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An overview of current and emerging devices for percutaneous left atrial appendage closure

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ABSTRACT

Atrial fibrillation (AF) is common and is a prominent risk factor for ischemic stroke. Oral anticoagulant (OAC) therapy has been the main strategy for stroke prevention in AF patients; however, OAC therapy carries a bleeding risk and is not tolerated by all patients. Left atrial appendage (LAA) closure offers a non-pharmacological alternative for stroke prevention in patients with non-valvular AF. In this update, an overview of current and emerging LAA occluders is given – with special attention to the key design features of every single device and, if available, preclinical or clinical data.

Introduction

Atrial fibrillation (AF) is the most common cardiac arrhythmia encountered in clinical practice, affecting 2–3% of the population and its prevalence increases with age [1–4]. Around 20–35% of ischemic strokes are attributable to AF, and even more may be associated with undiagnosed subclinical AF [5–9]. The main strategy for prevention of ischemic stroke in patients with AF is oral anticoagulant (OAC) therapy using vitamin K antagonists (VKA, e.g. warfarin) or novel oral anticoagulants (NOACs) [10]. However, despite the efficacy of this pharmacotherapy, low patients' compliance, complex drug interactions and risk of bleeding limit their use in selected patient groups [11,12]. Thus, a non-pharmacological alternative for stroke prevention in patients with AF is warranted [13–16].

It has been reported that up to 90% of left atrial (LA) thrombi are located in the left atrial appendage (LAA) among patients with non-valvular AF (NVAF) [17]. A device-based therapeutic strategy that has shown promise is percutaneous, transcatheter closure of the LAA using dedicated occluders. Prior randomized trials have shown that LAA closure (LAAC) is non-inferior to conventional VKA therapy in non-valvular AF [18–20]. In terms of long-term results based on a patient-level meta-analysis, LAAC was shown to provide stroke reduction in non-valvular AF comparable to VKA with additional reductions in major bleeding and mortality [21].

Although the implant success rate has increased and complications have decreased over time [22], there are still anatomically and technically complicated cases where novel LAA occluders may simplify the procedure and thus might potentially improve the clinical outcome. This review aims to give an overview of the current and emerging LAA occluders with special focus on device design, implantation technique, and – if available – preclinical or clinical data.

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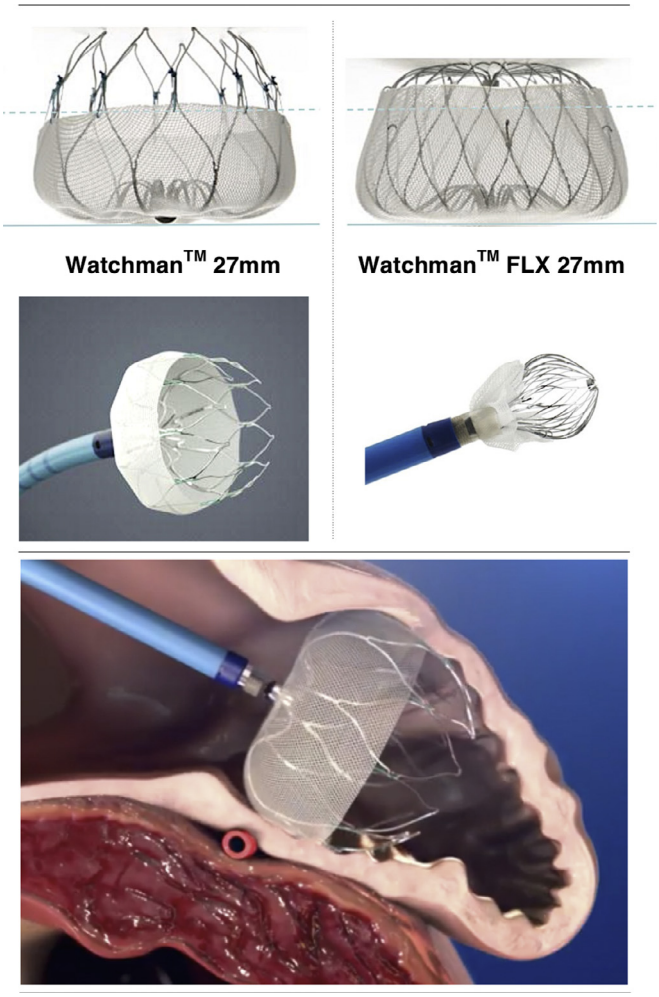

Fig. 1. The Watchman™ device has 10 active fixation anchors attached to a nitinol frame along with a polyethylene terephthalate (PET) membrane that covers up to half of the device to block emboli and promote healing. The new Watchman™ FLX has a shorter device length than the current Watchman™ device which should facilitate treatment of complex shallow LAA anatomies and an atraumatic tip which should allow a safer advancement and – if needed, repositioning – of the device into the LAA.

Overview of different devices

WATCHMAN™ LAA closure device

The Watchman™ device (Boston Scientific, MA, USA) is the most studied LAA closure device currently in use. The device has 10 active fixation anchors attached to a nitinol frame along with a 160 μm polyethylene terephthalate (PET) membrane that covers up to half of the device to block emboli and promote healing (Fig. 1). The device is delivered through a 14 Fr sheath and is fully retrievable prior to release. The current device is FDA-approved for use in patients with NVAF who are seeking an alternative to long-term warfarin anticoagulant therapy.

The Watchman™ device is the only LAA occluder to date that has been studied in two randomized controlled trials comparing the LAA occluder with VKA therapy in patients with NVAF and a CHADS2-score ≥ 1 (PROTECT-AF trial) [18] or ≥ 2 (PREVAIL trial) [23]. Combined five-year results from the PROTECT-AF and PREVAIL trials demonstrated that LAA closure with Watchman™ provides stroke prevention comparable to VKA, with additional reductions in major bleeding – particularly hemorrhagic stroke – and even all-cause mortality [21]. The prospective, randomized ASAP-TOO trial, investigating the use of the Watchman™ device in patients with NVAF who are deemed not suitable for OAC therapy, is currently ongoing.

The company is currently working on a new generation Watchman device – the Watchman™ FLX LAA closure device. The Watchman™ FLX device is approximately 20% shorter in length, allowing treatment of LAAs with less depth, and should also allow coverage of a wider range of LAA Ostia measuring 15 to 32 mm in diameter. The closed distal end design implicates that the device may be partially deployed and advanced into the LAA with less risk of LAA perforation and this should also make a partial recapture and repositioning of the device more feasible and safe (Fig. 1). After initial experience with the new Watchman™ FLX in some selected sites, the company paused the program due to some reported device embolizations. The device has currently undergone a re-design and is expected to enter a new clinical trial in the second half of 2018.

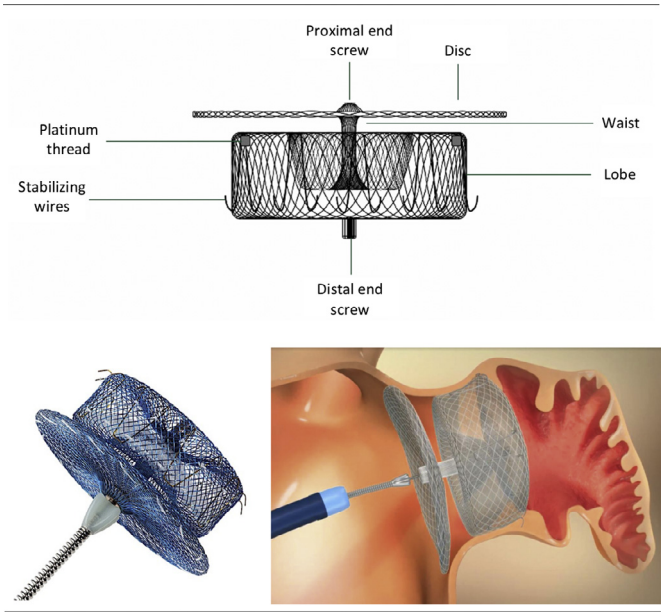

Fig. 2. The AMPLATZER™ Amulet™ LAA occluder is made of a braided nitinol mesh with two polyester patches sewn on to a distal lobe and disc connected by a short waist. There are hooks on the lobe that anchors to the LAA and the disc covers the LAA ostium.

AMPLATZER™ Amulet™ LAA occluder

The AMPLATZER™ Amulet™ LAA occluder (Abbott, MN, USA) is a self-expanding device made of a braided nitinol mesh with two polyester patches sewn on to a distal lobe and proximal disc connected by a short waist (Fig. 2). The flexible nitinol braid allows the device to conform to different types of LAA anatomy and the device covers 'landing zones' from 11 to 31 mm in diameter. The proximal device positioning allows for placement regardless of distal anatomy or existence of multiple lobes. The device is delivered through sheaths of 12 or 14 Fr in size. The device adopts an "anchor and seal" approach, with the lobe anchoring in the LAA and the disc sealing the LAA ostium.

In a prospective, observational study including 1088 patients implanted with the Amulet™ device, procedural success was reported to be 99.0%. Major adverse events were observed in 3.2% of patients within the index hospitalization, including 26 major bleeding events (2.4%), 2 strokes (0.2%), and 2 deaths (0.2%). Less than one-fifth of patients were discharged on anticoagulants (18.9%). Adequate sealings (< 3 mm peri–device leak) were

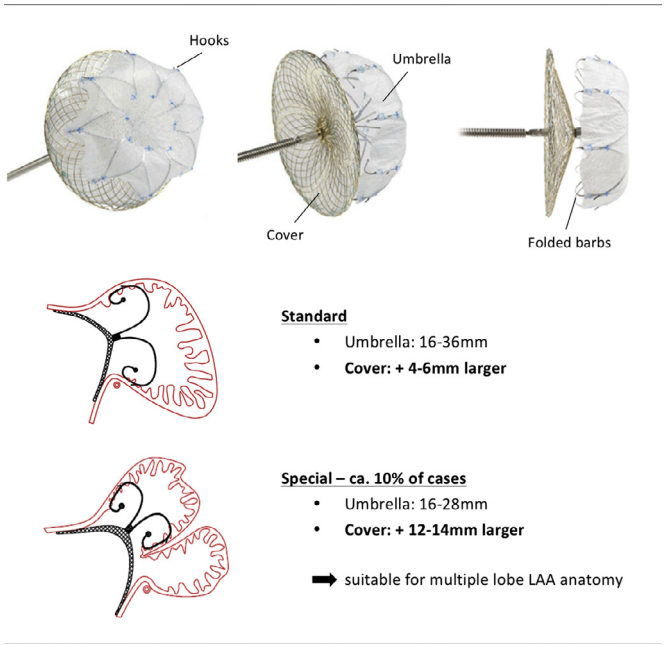

Fig. 3. The LAmbre™ LAA closure system is a self-expanding, nitinol-based meshwork that consists of a hook-embedded umbrella connected to a fabric cover through a short central waist. The device has two configurations: a 'standard' one targeting single-lobe LAA and a 'special' one targeting multi-lobe LAA anatomy.

observed in 98.2% of patients at follow-up transesophageal echocardiography (TEE). Device thrombus was found in 10 patients (1.5%). Long-term clinical outcome data are anticipated in the future [24].

In some countries, the previous version of the device, the AMPLATZER™ cardiac plug (ACP), is still available with its use backed-up by an earlier registry comprising 1047 patients from 22 centers [25]. Compared with the Amulet™ device, the ACP has less stabilizing wires and does not come with the inverted end-screw at the disc – which is believed to reduce the risk of device thrombosis.

The currently ongoing Amulet™ IDE trial is a worldwide, prospective, randomized controlled trial, designed to evaluate the safety and effectiveness of the Amulet™ LAA occluder as compared to the Watchman™ closure device in patients at increased bleeding risk during OAC. Results of this trial are expected in 2020–2021.

LAmbre™ LAA closure system

The LAmbre™ LAA closure system (LifeTech Scientific Co. Ltd.) is a self-expanding, nitinol-based meshwork that consists of a hook-embedded umbrella connected to a fabric cover through a short central waist. The device comes in sizes between 16–36 mm and is delivered through sheaths of 8 or 10 Fr in size. The device has two configurations: a 'standard' one targeting single-lobe LAAs and a 'special' one targeting multi-lobe LAA anatomies. The latter configuration has a much smaller umbrella size relative to the fabric cover allowing the umbrella to anchor deeply into one of the lobes while adequately sealing the LAA with the larger-sized cover. There are 8 stabilizing double-hook systems with big hooks (or folded barbs) catching the pectinate muscles in the LAA while the small shoulder hooks engage into the appendage wall to lower the risk of device migration/embolization (Fig. 3).

The implantation technique is different from the other two commercially available LAA occluders in the way that the delivery sheath is positioned at the very proximal portion of the LAA and the umbrella is deployed at the landing zone by pushing forward the delivery cable. The cover is then released to cover the LAA ostium by unsheathing. The device can be fully recaptured and redeployed if the device position is considered suboptimal. Clinical experiences in 153 patients demonstrated successful LAA occlusion in 152 patients, and serious complications in 5 patients. During the 12-month follow-up, ischemic stroke occurred in 2 patients, 1 patient had incomplete LAA sealing, and there was no device embolization [26]. The device obtained CE mark approval in June 2016. A head-to-head comparison between the LAmbre™ and Watchman™ device in order to obtain FDA-approval is currently in protocol review process, and is expected to start early 2019.

WaveCrest™ LAA occlusion system

The WaveCrest™ LAA occlusion system (Coherex Medical, Biosense Webster Inc., CA, USA) consists of a nitinol frame with retractable coils and anchors at the distal edge to enable optimal device positioning and anchoring. A polytetrafluoroethylene (PTFE) layer covers the LA side of the device without any metal hub to minimize the risk of thrombus formation and the device also includes a foam "cuff" at its distal edge to minimize residual leak (Fig. 4). The device comes in three sizes (22, 27, 32 mm) covering appendage ostial diameters from 14 mm to 32 mm. The device can be fully recaptured and repositioned prior to release. The WaveCrest™ guiding sheath has a 15 Fr inner lumen diameter and comes in four different shapes with different angles (60°, 75°, 90°, 90°-S-curve) facilitating to obtain a coaxial position of the occluder into the appendage during implantation. The WaveCrest™ system was designed to be implanted in an ostial position at the LAA orifice, without requiring significant implant depth. It has two unique features: (1) the system allows contrast injection within the LAA distal of the device for assessment of leakage after device deployment and before final release, thereby also allowing angiographic verification of complete seal during tug testing; (2) since the device-unsheathing phase is uncoupled from the anchoring phase, it is possible to fine-tune the final position of the deployed device before unrolling, and thus engaging, the tissue anchors.

The Coherex WaveCrest I trial assessed device implantation safety and closure efficacy in 73 patients. Three of the implants were unsuccessful due to unfavorable anatomy and device malfunctioning. TEE at 45 days post-procedure showed 97% successful LAA closure with no residual flow > 3 mm. Two patients (2.7%) developed pericardial effusion, whereas there was no device embolization or stroke throughout the 45 days follow-up period [27]. The WaveCrest™ LAA occlusion system received CE-mark approval in 2013. The WaveCrest II trial, comparing the device in a 1:1 ratio to the Watchman™ device, is currently ongoing.

UltraSeal™ LAA closure device

The UltraSeal™ LAA closure device (Cardia Inc., USA) has two components. The distal part is a soft, cylindrical-shaped nitinol bulb with six pairs of hooks for anchoring of the device; this bulb is made of loops to adjust to the shape of the LAA and limit the 'jump-out' of the catheter for precise placement. The second component is a proximal sail, which is 6 mm larger than the distal bulb and is made of three leaflets to adjust maximally to the shape of the LAA ostium. The bulb and sail are connected with a flexible articulating center-post (or "joint") made of titanium that allows the device to conform to the most complex LAA morphologies (Fig. 5**A**). There are nine sizes for the distal bulb ranging from 16 to 32 mm. The UltraSeal™ LAA closure device is delivered by a 10 or 12 Fr sheath and can be retrieved and redeployed to ensure accurate placement.

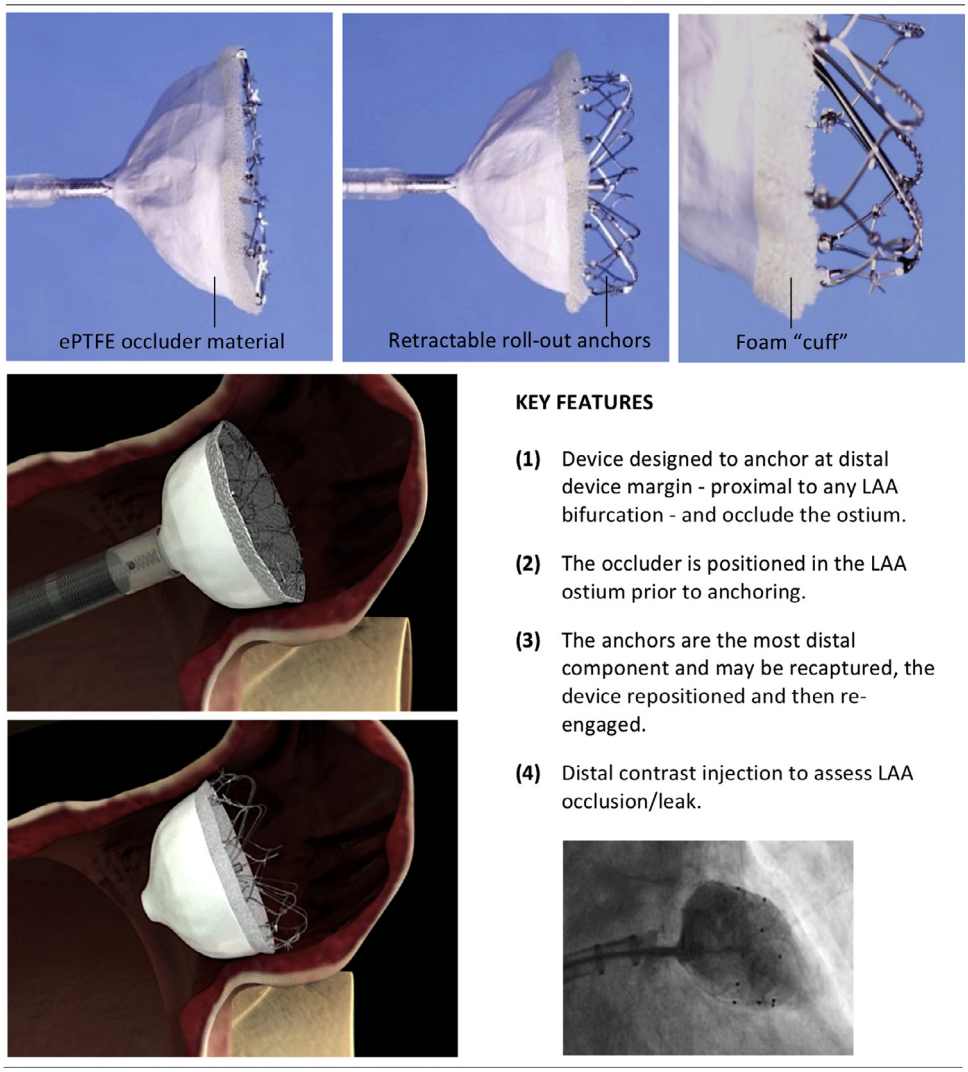

Fig. 4. The WaveCrest™ LAA occlusion system consists of a nitinol frame with retractable coils and anchors at the distal edge. A polytetrafluoroethylene (PTFE) layer at the left atrial side should minimize the risk of thrombus formation, while a foam "cuff" at its distal edge should minimize the risk of residual leak.

A multicenter observational study, involving 80 patients with a high CHADS-VASc and HAS-BLED score, showed high procedural success (99%), one device embolization, and residual leaks $\geq$ 5 mm in 4% of cases. There were no pericardial effusions or in-hospital mortality reported. At 45–90 days TEE follow-up, 2 devices were reported with device-related thrombus and 2 cases had significant peri–device leak $\geq$ 3 mm. The Ultraseal™ device received CE mark approval in 2016 and a large IDE trial to obtain FDA-approval is underway.

SeaLA™ LAA occluder

The SeaLA™ LAA occluder is a self-expanding, nitinol-based device, which consists of two parts: a distal anchoring part and a more proximal 'plate' to obtain sealing. The nitinol braiding mesh for both components helps to adapt to different LAA morphologies. The device adopts the "anchor and seal" principle. The distal part has nine hooks to assure anchoring and the proximal plate has a small tapered waist that should optimize wall apposition with the LA(A) wall and, hence, provide better sealing (Fig. 5**B**). The device is designed to be fully retrievable and repositionable, and is delivered through 9 or 12 Fr sheaths. As the device does not need a deep LAA implantation, a proximal implant position allows for placement regardless of distal anatomy, depth or lobe morphology.

Initial experience with 11 human implants between Dec 2016 and Oct 2017 in Argentina and China were all successful. No complications or residual leak were reported. A worldwide, combined CFDA/FDA/CE Mark approval clinical study is planned.

Omega™ LAA occlusion device

The Omega™ LAA occlusion device (Vascular Innovations, Thailand) is a self-expanding platinum-coated nitinol, dual-layered "disc-and-cup" combination. Unique features of the device are: (1) the "self-retaining inverted cup (SRIC)" with 8 circumferentially interspersed hooks, which promotes device stability into the neck of the LAA; (2) a very flexible 'waist' which allows the device to conform to the most complex LAA morphologies; and (3) a platinum coating which should provide favourable biocompatibility (Fig. 5**C**). Animal studies were successfully completed in Q2 2018, demonstrating easy device deployment, satisfactory device repositionability and retention, and adequate LAA sealing. A human clinical trial is planned for 2018–2019.

Occlutech™ LAA occluder

The Occlutech™ LAA occluder (Occlutech Int. AB, Sweden) is a self-expanding, nitinol-based, tapered cylindrical shape mesh with

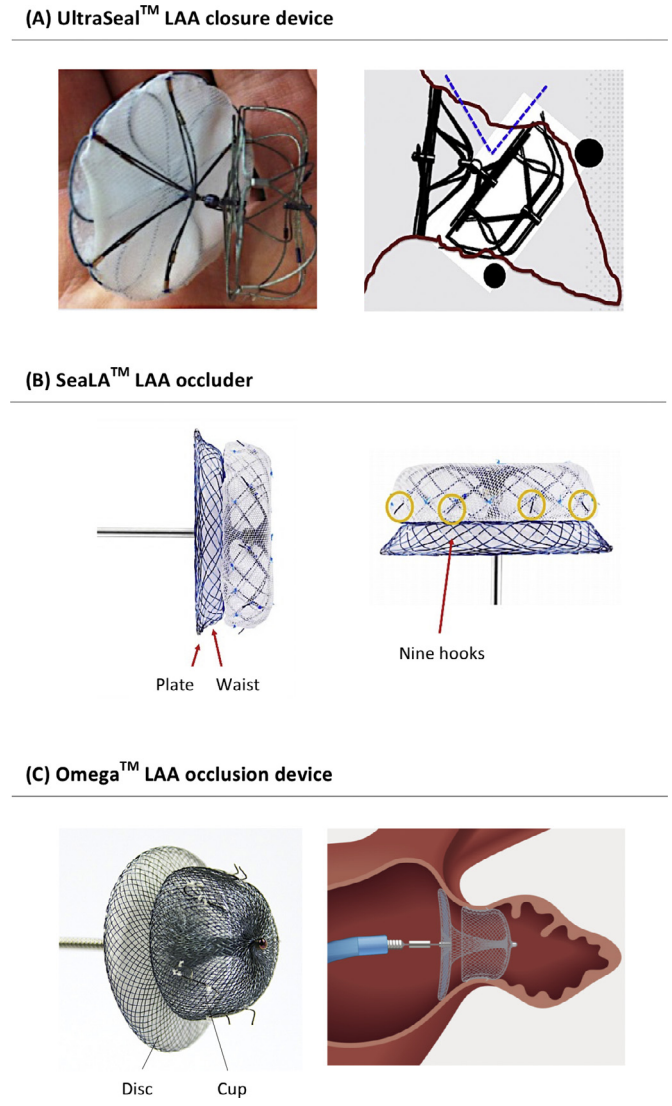

Fig. 5. **(A)** The UltraSeal™ LAA closure device consists of a distal bulb with 6 pairs of hooks and a proximal sail. The two components are connected with a flexible articulating center-post allowing the device to conform to different LAA morphologies and occlude LAAs with a short landing zone. **(B)** The SeaLA™ LAA occluder also adopts the "anchor and seal" principle. The distal part has nine hooks to assure anchoring and the proximal plate has a small tapered waist that should optimize wall apposition and hence provide better sealing. **(C)** The Omega™ LAA occluder is a self-expanding, platinum-coated nitinol, dual-layered "disc-and-cup" combination with 8 circumferentially interspersed hooks, which promotes device stability, and a very flexible waist which allows the device to conform to the most complex LAA morphologies.

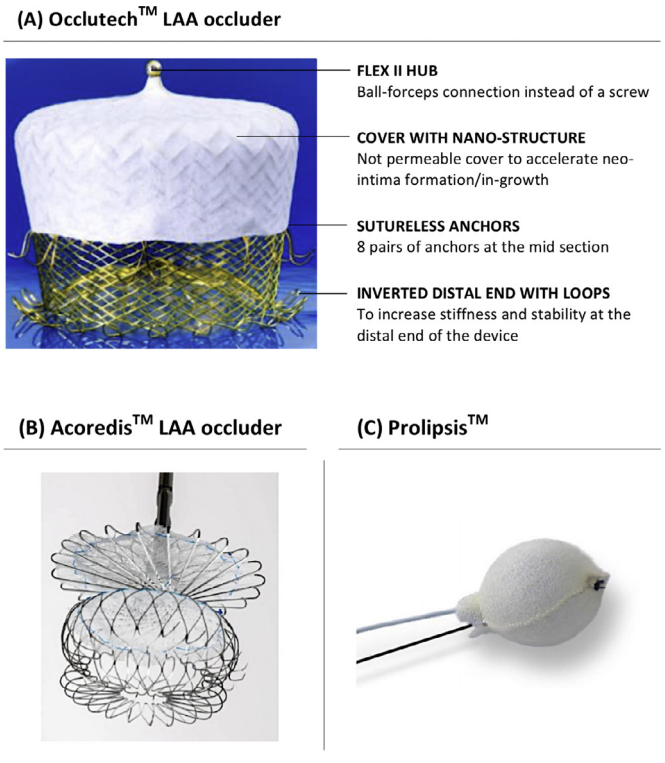

Fig. 6. **(A)** The Occlutech™ LAA occluder has rounded loops instead of hooks at its distal end to increase stiffness and stability at the distal end of the device; it also makes the device fully recapturable. It has recently been re-designed with the addition of 8 pairs of anchors at the mid section. **(B)** The Acoredis™ LAA occluder consists of a proximal disc and distal lobe. A flexible membrane improves the adaptability of the device. The flexible design of the waist should facilitate self-orientation of the disc. The plain surface of the disc should shorten the endothelialization period. **(C)** The Prolipsis™ device consists of a polyurethane patch surrounding a compliant detachable balloon, both bio-absorbable. During the procedure, the balloon is inflated under echocardiographic guidance until no residual LAA flow is seen.

rounded loops instead of hooks at its distal end to increase stiffness and stability at the distal end of the device. The occluder is covered with a non-woven, polyurethane layer, which allows immediate occlusion of the appendage and improves endothelialization. The flex hub – which initially attaches to the delivery system – is round, aiming to keep the risk of device-related thrombus formation as low as possible. Due to reported device embolizations during the initial clinical studies, the Occlutech LAA occluder was voluntarily withdrawn in August 2016, and re-designed with the addition of 8 pairs of anchors to the mid-section (Fig. 6**A**). The occluder comes in sizes between 18–33 mm and is delivered through sheaths of 12 or 14 Fr in size. The delivery sheath is steerable and has the flexibility to bend 180° to adapt to the axis of the LAA. This feature should be useful in case of complex LAA morphologies – e.g., reversed chicken wing – or in cases in which the transseptal puncture is challenging (or suboptimal) [28].

Animal implants with the re-designed Occlutech™ LAA occluder were performed in Q1-2018 and a CE Mark trial is anticipated in 2018–2019, with an expected commercial re-launch by the company in 2020.

Acoredis™ LAA occlude

The Acoredis™ LAA occluder is a self-expanding, nitinol-based device with a proximal disc and distal lobe with fixation barbs around the perimeter of the lobe. A flexible membrane improves the adaptability of the device to the morphology of the LAA. The nitinol frame of the distal lobe is designed in such way that there is reduced radial force and increased X-ray visibility. The flexible design of the waist should facilitate self-orientation of the disc. The plain surface of the disc should shorten the endothelialization period (Fig. 6**B**).

Initial experiments in pigs demonstrated good device endothelialization after approximately 12 weeks. First-in-human implants are planned, and a clinical trial is anticipated in 2019.

Prolipsis™

The Prolipsis™ device consists of a polyurethane patch surrounding a compliant detachable balloon; both components are bio-absorbable (Fig. 6**C**). The balloon is compliant and is designed

Table 1
Relevance, approval status and number of devices implanted since commercial launch.

Device	Approval status	Number of patients treated	Others
1. Watchman	CE 2005 FDA 2015	~50,000	New generation (Watchman FLX) withdrawn in 2016 – Redesign currently underway
2. Amulet	CE 2013 – Old generation (ACP) CE marked since 2008	Not disclosed, several thousands	
3. LAmbre	CE 2016	~2000	FDA trials anticipated in early 2019
4. WaveCrest	CE 2013	~400	Further clinical trials currently underway
5. UltraSeal	CE 2016	~500	FDA trials being planned, aiming for a study population of around 1000 patients
6. SeaLA	Nil	Not yet for clinical use	Clinical trials in USA, Europe and China being planned
7. Omega	Nil	Not yet for clinical use	Animal trials completed. Clinical trials being planned
8. Occlutech	Nil – CE mark approved once in June 2016. Voluntary recall in August 2016	500 before recall – Commercial re-launch expected in 2019	Clinical trials with re-designed device anticipated in Q3 2018
9. Acoredis	Nil	Not yet for clinical use	Animal trials currently underway
10. Prolipsis	Nil	Not yet for clinical use	Clinical trials currently underway. Additional larger European and/or US clinical trials planned
11. Lariat	CE 2015 FDA 2006	~7,000	Further trials currently underway
12. Sierra	Nil	Not yet for clinical use	Early feasibility study protocol trials in USA and Canada currently underway. Clinical trials anticipated in early 2019.

to take the shape of the LAA with sizes between 12 and 25 mm. The device is delivered through a 13 Fr sheath. The procedure is performed with TEE guidance and the balloon is inflated until there is 'no flow' around the device. An elastic valve maintains balloon inflation, which in turn ensures that the device remains securely in position. The polyurethane patch takes two weeks to be completely endothelialized. The aim is to seal the LAA acutely with this polyurethane patch and that the LAA remains occluded after both the balloon and patch eventually disappear (or get biodegraded).

There is another approach to deploy the polyurethane patch using surgical adhesives, known as the "Transcatheter Patch (TP) approach" (in contrast to the "Immediate Release Patch (IRP) approach" using the Prolipsis™ described above). This approach involves use of a pH-activated polyethylene glycol based surgical adhesive, which is inactive under acidic conditions and can be activated by being exposed to alkaline solution after the device has been positioned and inflated. Compared with the IRP approach, this process takes 45 min of waiting time, and IV contrast use may be contraindicated due to changes in pH with contrast administration.

Initial clinical experience involving 30 patients was successful in all 10 implantations using the IRP approach with Prolipsis™ device, and in 17 out of 20 implantations using the TP approach with surgical adhesives (the patch failed to attach in the remaining 3 cases). Full LAA occlusion and no complications were reported in the IRP group with a follow-up of up to five years. There was 1 case of residual opening and 1 other case of device-related thrombosis in the TP group [29,30]. Safety and efficacy of the device is to be further evaluated with ongoing human implants and further collection of long-term follow-up data. Additional larger EU and/or US clinical trials are also anticipated.

Lariat™ suture delivery device

The Lariat™ RS device (SentreHEART, CA, USA) consists of three components: (1) a 15 mm compliant occlusion balloon catheter (EndoCATH); (2) 0.025 inch and 0.035 inch magnet-tipped guidewires (FindrWIRZ); and (3) a 12 Fr compatible suture delivery device (Lariat™) (Fig. 7). The procedure involves four basic steps: (1) pericardial and transseptal access; (2) placement of the endocardial magnet-tipped guidewire in the apex of the LAA with balloon identification of the LAA ostium; (3) connection of the epicardial and endocardial magnet-tipped guidewires for stabilization of the LAA; and (4) snare capture of the LAA with closure confirmation and release of the pre-tied suture for LAA ligation. The new Lariat™ RS facilitates retraction of the snare post-suture deployment and tightening. After the procedure, the patient will only

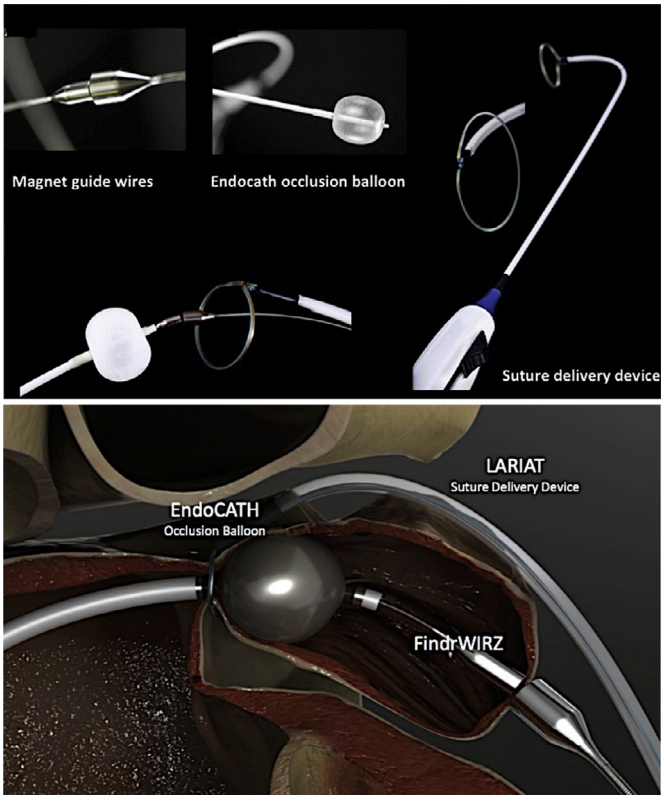

Fig. 7. The Lariat™ RS device consists of three components: (1) a 15 mm compliant occlusion balloon catheter (EndoCATH); (2) 0.025-inch and 0.035-inch magnet-tipped guidewires (FindrWIRZ); and (3) a suture delivery device (Lariat). The procedure involves both a pericardial and transseptal access, connection of the epicardial and endocardial magnet-tipped guidewires, and snare capture of the LAA with closure confirmation and release of the pre-tied suture for LAA ligation.

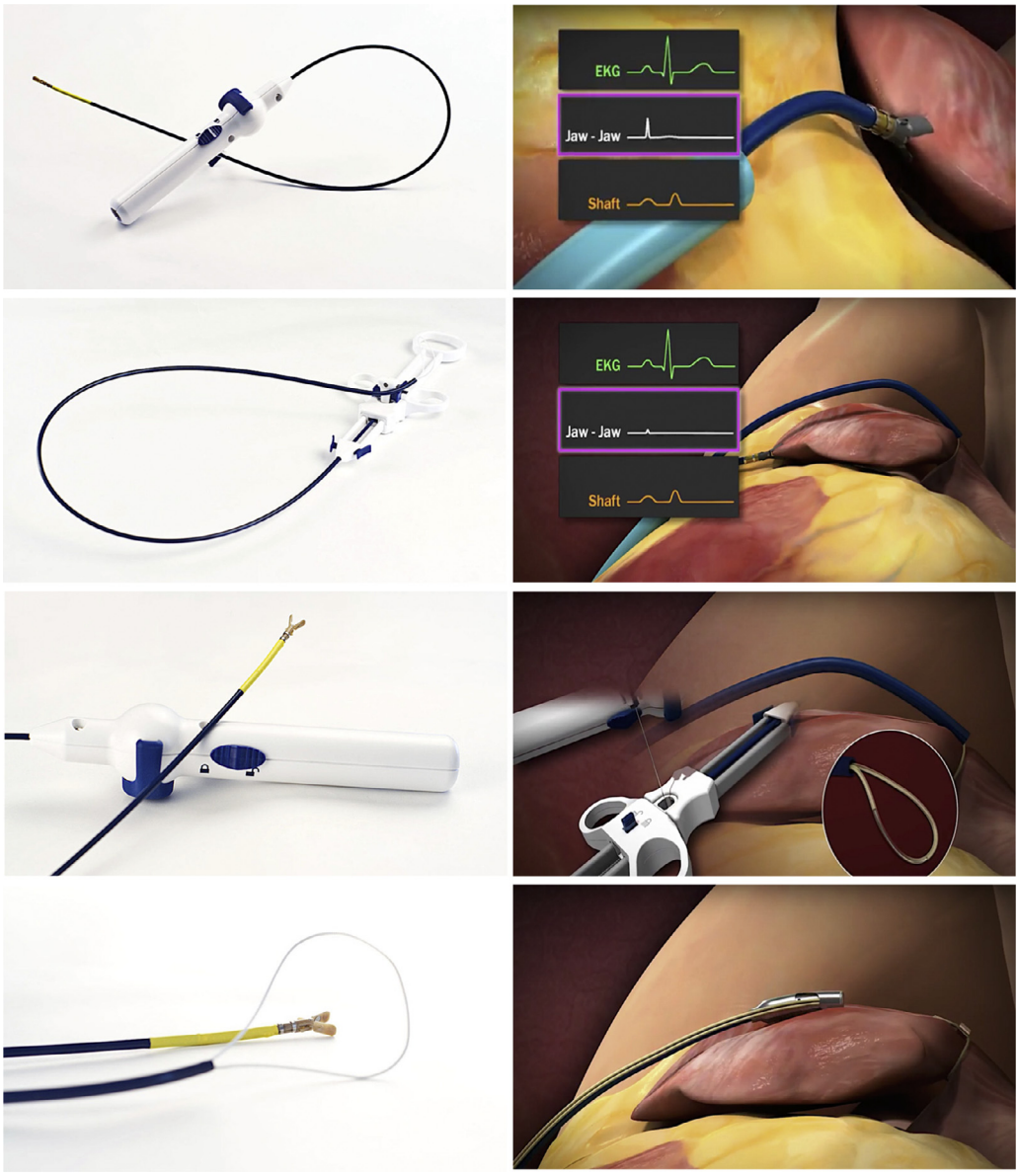

Fig. 8. The Sierra™ ligation system performs LAA closure using a percutaneous pericardial approach. There are two main components to the Sierra™ Ligation System: an Appendage Stabilizer and a Ligating Device. The Stabilizer is used to find the LAA using fluoroscopic and ultrasound imaging, and by reading the ECG signals from the surface of the heart. The Ligating Device consists of a suture-like loop that gets positioned around the LAA.

have a suture left and, therefore, suffers no risk of device embolization or device erosion.

Clinical experience in 139 patients showed a 99% procedural success rate, but there was a concern of procedure-related pericarditis. Over a mean follow-up of 2.9 years, the annual event rate of stroke and systemic embolism was 1.0% vs. an expected event rate of 6.2% in the study population [31]. Apart from the benefits of the mechanical isolation of the LAA, Lakkireddy et al. also demonstrated that the Lariat™ system can lower the recurrence rate of AF in patients undergoing AF ablation plus Lariat™ procedure as compared to AF ablation alone (35% vs 61% $p = 0.028$), presumably due to its additional benefit in terms of electrical isolation of the LAA [32]. The prospective, multicenter US IDE aMAZE trial assessing the benefit of LAA ligation in the prevention of AF in persistent and long-standing persistent AF is on-going with the first interim analysis of 400 patients expected by the end of 2018 [33]. FDA and CE mark approvals for this device are in place.

Sierra™ ligation system

The Sierra™ ligation system (Aegis Medical) is a minimally invasive solution for LAA closure using a percutaneous pericardial approach. The Sierra™ ligation system performs LAA closure in the closed pericardial space through one small puncture through the skin of the chest. There are two main components to the Sierra™ Ligation System: an Appendage Stabilizer and a Ligating Device (Fig. 8). The Stabilizer is used to find the LAA using fluoroscopic and ultrasound imaging, and by reading the ECG signals from the surface of the heart. Once the LAA is identified, the Stabilizer guides the Ligating Device to the appendage. The Ligating Device consists of a suture-like loop that gets positioned around the LAA. Once in place, the loop is cinched down and locked in place to stop the blood flow to the LAA.

Unlike other endocardial LAA closure devices, this epicardial device allows the physician to close the LAA without entering the vascular system or the cavities of the heart. The Sierra™ Ligation

System is an investigational device, not yet approved for commercial use.

Conclusions

Despite the growing interest in percutaneous LAA closure for stroke prevention in patients with NVAF, there is still need for better LAA closure device designs to obtain consistently acceptable low peri–procedural complication rates and improve clinical outcomes.

To date, the PROTECT-AF and PREVAIL trials remain the landmark studies in the field of percutaneous LAA closure therapy, and these are all studies involving the Watchman™ device. However, even these landmark trials have their controversies. E.g. 15% of patients in the Watchman™ arm of the PROTECT-AF trial remained on VKA therapy, while the first co-primary efficacy endpoint (composite of stroke, systemic embolism, and cardiovascular /unexplained death) in the PREVAIL trial did not achieve non-inferiority of the device to warfarin – although, numerically, the event rates were actually similar. This failure to meet the pre-specified criteria of non-inferiority in the PREVAIL study has been associated with the low incidence of ischemic strokes/systemic embolism in the VKA arm (only 1 in 138 patients) and the relatively short follow-up time.

Evidence in terms of large scale randomized control trials concerning other LAAC devices, or comparison between LAAC and NOAC are still lacking. Yet, data is available showing that LAAC therapy can serve as a viable, if not the only, option for patients who are at high risk of ischemic stroke but cannot tolerate long-term OAC therapy.

Therefore, it has become important not only to provide evidence on safety and efficacy of different LAAC devices, but also to understand the technical details and specific differences of the different available or emerging LAA closure devices. In this update, an overview of current and emerging LAA occluders are given – with special attention to the key design features of every single device and, if available, preclinical or clinical data. (Table 1)

Declarations of interest

- Jai-Wun Park is a clinical proctor for LAmbre™ LAA closure system, AMPLATZER™ Amulet™ LAA occlude, and UltraSeal™ LAA closure device.
- Yat-Yin Lam is a clinical proctor for LAmbre™ LAA closure system and consultant for Lifetech Scientific Inc.
- Tom De Potter has received institutional research grants from Boston Scientific.
- Josep Rodés-Cabau has received institutional research grants from Cardia Inc.
- Marcus Sandri is a consultant for Acoredis™ LAA occluder.
- Eleftherios Sideris is a consultant for the Prolipsis™ device.
- Trevor McCaw is an equity holder in Aegis Medial.
- Randall J. Lee is a consultant with equity in SentreHEART, Inc.
- Horst Sievert is a consultant and has received grants and honorarium from Boston Scientific, Lifetech Scientific Inc., and Occlutech international AB.
- Lars Søndergaard is a consultant for and has received institutional research grants from Abbott and Boston Scientific.
- Ole De Backer has been consultant for Abbott and Boston Scientific.

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