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Research article

Left atrial appendage closure in patients with reversed chicken-wing morphology: Anatomical features and procedural strategy

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ABSTRACT

Background: Left atrial appendage (LAA) closure (LAAC) in atrial fibrillation (AF) patients with the reversed chicken-wing (RCW) LAA is challenging.
Aims: To elucidate the LAAC strategy of the RCW-LAA.
Methods: A total of 802 AF patients who were enrolled in the LAACablation registry for LAAC procedure were included, 55 of whom presented with the RCW-LAA. The WATCHMAN device was implanted using the standard protocol when the sheath depth was no less than the device depth (the simple group). For those with a sheath depth of less than the device depth (the complex group), device deployment was attempted with acceptable protrusion or after a repeated atrial transseptal puncture (re-ATP) at a more inferior and anterior position. The anatomical and procedural features were compared between groups and before and after the re-ATP.
Results: The success rate of LAAC was significantly lower in patients with the RCW-LAA than with the other morphologies (92.7% vs. 98.8%, $p = 0.001$). Compared with the simple group, the complex group had shorter root depth and shorter neck length, and more LAAs in the complex group were at lower position (all $p < 0.05$). The sheath depth after the re-ATP was significantly greater than that before the re-ATP (18.8 ± 3.4 mm vs. 14.7 ± 2.6 mm, $p < 0.001$). For the patients who underwent re-ATP, the sheath went significantly deeper in successful procedures than in aborted procedures (19.7 ± 3.3 mm vs. 15.8 ± 1.8 mm, $p = 0.040$).
Conclusions: The anatomical features of the RCW-LAA were related to the complexity of the LAAC procedure. The re-ATP at an inferior and anterior location could increase the success rate of LAAC.
ClinicalTrials.gov: NCT03788941.

Abbreviations: LAA, left atrial appendage; LAAC, left atrial appendage closure; RCW-LAA, reversed chicken-wing left atrial appendage; Re-ATP, repeated atrial transseptal puncture; PASS, Position-Anchoring-Size-Seal; PDL, peri-device leak; DRT, device-related thrombus.

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1. Introduction

Interventional left atrial appendage occlusion (LAAC) has been reported to be an effective and safe alternative to standard oral anticoagulants for prophylaxis against thromboembolic events in patients with non-valvular AF who were prone to develop adverse effects with oral anticoagulants [1-3].

LAA anatomy is complex and heterogeneous. It remains elusive how the complex morphology of LAA impacts the LAAC procedure. Some studies mentioned that the interventional LAAC procedure was challenging due to chicken-wing-like LAA configuration with a short neck and a subsequent severe bend [4,5]. Nevertheless, the procedural strategies discussed in the previous reports were exclusively using the plate devices rather than the cage devices. Moreover, in the chicken-wing LAA with an upward bend, also called reversed chicken-wing LAA (RCW-LAA), the LAAC procedure is more challenging and might need different strategies to achieve a successful closure. Furthermore, RCW-LAA was associated with a higher risk of adverse cardiac and cerebrovascular events [6]. Therefore, this study aimed to elucidate the anatomical characteristics of the LAA and to explore the feasible procedural strategy accordingly to improve the success rate of LAAC using the WATCHMAN device.

2. Methods

2.1. *Patient selection and study design*

A total of 802 patients with AF who prospectively enrolled in the LAACablation registry from 2018 to 2020 were included. The LAACablation registry (ClinicalTrials.gov ID: NCT03788941) is a physician-initiated, non-company-sponsored, prospective observational study recruiting patients who plan to receive LAAC procedure from Shanghai Xinhua Hospital, one of the largest electrophysiological centers in China. All enrolled patients met the indications of LAAC and were excluded from contraindications. Detailed inclusion and exclusion criteria for LAACablation registry were shown in Supplmental Table 1. The current study was the subgroup analyses of the LAACablation registry. The study was approved by the Ethics Committee of Xinhua Hospital Affiliated to Shanghai Jiaotong University School of Medicine and the informed consents were obtained.

All LAAs were categorized into widely accepted four shapes, such as cactus, cauliflower, windsock, and chicken-wing shapes [7]. The chicken-wing LAA was further divided into conventional chicken-wing LAAs and RCW-LAA based on a downward or upward orientation of the apex by angiography at a right anterior oblique (RAO) of 30° and a caudal (CAU) of 20°. The patients presented with RCW-LAA morphology were further included in the sub-group analysis of the present study (Fig. 1).

2.2. *Preparation of LAAC procedure*

All patients underwent contrast-enhanced ECG-gated cardiac CT scan and transesophageal echocardiography to exclude the LAA thrombus. Three-dimensional structures of the left atrium were reconstructed. The position of LAA was determined by its spatial relationship to the left superior pulmonary vein from the anterior-posterior view. The LAA position was categorized as high type or low type if the superior margin of the LAA orifice was higher than the superior margin of the left superior pulmonary vein orifice or lower than the midpoint of the left superior pulmonary vein orifice, and medium type if it was in between [8]. All patients received anticoagulation therapy.

2.3. *LAAC procedure and measurement*

2.3.1. *LAA angiography and measurement*

LAA angiography and LAAC were performed as described previously [9]. RadiAnt DICOM Viewer (released on 2021.2.2; Medixant, Poznan, Poland) was used to measure and analyze the images from the LAA angiography and procedural fluoroscopy.

The anatomy of RCW-LAA was analyzed (Fig. 2). The root depth was denoted as the axial length from the ostium to the opposite

Table 1

Baseline characteristics of patients with reversed chicken-wing-shaped LAA.

	All patients (n = 55)	Simple group (n = 34)	Complex group (n = 21)	P-value
Male gender	34 (61.8%)	19 (55.9%)	15 (71.4%)	0.249
Age, years	70.2 ± 6.6	70.1 ± 7.0	70.5 ± 6.3	0.836
Paroxysmal AF	25 (45.5%)	16 (47.1%)	9 (42.9%)	0.761
CHA_2DS_2-VASc	3.5 ± 1.5	3.5 ± 1.7	3.4 ± 1.2	0.776
HAS-BLED	2.3 ± 0.7	2.3 ± 0.7	2.4 ± 0.8	0.434
Stroke	16 (29.1%)	11 (32.3%)	5 (23.8%)	0.498
Hypertension	29 (52.7%)	21 (61.8%)	8 (23.5%)	0.088
Diabetes mellitus	21 (38.2%)	13 (38.2%)	8 (23.5%)	0.992
CAD	14 (25.5%)	10 (29.4%)	4 (19.0%)	0.391
LVEF, %	63.1 ± 5.9	64.0 ± 5.1	61.4 ± 7.0	0.148
LA diameter, mm	42.1 ± 6.6	40.9 ± 5.8	44.5 ± 7.8	0.070

AF: atrial fibrillation; CAD: coronary artery disease; LA: left atrium; LAA: left atrial appendage; LVEF: left ventricular ejection fraction.

wall of the LAA and the neck length was denoted as the length of the superior margin of the LAA root before the bend. The axial angle was determined by the orientation of the axial deviation from the horizontal line with a positive angle indicating an upward orientation. The bending angle of the RCW-LAA, indicating the first bend of the dominant lobe, was measured as the angle between the axes before and after the first bend. According to the position of the sheath tip at the ostium during LAA angiography, the height of the sheath was categorized into high, medium, and low, representing the high, middle, and low one-third of the ostium, respectively.

2.3.2. LAAC device implantation

All patients were implanted with the WATCHMAN 2.5 generation device (Boston Scientific Corporation, Natick, MA, USA), sizing from 21 to 33 mm. The implanted device should fulfill the criteria of PASS (Position-Anchoring-Size-Seal) under the guidance of transesophageal echocardiography and/or fluoroscopy [3,10]. After the deployment, intra-procedural transesophageal echocardiography and/or angiography were further performed to re-verify the appropriate implantation of the device.

The device size was determined by cardiac CT, transesophageal echocardiography, and LAA angiography [11]. Device depth represented the full depth once the device size has been confirmed. The best position of the access sheath with proper depth and coaxiality before deployment was measured from fluoroscopy (Fig. 2). The angle of the access sheath was measured by the same method as the axial angle. The sheath depth was defined as the maximal length of the access sheath that advanced across the LAA ostium, which indicated the available depth for device implantation. All the measurements about the implantation were taken at the RAO of 30° and the CAU of 20°. Necessary adjustment of the angiographic view was allowed for a better view of the LAA or assistance for the implantation procedure.

2.3.3. LAAC strategy for RCW LAA

Since the lack of sufficient depth is the main obstacle for most challenging cases, the LAAC procedure was categorized into simple or complex procedure groups based on the sheath depth and device depth. After the LAA angiography, the device size was determined, and therefore the device depth was fixed. The sheath was inserted into the LAA and tried to achieve enough depth and good coaxiality for the device, with necessary rotation (mostly counterclockwise) or sheath bending. The sheath depth measured at this time was compared with the determined device depth. The simple group was characterized by the sheath depth of no less than the device depth, and therefore, a satisfying depth as well as coaxiality could be easily achieved for most cases. The complex group, with the initial sheath depth of less than the device depth, should be deployed with appropriate protrusion (usually less than 1/3 of the Watchman device size). If still failed to fulfill the PASS criteria, a repeated atrial transseptal puncture (re-ATP) was applied. The re-ATP aimed to achieve a more inferior and anterior location compared with the previous one, which might allow the sheath to be advanced deeper into the LAA and to obtain a greater sheath depth [Fig. 3(A-H)].

2.4. Follow-up imaging analyses

After the procedure, patients were generally administered with oral anticoagulants for the first 3 months if there were no contraindications. The transesophageal echocardiography was scheduled at 3 months to detect any peri-device leaks (PDLs) and device-related thrombus (DRT). If a satisfactory seal at 3 months, defined as no DRT and PDLs ≤5 mm, was achieved, patients were put on dual antiplatelet (Aspirin 100 mg + clopidogrel 75 mg) until 6 months, after which a single antiplatelet was continued. If PDL >5 mm or a DRT was found, anticoagulants were continued until a repeated transesophageal echocardiography to verify thrombus dissolution.

2.5. Postprocedural complications and adverse events

Major periprocedural complications within 7 days of the index procedure were defined as cardiac tamponade, device embolism, thromboembolism (stroke, transient ischemic attack [TIA] and systemic embolism), major bleeding, and death. Minor periprocedural complications included pericardial effusion not requiring pericardiocentesis, transient air embolism, and femoral complications. Adverse events evaluation at 1-year follow-up included all-cause death, thromboembolic events (strokes, TIAs, and systemic

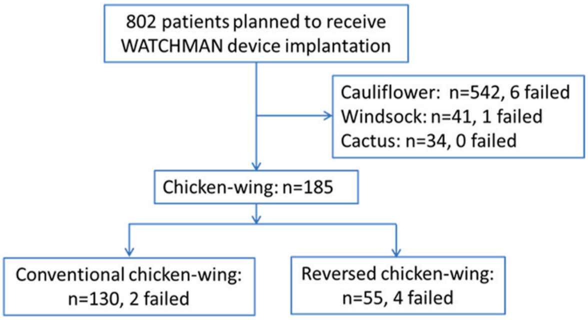

Fig. 1. Flow diagram of inclusion criteria and summaries regarding the number of failed LAAC procedures in different LAA morphologies. LAA: left atrial appendage; LAAC, left atrial appendage occlusion.

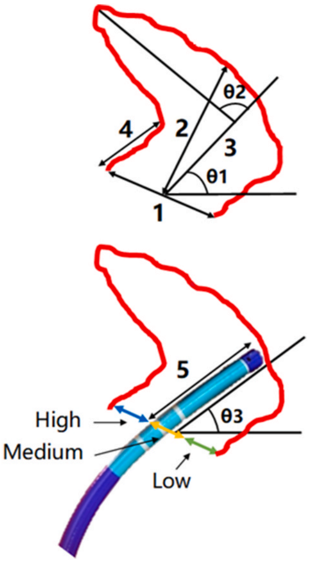

Fig. 2. The measurement of LAA anatomical features and LAAC procedure from angiography at a right anterior oblique (RAO) of 30° and caudal (CAU) of 20°. 1: ostium width; 2: root depth; 3: root axis; 4: neck length; 5: sheath depth; θ1: axial angle; θ2: bending angle; θ3: angle of the sheath. The height of the sheath indicated its position entering the LAA ostium, classified as high (black), medium (blue) or low (orange), representing the high, middle, or low 1/3 of the ostium, respectively. LAA, left atrial appendage; LAAC, left atrial appendage occlusion. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

embolisms), and nonprocedural major bleeding.

2.6. Statistical analyses

Continuous variables were expressed as the mean ± standard deviation or median (25th, 75th percentile) when appropriate, and categorical variables were described as the frequency (percentage). The *t*-test was used to compare continuous parameters between the groups if the data were normally distributed. Nonnormally distributed variables were analyzed using the Wilcoxon rank sum test. Categorical factors were compared between the groups using the Pearson chi-square test for independence. All P-values were two-sided, and a P-value of <0.05 was considered to indicate statistical significance. Statistical analyses were performed using IBM SPSS Statistics (version 22).

3. Results

A total of 802 patients were included in the LAACablation, with mean CHA_2DS_2-VASc and HAS-BLED scores of 3.4 ± 1.6 and 2.2 ± 1.0, respectively. Among all patients, there were 542 (67.6%) cauliflowers, 185 (23.1%) chicken-wings, 41 (5.1%) windsocks and 34 (4.2%) cactuses, detected from the LAA angiography. Chicken-wing LAAs were further categorized into 130 conventional chicken-wing LAAs and 55 RCW-LAAs (Fig. 1).

3.1. Baseline characteristics

Successful LAAC was achieved in 789 (98.4%) patients. A total of 13 LAAC procedures failed, including 6 (1.1%) with cauliflower-shaped LAA (4 with an ostium width >30.5 mm, 1 with insufficient depth, and 1 with unsealed lobes), 1 (2.4%) with windsock-shaped LAA (ostium width >30.5 mm), 2 (1.5%) with the conventional LAA (1 with an ostium width >30.5 mm and 1 with insufficient depth), and 4 (7.3%) with the RCW-LAA (4 with insufficient depth). The success rate of LAAC was significantly lower in the RCW-LAA than in the other morphological categories (92.7% vs. 98.8%, $p = 0.001$).

There were 133 (24.5%) patients with cauliflower-shaped LAA suffered a previous stroke, 10 (25.0%) patients with windsock-shaped LAA, 9 (27.3%) patients with cactus-shaped LAA, 45 (35.2%) patients with conventional chicken-wing LAA, and 16 (29.1%) patients with the RCW-LAA. The prevalence of stroke history was statistically similar among patients with cauliflower-, windsock-, cactus- and RCW-shaped LAAs. Nevertheless, the prevalence of stroke history was significantly higher in the conventional chicken-wing LAA compared with all other morphological categories (35.2% vs. 25.1%, $p = 0.018$).

Baseline characteristics of all the patients with the RCW-LAA are summarized in Table 1. The mean age of the cohort was 70.2 ± 6.6 years. A total of 34 (61.8%) patients were males. The mean score of CHA2DS2-VASc and HAS-BLED was 3.3 ± 1.3 and 2.3 ± 0.7, respectively.

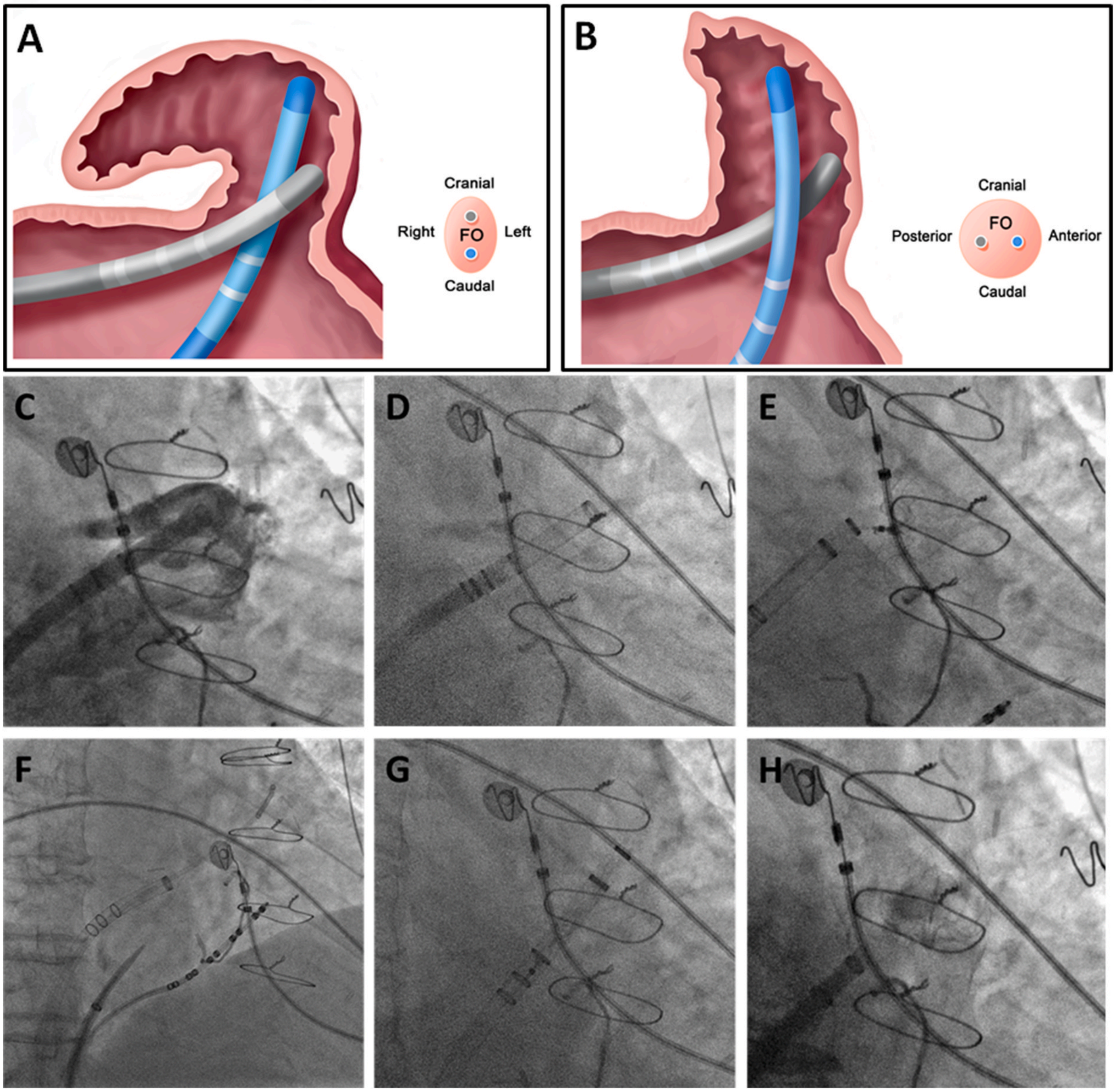

Fig. 3. The change in the direction and the depth of the sheath before and after the re-ATP at a more inferior and anterior position of FO during the LAAC procedure from the sagittal section (A) and the coronal section (B), and an example of how the re-ATP helped achieving the LAAC after a failed deployment due to insufficient depth of the sheath (C ~ H). Before the re-ATP, the sheath (grey) was superior and posterior. After the re-ATP, the sheaths (blue) were shifted to a more inferior and anterior position with a greater available depth of the sheath (A, B). (C) LAA angiography; (D) sheath in the LAA showing insufficient depth of the sheath; (E) device deployment for the first time after which the independent movement was observed during the tug test and the device was recaptured afterward; (F) re-ATP at a more inferior and anterior site compared to the previous one; (G) device deployment for the second time with the sheath presenting a greater angle; (H) angiography after the release showing a perfect closure of the LAA. FO, foramen ovale; LAAC, left atrial appendage closure; Re-ATP, repeated atrial transseptal puncture. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

3.2. RCW-LAA anatomy and procedural information

According to the anatomical relationship of the LAA to the left superior pulmonary vein, 33 (60.0%) RCW-LAAs were classified as low type, 20 (36.3%) as medium type, and 2 (3.6%) as high type. The number of bends through the dominant lobe of the RCW-LAA was also heterogeneous, including 43 (78.2%) patients with 1 obvious bend, 11 (20%) patients with 2 obvious bends, and 1 (1.8%) patients with 3 obvious bends. The parameters of the RCW-LAA are depicted in Table 2. The mean bending angle of the RCW-LAA was 115.4° (91.8°,140.0°), and 42 (76.4%) patients had a bending angle of more than 90°.

The proper size of the WATCHMAN device was determined based on the assessment of the RCW-LAA anatomy. The device size was 4.2 ± 1.3 mm wider than the width of the ostium.

Patients who had the RCW-LAA were divided into the simple group ($n = 34$) and the complex group ($n = 21$). The root depth of the complex group was significantly shorter than that of the simple group (15.0 ± 3.7 mm vs. 19.7 ± 4.2 mm, $p < 0.001$), and so was the neck length (7.9 ± 2.3 mm vs. 9.7 ± 3.4 mm, $p = 0.020$). Regarding the LAA position, more LAAs were situated at the lower position in the complex group ($p = 0.048$). The position of sheath tended to be different between the two groups, and the proportion of sheath at high position in complex group was significantly higher (61.9% vs. 29.4%, $p = 0.018$).

Successful implantation of the device was achieved in all patients of the simple group. Among these patients, 31 (91.2%) implants succeeded with 1 attempt of deployment. Implantation in 3 patients in the complex group was achieved with an acceptable protrusion. Eighteen patients received a re-ATP at a more inferior and anterior location. Compared with the 3 patients who didn't undergo re-ATP, the sheath depth for patients received re-ATP was significantly shorter (14.7 ± 2.6 mm vs. 18.2 ± 2.4 mm, $p = 0.040$), and the difference between the sheath depth and device depth was significantly greater (−4.2 ± 2.3 mm vs. 0.2 ± 1.2 mm, $p = 0.009$). No other significant difference was found in the LAA anatomical parameters between the patients who received re-ATP and the 3 patients with implantation by an acceptable protrusion.

The sheath depth was significantly greater after the re-puncture (18.8 ± 3.4 mm vs. 14.7 ± 2.6 mm, $p < 0.001$) while the angle of the sheath was significantly greater ((52.7°(41.2°, 67.8°) vs. 30.2°(24.0°, 36.6°), $p < 0.001$). The position of the sheath was lower than before in 14 (77.8%) patients, while it was not significantly changed in the other 4 patients.

Among the 18 patients who underwent re-ATP, successful implantation was achieved in 14 patients, while 4 procedures were aborted after at least two attempts (Table 3). The success rate in the complex group was significantly lower than that in the simple group (81.0% vs. 100%, $p = 0.008$). The sheath depth and the angle of the sheath before re-ATP were also similar. Nevertheless, the sheath was significantly deeper in patients who were successfully implanted than in patients whose procedure was aborted (19.7 ± 3.3 mm vs. 15.8 ± 1.8 mm, $p = 0.040$). All the sheath depth after the re-ATP became greater than the device depth for successful implantations while it was still less than the device depth for the aborted implantations. The difference in the sheath depth and device depth was statistically significant between these two groups (1.0 ± 1.8 mm vs. −3.0 ± 1.6 mm, $p = 0.001$).

3.3. Post-procedure follow-ups

Follow-up imaging at 3 months was performed for 46 (90.2%) patients, including 33 from the simple group and 13 from the complex group. Among them, satisfactory closure was achieved in all patients. PDL was observed in 8 (24.2%) patients in the simple group and 5 (38.5%) patients in the complex group ($p = 0.335$). No DRT was identified.

During the 1-year follow-up period, no major periprocedural complications were observed. The femoral hematoma was observed in 1 (1.8%) case in the complex group. One patient from the simple group experienced ischemic stroke 4 months after the procedure, whose transesophageal echocardiography at 3-month follow-up showed a satisfactory closure and no PDL was present. No major bleeding was observed. One mild gingival bleeding and one dermal ecchymosis were reported within 1 month after the procedure and

Table 2
The LAA anatomy and procedural characteristics for the simple and complex group.

	All patients (n = 55)	Simple group (n = 34)	Complex group (n = 21)	P-value
Ostium width, mm	20.9 ± 3.6	21.0 ± 3.3	20.9 ± 4.2	0.98
Root depth, mm	17.9 ± 4.6	19.7 ± 4.2	15.0 ± 3.7	<0.001
Neck length	9.0 ± 3.1	9.7 ± 3.4	7.9 ± 2.3	0.020
Axial angle	34.1 (10.5, 55.5)	34.0 (10.5, 60.0)	37.0 (10.1, 53.1)	0.768
Bending angle	115.4 (91.8,140.0)	117.6 (89.4, 145.7)	115.4 (91.1,138.6)	0.901
LAA position				0.048
High	33 (60.0%)	24 (70.5%)	9 (42.8%)	
Medium	20 (36.3%)	10 (29.4%)	10 (47.6%)	
Low	2 (3.6%)	0 (0.0%)	2 (9.5%)	
WATCHMAN device size[a]				0.813
21 mm	19 (34.5%)	13 (38.2%)	8 (38.1%)	
24 mm	13 (23.6%)	8 (23.5%)	5 (23.8%)	
27 mm	10 (18.1%)	7 (20.6%)	3 (14.3%)	
30 mm	10 (18.1%)	7 (20.6%)	3 (14.3%)	
33 mm	3 (5.5%)	1 (2.9%)	2 (9.5%)	
Sheath depth, mm	19.0 ± 4.2	21.3 ± 3.0	15.2 ± 2.8	<0.001
Angle of the sheath	31.1 (21.1, 40.8)	32.7 (19.7, 41.5)	30.3 (23.0, 37.8)	0.965
Position of the sheath				0.060
High	23 (41.8%)	10 (29.4%)	13 (61.9%)	
Medium	24 (43.6%)	18 (52.9%)	6 (28.6%)	
Low	8 (14.5%)	6 (17.6%)	2 (9.5%)	
Number of repositions/recaptures, n	0.6 ± 0.8	0.1 ± 0.3	1.4 ± 0.7	<0.001
Success rate, %	92.7	100	81.0	0.008

Continuous variables were expressed as the mean ± standard deviation or median (25th, 75th percentile).
LAA: left atrial appendage.
[a] Devices chosen for patients whose procedures were finally aborted were also included.

Table 3

The LAA anatomy and procedural characteristics for patients who underwent repeated atrial transseptal puncture.

	Patients who underwent re-ATP (n = 18)	Successful LAAC (n = 14)	Aborted LAAC (n = 4)	p-value
Before re-ATP				
Sheath depth, mm	14.7 ± 2.6	15.0 ± 2.7	13.7 ± 1.8	0.410
Angle of the sheath	30.2 (24.0, 36.6)	30.7 (24.4, 36.6)	27.5 (18.6,50.1)	0.825
Position of the sheath				0.156
High	11 (61.1%)	9 (64.3%)	2 (50.0%)	
Medium	6 (33.6%)	5 (35.7%)	1 (25.0%)	
Low	1 (5.6%)	0 (0.0%)	1 (25.0%)	
After re-ATP				
Sheath depth, mm	18.8 ± 3.4	19.7 ± 3.3	15.8 ± 1.8	0.040
Angle of the sheath	52.7 (41.2, 67.8)	52.7 (38.7,67.8)	52.4 (42.5,77.2)	0.495
Position of the sheath				0.518
High	0 (0.0%)	0 (0.0%)	0 (0.0%)	
Medium	7 (38.9%)	8 (57.1%)	3 (75.0%)	
Low	11 (61.1%)	6 (42.9%)	1 (25.0%)	

Continuous variables were expressed as the mean ± standard deviation or median (25th, 75th percentile).

LAA: left atrial appendage; LAAC: left atrial appendage occlusion; Re-ASP: repeated atrial transseptal puncture.

were relieved after switching from oral anticoagulant to antiplatelets. Both patients were from the simple group. No major periprocedural complications or other adverse events were observed. The incidence of both major and minor periprocedural complications were similar between the simple and complex groups.

4. Discussion

4.1. Main findings

The main findings of present study are as follows: 1) The success rate of LAAC was significantly lower in the RCW-LAA than in the other morphological categories; 2) the anatomical features of the RCW-LAA such as lower position of LAA and earlier bending were associated with the complexity of the LAAC procedure; and 3) ATP at a more inferior and anterior position was effective in obtaining more depth for cage devices and achieving a higher success rate of LAAC for the RCW-LAA.

4.2. LAA morphology and stroke risk

In the present study, the stroke risk was higher in patients with chicken-wing-shaped LAAs. Nevertheless, some previous studies showed that LAA with chicken-wing morphology was associated with a lower risk of stroke compared with the other morphological categories [7,12]. It may have been partly due to the inclusion of the different patient cohorts. The previous studies mainly included patients with AF, regardless of their CHA_2DS_2-VASc scores and stroke risk. The proportion of patients with a CHA_2DS_2-VAS_C score of ≥2 was only 14% in the study by Di Biase et al. indicating that the population mainly consisted of AF patients with low stroke risk. Therefore, the risk of chicken-wing-shaped LAA might have been underestimated in AF patients with high stroke risk. Moreover, Bosi et al. reported that the chicken-wing-shaped LAA was the one with the lowest velocities both in the normal and AF conditions among all LAA shapes, making the LAA region most subjected to fluid stagnation and potential thrombus development [13]. Expect the LAA morphology, a smaller LAA ostium was independently associated with a higher stroke risk [14] while the present study showed a relatively small ostium width in the RCW-LAAs. More studies are needed to identify which, if any, of the morphological features of LAA is a clinically significant risk factor for the development of stroke.

4.3. Successful rate of LAAC in patients with RCW-LAA

The success rate of the LAAC was reported as 95%–99% in large-scale clinical trials [15-17]. However, the device implant success rate for different LAA morphologies has seldom been reported. The success rate was high and similar across the four typical anatomical structures (all ≥97.5%) in the German LAARGE registry [18]. Regarding the different devices, Chen et al. found a similar implant success rate among the LAmbre, Amulet, and Watchman devices (99%–100%) [19]. However, in clinical practice the WATCHMAN device was less selected for the procedure with complex LAA morphology like chicken-wing-shaped LAA [19], implying the difficulty of cage device implantation in such cases.

The presence of a chicken-wing-shaped LAA constitutes a challenge that requires specific occlusion strategies. Plug device and "sandwich" technique was recommended for such LAAs [4,5,20]. In general, the presence of an early and severe bend in the chicken-wing-shaped structure provides an obstacle to the successful deployment of a cage device. In this present study, an earlier bend was associated with the complexity of the procedure with the RCW-LAA, not only because an earlier bend was often accompanied with less depth for device deployment but the radial strength would be substantially decreased. Moreover, LAAs with lower position, resulting in higher position of the sheaths, implied less possibility of using the distal lobe in case of insufficient depth for the cage devices deployment even with a double-curve sheath. Therefore, while the overall success rate for all the LAA morphologies in our study was consistent with the previous reports (98.4%) where patients were implanted exclusively with the WATCHMAN device, a significantly lower success rate for the RCW-LAA was observed. No procedural strategy on the cage device for chicken-wing-shaped or reversed chicken-wing-shaped LAA has been reported before.

4.4. *Sheath depth and LAAC*

From the past experience in our center, the sheath depth was the core determining factor for the LAAC procedure, which was proved in the present study as well. In the RCW-LAA with enough root depth, the LAAC procedure is similar to other morphological categories. The LAAC procedures in the simple group of the present study all succeeded with a single conventional ATP, as well as fewer attempts of deployment. Nevertheless, due to the unique shape of the RCW-LAA, the root depth was insufficient on many occasions, especially when the ostium diameter was relatively wide. The attempt of deployment of the WATCHMAN device with acceptable protrusion was recommended. However, since the body of the cage occluder could provide only limited support for the RCW-LAA, the stability of the occluder mainly depended on the radial support from the shoulder. Therefore, this strategy was effective only in very few cases. For all the cases with insufficient sheath depth, an ATP at a more inferior and anterior location was efficient and safe to advance the sheath into the chicken-wing apex to create a greater sheath depth. All those cases without a sufficient sheath depth even after re-ATP failed the procedure.

A more inferior and anterior ATP was effective in obtaining a coaxial alignment between the delivery sheath and the RCW-LAA [21]. As fixed curve sheaths were mostly used for the LAAC procedure, the height and depth of the sheath were mainly determined by the ATP position. Also in our study, a more inferior and anterior ATP was effective in obtaining a higher sheath position and greater sheath depth. Unlike the ordinary LAAs that were bent forward and rightward, the RCW-LAAs were bent upward and leftward, therefore the sheath was limited by the posterior or septal margin of the LAA orifice and could not be advanced further due to hitting the anterior or lateral wall. After the re-puncture, the sheath was less limited by the ostium and then could be advanced deeper when it was rotated counterclockwise, which eventually achieved enough depth for device implantation. Therefore, a cardiac CT or transesophageal echocardiography before the procedure is strongly recommended to recognize the RCW-LAAs and preplan the ATP position, which might avoid re-ATP and avoid related complications. Moreover, with the introduction of the novel WATCHMAN FLX device, insufficiency in sheath depth in most cases might be rectified because of its shorter device depth and atraumatic closed end [22].

5. Limitations

This was a prospective observational study with no control group from single center. This study was also limited by its small size of the patients with RCW-LAAs. Because of the unavailability of the novel WATCHMAN FLX device, only strategy regarding the implantation of the WATCHMAN 2.5 generation was described in this article.

6. Conclusion

LAAC is challenging in patients with the RCW-LAA structure in our high-volume center. The anatomical features of RCW-LAA like low position and earlier severe bending contribute to the complexity of LAAC procedure. ATP at an inferior and anterior location is efficient in increasing the success rate of WATCHMAN device implantation in the RCW-LAA without inducing additional complications.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.heliyon.2022.e12662.

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