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Clinical Research

Initiation and development of a percutaneous left atrial appendage closure programme: A French centre's experience and literature review☆

Emeric Albert[a,b], Tania Puscas[b], Gabriel Seret[a,c], Noémie Tence[b], Denis Amet[b], Emilie Varlet[b], Dorra Raboudi M'Barek[b], Fabien Picard[a,c], Akli Otmani[b], Laurent Sabbah[d], Julien Le Guen[e], Eric Bodiguel[f,g], Valerie Domigo[f], Gilles Soulat[a,h], Christian Spaulding[a,b], Eloi Marijon[a,b,*]

[a] *Université Paris Cité, Inserm, PARCC, 75015 Paris, France*
[b] *Department of Cardiology, Georges Pompidou European Hospital, AP-HP, 75015 Paris, France*
[c] *Department of Cardiology, Cochin Hospital, AP-HP, 75015 Paris, France*
[d] *Department of Cardiology, Necker Hospital, AP-HP, 75015 Paris, France*
[e] *Department of Geriatry, Georges Pompidou European Hospital, AP-HP, 75015 Paris, France*
[f] *Department of Neurology, Saint Anne Hospital, Université Paris-Cité, 75014 Paris, France*
[g] *Emergency Department, Georges Pompidou European Hospital, AP-HP, 75015 Paris, France*
[h] *Department of Radiology, Georges Pompidou European Hospital, AP-HP, 75015 Paris, France*

HIGHLIGHTS

- Trend to fewer periprocedural complications over the years.
- Significant decrease of thromboembolic and haemorrhagic events post procedure.
- Almost half of haemorrhagic events occur during the first 3 months.

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SUMMARY

Background: Percutaneous left atrial appendage closure may be considered in selected patients with atrial fibrillation at significant risk of both thromboembolism and haemorrhage.
Aims: To report the experience of a tertiary French centre in percutaneous left atrial appendage closure and to discuss the outcomes compared with previously published series.
Methods: This was a retrospective observational cohort study of all patients referred for percutaneous left atrial appendage closure between 2014 and 2020. Patient characteristics, procedural management and outcomes were reported, and the incidence of thromboembolic and bleeding events during follow-up were compared with historical incidence rates.
Results: Overall, 207 patients had left atrial appendage closure (mean age 75.3 ± 8.6 years; 68% men; CHA_2DS_2-VASc score 4.8 ± 1.5 ; HAS-BLED score 3.3 ± 1.1), with a 97.6% (n = 202) success rate. Twenty (9.7%) patients had at least one significant periprocedural complication, including six (2.9%) tamponades and three (1.4%) thromboembolisms. Periprocedural complication rates decreased from earlier to more recent periods (from 13% before 2018 to 5.9% after; P = 0.07). During a mean follow-up of 23.1 ± 20.2 months, 11 thromboembolic events were observed (2.8% per patient-year), a 72% risk reduction

Abbreviations: AF, atrial fibrillation; CHA_2DS_2-VASc, Congestive heart failure, Hypertension, Age≥75 years (Doubled), Diabetes, Stroke/transient ischaemic attack/thromboembolism (Doubled)–Vascular disease, Age 65–74 years and Sex category (female); CT, computed tomography; HAS, Haute Autorité de Santé; HAS-BLED, Hypertension, Abnormal renal and liver function, Stroke–Bleeding, Labile international normalized ratio, Elderly, Drugs or alcohol; LAA, left atrial appendage; SAE, serious adverse event; TOE, transoesophageal echocardiography.

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* Corresponding author at: Hôpital Européen Georges Pompidou, Département de Cardiologie, 20–40, rue Leblanc, 75908 Paris Cedex 15, France.
E-mail address: eloi_marijon@yahoo.fr (E. Marijon).

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compared with the estimated theoretical annual risk. Conversely, 21 (10%) patients experienced bleeding during follow-up, with almost half of the events occurring during the first 3 months. After the first 3 months, the risk of major bleeding was 4.0% per patient-year, a 31% risk reduction compared with the expected estimated risk.
Conclusion: This real-world evaluation emphasizes the feasibility and benefit of left atrial appendage closure, but also illustrates the need for multidisciplinary expertise to initiate and develop this activity.

Background

Atrial fibrillation (AF), the most common sustained arrhythmia in both men and women, is associated with significant morbidity and mortality, including a fivefold increase in stroke risk [1,2]. According to the European Society of Cardiology guidelines, anticoagulation should be considered in all patients with atrial fibrillation and a CHA_2DS_2-VASc (Congestive heart failure, Hypertension, Age $\geq$ 75 years [Doubled], Diabetes, Stroke/transient ischaemic attack/thromboembolism [Doubled]–Vascular disease, Age 65–74 years and Sex category [female]) score of 1 in men and 2 in women, and is recommended in patients with a CHA_2DS_2-VASc score $\geq$ 2 in men or $\geq$ 3 in women [3]. Treatment with oral anticoagulation decreases cardioembolic risk by almost 70% in patients with AF, but is associated with higher rates of major extracranial bleeding and intracranial haemorrhage [4].

In France, the reported incidence of AF is increasing due to ageing of the population and the improvement in detection techniques. Although the availability of direct oral anticoagulation in 2012 led to an increase in the number of anticoagulated patients with AF [5], it is estimated that around 15% of patients are not anticoagulated because of renal failure, a very low CHA_2DS_2-VASc score or a presumed high risk of bleeding [6–8].

In patients with non-valvular AF, 90% of intracardiac thrombi develop in the left atrial appendage (LAA) [9]. This finding provided a rationale for LAA closure to prevent thromboembolism in patients with AF [10–12]. According to the 2020 European Society of Cardiology AF guidelines, LAA closure may be considered for stroke prevention in patients with AF and contraindications for long-term anticoagulant treatment (e.g. intracranial bleeding without a reversible cause) [3]. The French Health Authority (Haute Autorité de Santé [HAS]) recommended percutaneous LAA closure for patients with non-valvular AF with a high risk of thromboembolism (CHA_2DS_2-VASc score $\geq$ 4) and with a formal and permanent contraindication for anticoagulants (validated by a multidisciplinary committee) [13]. However, LAA closure can be associated with a significant risk of complications (tamponade, migration of the prosthesis, stroke, bleeding) [14], and although the HAS recognizes the efficacy of LAA closure in reducing thromboembolism, uncertainties remain regarding the net benefit of the procedure because of the 6–16% risk of serious periprocedural complications and the steep learning curve.

The objective of this study was to assess patient outcomes during and after percutaneous LAA closure outside the setting of a randomized trial.

Methods

Population and study design

This was a retrospective observational cohort study conducted in a French tertiary care hospital. Data were collected according to the Commission Nationale Informatique et Libertés (CNIL; number 2225833). The study adhered to the international standards of scientific studies and the Declaration of Helsinki principles.

All patients referred to the interventional cardiology unit for percutaneous LAA closure between March 2014 and December 2020 were included consecutively, independent of the procedure indication. Hospital records were used as main data source, and vital status during follow-up was collected using the MatchID database (a National Institute of Statistical and Economical Study [Insitut National de la Statistique et des Etudes Economiques (INSEE)] open-source database recording all French deaths). The first half of the patients (which corresponds to the first 100 patients operated on in a specific hybrid room) was compared with the second half (for whom LAA closure procedures were performed in the electrophysiology laboratory exclusively).

Local protocol and follow-up

All patients were hospitalized and gave written consent for percutaneous LAA closure. Preprocedural planning included systematic computed tomography (CT) scanning, except for patients who presented severe chronic kidney disease. Device choice relied mostly on operator experience and preference, with some anatomies requiring the selection of a specific device: Amulet™ (Abbott Vascular, Santa Clara, CA, USA); WATCHMAN™ or WATCHMAN FLX™ (Boston Scientific, Marlborough, MA, USA) starting in 2019.

Procedures were performed under general anaesthesia, transoesophageal echocardiography (TOE) and fluoroscopic guidance. Venous femoral access was obtained, and a bolus of heparin (100 units/kg) was administered after transeptal puncture. All patients were discharged 48 hours after LAA closure, except when a major periprocedural complication occurred. All patients had a transthoracic echocardiogram before discharge.

The antithrombotic strategy following LAA closure was left to the discretion of the principal operator and was decided upon after estimation of the short-term benefit/risk ratio for patients according to medical history, mostly including the bleeding risk, but also specific contexts such as recent coronary angioplasty. Despite 64 patients being enrolled in two randomized controlled trials (ClinicalTrials.gov identifiers: NCT03273322 and NCT03795298) with specific recommendations, for the remainder, a relatively conservative approach was used, with anticoagulation as the first choice, then dual antiplatelet treatment, then single antiplatelet treatment and, finally, no antithrombotic treatment in some specific rare cases (e.g. amyloid angiopathy).

Cardiac imaging (by TOE and/or CT) was systematically offered to all patients at 3 months and 12 months and was performed when possible. Out of 202 patients who underwent LAA closure, 160 (77.3%) had at least one imaging during follow-up (either TOE or a CT scan or both, at 3 and/or 12 months).

Table 1
Baseline characteristics.

	Total	First period	Second period	*P*
	(*n* = 207)	(*n* = 104)	(*n* = 103)	
Male sex	141 (68)	74 (71)	67 (65)	0.35
Age (years)	75.3 ± 8.6	77.1 ± 7.9	73.5 ± 9.0	< 0.01
BMI (kg/m^2)	26.5 ± 5.1	26.1 ± 4.4	27.0 ± 5.7	0.21
Co-morbidities				
Heart failure	111 (54)	58 (56)	53 (51)	0.53
Hypertension	180 (87)	94 (90)	86 (83)	0.14
Diabetes mellitus	64 (31)	33 (32)	31 (30)	0.80
Stroke	76 (37)	45 (43)	31 (30)	0.05
Vascular disease	119 (57)	65 (62)	54 (52)	0.14
Abnormal liver function	7 (3)	4 (4)	3 (3)	1.0
Abnormal renal function	37 (18)	16 (15)	21 (20)	0.35
History of haemorrhagic event	166 (80)	94 (90)	72 (70)	< 0.01
Classification of AF				
Paroxysmal	79 (38)	47 (45)	32 (31)	0.21
Persistent	56 (27)	19 (18)	37 (36)	< 0.01
Permanent	72 (35)	38 (37)	34 (33)	0.06
Median CHA_2DS_2-VASc score	5 (4–6)	5 (4–6)	5 (3–5)	< 0.01[c]
Mean CHA_2DS_2-VASc score	4.8 ± 1.5	5.2 ± 1.4	4.5 ± 1.4	
Median HAS-BLED score	3 (3–4)	4 (3–4)	3 (2–4)	< 0.01[c]
Mean HAS-BLED score	3.3 ± 1.1	3.5 ± 0.9	3.0 ± 1.2	
LAA closure indication				< 0.01
Brain haemorrhage	53 (26)	30 (29)	23 (22)	
Gastrointestinal bleeding	73 (35)	33 (32)	40 (39)	
Urologic bleeding	18 (9)	10 (10)	8 (8)	
OPTION trial[a]	24 (12)	0 (0)	24 (23)	
Other[b]	39 (19)	31 (30)	8 (8)	

Data are expressed as number (%), mean ± standard deviation or median (interquartile range). AF: atrial fibrillation; CHA_2DS_2-VASc: Congestive heart failure, Hypertension, Age ≥ 75 years (Doubled), Diabetes, Stroke/transient ischaemic attack/thromboembolism (Doubled)–Vascular disease, Age 65–74 years and Sex category (female); HAS-BLED: Hypertension, Abnormal renal and liver function, Stroke–Bleeding, Labile INR, Elderly, Drugs or alcohol; INR: international normalized ratio; LAA: left atrial appendage.
[a] ClinicalTrials.gov identifier: NCT03795298.
[b] Haemoptysis, ophthalmological bleeding, cholesterol emboli, INR imbalance, muscle bleeding.
[c] Non-parametric Mann-Whitney U test.

Study outcomes

The primary endpoint was the occurrence of any serious adverse events (SAEs) during the periprocedural period or follow-up after discharge.

The periprocedural period was defined as the time from the day of the procedure to day 7 or discharge, whichever came last. Periprocedural SAEs included pericardial effusion requiring surgical or percutaneous drainage, device migration, ischaemic stroke, major bleeding (Bleeding Academic Research Consortium [BARC] 3 or 5) [15], vascular access injury and death. A comparison was made between periprocedural complications occurring from 04 March 2014 to 18 July 2018 (first period) and 19 July 2018 to December 2020 (second period).

Follow-up SAEs included bleeding requiring hospitalization, thromboembolic events (including stroke) and death.

Device-related thrombosis is defined as thrombus on the atrial side of the device detected by echocardiography or CT scanner.

Statistical analysis

Continuous data are displayed as mean ± standard deviation or median (interquartile range), as appropriate, and were compared with Student's *t* test or the non-parametric Mann–Whitney *U* test, respectively. Categorical data are described as number (percentage), and were compared with the χ^2 test. All *P* values are two-sided, and *P*-values < 0.05 were considered statistically significant without adjustments for multiple comparisons.

Time-to-event analyses were performed, with all subjects who did not have an event or were lost to follow-up being censored at the time of last documented follow-up. Kaplan–Meier curves are presented for graphical assessment of time-dependent events.

The statistical analyses were carried out with pvalue.io software, which is a graphical interface to the R statistical analysis software (R Foundation for Statistical Computing, Vienna, Austria).

Results

Study population

A total of 207 patients were referred for LAA closure: 104 between 2014 and 18 July 2018 (first period), and 103 between 19 July 2018 and December 2020 (second period). The mean patient age was 75.3 ± 8.6 years, and most were men (68%) (Table 1). The study population was, as expected, characterized by a high thromboembolic risk (median CHA_2DS_2-VASc score 5; interquartile range 4–6) and a frequent history of significant haemorrhagic event (80%); the median HAS-BLED score (Hypertension, Abnormal renal and liver function, Stroke–Bleeding, Labile international normalized ratio, Elderly, Drugs or alcohol) was 3 (interquartile range 3–4). The main reason for LAA closure was a contraindication to long-term anticoagulation (87%), mostly because of gastrointestinal (35%) or neurological (26%) bleeding.

Most patients (74%) fulfilled HAS indications for LAA closure: 100% had non-valvular AF; 87% had a contraindication for chronic anticoagulation therapy; and 80% had a CHA_2DS_2-VASc score ≥ 4.

Patients undergoing LAA closure during the second period were younger (73.5 ± 9.0 vs. 77.1 ± 7.9 years; *P* < 0.01), more often had persistent AF (36% vs. 18%; *P* < 0.01), had lower CHA_2DS_2-VASc and HAS-BLED scores (both *P* < 0.01) and less often had a history of stroke (30% vs. 43%; *P* = 0.05) or haemorrhagic events (70% vs. 90%; *P* < 0.01).

Table 2
Procedural data.

	Total	First period	Second period	*P*
	(*n* = 207)	(*n* = 104)	(*n* = 103)	
Type of device				
n	205	117	88	0.06
Watchman	135 (66)	62 (60)	73 (72)	
Amulet	70 (34)	42 (40)	28 (28)	
Successful implantation				0.68
Yes	202 (97.6)	102 (98.1)	100 (97.1)	
No	5 (2.4)	2 (1.9)	3 (2.9)	
Perprocedural complication	3 (1.4)	2 (1.9)	1 (0.9)	
Unsuitable anatomy	2 (1.0)	0 (0)	2 (2.0)	
Concomitant AF ablation				
n	207	117	90	< 0.01
Yes	23 (11)	1 (1)	22 (21)	
Any major procedure-related complication	20 (9.7)	14 (13)	6 (5.9)	0.07
Pericardial effusion requiring drainage	6 (2.9)	4 (3.8)	2 (1.9)	0.68
Percutaneous	3 (1.4)	2 (1.9)	1 (1.0)	-
Surgical	3 (1.4)	2 (1.9)	1 (1.0)	-
Ischaemic stroke	2 (1.0)	1 (1.0)	1 (1.0)	1
Other systemic embolism	1 (0.5)	1 (1.0)	0 (0)	1
Device embolization	3 (1.4)	2 (1.9)	1 (1.0)	1
Vascular access complication (BARC 3 or 5)	8 (3.9)	6 (5.8)	2 (1.9)	0.28
Death	1 (0.5)	1 (1.0)	0 (0)	1
Other relevant complication[a]	2 (1.0)	1 (1.0)	1 (1.0)	1

Data are expressed as number (%). AF: atrial fibrillation; BARC: Bleeding Academic Research Consortium.
[a] Pneumonia, other major bleeding.

Procedural results

The success rate was 97.6%. Failed procedures were due to three periprocedural complications (two pericardial effusions requiring surgical drainage and one device migration) and two cases of unsuitable anatomy of the LAA. The rate of intraprocedural recapture was 31%, whereas in 69% of cases LAA closure was successfully positioned at the first deployment. Concomitant AF ablation was performed in 23 cases (11%).

There were a total of 23 periprocedural SAEs, which occurred in 20 patients (9.7%). These included six pericardial effusions requiring intervention (three treated percutaneously, three surgically), three device migrations (one during the procedure, which was extracted surgically; two detected after the procedure and extracted percutaneously), two ischaemic strokes (one occurred in a patient who had cardiac tamponade requiring surgical drainage and sternotomy, whereas the second occurred following the formation of thrombus on the external side of the device), eight vascular access complications (including five patients with a loss in haemoglobin levels of > 3 g/dL and/or requiring transfusion, and three patients requiring invasive treatment with femoral stenting or arterial embolization) and one death as a result of mesenteric ischaemia of embolic origin (presence of a thrombus at the end of the sheath during the procedure). The other SAE complications included one patient with deglobulization without apparent bleeding and one inhalation pneumonia requiring orotracheal intubation and transfer to intensive care.

A comparison between the first and second periods showed a declining trend in the number of periprocedural complications: 14 (13%) vs 6 (5.9%), respectively ($P = 0.07$) (Table 2).

Postprocedural management and events during follow-up

About one third of patients were discharged from hospital on anticoagulants, one third on dual antiplatelet therapy and one third on an antiplatelet/anticoagulant combination or an antiplatelet only. At month 3, most patients (80%) were on single antiplatelet therapy and 9% were on no antithrombotic therapy. At month 12, the number of patients without antithrombotic therapy increased to 23% (with 69% on single antiplatelet therapy) (Fig. 1).

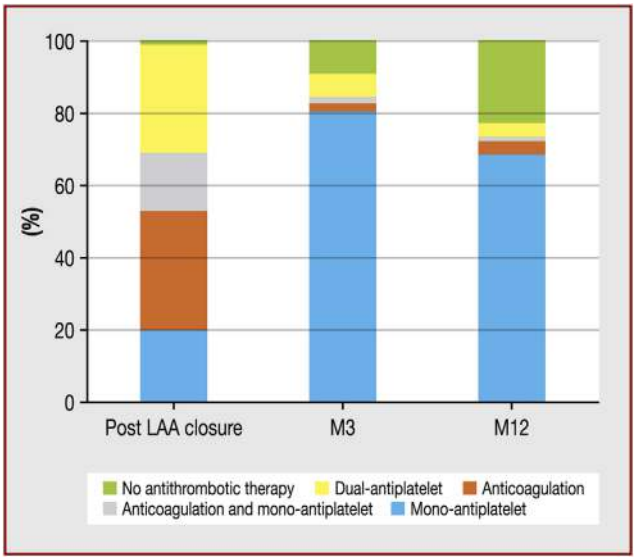


Fig. 1. Postprocedural antithrombotic management. LAA: left atrial appendage; M3: month 23; M12: month 12.

Out of 202 patients who underwent LAA closure, 160 (77.3%) had at least one imaging during follow-up (TOE or a CT scan or both, at 3 and/or 12 months). A total of 79 patients (38.1%) were investigated by both TOE and a CT scan at 3 and/or 12 months. The details of different findings after LAA closure are reported in Table 3. Among those patients with TOE and a CT scan at the same time point, 44 (55.7%) demonstrated no significant discrepancy, whereas 35 (44.3%) presented with a significant degree of discordance. Overall, only one LAA closure assessed by TOE had a significant peridevice leak (defined as > 5 mm) at 3 months (Fig. 2).

Fourteen patients (6.8%) were lost to follow-up after their LAA closure. During a mean follow-up of 23.1 ± 20.2 months, three device-related thrombi (1.4%) were identified without associated clinical thromboembolic events, whereas one pericardial effusion

Table 3
Cardiac imaging performed during follow-up after left atrial appendage closure.

	At 3-month follow-up	At 12-month follow-up
	(*n* = 153)	(*n* = 66)
TOE only		
n	23 (15)	13 (20)
Complete closure	20 (87)	9 (69)
Incomplete closure[a]	3 (13)[b]	4 (31)[b]
CT only		
n	56 (37)	20 (30)
Complete closure	19 (34)	7 (35)
Incomplete closure[a]	37 (66)	13 (65)
TOE and CT		
n	74 (48)	33 (50)
Complete closure	32 (43)	12 (36)
Incomplete closure[a]	9 (12)	5 (15)
Discordant	33 (44)	16 (48)

Data are expressed as number (%). CT: computed tomography; TOE: transoesophageal echocardiography.

[a] Incomplete closure is defined as colour Doppler flow by TOE or arterial or venous opacification by CT.

[b] Only one significant peridevice leak > 5 mm.

Fig. 2. Imaging at 3 months demonstrating a significant peridevice leak (7–8 mm), visible on transoesophageal echocardiography (three- and two-dimensional) and computed tomography scan.

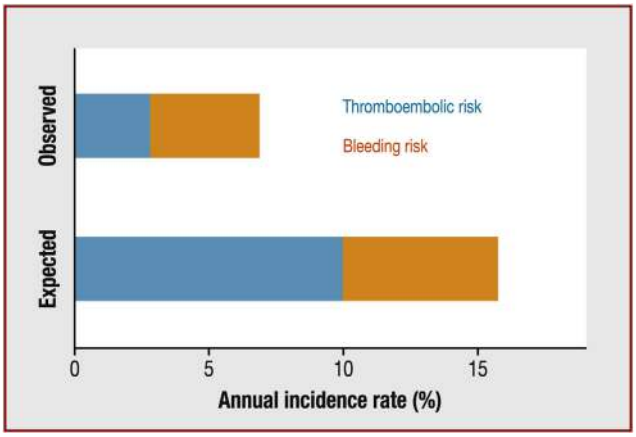


Fig. 3. Total events (observed versus expected).

was surgically drained 2 months after the procedure. A total of 55 patients (27% of the study population) died during follow-up; the survival rate at 2 years was 80.7% (95% confidence interval [CI] 74.8–87.0).

Eleven thromboembolic events (5.3%) occurred during follow-up (2.8% [95% CI 1.2–4.5%] per patient-year), including 10 ischaemic strokes (2.6% [95% CI 1.0–4.2%] per patient-year) and one embolic event involving the central retinal artery. The annual thromboembolic rate during follow-up was 72% lower than the expected 10% rate according to the mean CHA_2DS_2-VASc score of the population, and the stroke rate was 64% lower than the expected 7.2% rate (Fig. 3).

Bleeding requiring transfusion or hospitalization occurred in 21 patients (10%) A large percentage of bleeding events (nine events or 42.9% of the total) occurred during the first 3 months after LAA closure when patients were on dual antiplatelet therapy or anticoagulation. After the first 3 months after the procedure, the bleeding risk decreased to 4.0% (95% CI 2.0–6.0%) per patient-year, 31% less than predicted by the mean HAS-BLED score [16].

Discussion

This real-world study reports the experience of a French tertiary care hospital with percutaneous LAA closure. As all patients with an indication for the procedure were included, this analysis provides a robust assessment of the feasibility and benefit of this treatment, with no significant selection bias.

The study population was at similar risk of ischaemic and haemorrhagic events compared with cohorts assessed in previous studies (Table 4). This study suggests that LAA closure may prevent a significant percentage of thromboembolic events, with a relative risk reduction similar to that described in landmark studies such as EWOLUTION (for thromboembolic events) [17] and CAP and CAP 2 (for ischaemic strokes) [18]. In our cohort, the number needed to treat to prevent one thromboembolism compared with what would have been expected based on the mean CHA_2DS_2-VASc score was seven, with approximately 29 thromboembolic events prevented in the study sample.

However, this procedure has a non-negligible periprocedural complication rate, despite the downward trend over time (in 2020, only one periprocedural complication occurred in 50 procedures), which can be explained by the learning curve for this new procedure and the inclusion of younger and less co-morbid patients in the more recent years. Periprocedural complication rates vary according to criteria and definitions used in studies, ranging from 0.5% (PINNACLE FLX [19]) to 7.4% (PROTECT AF [11]). In the present study, more major complications were reported than in the

Table 4
Comparison of studies.

	HEGP	SWISS APERO [25]	AMULET IDE [21]	PINNACLE FLX [19]	FLAAC [22]	EWOLUTION [17,26,27]	PREVAIL [28]	RELEXAO [24]	NCDR LAAO Registry[w] [29]
Study design	Single centre, retrospective, non-randomized	Multicentre, prospective, randomized	Multicentre, prospective, randomized	Multicentre, prospective, non-randomized	Multicentre, prospective, non-randomized	Multicentre, prospective, non-randomized	Multicentre, prospective, randomized	Multicentre, retrospective, non-randomized	Multicentre, prospective, non-randomized
Location countries	France	International	International	USA	France	International	USA	France	USA
Number of patients included	207	221	1878	400	816	1014	407	469	49 357
Inclusion period	2014–2020	2018–2021	2016–2019	2018	2013–2015	2013–2015	2012–2014	2012–2017	2016–2019
Eligibility criteria	Contraindicated (87%) or not to anticoagulants	Contraindicated (87%) or not to anticoagulants	Not contraindicated to anticoagulants	Not contraindicated to anticoagulants	Contraindicated (95.7%) or not to anticoagulants	Contraindicated (72%) or not to anticoagulants	Not contraindicated to anticoagulants	Contraindicated (72.8%) or not to anticoagulants	Contraindicated or not to anticoagulants
Baseline characteristics									
Women	32.0	29.4	40.0	35.5	37.3	40.1	32.3	38.6	41.3
Age (years)	75.3 ± 8.6	76.9	75.1 ± 7.6	73.8 ± 8.6	75.5 ± 0.3	73.4 ± 9	74.0 ± 7.4	74.9 ± 8.9	76.5 ± 7.9 and 75.8 ± 8.2
Co-morbidities									
Heart failure	54	4.50	51.6	32	26	34	23	-	34.5 and 39.7
HTA	87	80.1	-	86	88	82	89	84.1	92 and 92.3
Diabetes mellitus	31	26.3	-	31	30	30	34	30.6	34.8 and 39.7
Ischaemic stroke	37	39.4	15.2	22	-	31	28	41.1	26.0 and 24.6
Vascular disease	57	-	-	55	45	42	46	43.4	37 and 53.1
CHA_2DS_2-VASc	4.8 ± 1.5	4.3 ± 1.4	4.6 ± 1.3	4.2 ± 1.5	4.6 ± 0.1	4.5 ± 1.6	3.8 ± 1.2	4.5 ± 1.4	5.3 ± 1.5 and 4.5 ± 1.4
HAS-BLED	3.3 ± 1.1	3.1 ± 0.9	3.3 ± 1.0	2.0 ± 1.0	3.2 ± 0.1	2.3 ± 1.2	2.0 ± 0.9	3.7 ± 1.0	3.0 ± 1.1 and 3.0 ± 1.1
Atrial fibrillation									
Paroxysmal	38	39.4	55.2	52	–	–	48.7[t]	–	59 and 50
Persistent	27	–	28.1	37	–	–	31.6	–	27 and 31.9
Permanent	35	–	16.7	11	–	–	15.6	51.2	13.6 and 17.6
Successful implantation									
Yes	97.6	-	98.4 and 96.4	98.8	98.5	98.5[p]	95.1	96.7	97.0 and 97.1
No (per-procedural complication)	1.4	–	–	–	0.2	–	–	–	–
No (unsuitable anatomy)	1.0	–	–	0.8	1.0	–	–	–	–
No (other)	-	–	–	0.5[k]	0.2[n]	–	–	–	–
Periprocedural complications									
At least one complication	9.7	9.0 and 2.7[c]	4.5 and 2.5[g]	0.5[l]	4.3	3.6[q]	4.2	–	4.1 and 2.0
Vascular access complication	3.9	5.4 and 4.5	–	0.0	2.1	0.7	-	–	0.1 and 0.1[x]

Table 4 (*Continued*)

	HEGP	SWISS APERO [25]	AMULET IDE [21]	PINNACLE FLX [19]	FLAAC [22]	EWOLUTION [17,26,27]	PREVAIL [28]	RELEXAO [24]	NCDR LAAO Registry[w] [29]
Device embolization	1.4	0.9 and 0.9	–	0.0	0.2	0.2	0.7	–	0.03 and 0.03
Stroke	1.0	1.8 and 0.0	–	0.5	–	0.3	0.4	–	0.1 and 0.1
Pericardial effusion requiring drainage	2.9	2.7 and 0.0	–	0.0	1.20	0.4	1.90	–	1.2 and 0.5
Death	0.5	1.8 and 0.0[d]	–	0.0	0.6	0.7	–	–	0.3 and 0.1
Follow-up									
Duration (months)	23.1 ± 20.2	-	18	12	16 ± 0.3	24[r]	47.9 ± 19.4	13 ± 13	
Device thrombus	1.4	0.9 and 3.0[e]	3.3 and 4.5[h]	1.8	3.8/patient-year	4.1	-	5.4/patient-year[u]	–
Complete closure at 3 months	34[a]	32.4 and 30.0[f]	98.9 and 96.8[i]	–	Unknown[o]	–	–	–	–
Complete closure by TOE at 12 months	–	–	–	100[m]	–	99[s]	–	–	–
Ischaemic stroke	2.6/patient-year	–	1.7 and 1.9/patient-year	2.6	3.1/patient-year	1.3/patient-year	1.7/patient-year	4.0/patient-year	-
Other systemic embolism	0.25/patient-year	–	0.30 and 0.20	0.30	0.27/patient-year	0.70/patient-year	0.09/patient-year	–	–
Thromboembolic events	2.8/patient-year	–	2.8 and 2.9	2.9	3.3/patient-year	2.0/patient-year	1.8/patient-year	–	–
Death	19.3		3.1 and 4.8	6.6	10.2/patient-year	16.4	1.8/patient-year	6.9/patient-year	–
Major bleeding during follow-up	4.0/patient-year[b]	–	7.9 and 8.0 [j]	7.9	4.8/patient-year	2.7/patient-year	–	3.8/patient-year	–
Device									
Amulet	34	50	50	0	52	0	0	42[v]	0
Watchman	66	50	50	100	46	100	100	58	100

Data are expressed as mean ± standard deviation or %. CHA_2DS_2-VASc: Congestive heart failure, Hypertension, Age ≥ 75 years (Doubled), Diabetes, Stroke/transient ischaemic attack/thromboembolism (Doubled)–Vascular disease, Age 65–74 years and Sex category (female); CT: computed tomography; HAS-BLED: Hypertension, Abnormal renal and liver function, Stroke–Bleeding, Labile international normalized ratio, Elderly, Drugs or alcohol; LAA: left atrial appendage; TOE: transoesophageal echocardiography.

[a] By CT scan and 87% by TOE.
[b] After 3 months postprocedure.
[c] At 45-day effusion.
[d] Procedure related.
[e] Amulet and Watchman at 45 days by CT scan; 2.1% and 5.5% at 45 days by TOE.
[f] Amulet and Watchman at 45 days by CT scan (arterial time); 86.3% and 72.5% at 45 days by TOE.
[g] More frequent pericardial effusion and device embolization for the Amulet occluder.
[h] Amulet and Watchman at 18 months.
[i] Device-based LAA occlusion with residual jet ≤ 5 mm at 45 days by TOE, no residual jet around the device; 63.0% Amulet and 46.1% Watchman.
[j] Assessed at month 12.
[k] Adequate compression and/or seal could not be achieved.
[l] Percutaneous catheter drainage of pericardial effusions, snaring of an embolized device, thrombin injection to treat femoral pseudoaneurysm and non-surgical treatment of access site complications were excluded from this endpoint.
[m] Peridevice flow ≤ 5 mm.
[n] Thrombus in the left appendage.
[o] 646 (80.3%) underwent follow-up imaging after hospital discharge (494/804 with TOE and 292/804 with CT scan).
[p] Unfavourable anatomy or mismatch between the size of the device and the LAA.
[q] For 30 days.
[r] Median 732 (interquartile range 677–757) days.
[s] 87% had TOE examination during their follow-up, adequate sealing: no leaks or peridevice leak ≤ 5 mm.
[t] Paced 2.6%, unknown 1.5%.
[u] 72.3% patients underwent LAA imaging at least once (TOE or a CT scan); thrombus 7.2% in the group with LAA imaging during follow-up.
[v] WaveCrest device (Coherex, Salt Lake City, UT, USA) 0.4%.
[w] All results are described for women and men.
[x] Arteriovenous fistula or pseudoaneurysm requiring a fibrin injection, angioplasty or surgical repair.

literature, which is partly explained by the less strict definition of serious periprocedural complication, a non-selected population and the learning curve. The main periprocedural complications remain those involving the vascular access and pericardial effusions. A large registry study [20] including 38,158 procedures reported a 1.39% risk of pericardial effusion requiring intervention, which is lower than the 2.9% rate in our cohort, probably because of more experienced operators.

In addition, the haemorrhagic event rate in the postprocedural period compared with the expected bleeding rate needs to be considered. This is particularly important given that LAA closure is specifically carried out in patients with contraindication for anticoagulation because of high bleeding risk. Most of the bleeding episodes occurred during the first 3 months after LAA closure, which is an expected finding given the treatment with dual antiplatelet therapy or anticoagulation during the early postprocedural period to prevent device-related thrombosis. Recent studies (AMULET IDE [21] and FLAAC [22]) reported similar or higher annual rates of significant bleeding after LAA closure, highlighting the high bleeding risk of this specific population, which is increased in the early postprocedural period. It is reasonable to expect the benefit of LAA closure in reducing haemorrhagic events to become apparent only after a few months, when dual antiplatelet therapy or anticoagulation has been interrupted.

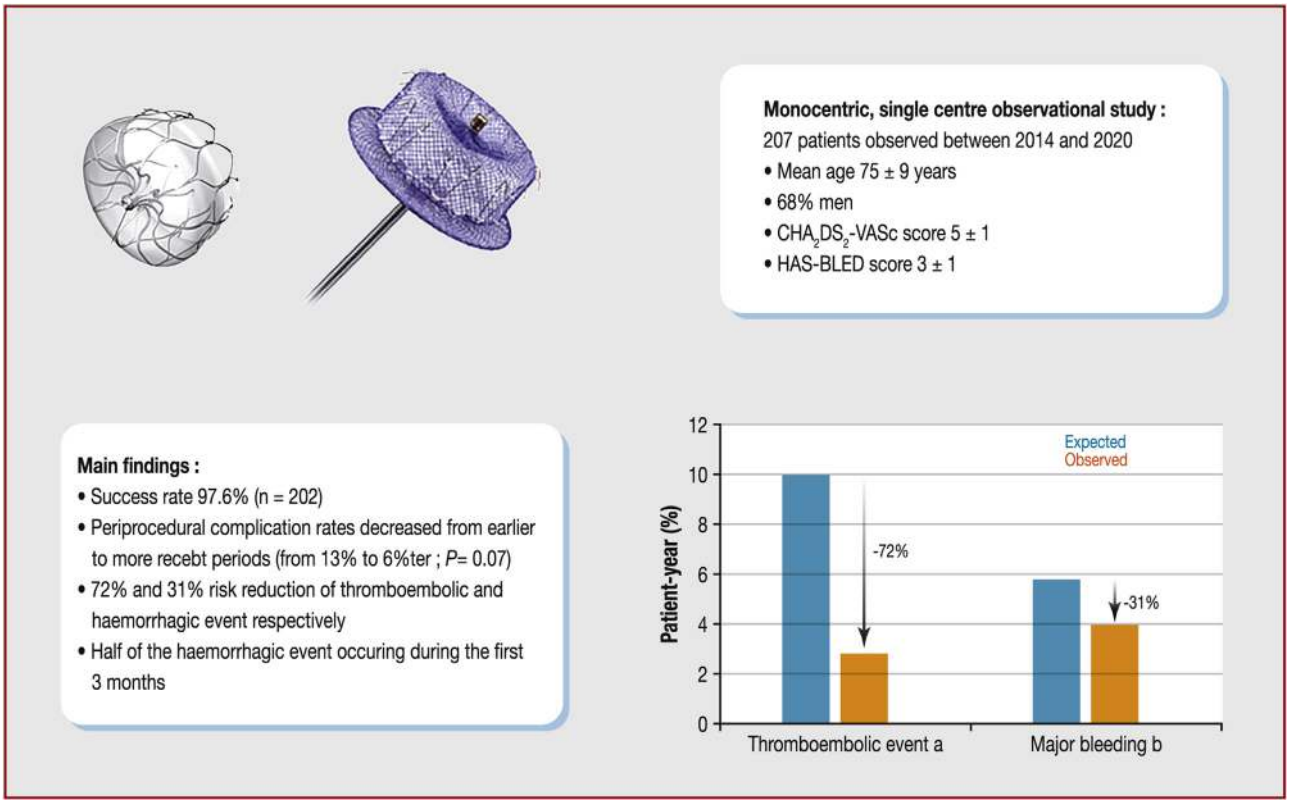
A recent study conducted by Aguelo et al. [23] in Spain has highlighted the difficulty of patient follow-up by imaging. This study included 137 percutaneous LAA closures. Follow-up by CT scan between 3 and 6 months found 56.9% of patent auricle at the arterial phase, compared with 66% by CT scan and only 13% by TOE at 3 months in the present study. The rate of device-related thrombosis (1.4%) was lower than the 7.2% per year in the French study conducted by Fauchier et al. [24]. This result can be explained by a different definition of device-related thrombosis and different imaging follow-up protocols. In the present study, device-related thrombosis was not associated with thromboembolic events.

Study limitations

The main limitation of this study is its retrospective nature. The effectiveness/efficacy of percutaneous LAA closure cannot be assessed in such retrospective cohort. Thus, some variables may be less well reported. In addition, some patients were lost to follow-up. Also, this was a single-arm study with no comparison group (thromboembolic and bleeding rates were compared with expected rates predicted by the mean CHA_2DS_2-VASc and HAS-BLED scores, but these comparisons should be interpreted with caution, as these scores are only modest predictors of the individual risk).

Conclusions

This retrospective single-centre evaluation emphasizes the extent to which percutaneous LAA closure may be a feasible and effective treatment to reduce the risk of thromboembolic events in patients who cannot take anticoagulation. Our findings also suggest the need to acknowledge the entire team's learning curve, with complication rates that are not negligible at the beginning of a centre's experience. Finally, in our experience, the risk of bleeding in the first few months is still significant, raising the unanswered question about the best antithrombotic strategy after LAA closure.



Central Illustration. Study design and key findings.

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None.

Disclosure of interest

E. M. Consultant for the companies Boston Scientific and Abbott.
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The other authors declare that they have no competing interest.

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