the LAA occluder (LAmbre, ACP, and WATCHMAN) (A). TEE images of left atrium and left atrial appendage (B,C). Preprocedural imaging (D,E). Image of oversize occluder not being able to cover the left atrial appendage (F). The occluder being partly deployed out of the delivery sheath, with the delivery cable being marked with the arrow (↑) (G). The atrial septum being punctured (H) and the puncture catheter being passed through the atrial septum into the left atrium (I). The pigtail catheter being advanced into the left atrium (J). The landing umbrella of the occluder being stretched out of the delivery sheath (K). The WATCHMAN occluder being deployed (L). The cover disc of the LAmbre occluder being sequentially stretched out (M). The occluder being implanted without residual leakage as per Doppler ultrasound (N). The occluder being completely released (O). ACP, Amplatzer Cardiac Plug; PV, pulmonary vein; MV, mitral valve; D1, the distance between the left lower PV; D2, the mitral annulus; D3, distance of 1.5 cm from point A; LAA, left atrial appendage; TEE, transesophageal echocardiography.

used, care was taken to ensure that the occluder was at the level of the LAA orifice or deeper (*Figure 1L*). The delivery cable was fixed, the delivery sheath was retrieved, and the occluder was implanted under TEE monitoring. A push-pull test was performed to verify its stability (*Figure 1M*). TEE was used to detect residual leakage, mitral reflux, left inferior PV blood flow, and pericardial effusion and to confirm occluder morphology and position (*Figure 1N*). The delivery cable was rotated counterclockwise to release the occluder (*Figure 1O*). If the patient also had an atrial septal defect which required closure, an atrial septal defect occluder was inserted and implanted under ultrasound guidance (17). After the position and shape of the occluder were reconfirmed with TEE, the delivery
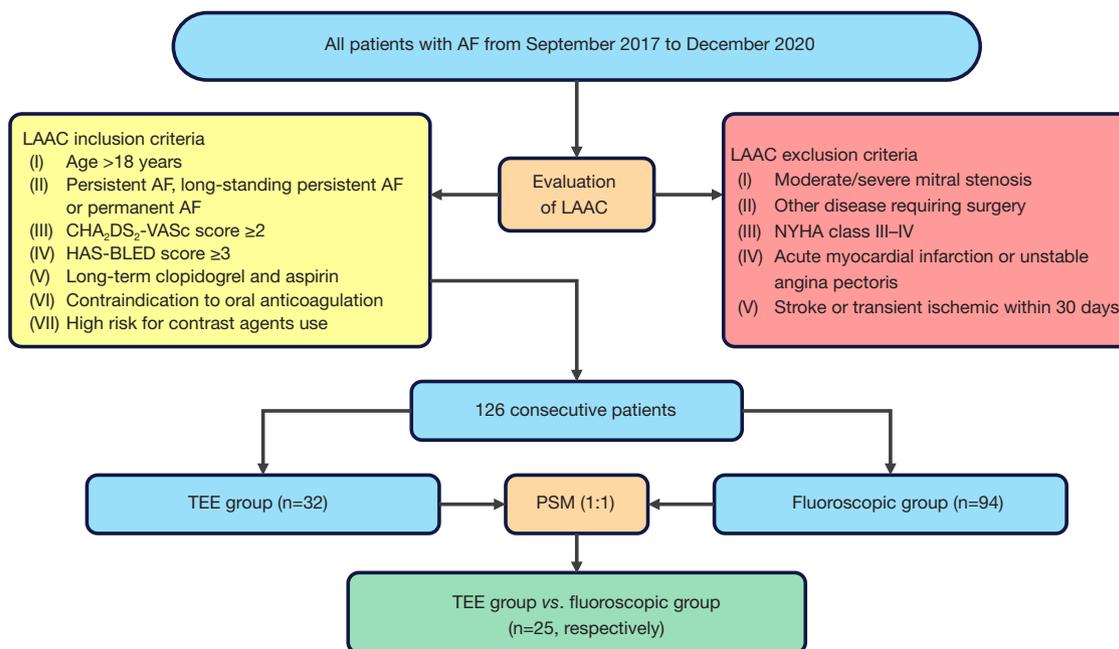
Figure 2 Patient flowchart. Among 126 eligible patients who received LAAC, 94 underwent the procedure under fluoroscopic image guidance while 32 were guided by TEE image. Following 1:1 PSM, 25 patients were included in each group for analysis. AF, atrial fibrillation; LAAC, left atrial appendage closure; TEE, transesophageal echocardiography; PSM, propensity score matching; CHA_2DS_2-VASc score, congestive heart failure, hypertension, age ≥75 years (doubled); diabetes mellitus prior to stroke or transient ischemic attack (doubled), vascular disease, age 65 to 74 years, and sex category (female); HAS-BLED score, hypertension, abnormal renal/liver dysfunction, stroke, bleeding history, elderly, drugs; NYHA class, New York Heart Association Classification of Heart Failure.

system was withdrawn. Pressure was applied to the femoral vein puncture site. The procedural time was defined as the interval from right femoral vein puncture to delivery system withdrawal. Patients were extubated in the operating room or the intensive care unit. Heparin was used for 24 h. Administration of oral aspirin (100 mg/d) and Plavix (75 mg/d) was initiated on postoperative day 2 and continued for 6 months. Patients underwent clinical and echocardiographic follow-up at the outpatient department at 1, 3, 6, 12, and 24 months postprocedure to be checked for complete closure of the LAAC and complications. The possible complications included peridevice leak in or out of hospital, myocardial infarction, device dislocation, malignant arrhythmia, stroke, death, pericardial effusions requiring intervention, pericarditis, thrombus, anesthetic reaction, and access-related complications such as hematoma or femoral arteriovenous fistula.

Statistical analysis

Continuous data are expressed as the mean and standard deviation (SD) or the median and interquartile range (IQR) according to the presence or absence of normal distribution, respectively. Categorical variables are presented as percentages. The Student t-test or Mann-Whitney test was used for continuous variables. Pearson χ^2 or Fisher exact test was used for categorical variables. Due to possible differences in baseline age, gender, weight, and ALT level between the TEE and fluoroscopic groups, a propensity score match analysis was performed based on these factors to minimize preoperative differences. All the analyses were performed with the statistical software packages R 3.3.2 (http://www.R-project.org; The R Foundation for Statistical Computing) and Free Statistics software version 1.5. A 2-tailed test was performed, and $P<0.05$ was considered statistically significant.

Results

From September 2017 to December 2020, 126 eligible patients underwent LAAC. Ultimately, the fluoroscopic image guidance was used in 94 patients while TEE image guidance was used in 32 patients (*Figure 2*). TEE was also
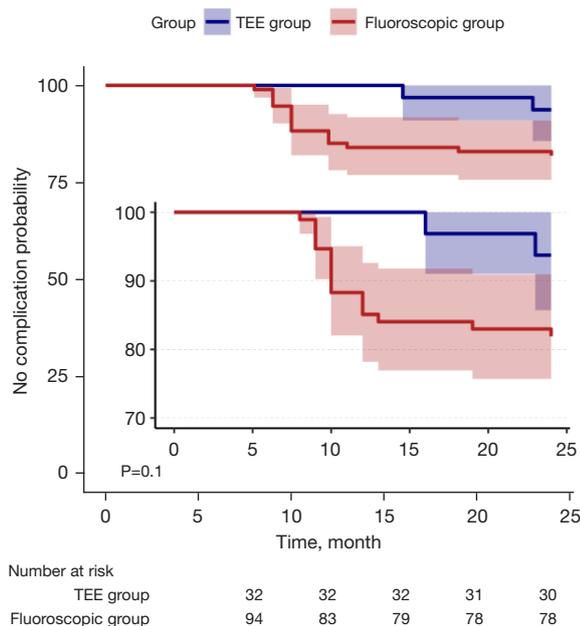
Figure 3 Non-complication probability curve for each group. No patients experienced peridevice leak during the perioperative period. There was no occurrence of malignant arrhythmia, stroke, death, pericarditis, thrombus, or anesthetic reaction during the follow-up. TEE, transesophageal echocardiography.

used routinely for patients in the fluoroscopic group to evaluate the efficacy (not for guidance) after the LAAC procedure. A considerably higher proportion of patients in the TEE group was allergic to contrast agents (21.9% *vs.* 0%; P<0.001), and their eGFR was also lower than that of the fluoroscopic group (52.7±8.8 *vs.* 71.8±15.9 mL/min; P<0.001), with the proportion of those with an eGFR less than 60 being higher (78.1% *vs.* 23.4%; P<0.001) (*Table 1*). The demographic characteristics of the 2 groups were different: the TEE group had a greater proportion of females (68.8% *vs.* 34.0%; P<0.001), higher mean age (75.4±7.9 *vs.* 65.7±10.0 years, P<0.001), a higher proportion of patients over 65 years old (90.6 % *vs.* 61.7%; P=0.005), lower weight (66.3±11.2 *vs.* 73.8±12.0 kg, P=0.002), and lower ALT level (17.7±9.7 *vs.* 25.8±15.7 U/L; P=0.007). In addition, the TEE group had a numerically but not significantly higher CHA$_2$DS$_2$-VASc score (P=0.106), smaller LAA diameter (P=0.344), and lower AST level (P=0.426). After propensity-score matching was completed for gender, age, weight, and ALT level, the distributions of demographic characteristics of the 2 groups (n=25 in each) were comparable.

Procedure findings

After propensity-score matching, there was no significant difference in device selection (P=0.103), diameter of cover disc (31.5±4.7 *vs.* 31.1±4.2 mm; P=0.753), diameter of landing umbrella (25.2±5.0 *vs.* 25.0±5.3 mm; P=0.906), success rate at the first attempt (under TEE observation, positions at 0°, 45°, 90°, and 135° are appropriate, with no residual shunt, good position, and stability without displacement; 100% *vs.* 100%; P>0.99), or hospitalization duration [5.0 (IQ1–IQ3: 3.0–7.0) *vs.* 5.0 (IQ1–IQ3: 3.0–6.0) days, P=0.498] between groups (*Table 2*).

Complications

The mean follow-up period for this study was 22.2±4.5 months (*Table 2*). Before propensity-score matching, there was 1 (4%) case of residual shunt and 1 (4%) case of pericardial effusion requiring pericardiocentesis drainage in the TEE group. The overall complication rate was 6.2%. There were 10 (10.6%) cases of residual shunts, 1 (1.1%) case of myocardial infarction, 1 (1.1%) case of device dislocation requiring open heart surgery, 2 (2.1%) cases of pericardial effusions treated by pericardiocentesis drainage, and 4 (4.3%) cases of access-related complications in the fluoroscopic group. The overall complication rate was 18.1%, and after-propensity score matching, the overall complication rate was 2 (8%) in the TEE group and 7 (28%) in the fluoroscopic group, which did not constitute a significant difference (P=0.138). Among patients with complications, the average cover disc diameter (30.7±4.6 *vs.* 32.0±4.4 mm) and landing umbrella diameter (25.1±4. 3 *vs.* 25.4±5.3 mm) of the LAA occluder device were both smaller than the average level of all patients. This may be related to the occurrence of residual shunts caused by the selection of a too-small occluder.

No patients experienced peridevice leak during the perioperative period, and no malignant arrhythmia, stroke, death, pericarditis, thrombus, or anesthetic reaction occurred during the follow-up. Finally, there was no significant difference in the non-complication probability curve between groups (P=0.1) (*Figure 3*).

Discussion

In this propensity score–matched and retrospective, single-center study of patients with AF in whom contrast agent use posed considerable risk, midterm follow-up results

Table 1 Demographics and baseline characteristics

Variables	Before matching				After matching			
	Total (n=126)	TEE group (n=32)	Fluoroscopic group (n=94)	P value	Total (n=50)	TEE group (n=25)	Fluoroscopic group (n=25)	P value
Gender				<0.001				>0.99
Male	72 (57.1)	10 (31.2)	62 (66.0)		21 (42.0)	10 (40.0)	11 (44.0)	
Female	54 (42.9)	22 (68.8)	32 (34.0)		29 (58.0)	15 (60.0)	14 (56.0)	
Age, years	68.1±10.4	75.4±7.9	65.7±10.0	<0.001	73.0±5.9	72.9±6.9	73.1±4.9	0.925
>65	87 (69.0)	29 (90.6)	58 (61.7)	0.005	46 (92.0)	22 (88.0)	24 (96.0)	0.609
Weight, kg	71.9±12.2	66.3±11.2	73.8±12.0	0.002	68.2±11.7	68.3±11.2	68.1±12.3	0.948
Allergic to contrast agent	7 (5.6)	7 (21.9)	0 (0.0)	<0.001	6 (12.0)	6 (24.0)	0 (0.0)	0.022
Diameter of LAA, mm	26.3±4.7	25.6±5.0	26.5±4.6	0.344	25.6±4.8	25.7±5.2	25.5±4.4	0.884
CHA_2DS_2-VASc score	4.0 (3.0, 5.0)	5.0 (3.8, 5.2)	4.0 (3.0, 5.0)	0.106	5.0 (3.0, 5.8)	4.0 (3.0, 5.0)	5.0 (4.0, 6.0)	0.022
Congestive heart failure/LV dysfunction	37 (29.4)	11 (34.4)	26 (27.7)	0.62	17 (34.0)	9 (36.0)	8 (32.0)	>0.99
Hypertension	78 (61.9)	18 (56.2)	60 (63.8)	0.581	30 (60.0)	13 (52.0)	17 (68.0)	0.386
Diabetes mellitus	32 (25.4)	5 (15.6)	27 (28.7)	0.217	13 (26.0)	2 (8.0)	11 (44.0)	0.01
Stroke/TIA/TE	72 (57.1)	16 (50.0)	56 (59.6)	0.46	22 (44.0)	11 (44.0)	11 (44.0)	>0.99
Vascular disease	46 (36.5)	8 (25.0)	38 (40.4)	0.176	21 (42.0)	7 (28.0)	14 (56.0)	0.086
Laboratory data								
eGFR, mL/min	67.0±16.7	52.7±8.8	71.8±15.9	<0.001	58.1±12.1	54.1±7.7	62.2±14.3	0.016
eGFR <60, mL/min	47 (37.3)	25 (78.1)	22 (23.4)	<0.001	29 (58.0)	19 (76.0)	10 (40.0)	0.022
AST, U/L	27.2±11.2	25.9±13.0	27.7±10.6	0.426	27.4±12.1	27.1±14.3	27.7±9.8	0.863
ALT, U/L	23.7±14.8	17.7±9.7	25.8±15.7	0.007	21.3±12.1	20.0±9.8	22.5±14.2	0.482

Data are expressed as the mean ± SD or median (IQR) for skewed variables or numbers (%) for categorical variables. Propensity-score matching for gender, age, weight and ALT. TIA, transient ischemic attack; TE, thromboembolic events; eGFR, estimated glomerular filtration rate; AST, aspartate transaminase; ALT, alanine aminotransferase; LAA, left atrial appendage; CHA_2DS_2-VASc, congestive heart failure, hypertension, age ≥75 years (doubled); diabetes mellitus prior to stroke or transient ischemic attack (doubled), vascular disease, age 65 to 74 years, and sex category (female); SD, standard deviation; IQR, interquartile range; LV, left ventricular.

showed that LAAC under TEE or fluoroscopy guidance were similar. Although the patients in the TEE group were older and had a lower eGFR, there was no significant difference in complications between the 2 groups. The overall complication rate in this study was 15.1%, which may be related to the broader range of complication definitions or the small overall sample size. However, the complications rate was also comparable to the results of other studies (18,19). Our findings further indicated that TEE and fluoroscopic image guidance had similar safety, especially for high-risk patients. Although there was no significant difference in the complication rates between the 2 groups, the complication rates (6.2% *vs*. 18.1%) and non-complication probability curve were slightly better in the TEE group than in the fluoroscopy group. A larger sample size study is necessary to clarify this issue.

LAAC is an effective treatment for reducing thromboembolism and stroke in patients with AF (20). Most patients undergoing LAAC are older adult individuals with many comorbidities, such as hepatic and/or renal insufficiency, and more frequently have a history of allergic reaction to contrast agents, and thus contrast agent use in these patients entails a higher risk (21). The multicenter Amplatzer Cardiac Plug registry indicates that chronic renal

Table 2 Procedure findings and complications

Variables	Before matching				After matching			
	Total (n=126)	TEE group (n=32)	Fluoroscopic group (n=94)	P value	Total (n=50)	TEE group (n=25)	Fluoroscopic group (n =25)	P value
Devices				0.045				0.103
LAmbre	98 (77.8)	26 (81.2)	72 (76.6)		37 (74.0)	20 (80.0)	17 (68.0)	
WATCHMAN	26 (20.6)	4 (12.5)	22 (23.4)		11 (22.0)	3 (12.0)	8 (32.0)	
ACP	2 (1.6)	2 (6.2)	0 (0.0)		2 (4.0)	2 (8.0.)	0 (0.0)	
Diameter of cover disc (mm)	32.0±4.4	31.3±4.3	32.2±4.4	0.305	31.3±4.4	31.5±4.7	31.1±4.2	0.753
Diameter of landing umbrella (mm)	25.4±5.3	24.5±4.9	25.8±5.5	0.296	25.1±5.1	25.2±5.0	25.0±5.3	0.906
Success at first attempt	123 (97.6)	32 (100.0)	91 (96.8)	0.57	50 (100.0)	25 (100.0)	25 (100.0)	>0.99
Hospitalization duration, days	5.0 (3.0, 6.0)	5.0 (3.8, 7.0)	5.0 (3.0, 6.0)	0.13	5.0 (3.0, 6.0)	5.0 (3.0, 7.0)	5.0 (3.0, 6.0)	0.498
Complication	19 (15.1)	2 (6.2)	17 (18.1)	0.153	9 (18.0)	2 (8.0)	7 (28.0)	0.138
Peridevice leak during the perioperative period	0 (0.0)	0 (0.0)	0 (0.0)	>0.99	0 (0.0)	0 (0.0)	0 (0.0)	>0.99
Residual shunt	11 (8.7)	1 (3.1)	10 (10.6)	0.287	6 (12.0)	1 (4.0)	5 (20.0)	0.189
Myocardial infarction	1 (0.8)	0 (0.0)	1 (1.1)	>0.99	1 (2.0)	0 (0.0)	1 (4.0)	>0.99
Device dislocation	1 (0.8)	0 (0.0)	1 (1.1)	>0.99	0 (0.0)	0 (0.0)	0 (0.0)	>0.99
Malignant arrhythmia	0 (0.0)	0 (0.0)	0 (0.0)	>0.99	0 (0.0)	0 (0.0)	0 (0.0)	>0.99
Stroke	0 (0.0)	0 (0.0)	0 (0.0)	>0.99	0 (0.0)	0 (0.0)	0 (0.0)	>0.99
Death	0 (0.0)	0 (0.0)	0 (0.0)	>0.99	0 (0.0)	0 (0.0)	0 (0.0)	>0.99
Pericardial effusions requiring intervention	3 (2.4)	1 (3.1)	2 (2.1)	>0.99	2 (4.0)	1 (4.0)	1 (4.0)	>0.99
Pericarditis	0 (0.0)	0 (0.0)	0 (0.0)	>0.99	0 (0.0)	0 (0.0)	0 (0.0)	>0.99
Thrombus	0 (0.0)	0 (0.0)	0 (0.0)	>0.99	0 (0.0)	0 (0.0)	0 (0.0)	>0.99
Anesthetic reaction	0 (0.0)	0 (0.0)	0 (0.0)	>0.99	0 (0.0)	0 (0.0)	0 (0.0)	>0.99
Access-related complications	4 (3.2)	0 (0.0)	4 (4.3)	0.571	1 (2.0)	0 (0.0)	1 (4.0)	>0.99
Follow-up, months	22.2±4.5	23.7±1.4	21.7±5.1	0.033	23.5±2.3	23.6±1.6	22.4±2.8	0.758

Data are expressed as the mean ± SD or median (IQR) for skewed variables or numbers (%) for categorical variables. Propensity score matching for gender, age, weight, and alanine aminotransferase. TEE, transesophageal echocardiography; ACP, Amplatzer Cardiac Plug; SD, standard deviation; IQR, interquartile range.

failure is an indication for LAAC in approximately 15% of patients who are at an increased risk for contrast-induced injury (22).

In this study, all patients in the TEE group had contraindications, such as renal insufficiency or a history of allergy to contrast agents. As a non-fluoroscopic image guidance method, percutaneous and non-fluoroscopic (PAN) procedures have yielded satisfactory results in patients with congenital and valvular heart diseases while reducing the risk associated with exposure to radiation and contrast agents (16,23). Therefore, the results of this study might have greater potential for promotion and application and can be applied to all patients receiving LAAC.

A lack of contrast agent use precludes the determination of LAA position via fluoroscopy and measurement of LAA via contrast-enhanced computed tomography (CT)

to inform occluder selection. To overcome this problem, we summarized our experiences and proposed a selection scheme for the 3 kinds of LAA occluders under sole TEE guidance, standardized the parameters that needed to be measured, and achieved favorable outcomes. The PAN procedure has several advantages. First, TEE allows clear visualization of the heart structures and atrial septal puncture points, thereby minimizing the risk of damage during septal puncture. Second, TEE can show the distance from the left lower PV and the mitral annulus to the LAA, which helps prevent the PV and the mitral valve from being obstructed by the cover disc. By using TEE, surgeons can obtain dynamic whole-procedure images, while fluoroscopy can only provide visualization for few seconds with use of contrast agent. For patients with thrombosis in the LAA, TEE is considered the preferred and most accurate diagnostic technique for localizing thrombus within the LAA, which facilitates completion of LAAC in patients with LAA thrombosis; meanwhile, fluoroscopic imaging has limitations in detecting LAA thrombus (24). Third, TEE provides real-time monitoring of occluders as they reach the landing zone, while the fluoroscopic guidance procedure requires marking the shape of LAA on the screen using a marker pen. The tension of the delivery sheath during the procedure may change the position of the LAA, which could lead to incorrect determination of the required occluder size. Meanwhile, compared to fluoroscopy, the chief surgeon is less prone to committing visual errors when measuring the size with TEE. Therefore, TEE technology not only has greater adaptability, but it is also considered an essential skill for cardiologists.

This study demonstrated that LAAC with TEE was feasible. It is suitable for a more diverse set of patients, and real-time dynamic images can increase the accuracy of operation and further reduce the operation risk. In addition, the non-fluoroscopic procedure also protects medical staff and patients from radiation damage. With the advancement of technology and instruments, the non-fluoroscopic procedure could be used in a broader patient population. It could benefit a large number of patients in poverty-stricken areas where medical resources are scarce by eliminating the dependence on interventional operating room availability.

Limitations

This study had several limitations. First, the sample size was relatively small, and the design was nonrandomized; thus, large, randomized controlled trials are required to further assess the efficacy and safety of non-fluoroscopic-guided LAAC. Second, this study relied on TEE imaging, and determining whether a TEE-guided procedure is an option for all patients, especially those with complex LAA anatomies and unclear TEE images, was beyond the scope of this analysis.

Conclusions

LAAC can be performed safely and effectively without radiation in patients who cannot tolerate fluoroscopy with contrast agents. LAAC under TEE guidance might provide a new alternative strategy to traditional fluoroscopy guidance for these patients and have a wide range of applications.

Acknowledgments

Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://qims.amegroups.com/article/view/10.21037/qims-23-169/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-23-169/coif). Deyuan Zhang is the chief scientist of LifeTech Scientific Corporation. Anning Li is the vice president of research and development at LifeTech Scientific Corporation. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was in accordance with the Declaration of Helsinki (as revised in 2013) and was approved by the Ethics Committee of Fuwai

Hospital of The Chinese Academy of Medical Sciences (No. 2018-9). Written informed consent was obtained from all patients enrolled in both groups.

Open Access Statement: This is an Open Access article distributed in accordance with the Creative Commons Attribution-NonCommercial-NoDerivs 4.0 International License (CC BY-NC-ND 4.0), which permits the non-commercial replication and distribution of the article with the strict proviso that no changes or edits are made and the original work is properly cited (including links to both the formal publication through the relevant DOI and the license). See: https://creativecommons.org/licenses/by-nc-nd/4.0/.

References

1. Furberg CD, Psaty BM, Manolio TA, Gardin JM, Smith VE, Rautaharju PM. Prevalence of atrial fibrillation in elderly subjects (the Cardiovascular Health Study). Am J Cardiol 1994;74:236-41.
2. Miyasaka Y, Barnes ME, Gersh BJ, Cha SS, Bailey KR, Abhayaratna WP, Seward JB, Tsang TS. Secular trends in incidence of atrial fibrillation in Olmsted County, Minnesota, 1980 to 2000, and implications on the projections for future prevalence. Circulation 2006;114:119-25.
3. January CT, Wann LS, Alpert JS, Calkins H, Cigarroa JE, Cleveland JC Jr, Conti JB, Ellinor PT, Ezekowitz MD, Field ME, Murray KT, Sacco RL, Stevenson WG, Tchou PJ, Tracy CM, Yancy CW; American College of Cardiology/American Heart Association Task Force on Practice Guidelines. 2014 AHA/ACC/HRS guideline for the management of patients with atrial fibrillation: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and the Heart Rhythm Society. J Am Coll Cardiol 2014;64:e1-76.
4. Spivey CA, Liu X, Qiao Y, Mardekian J, Parker RB, Phatak H, Masseria C, Kachroo S, Abdulsattar Y, Wang J. Stroke associated with discontinuation of warfarin therapy for atrial fibrillation. Curr Med Res Opin 2015;31:2021-9.
5. Steger C, Pratter A, Martinek-Bregel M, Avanzini M, Valentin A, Slany J, Stöllberger C. Stroke patients with atrial fibrillation have a worse prognosis than patients without: data from the Austrian Stroke registry. Eur Heart J 2004;25:1734-40.
6. Ostermayer S, Reschke M, Billinger K, Trepels T, Büschek F, Bayard Y, Sievert H. Percutaneous closure of the left atrial appendage. J Interv Cardiol 2003;16:553-6.
7. Reddy VY. Left atrial appendage closure devices: A reasonable therapeutic alternative. Heart Rhythm 2018;15:302-5.
8. Reddy VY, Sievert H, Halperin J, Doshi SK, Buchbinder M, Neuzil P, Huber K, Whisenant B, Kar S, Swarup V, Gordon N, Holmes D; PROTECT AF Steering Committee and Investigators. Percutaneous left atrial appendage closure vs warfarin for atrial fibrillation: a randomized clinical trial. JAMA 2014;312:1988-98.
9. Roguin A, Goldstein J, Bar O, Goldstein JA. Brain and neck tumors among physicians performing interventional procedures. Am J Cardiol 2013;111:1368-72.
10. Kirchhof P, Benussi S, Kotecha D, Ahlsson A, Atar D, Casadei B, et al. 2016 ESC Guidelines for the management of atrial fibrillation developed in collaboration with EACTS. Europace 2016;18:1609-78.
11. Boersma LV, Schmidt B, Betts TR, Sievert H, Tamburino C, Teiger E, Pokushalov E, Kische S, Schmitz T, Stein KM, Bergmann MW; EWOLUTION investigators. Implant success and safety of left atrial appendage closure with the WATCHMAN device: peri-procedural outcomes from the EWOLUTION registry. Eur Heart J 2016;37:2465-74.
12. Kobayashi D, Takahashi O, Ueda T, Deshpande GA, Arioka H, Fukui T. Risk factors for adverse reactions from contrast agents for computed tomography. BMC Med Inform Decis Mak 2013;13:18.
13. Wang Y, Bellomo R. Cardiac surgery-associated acute kidney injury: risk factors, pathophysiology and treatment. Nat Rev Nephrol 2017;13:697-711.
14. Meier B, Blaauw Y, Khattab AA, Lewalter T, Sievert H, Tondo C, Glikson M. EHRA/EAPCI expert consensus statement on catheter-based left atrial appendage occlusion. EuroIntervention 2015;10:1109-25.
15. Hindricks G, Potpara T, Dagres N, Arbelo E, Bax JJ, Blomström-Lundqvist C, et al. 2020 ESC Guidelines for the diagnosis and management of atrial fibrillation developed in collaboration with the European Association for Cardio-Thoracic Surgery (EACTS): The Task Force for the diagnosis and management of atrial fibrillation of the European Society of Cardiology (ESC) Developed with the special contribution of the European Heart Rhythm Association (EHRA) of the ESC. Eur Heart J 2021;42:373-498.
16. Wang DD, Eng M, Kupsky D, Myers E, Forbes M, Rahman M, Zaidan M, Parikh S, Wyman J, Pantelic M, Song T, Nadig J, Karabon P, Greenbaum A, O'Neill W. Application of 3-Dimensional Computed Tomographic

Image Guidance to WATCHMAN Implantation and Impact on Early Operator Learning Curve: Single-Center Experience. JACC Cardiovasc Interv 2016;9:2329-40.

17. Pan X, Li S, Hu S, Ouyang W, Zhang F, Zhang D, Tian P, Zhang Y, Pang K. Feasibility of transcatheter closure of atrial septal defect under the guidance of transthoracic echocardiography. Zhonghua Xin Xue Guan Bing Za Zhi 2014;42:744-7.

18. Lakkireddy D, Thaler D, Ellis CR, Swarup V, Sondergaard L, Carroll J, Gold MR, Hermiller J, Diener HC, Schmidt B, MacDonald L, Mansour M, Maini B, O'Brien L, Windecker S. Amplatzer Amulet Left Atrial Appendage Occluder Versus Watchman Device for Stroke Prophylaxis (Amulet IDE): A Randomized, Controlled Trial. Circulation 2021;144:1543-52.

19. Sedaghat A, Al-Kassou B, Vij V, Nelles D, Stuhr M, Schueler R, Omran H, Schrickel JW, Hammerstingl C, Nickenig G. Contrast-free, echocardiography-guided left atrial appendage occlusion (LAAo): a propensity-matched comparison with conventional LAAo using the AMPLATZER™ Amulet™ device. Clin Res Cardiol 2019;108:333-40.

20. Reddy VY, Doshi SK, Sievert H, Buchbinder M, Neuzil P, Huber K, Halperin JL, Holmes D; PROTECT AF Investigators. Percutaneous left atrial appendage closure for stroke prophylaxis in patients with atrial fibrillation: 2.3-Year Follow-up of the PROTECT AF (Watchman Left Atrial Appendage System for Embolic Protection in Patients with Atrial Fibrillation) Trial. Circulation 2013;127:720-9.

21. Wagdi P, Ritter M. Patient radiation dose during percutaneous interventional closure of interatrial communications. J Cardiol 2009;53:368-73.

22. Tzikas A, Shakir S, Gafoor S, Omran H, Berti S, Santoro G, et al. Left atrial appendage occlusion for stroke prevention in atrial fibrillation: multicentre experience with the AMPLATZER Cardiac Plug. EuroIntervention 2016;11:1170-9.

23. Bu H, Gao L, Zhang W, Wu Q, Jin W, Tang M, Zhao T. Application of perimembranous ventricular septal defects closure solely by femoral vein approach under transesophageal echocardiography guidance. Zhong Nan Da Xue Xue Bao Yi Xue Ban 2017;42:802-7.

24. Mohandes M, Pernigotti A, Morr CI, Bardají A. Percutaneous Left Atrial Appendage Closure in the Presence of Thrombus Using LAmbre Device and Cerebral Protection System. Korean Circ J 2020;50:281-3.