CLINICAL INVESTIGATIONS

Procedural success and intra-hospital outcome related to left atrial appendage morphology in patients that receive an interventional left atrial appendage closure

Christian Fastner | Michael Behnes | Benjamin Sartorius | Annika Wenke |
Ibrahim El-Battrawy | Uzair Ansari | Ishar-Singh Gill | Martin Borggrefe | Ibrahim Akin

First Department of Medicine, University
Medical Center Mannheim, University of
Heidelberg, Mannheim, Germany

Correspondence

Christian Fastner, MD, First Department of
Medicine, University Medical Center
Mannheim, Theodor-Kutzer-Ufer 1-3, 68167
Mannheim, Germany
Email: christian.fastner@umm.de.

Background: The interventional left atrial appendage (LAA) closure represents an emerging alternative to oral anticoagulation for stroke prevention in certain atrial fibrillation patients. Preliminary results have suggested high procedural success rates and fewer peri-interventional complications; however, there persists an insufficient understanding of the role of many underlying confounding variables (e.g., anatomical characteristics).

Hypothesis: It was investigated whether varying LAA morphologies influence procedural success as well as in-hospital outcome.

Methods: Sixty-seven patients ineligible for long-term oral anticoagulation were included in this single-center, prospective, observational registry spanning from the years 2014 to 2016. Interventions were performed with the Watchman occluder (Boston Scientific, Natick, MA) or the Amplatzer Amulet (St. Jude Medical, St. Paul, MN), at the operator's discretion. Results derived from the data describing procedural success, fluoroscopy, and peri-interventional safety events were classified according to the presenting LAA morphology (cauliflower, cactus, windsock, and chicken wing).

Results: Rates of successful implantation were high across all groups ($\geq 98\%$; $P = 0.326$). Surrogate parameters underlining procedural complexity like median total duration ($P = 0.415$), median fluoroscopy time ($P = 0.459$), median dose area product ($P = 0.698$), and the median amount of contrast agent ($P = 0.076$) demonstrated similar results across all groups. Likewise, the periprocedural complication rate was not significantly different and was mainly restricted to minor bleeding events.

Conclusions: Irrespective of the varying morphological presentation of the LAA, the procedural success rates, interventional characteristics, and safety events did not significantly differ among patients receiving an interventional LAA closure.

KEYWORDS

Atrial Fibrillation, Left Atrial Appendage, Left Atrial Appendage Morphology, Procedural Characteristics, Interventional Complications

1 | INTRODUCTION

Atrial fibrillation (AF), the most common of sustained cardiac arrhythmias, has an existing age-dependent prevalence of 1% to 2% among the Western population.¹ Strokes signify a relevant and seemingly frequent complication of this entity, highlighted by the consistent

observation of death and/or permanent disability.^{2,3} A useful tool often used to assess an individual patient's risk of developing a stroke is the CHA₂DS₂-VASc score.⁴ Vitamin K antagonists (VKA; e.g., warfarin and phenprocoumon) have traditionally been the treatment of choice for AF patients associated with an increased thromboembolic risk (i.e., CHA₂DS₂-VASc score ≥ 2); however, the introduction of

direct oral anticoagulants (OACs) has offered an interesting therapeutic alternative for all eligible patients.⁴

In the real-world setting, a significant proportion of AF patients presents limitations to treatment with OACs.⁵ These include patient groups prone to bleeding (i.e., with a higher bleeding risk as calculated by a HAS-BLED score ≥ 3), such as older and frail patients, patients on dialysis,^{4,6,7} as well as patients previously affected by a bleeding event.⁵ Thromboembolic risk could potentially be circumvented in some of these nonvalvular AF patients with an interventional left atrial appendage (LAA) closure (LAAC).⁸ Clinical outcomes associated with LAAC are non-inferior to VKA use in AF patients with moderate stroke risk, and they share a relatively better bleeding profile.⁹ Patients ineligible for OAC therapy could safely be prescribed dual antiplatelet therapy agents until the LAA occlusion device is sufficiently endothelialized.^{10,11}

Although an appreciable number of trials have investigated various aspects of the LAAC procedure, the impact of LAA anatomy on procedural characteristics and peri-interventional safety events has not been sufficiently elucidated. LAA anatomy is known to be highly heterogeneous; however, 4 typical morphologies have been well described^{12,13}: the cauliflower, cactus, windsock, and chicken wing presentations. The chicken wing morphology represents an especially challenging anatomy from an interventional perspective.¹⁴ The purpose of this observational study was to investigate the procedural efficacy and safety outcomes related to different LAA morphologies in a real-world cohort.

2 | METHODS

2.1 | Enrollment

This was a single-center, prospective, observational study conducted between 2014 and 2016, which included 67 consecutive patients diagnosed with any of the 3 types of nonvalvular AF and having a calculated CHA₂DS₂-VASc score ≥ 2 , thus, in essence, requiring therapeutic anticoagulation with an OAC. The aim was to assess an all-comers collective representative of daily routine. Further inclusion criteria were age ≥ 18 years, relative or absolute contraindications associated with long-term OAC use (i.e., major bleeding with tendency to recur, HAS-BLED score ≥ 3 , and neurological symptoms presenting while on treatment with an OAC or intolerance to OACs in general). Patients were excluded if ≥ 1 of the following criteria were evident: single episode of AF or AF due to a treatable cause, catheter ablation of AF within 30 days prior to or after potential LAAC, electrical cardioversion within 30 days post-LAAC, congestive heart failure corresponding to New York Heart Association (NYHA) functional class IV, myocardial infarction (MI) within the last 3 months, atrial septum defect (ASD) or interventional/surgical occlusion of an ASD, presence of a mechanical heart valve, post-heart transplant status, symptomatic carotid artery stenosis, transient ischemic attack (TIA) or stroke within the last 30 days, intracerebral bleeding within the last 3 months, acute infection, existing or planned pregnancy, and existing thrombus.

The study was conducted according to the principles outlined in the Declaration of Helsinki and was approved by the medical ethics

committee II of the Faculty of Medicine in Mannheim, University of Heidelberg, Germany. A written informed consent was obtained from all patients included in this study.

2.2 | Procedure

Preprocedural requirements included a routine electrocardiogram, and standard blood analyses. To ascertain the appropriate size for either device, a transesophageal TEE was also performed, as recommended, to quantify the following LAA parameters¹⁵: LAA ostium, landing zone and depth of the LAA, as well as those additionally differentiating the main lobes from the smaller side lobes. Furthermore, the possible presence of intra-atrial or LAA thrombi was also effectively excluded.

3 experienced interventional cardiologists, each having implanted ≥ 50 LAAC devices prior to the study, performed the LAAC. The intervention was carried out as previously described.¹⁶ Patients received either the Watchman occluder (Boston Scientific, Natick, MA) or the Amplatzer Amulet device (St. Jude Medical, St. Paul, MN). The size of the device eventually chosen was $\geq 20\%$ larger than the measured diameter at the landing zone. The compression of the device after its deployment at site was subsequently measured with a 2-dimensional (2D) TEE. An optimal result was generally defined by a device compression of $\geq 10\%$ in the absence of any relevant peri-device leaks (i.e., < 5 mm), as well as evidence excluding significant attachment or compression effects of the device on neighboring structures such as the circumflex coronary artery, the mitral annulus, or the pulmonary veins. At the end of the intervention, the primary access sites were closed with either an Angio-Seal Evolution (St. Jude Medical) prescribed for arterial access points, or with 2 ProGlide (Abbott Vascular, Santa Clara, CA) reserved for the venous access points. This was followed by the use of a compression band for ≥ 6 hours. Patients were administered a loading dose of 250 mg acetylsalicylic acid and 600 mg clopidogrel immediately after the procedure.

2.3 | LAA anatomy

The individual LAA morphology was determined by angiography in right and left anterior oblique projections by the experienced interventionalists. The classification was in accordance with the definitions defined by Wang et al.¹³

2.4 | Intrahospital follow-up

Post-interventional follow-up on the next day included a transthoracic echocardiogram and a chest X-ray, performed to rule out device dislodgment and pericardial effusion. An electrocardiogram was recorded to exclude a new bundle branch block (BBB) or atrioventricular (AV) block, and repetitive, thorough clinical examinations were carried out to comprehensively rule out associated clinical complications, including residual bleeding at the access sites.

2.5 | Outcome measures

The primary outcome measure for our in-hospital registry was the rate of successful device implantations without relevant peri-device leak (i.e., <5 mm) for each LAA morphology. Secondary outcome measures were outlined by procedural duration, radiation exposure, use of contrast agents, as well as the rate of peri-interventional safety events (e.g., bleeding events and circulatory depression). Events associated with the procedure and resulting in death, aggravated morbidity, or prolonged hospitalization were classified as complications. All transpiring clinical events not directly linked to the procedure were termed as adverse events. Major complications constituted the Bleeding Academic Research Consortium (BARC) definition type 3 or 5 bleedings,¹⁷ device embolization, circulatory failure, cardiopulmonary resuscitation, and death.

2.6 | Statistical analysis

Statistical analyses were performed with SPSS Statistics (IBM Corp., Armonk, NY) and GraphPad Prism (GraphPad Software, Inc., La Jolla, CA). Data are presented as medians with interquartile ranges (25th and 75th percentiles) or as frequencies with group-related percentages. Normal distribution of data was tested with the Kolmogorov-Smirnov test. In cases of normal distribution, a 1-way ANOVA was applied to compare scaled data for equal variances and the Welch test for unequal variances. Abnormally distributed scaled variables were compared using the Kruskal-Wallis test. Categorical variables were compared using the χ^2 test. *P* values <0.05 (2-tailed) were considered significant.

3 | RESULTS

3.1 | Baseline characteristics

Of the 67 patients participating in this study, 17 (25.4%) presented with an LAA in the cauliflower shape, 12 (17.9%) presented with an LAA in the cactus shape, 13 (19.4%) presented with an LAA in the chicken wing shape, and 25 (37.3%) presented with an LAA in the windsock shape. The baseline characteristics, including the indication for LAAC, median CHA₂DS₂-VAsC score, and median HAS-BLED score for each group, are listed in Table 1. These baseline characteristics were evenly distributed among the 4 groups without any exceptions.

Interestingly, characteristics known to influence bleeding events—such as female sex, high body mass index, arterial hypertension, diabetes mellitus, and renal and liver insufficiency—did not significantly vary among the different groups. All referred patients presented a pronounced cardiovascular risk profile. The most frequent indication for a LAAC was a prior bleeding (77.6%), and gastrointestinal bleeding represented a common cause of this clinical event (41.8%). The data suggest that at least half of the patients (50.7%) were not treated with anticoagulants as prescribed at the time of hospital admission. Table 2 summarizes the 2D TEE and functional echocardiographic measurements.

3.2 | Implantation success and procedural data

A little more than half of all patients received the Watchman occluder (55.2%), with the presenting LAA morphology not significantly influencing the interventionalist's choice of device type (*P* = 0.455; Table 3). Measures of primary outcome distinctly suggested that 90% of all interventions were successful. All LAA morphologies, excluding the windsock shape, exhibited successful post-interventional closure of the LAA (up to 100%), with the exceptional cases bearing no statistical relevance (*P* = 0.326).

The slightly lower success rate was attributed primarily to 2 patients, the first of whom suffered a peri-interventional cardiac arrest in light of a highly reduced left ventricular ejection fraction (LVEF) aggravated significantly by deep conscious sedation, resulting ultimately in death. The second patient presented with a complicated flat tube-shaped LAA morphology, classified essentially as a windsock-like configuration.

The Figure 1 and Table 3 show that specific interventional characteristics such as procedural duration (*P* = 0.415), fluoroscopy time (*P* = 0.459), dose area product (*P* = 0.698), and use of contrast agent (*P* = 0.076) also did not significantly differ between the different LAA morphologies, although a statistical trend demonstrating lesser use of contrast agent was evident in the cactus LAA group.

3.3 | Intrahospital safety events

Overall complication rates (Table 4) were dominated by access-site complications of minor relevance. Approximately 85.7% of all bleeding complications were minor bleedings classified as BARC type 1 and 2. There were no recorded cases of severe conduction blocks such as BBB or AV blocks. All patients exhibiting post-interventional pericardial effusion on echocardiography were treated conservatively, with none requiring any form of transfusion. A single patient with a pre-existing highly reduced LVEF (28%) died from an acute heart failure exacerbated by a severe presentation of urosepsis 20 days after successful LAA implantation (i.e., adverse event). Interestingly, there were also no instances of periprocedural or in-hospital TIA or stroke. Patients were discharged at an average of 4 to 5 days after the intervention (*P* = 0.399; Table 3).

4 | DISCUSSION

Interventional LAAC has been reported to be an effective and safe alternative to standard OAC for the prophylaxis against thromboembolic events in nonvalvular AF patients prone to develop complications associated with OAC use.⁸ Like any catheter-based medical intervention, LAAC also presents an inherent risk for certain complications.^{16,18} This study aims to report on the procedural outcome and the complication rates associated with the different LAA morphologies.

The proportional distribution of the 4 varying morphological entities in this study corresponds to that of previously published reports (based on computed tomography), and, therefore, can be considered reliable.¹³ Although earlier studies suggested a significant learning curve leading only gradually to greater procedural success,¹⁹ recently

TABLE 1 Baseline characteristics

	Cauliflower, n = 17	Cactus, n = 12	Windsock, n = 25	Chicken Wing, n = 13	P Value ¹
Male sex	11 (64.7)	9 (75.0)	15 (60.0)	12 (92.3)	0.199
Age, y	80 (71–84)	80 (75–84)	77 (69–81)	81 (73–83)	0.523
Height, m	1.70 (1.63–1.75)	1.69 (1.64–1.77)	1.72 (1.67–1.78)	1.70 (1.67–1.78)	0.306
Weight, kg	78.0 (66.5–87.0)	80.5 (66.5–85.0)	82.0 (67.5–93.0)	89.0 (74.5–96.5)	0.613
BMI, kg/m ²	26.3 (24.2–30.3)	27.0 (23.7–29.3)	27.1 (23.8–31.0)	28.4 (25.4–34.3)	0.729
CHA ₂ DS ₂ -VASc score	4 (3–5)	4 (3–5)	4 (2–5)	5 (3–6)	0.603
HAS-BLED score	4 (3–5)	4 (3–5)	4 (3–5)	4 (3–4)	0.673
Indication for LAAC					0.074
Prior bleeding	14 (82.4)	11 (91.7)	20 (80.0)	7 (53.8)	
Tendency of falling	0 (0.0)	0 (0.0)	3 (12.0)	0 (0.0)	
OAC refusal	1 (5.9)	0 (0.0)	2 (8.0)	3 (23.1)	
Stroke under OAC	1 (5.9)	1 (8.3)	0 (0.0)	3 (23.1)	
RRT	1 (5.9)	0 (0.0)	0 (0.0)	0 (0.0)	
Type of AF					0.768
Paroxysmal	11 (64.7)	7 (58.3)	13 (52.0)	8 (61.5)	
Persistent	3 (17.6)	1 (8.3)	2 (8.0)	2 (15.4)	
Permanent	3 (17.6)	4 (33.3)	10 (40.0)	3 (23.1)	
Heart rhythm at hospitalization					0.344
SR	4 (23.5)	4 (33.3)	5 (20.0)	6 (46.2)	
AF	10 (58.8)	6 (50.0)	16 (64.0)	6 (46.2)	
PM	1 (5.9)	2 (16.7)	4 (16.0)	1 (7.7)	
Undefined	2 (11.8)	0 (0.0)	0 (0.0)	0 (0.0)	
Arterial HTN	17 (100.0)	11 (91.7)	24 (96.0)	13 (100.0)	0.532
DM	8 (47.1)	4 (33.3)	6 (24.0)	5 (38.5)	0.474
Prior apoplexy					0.461
TIA	1 (5.9)	3 (25.0)	2 (8.0)	2 (15.4)	
Stroke	2 (11.8)	2 (16.7)	3 (12.0)	3 (23.1)	
Prior systemic embolization	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	—
PAD	1 (5.9)	0 (0.0)	3 (12.0)	2 (15.4)	0.509
CHD	11 (64.7)	6 (50.0)	14 (56.0)	7 (53.8)	0.871
CABG	3 (17.6)	2 (16.7)	4 (16.0)	0 (0.0)	0.471
CKD	8 (47.1)	4 (33.3)	12 (48.0)	2 (15.4)	0.209
GFR, mL/min	59 (38–70)	70 (45–70)	70 (42–70)	70 (49–70)	0.429
Liver insufficiency	2 (11.8)	0 (0.0)	3 (12.0)	0 (0.0)	0.359
Prior bleeding					0.154
Intracranial	4 (23.5)	4 (33.3)	4 (16.0)	2 (15.4)	
GI	4 (23.5)	6 (50.0)	16 (64.0)	2 (15.4)	
Muscle	2 (11.8)	0 (0.0)	0 (0.0)	1 (7.7)	
Epistaxis	1 (5.9)	0 (0.0)	1 (4.0)	0 (0.0)	
Urinary tract	2 (11.8)	1 (8.3)	1 (4.0)	3 (23.1)	
Labile INR	1 (5.9)	1 (8.3)	2 (8.0)	0 (0.0)	0.770
Prior PVI	2 (11.8)	0 (0.0)	3 (12.0)	2 (15.4)	0.607
Cardiac device					0.306
PM	5 (29.4)	3 (25.0)	5 (20.0)	1 (7.7)	
ICD	2 (11.8)	0 (0.0)	0 (0.0)	0 (0.0)	
Optimizer	1 (5.9)	0 (0.0)	0 (0.0)	0 (0.0)	
CRT-D	0 (0.0)	0 (0.0)	1 (4.0)	0 (0.0)	
Anticoagulation at hospitalization					0.110
None	8 (47.1)	5 (41.7)	14 (56.0)	7 (53.8)	
Phenprocoumon	4 (23.5)	1 (8.3)	7 (28.0)	0 (0.0)	
Rivaroxaban	3 (17.6)	3 (25.0)	2 (8.0)	4 (30.8)	

(Continued)

TABLE 1 Continued

	Cauliflower, n = 17	Cactus, n = 12	Windsock, n = 25	Chicken Wing, n = 13	P Value ¹
Dabigatran	0 (0.0)	0 (0.0)	1 (4.0)	2 (15.4)	
Apixaban	2 (11.8)	3 (25.0)	1 (4.0)	0 (0.0)	
LMWH	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	

¹ Abbreviations: AF, atrial fibrillation; BMI, body mass index; CABG, coronary artery bypass grafting; CHA₂DS₂-VASC, congestive HF, HTN, age ≥75 years, DM, stroke/TIA, vascular disease, age 65–74 y, sex category (female); CHD, coronary heart disease; CKD, chronic kidney disease; CRT-D, cardiac resynchronization therapy device; DM, diabetes mellitus; GFR, glomerular filtration rate; GI, gastrointestinal; HAS-BLED, HTN, abnormal renal and liver function, stroke, bleeding history or predisposition, labile INR, age >65 years, drugs or alcohol; HF, heart failure; HTN, hypertension; ICD, implantable cardioverter-defibrillator; INR, international normalized ratio; IQR, interquartile range; LAAC, left atrial appendage closure; LMWH, low-molecular-weight heparin; OAC, oral anticoagulation; PAD, peripheral arterial disease; PM, pacemaker; PVI, pulmonary vein isolation; RRT, renal replacement therapy; SR, sinus rhythm; TIA, transient ischemic attack.

Data are presented as n (%) or median (IQR).

² P values for the comparison of 4 groups.

TABLE 2 Echocardiographic characteristics

	Cauliflower, n = 17	Cactus, n = 12	Windsock, n = 25	Chicken Wing, n = 13	P Value ¹
LVEF					0.800
Normal	14 (82.4)	9 (75.0)	19 (76.0)	10 (76.9)	
Mildly impaired	2 (11.8)	0 (0.0)	3 (12.0)	2 (15.4)	
Moderately impaired	1 (5.9)	1 (8.3)	3 (12.0)	0 (0.0)	
Severely impaired	0 (0.0)	2 (16.7)	0 (0.0)	1 (7.7)	
LVEDD, mm	48 (46–54)	46 (42–55)	49 (43–53)	47 (41–54)	0.915
Aortic bulge, mm	32 (28–35)	32 (28–35)	31 (28–35)	32 (31–36)	0.786
LA diameter, mm	45 (41–50)	48 (45–55)	51 (46–56)	51 (41–57)	0.197
LA area, cm ²	22 (17–28)	24 (22–28)	26 (24–29)	24 (14–32)	0.111
LA volume, cm ³	78 (56–93)	83 (75–118)	103 (88–116)	72 (43–144)	0.171
Ostial diameter, mm					
45°	18 (15–23)	20 (14–25)	21 (17–24)	20 (16–21)	0.619
90°	21 (17–27)	19 (14–22)	20 (18–24)	17 (15–21)	0.081
135°	21 (18–24)	18 (16–22)	21 (19–25)	21 (15–24)	0.594
LAA depth, mm	33 (25–37)	25 (19–28)	29 (25–36)	29 (27–40)	0.052
Landing zone, mm	20 (15–26)	17 (15–21)	20 (16–22)	17 (16–21)	0.643
Aortic valve					
Stenosis	0 (0.0)	1 (8.3)	3 (12.0)	2 (15.4)	0.446
Insufficiency	4 (23.5)	4 (33.3)	12 (48.0)	6 (46.2)	0.340
Pulmonary valve					
Stenosis	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	—
Insufficiency	1 (5.9)	0 (0.0)	0 (0.0)	0 (0.0)	0.424
Mitral valve					
Stenosis	1 (5.9)	2 (16.7)	1 (4.0)	1 (7.7)	0.597
Insufficiency	10 (58.8)	7 (58.3)	20 (80.0)	9 (69.2)	0.284
Tricuspid valve					
Stenosis	0 (0.0)	1 (8.3)	0 (0.0)	0 (0.0)	0.206
Insufficiency	11 (64.7)	5 (41.7)	14 (56.0)	5 (38.5)	0.402

¹ Abbreviations: IQR, interquartile range; LA, left atrial; LAA, left atrial appendage; LVEDD, left ventricular end-diastolic diameter; LVEF, left ventricular ejection fraction.

Data are presented as n (%) or median (IQR).

² P values for the comparison of 4 groups.

published data demonstrate a much better rate of successful implantation for both devices (>95%).^{10,11,20} Our documented success rate of ≥98%, irrespective of the LAA morphology, perfectly corresponds to these data.

LAAC device anchoring can prove to be difficult in the case of challenging LAA morphology (e.g., the chicken wing-configured

LAA with a short neck and a subsequent severe bend)¹⁴; however, our analysis could not highlight any statistically significant difference influencing the success of device implantation in such a scenario.

Comparative data pertaining to procedural specifications, such as total duration, fluoroscopy time, dose area product, and amount of

TABLE 3 Interventional data

	Cauliflower, n = 17	Cactus, n = 12	Windsock, n = 25	Chicken Wing, n = 13	P Value ¹
Type of LAA occluder					0.455
Watchman	8 (47.1)	5 (41.7)	15 (60.0)	9 (69.2)	
Amulet	9 (52.9)	7 (58.3)	10 (40.0)	4 (30.8)	
Successful implantation	17 (100.0)	12 (100.0)	23 (92.0)	13 (100.0)	0.326
All lobes covered	14 (82.4)	11 (91.7)	21 (84.0)	11 (84.6)	0.901
Positioning attempts	2 (1–2)	1 (1, 2)	1 (1–3)	3 (1–3)	0.362
Change of occluder size	1 (1–2)	1 (1–1)	1 (1–1)	1 (1–1)	0.911
Total duration, min	105 (78–121)	96 (75–118)	85 (68–110)	105 (75–128)	0.415
Fluoroscopy time, min	11 (8–19)	8 (5–14)	8 (6–14)	12 (8–13)	0.459
Reference dose, Gy*cm ²	56 (42–84)	59 (28–81)	64 (44–93)	58 (48–88)	0.698
Amount of contrast agent, mL	178 (125–210)	115 (97–160)	161 (127–219)	144 (115–175)	0.076
Days on ICU	1 (0–1)	1 (1–1)	1 (1–1)	1 (0–1)	0.930
Hospital LOS, d	5 (3–7)	4 (3–6)	4 (3–6)	5 (4–6)	0.399

Abbreviations: ICU, intensive care unit; IQR, interquartile range; LAA, left atrial appendage; LOS, length of stay.

Data are presented as n (%) or median (IQR).

¹ P values for the comparison of 4 groups.

FIGURE 1 During percutaneous closure of the LAA, specific interventional characteristics of (A) procedural time, (B) fluoroscopy time, (C) reference dose, and (D) amount of contrast agent did not significantly differ between the 4 different LAA morphologies. Abbreviations: LAA, left atrial appendage.

contrast agent used were not statistically different among the varying groups. Interestingly, there was a statistical trend depicting lesser use of contrast agent in patients presenting with the cactus-shaped LAA morphology. This configuration essentially describes a dominant

central lobe with secondary lobes extending from the center.¹³ One could speculate that the cactus shape represents better access for a LAAC device, permitting easy maneuverability and thereby helping the device anchor in the cylindrical main lobe. Thus, a lesser amount

TABLE 4 Periprocedural safety events

	Cauliflower, n = 17	Cactus, n = 12	Windsock, n = 25	Chicken Wing, n = 13	P Value ¹
Patients with complications	9 (52.9)	4 (33.3)	10 (40.0)	6 (46.2)	0.733
Major complications	3 (17.6)	1 (8.3)	4 (16.0)	0 (0.0)	0.419
Device embolization	1 (5.9)	0 (0.0)	0 (0.0)	0 (0.0)	0.394
Respiratory insufficiency	1 (5.9)	0 (0.0)	0 (0.0)	0 (0.0)	0.394
CPR	0 (0.0)	0 (0.0)	2 (8.0)	0 (0.0)	0.326
Intrahospital death	0 (0.0)	0 (0.0)	1 (4.0)	1 (7.7)	0.577
Atrial shunt	1 (5.9)	0 (0.0)	0 (0.0)	0 (0.0)	0.403
Bleeding events					0.309
Groin bruise	4 (23.5)	2 (16.7)	4 (16.0)	4 (30.8)	
Groin hemorrhage from the arterial access	3 (17.6)	1 (8.3)	1 (4.0)	0 (0.0)	
Groin hemorrhage from the venous access	0 (0.0)	0 (0.0)	3 (12.0)	2 (15.4)	
Pseudoaneurysm	0 (0.0)	1 (8.3)	0 (0.0)	0 (0.0)	
Pericardial effusion	2 (11.8)	0 (0.0)	1 (4.0)	0 (0.0)	
BARC score					0.498
1	4 (23.5)	2 (16.7)	4 (16.0)	4 (30.8)	
2	4 (23.5)	1 (8.3)	3 (12.0)	2 (15.4)	
3a	1 (5.9)	1 (8.3)	1 (4.0)	0 (0.0)	
3b	0 (0.0)	0 (0.0)	1 (4.0)	0 (0.0)	
3c	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
4	—	—	—	—	
5a	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
5b	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	

Abbreviations: BARC, Bleeding Academic Research Consortium; CPR, cardiopulmonary resuscitation.

Data are presented as n (%).

¹ P values for the comparison of 4 groups.

of contrast agent would be needed to completely demarcate this anatomy. In general, TEE measurements of the LAA did not statistically vary between the different morphologies.

It had been suggested that the presenting LAA anatomy should influence the selection of a particular LAAC device.¹⁵ Data derived from this present study do not support this hypothesis, as the distribution of the 2 available devices was significantly even between the varying LAA configurations.

At first glance, the rate of safety events seems to be high across all groups, but this was influenced by both a meticulous registration of the occurring events as well as a result of many minor bleedings (BARC type 1 and 2) being classified as bleeding complications (up to 85.7%). A significant proportion of these minor bleedings were due to arterial access site bleeding, compounded by the customary insertion of an additional small arterial sheath (5-F) in our center. Lower rates of secondary bleeding are possible if this optional vascular access is abandoned; however, this comes at the cost of decreased procedural safety.²¹

An introspective study identifying the cause of death of the 2 patients included in this trial suggested that at least 1 of these patients died due to an unrelated event, permitting this case to be subsequently classified as an adverse event. The other patient presented with a windsock-shaped LAA and died during the intervention, right after transseptal puncture. A TEE and angiography confirmed the correct site of puncture with no evidence of pericardial effusion

buildup. A comprehensive post-resuscitation analysis of the situation identified the cause of death was due to a pulseless electrical activity generated by necessary conscious sedation aggravating an already highly reduced LVEF. Although it can be effectively demonstrated that other complex cardiac interventions can be safely performed in patients with a severely reduced LVEF,^{22,23} there are questions concerning the collective benefit for such patients treated with an LAAC, especially when considering the high risk of thrombus formation in the left atrial cavity outside the LAA.¹⁷ There exists little data addressing this particular issue.²⁴ A single embolized Watchman occluder in the cauliflower-LAA group did not constitute any statistical significance, and the device could be successfully retrieved without causing any further complications.²⁵

An interesting adjunct to our result was that not a single case of periprocedural TIA or stroke was registered. There were also no significant differences between the varying groups in relation to safety events, time spent in the intensive care unit, or for the total duration of hospitalization.

Although a prospective observational registry for the Amplatzer first- and second-generation devices has already reported no statistical difference between the different LAA morphologies with regard to independent predictors of major adverse events (e.g., device repositioning, change of device size, no procedural success, device embolization),²⁶ the present registry confirms these findings in both the Watchman as well as the Amulet device.

4.1 | Study limitations

These analyses were based on the observational registry data of a limited patient collective with the inherent limitations of this study type. Due to the observational all-comers approach, the device type was not randomized for the different LAA anatomies and the patients were not assessed so as to reveal significant differences between the 4 groups. Respecting the observational character of this registry, the conduct of the intervention as a whole was not influenced by the study investigators and was primarily based on the interventionalists' discretion. This individualized decision algorithm could have significantly influenced the outcome, but such results would surely have been reflected in the clinical scenario. Moreover, follow-up time was limited to the end of hospitalization. Despite all the limitations of this observational registry, it serves as a data source for an understudied topic. Larger randomized studies are needed in the future to complement current information and further investigate the impact of LAA morphologies while describing efficacy and safety of the LAAC procedure.

5 | CONCLUSION

Irrespective of the varying morphological presentations of the LAA, the procedural success rates, interventional characteristics, and safety events did not significantly differ among patients receiving an interventional LAA closure.

Author Contributions

C.F. and I.A. conceived the study, participated in its design and coordination, participated in data analysis and interpretation, and helped to draft and revise the manuscript for important intellectual content. M. Behnes conceived the study, participated in its design and coordination, participated in data analysis and interpretation, and revised the manuscript for important intellectual content. B.S., I.-S.G., A.W., I.E.-B., and U.A. participated in the study design and coordination, as well as data analysis, and revised the manuscript. M. Borggreffe participated in the study design and coordination, as well as data acquisition, and revised the manuscript for important intellectual content.

Conflicts of interest

The authors declare no potential conflicts of interest.

REFERENCES

- Go AS, Hylek EM, Phillips KA, et al. Prevalence of diagnosed atrial fibrillation in adults: national implications for rhythm management and stroke prevention: the Anticoagulation and Risk Factors in Atrial Fibrillation (ATRIA) Study. *JAMA*. 2001;285:2370–2375.
- Marini C, De Santis F, Sacco S, et al. Contribution of atrial fibrillation to incidence and outcome of ischemic stroke: results from a population-based study. *Stroke*. 2005;36:1115–1119.
- Gage BF, Waterman AD, Shannon W, et al. Validation of clinical classification schemes for predicting stroke: results from the National Registry of Atrial Fibrillation. *JAMA*. 2001;285:2864–2870.
- Kirchhof P, Benussi S, Kotecha D, et al. 2016 ESC Guidelines for the management of atrial fibrillation developed in collaboration with EACTS: the Task Force for the 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. Endorsed by the European Stroke Organisation (ESO). *Eur Heart J*. 2016;37:2893–2962.
- Alamneh EA, Chalmers L, Bereznicki LR. Suboptimal use of oral anticoagulants in atrial fibrillation: has the introduction of direct oral anticoagulants improved prescribing practices? *Am J Cardiovasc Drugs*. 2016; 16:183–200.
- Gafoor S, Franke J, Bertog S, et al. Left atrial appendage occlusion in octogenarians: short-term and 1-year follow-up. *Catheter Cardiovasc Interv*. 2014;83:805–810.
- Shah M, Avgil Tsadok M, Jackevicius CA, et al. Warfarin use and the risk for stroke and bleeding in patients with atrial fibrillation undergoing dialysis. *Circulation*. 2014;129:1196–1203.
- Peritz DC, Chung EH. Left atrial appendage closure: an emerging option in atrial fibrillation when oral anticoagulants are not tolerated. *Cleve Clin J Med*. 2015;82:167–176.
- Holmes DR Jr, Doshi SK, Kar S, et al. Left atrial appendage closure as an alternative to warfarin for stroke prevention in atrial fibrillation: a patient-level meta-analysis. *J Am Coll Cardiol*. 2015;65:2614–2623.
- Reddy VY, Möbius-Winkler S, Miller MA, et al. Left atrial appendage closure with the Watchman device in patients with a contraindication for oral anticoagulation: the ASAP study (ASA Plavix Feasibility Study With Watchman Left Atrial Appendage Closure Technology). *J Am Coll Cardiol*. 2013;61:2551–2556.
- Urena M, Rodés-Cabau J, Freixa X, et al. Percutaneous left atrial appendage closure with the Amplatzer cardiac plug device in patients with nonvalvular atrial fibrillation and contraindications to anticoagulation therapy. *J Am Coll Cardiol*. 2013;62:96–102.
- Lupercio F, Carlos Ruiz J, Briceno DF, et al. Left atrial appendage morphology assessment for risk stratification of embolic stroke in patients with atrial fibrillation: a meta-analysis. *Heart Rhythm*. 2016;13:1402–1409.
- Wang Y, Di Biase L, Horton RP, et al. Left atrial appendage studied by computed tomography to help planning for appendage closure device placement. *J Cardiovasc Electrophysiol*. 2010;21:973–982.
- Freixa X, Tzikas A, Basmadjian A, et al. The chicken-wing morphology: an anatomical challenge for left atrial appendage occlusion. *J Interv Cardiol*. 2013;26:509–514.
- Meier B, Blaauw Y, Khattab AA, et al. EHRA/EAPCI expert consensus statement on catheter-based left atrial appendage occlusion. *EuroIntervention*. 2015;10:1109–1125.
- Fastner C, Behnes M, Sartorius B, et al. Left atrial appendage morphology, echocardiographic characterization, procedural data and in-hospital outcome of patients receiving left atrial appendage occlusion device implantation: a prospective observational study. *BMC Cardiovasc Disord*. 2016;16:25.
- Mehran R, Rao SV, Bhatt DL, et al. Standardized bleeding definitions for cardiovascular clinical trials: a consensus report from the Bleeding Academic Research Consortium. *Circulation*. 2011;123:2736–2747.
- Saw J, Lempereur M. Percutaneous left atrial appendage closure: procedural techniques and outcomes. *JACC Cardiovasc Interv*. 2014;7:1205–1220.
- Holmes DR, Reddy VY, Turi ZG, et al; PROTECT AF Investigators. Percutaneous closure of the left atrial appendage versus warfarin therapy for prevention of stroke in patients with atrial fibrillation: a randomised non-inferiority trial [published correction appears in *Lancet*. 2009;374:1596]. *Lancet*. 2009;374:534–542.
- Boersma LV, Schmidt B, Betts TR, et al; 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;37:2465–2474.
- Möbius-Winkler S, Majunke N, Sandri M, et al. Percutaneous left atrial appendage closure: technical aspects and prevention of periprocedural complications with the Watchman device. *World J Cardiol*. 2015;7:65–75.
- El-Mawardi M, Wübken-Kleinfeld N, Schwarz B, et al. Transcatheter aortic valve implantation in patients with severely reduced left ventricular systolic function: a single-center experience. *Clin Res Cardiol*. 2014;103:621–630.
- Schäfer U, Maisano F, Butter C, et al. Impact of preprocedural left ventricular ejection fraction on 1-year outcomes after MitraClip

- implantation (from the ACCESS-EU phase I, a prospective, multicenter, nonrandomized postapproval study of the MitraClip therapy in Europe). *Am J Cardiol.* 2016;118:873–880.
24. Patel MR, Biviano AB. Atrial fibrillation ablation and left appendage closure in heart failure patients. *Curr Opin Cardiol.* 2015;30:259–266.
 25. Fastner C, Lehmann R, Behnes M, et al. Veno-venous double lasso pull-and-push technique for transseptal retrieval of an embolized Watchman occluder. *Cardiovasc Revasc Med.* 2016;17:206–208.
 26. Koskinas KC, Shakir S, Fankhauser M, et al. Predictors of early (1-week) outcomes following left atrial appendage closure with Amplatzer devices. *JACC Cardiovasc Interv.* 2016;9:1374–1383.

How to cite this article: Fastner C, Behnes M, Sartorius B, et al. Procedural success and intra-hospital outcome related to left atrial appendage morphology in patients that receive an interventional left atrial appendage closure. *Clin Cardiol.* 2017;40:566–574. <https://doi.org/10.1002/clc.22699>