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Review

2021. The year in review. Structural heart interventions

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ABSTRACT

Since the beginning of 2020, the corona virus (COVID-19) pandemic redefined in many ways the practice of cardiology, research and cardiology conferences. Virtual conferences replaced most major in-person venues. The number of "elective" structural heart interventions declined and clinical research endured major setbacks in regards to academic and industry-sponsored clinical trials. In this review, we attempt to provide a broad overview of the field for general and interventional cardiologists with a specific interest in structural heart interventions.

1. Introduction

2021 was a year of intense research on valvular heart disease and we have witnessed substantial progress in all aspects of structural heart interventions. Since the beginning of 2020, the corona virus (COVID-19) pandemic redefined in many ways the practice of cardiology, research and cardiology conferences. Virtual conferences replaced most major in-person venues. The number of "elective" structural heart interventions declined and clinical research endured major setbacks in regards to academic and industry-sponsored clinical trials. In this review, we attempt to provide a broad overview of the field for general and interventional cardiologists with a specific interest in structural heart interventions. We have included the major randomized controlled trials and late breaking studies presented at the ACC, SCAI, TCT, ESC, CRT and AHA conferences. In December 2021, ESC and EACTS published their 2021 ESC/EACTS Guidelines for the management of valvular heart disease [1], one year after the publication of ACC/AHA [2].

1.1. Transcatheter aortic valve replacement (TAVR)

Among low-risk AS patients who received the SAPIEN 3 valve (RCT, n:1000), the primary endpoint remained significantly lower at 2 years with TAVR versus surgery (SAVR) (11.5% vs. 17.4%; p: 0.007), but initial differences in death and stroke favoring TAVR were diminished; patients who underwent TAVR had increased rates of valve thrombosis (2.6% vs 0.7%; p:0.02) in the PARTNER-3 trial [3]. Valve thrombosis was defined according to Valve Academic Research Consortium (VARC) criteria: thrombus associated with an implanted valve that interferes with valve function or warrants treatment (anticoagulation or explantation).

The 2-year data from the Evolut Low-Risk Trial (RCT, n: 1468) showed that the primary outcome of all-cause mortality and disabling stroke occurred in 4.3% of TAVR and 6.3% of SAVR patients at 2 years, a non-statistically significant difference. The need for permanent pacemaker was significantly higher in the TAVR arm (21.1% vs 7.9%) [4].

Abbreviations: ACC, American College of Cardiology; SCAI, Society of Cardiovascular Angiography and Interventions; TCT, Transcatheter Cardiovascular Therapeutics; ESC, European Society of Cardiology; CRT, Cardiovascular Research Technologies (CRT); AHA, American Heart Association; EACTS, European Association for Cardio-Thoracic Surgery; AS, aortic stenosis; TAVR, transcatheter aortic valve replacement; SAVR, Surgical aortic valve replacement; RCT, randomized-controlled trial; FDA, US Food and Drug Administration; IDE, Investigational Device Exemption; AMI, acute myocardial infarction; HF, heart failure; CAD, coronary artery disease; PCI, percutaneous coronary intervention; CT, computed tomography; VKA, vitamin K antagonists; KCCQ-OS, Kansas City Cardiomyopathy Questionnaire Overall Summary Score; AKI, acute kidney injury; CKD, Chronic kidney disease.

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An analysis of the AMTRAC registry (n: 8626) evaluated TAVR in patients younger than 70 years old who were rejected for surgery. The outcomes were similar to those for older TAVR patients [5].

In the SURTAVI trial (RCT, n: 1660) of intermediate-risk patients the rate of all-cause mortality or disabling stroke was no different between the TAVR and SAVR arms at 5 years (31.3% vs 30.8%) [6].

Since mid-2020, FDA has removed the precaution from commercial labeling regarding TAVR in the patients with bicuspid aortic valve using SAPIEN-3 or Evolut-R/Pro [7]. For low-risk patients with bicuspid AS, TAVR appeared to be safe, with short length of hospital stay, zero mortality, and no disabling strokes at 30 days in the LRT trial [8]. Moreover, a meta-analysis of the FDA-approved IDE trials of low-risk patients with bicuspid AS undergoing TAVR demonstrated 30-day outcomes comparable to low-risk tricuspid AS patients, except for a trend toward higher stroke in bicuspid AS patients [9].

The AVATAR trial (RCT, n: 157) evaluated early SAVR in the treatment of asymptomatic severe AS. Patients randomized to early surgery had a significantly lower incidence of primary composite endpoint comprising all-cause death, AMI, stroke or unplanned HF hospitalization than those in the conservative arm (15.2% vs 34.7%, $p = 0.02$) [10]. Improved outcomes were mainly driven by a significant decrease in heart failure hospitalizations (4.01% vs 12.94%;HR:0.32, CI: 0.08–1.19).

The results of the EARLY-TAVR (Evaluation of TAVR Compared to Surveillance for Patients With Asymptomatic Severe Aortic Stenosis) and PROGRESS (Management of Moderate Aortic Stenosis by Clinical Surveillance or TAVR) are expected in 2022.

1.1.1. Aortic Stenosis and PCI

The ACTIVATION trial (RCT,n:235) compared PCI vs no-PCI prior to TAVR in patients with severe aortic stenosis and obstructive CAD. The observed rates of death (13.4% vs 12.1%) and rehospitalization at 1 year (34.5% vs 33.6%) were similar between PCI and no PCI prior to TAVR; however, the non-inferiority margin was not met, and PCI resulted in a higher incidence of bleeding (41.2% vs 21.7%) [11]. The majority of bleeding occurred in the first 30 days after TAVR.

1.1.2. Arrhythmias

An analysis of the PARTNER-3 trial showed that patients with atrial fibrillation (AF) had a higher risk for the composite outcome of death, stroke or rehospitalization (HR 1.80, $p = 0.0046$) and rehospitalization alone (HR 1.8, $p = 0.015$), but not death or stroke [12]. In another analysis, early post-operative AF or flutter (POAF) was more frequent following SAVR compared with TAVR. Late POAF, but not early POAF, was significantly associated with worse outcomes at 2 years, irrespective of treatment modality [13].

A meta-analysis of 78 studies attempted to identify the predictors of permanent pacemaker implantation after TAVR. Male sex (OR, 1.16), baseline Mobitz type-1 s-degree atrioventricular block (OR, 3.13), left anterior hemiblock (OR, 1.43), bifascicular block (OR, 2.59), right bundle-branch block (OR, 2.48) and periprocedural atrioventricular block (OR, 4.17) were identified as potent predictors [14].

1.1.3. Cerebral protection

The REFLECT I trial (observational, n:375), which was stopped early, demonstrated that the TriGuard HDH cerebral embolic protection device during TAVR was safe in comparison with historical TAVR data but did not meet the predefined effectiveness endpoint compared with unprotected TAVR controls [15].

1.1.4. Type of anesthesia

The SOLVE-TAVI trial (RCT, n:447) in intermediate- to high-risk patients undergoing TAVR, showed that newer-generation self-expanding valves (SEV) and balloon-expandable valves (BEV) as well as conscious sedation (CS) and general anesthesia (GA) yield similar clinical outcomes at 1 year [16].The rates of all-cause mortality, stroke, moderate or severe paravalvular leakage, and permanent pacemaker implantation were similar between the BEV and SEV group (38.3% vs. 40.4%; $p = 0.66$) at 1 year. Regarding the anesthesia comparison, the combined endpoint of all-cause mortality, stroke, myocardial infarction, and acute kidney injury occurred with similar rates in the GA and CS groups (25.7% vs. 23.8%;$p = 0.63$).

1.1.5. Antithrombotic therapy

In the POPTAVI trial (RCT, n: 665) the incidence of bleeding and the composite of bleeding or thromboembolic events at 1 year were significantly less frequent with aspirin than with aspirin plus clopidogrel administered for 3 months [17].Symptomatic clinical aortic valve thrombosis occurred in 3 patients (0.9%) in the aspirin-alone group and in 1 patient (0.3%) in the aspirin–clopidogrel group. In addition, an increased valve gradient (>10 mmHg) was observed in 10 patients (3.0%) and 11 patients (3.3%), respectively.

In the POPular TAVI EU (RCT,n:213) patients undergoing TAVR who were receiving oral anticoagulation, the incidence of serious bleeding over a period of 1 month or 1 year was lower with oral anticoagulation alone than with oral anticoagulation plus clopidogrel (21.7% vs 34.6%; $P = 0.01$) [18].,

The ENVISAGE-TAVI AF trial (RCT,n:1426) showed that in patients with AF who underwent TAVR, edoxaban was non-inferior to vitamin K antagonist [19].

The importance of subclinical leaflet thrombosis characterized by hypoattenuated leaflet thickening (HALT) and reduced leaflet motion by CT remains unclear [20]. HALT is more frequent in transcatheter compared with surgical valves at 30 days, but not at 1 year and it results in significantly increased aortic valve gradients [21].

In a substudy of the GALILEO-4D trial (RCT, n: 231) involving patients without an indication for long-term anticoagulation, rivaroxaban was more effective than an antiplatelet-based strategy in preventing subclinical leaflet-motion abnormalities. However, in the main trial, rivaroxaban was associated with a higher risk of death or thromboembolic complications and a higher risk of bleeding than the antiplatelet-based strategy [22].

The ATLANTIS trial (RCT,n:451) randomized TAVR patients in need for oral anticoagulation (OAC) to either apixaban 5 mg twice daily or vitamin K antagonist (VKA). In the intention-to-treat analysis, the primary endpoint—a composite of death, MI, stroke, systemic emboli, intra-cardiac or bioprosthesis thrombus, deep vein thrombosis or pulmonary embolism, and major bleeding over 1 year—was similar for the apixaban and VKA arms [23].

The importance of subclinical leaflet thrombosis and the optimal type and dose of anticoagulation to safely prevent it remain to be determined.

1.1.6. Vascular access

In a STS/ACC TVT Registry analysis (n:4219), percutaneous transaxillary access appeared to be safe and effective compared to surgical cut-down with similar rates of all-cause mortality (4.8% vs 4.1%), stroke (7.7% vs 6.5%), life-threatening bleeding (0.3% vs 0.1%; $p = 0.31$) but with a higher rate of major vascular complication (3.0% vs 1.5%, $p = 0.02$) [24].

A meta-analysis of five observational studies (2470 patients) comparing trans-carotid to transfemoral access for TAVR showed comparable procedural and clinical outcomes [25].

A single-center, retrospective analysis of 185 patients suggested that trans-caval access is a safe approach as compared to other alternative access techniques, with lower risk of kidney injury and shorter hospital stay [26].

The CHOICE-CLOSURE trial (RCT, n:516) compared a pure plug-based closure device (MANTA) with a primary suture-based technique (ProGlide) in TAVR. The MANTA was associated with a higher rate of access-site or access-related vascular complications (19.4% vs 12.0% $p = 0.029$) but a shorter time to hemostasis (80 vs. 240 s, $p < 0.001$)

compared to ProGlide [27].

1.1.7. Kidney disease

In an analysis of the PARTNER 2A trial (RCT,n: 1045) intermediate-risk patients with severe AS and CKD, TAVR was associated with a similar risk at 5 years compared to SAVR for the primary endpoints [28]. The primary endpoint of the PARTNER 2A was a composite of death, stroke, rehospitalization, and new hemodialysis 5 years after SAVR or TAVR with the SAPIEN XT or SAPIEN 3.

In the BRAVO 3 trial (RCT,n:802), acute kidney injury (AKI) occurred in 10.7% at 7 days and 17% at 30 days. AKI was associated with a significantly greater adjusted risk for 30-day death. Multivariate predictors of AKI at 30 days included baseline hemoglobin, body weight, and prior coronary artery disease, and predictors at 7 days included pre-existing vascular disease, CKD, transfusion, and valve post-dilation [29].

1.1.8. Other

Coronary obstruction during TAVR is a rare (0.7%) but disastrous complication with estimated 30-day mortality of 40–50%. The BASILICA technique entails intentional electrosurgical crossing and laceration of valve leaflets to prevent coronary obstruction during TAVR [30].

The international BASILICA registry (n: 214) demonstrated 86.9% procedural success and low rates of 30-day stroke (2.8%) and death (2.8%) [31].One-year outcomes from the BASILICA trial (observational, n:28) indicated no late stroke, myocardial infarction, or death related to BASILICA [32].

In the AMTRAC Valve Registry ($n = 7303$) 27.2% patients who underwent TAVR had a baseline MR grade $\geq$ moderate. MR regressed in 44.1%. 4-year mortality and CHF were higher for those with MR persistence, but not for those with MR regression after TAVR. In a propensity score-matched cohort with significant residual MR after TAVR, staged mitral intervention (repair or replacement) was associated with a better functional class [33]. A similar analysis (observational, n: 2964) showed a higher prevalence of baseline MR grade $\geq$ moderate (41.6%) which was also associated with increased mortality; however, the use of newer generation self expandable valves was associated with higher survival rate at 1 year irrespective of the degree of pre-procedural MR. [34]

An analysis of the PARTNER-IIa trial showed that worsening tricuspid regurgitation (TR) occurred in 17.3% of TAVR and 27.0% of SAVR patients. Worsening TR is associated with female sex, AF, right ventricular enlargement, and SAVR. Regardless of mode of AVR, worsening TR was similarly associated with a poor prognosis [35].

Analysis of the PARTNER-3 trial demonstrated that predilation and direct TAVR were safe in patients with low surgical risk and favorable aortic valve anatomy. Direct TAVR decreased the procedure duration and did not predispose to more postdilation [36].

An analysis of the National Inpatient Sample and a meta-analysis demonstrated the safety of TAVR in cancer patients [37,38].

Key points

TAVR

- ➢ Sustained 2-year benefits in low-risk patients.
- ➢ Sustained 5-year benefits in intermediate-risk patients.
- ➢ Effective for bicuspid aortic valve even in low-risk patients.
- ➢ PCI as effective before or after TAVR.
- ➢ Late post-operative atrial fibrillation or flutter is associated with worse outcomes.
- ➢ The importance of subclinical leaflet thrombosis remains unclear.
- ➢ Single antiplatelet therapy without anticoagulation is probably the preferred antithrombotic regimen.
- ➢ Trans-axillary, trans-carotid and trans-caval alternative access are safe and effective in TAVR, although data are limited.
- ➢ Persistent at least moderate MR after TAVR is associated with worse outcomes.
- ➢ Worsening TR after TAVR is associated with poor prognosis.
- ➢ Direct TAVR safe is safe even in low risk patients with favorable anatomy.
- ➢ TAVR is safe in cancer patients.

1.2. Transcatheter edge-to-edge repair (TEER), transcatheter mitral valve replacement (TMVR)

1.2.1. Transcatheter Edge-to-Edge Repair (TEER)

Transcatheter edge-to-edge repair (TEER) is now the standard of care for patients with symptomatic functional MR (FMR) despite guideline-directed medical therapy (GDMT) without an alternative indication for cardiac surgery. The 2020 ACC/AHA guidelines upgraded its use to a Class 2a recommendation for select primary MR (PMR), while the 2021 ESC/EACTS guidelines gave a IIb recommendation. A new class 2a recommendation for select FMR patients was given by both the ACC/AHA and the ESC/EACTS guidelines [1,2].

Over 33,000 patients have received TEER in the United States with continuously improving 30-day mortality (4.6%) and an average length of stay of one day [39].

3-year outcomes of the COAPT trial (RCT, n: 614) that randomized patients with HF and moderate-to-severe or severe FMR who remained symptomatic despite GDMT, showed sustained 3-year improvements in MR severity, quality-of-life, and functional capacity with MitraClip compared to GDMT alone. The annualized rates of heart failure hospitalizations (HFHs) per patient-year were 35.5% vs 68.8% ($p < 0.001$) and mortality 42.8% vs 55.5% ($p = 0.001$).Moreover, patients assigned to GDMT alone who crossed over and were treated with TEER, the subsequent composite rate of mortality or HFH was reduced compared with those who continued on GDMT alone ($p = 0.006$) [40].

2-year outcomes of CLASP study (observational, n: 124) demonstrated sustained favorable outcomes with the PASCAL device in FMR and PMR. Results showed high survival (72% FMR, 94% PMR) and freedom from HF rehospitalization rates (78% FMR, 97% PMR) with a significantly reduced annualized HFFs [41].

Although the COAPT trial has clearly defined the criteria for better TEER outcomes in FMR, up to half of real-world patients do not meet these highly selective criteria [42].

Several subgroup analyses have been performed in the COAPT trial. Baseline predictors of clinical super-responders were lower serum creatinine and KCCQ-OS score [43]. The impact of TEER in HFH was less pronounced in women compared with men beyond the first year after treatment [44] Diabetic and non-diabetic patients had consistent reductions in the 2-year rates of death and HFH and improvements in QOL and functional capacity following TEER [45]. Despite the worse prognosis of heart failure patients with a history of AF, MR reduction with the MitraClip still afforded substantial clinical benefits [46]. COPD was associated with attenuation of the survival benefit of TEER versus GDMT; however, the benefits of TEER on both HFH and health status were similar regardless of COPD [47].

The first report of CUTTING-EDGE registry (n: 332) reported that MV surgery after TEER carries high mortality (24.1% at 1 year and 31.7% at 3 years after MV surgery) and morbidity risks; moreover, only <10% of patients underwent MV repair [48].

The role of TEER in post-MI MR was evaluated in a retrospective international registry of 471 patients with at least moderate-to-severe MR following MI. The immediate procedural success did not differ between patients who underwent surgical MV repair or replacement (SMVR) and TEER (92% vs. 93%, $P = 0.53$). However, in-hospital and 1-year mortality rates were significantly higher in SMVR than in TEER (16% vs. 6%, $P = 0.03$ and 31% vs. 17%, $P = 0.04$) [49].

Two retrospective studies suggested that TEER can be safely performed with moderate conscious sedation and with same-day discharge [50].

1.2.2. TMVR

One-year outcomes were reported of the MITRAL trial (observational, n:30) evaluating transseptal mitral valve-in-valve (MViV) with the SAPIEN 3 in high-risk patients with failed surgical mitral bioprostheses. Transseptal MViV was associated with 100% technical success, low procedural complication rates, and very low mortality (3.4% in

1 month and 17.3% in 1 year) [51, 52].

The first single-arm prospective study evaluating transseptal mitral valve in ring (MViR) with the SAPIEN 3 in high-risk patients with failed surgical annuloplasty rings yielded a 30-day mortality rate 6.7% lower than predicted by the Society of Thoracic Surgeons score. At 1 year, transseptal MViR was associated with symptom improvement and stable valve performance [53].

2-year outcomes after the implantation of the TENDYNE valve showed an all-cause mortality of 39.0% with the majority of deaths (43.6%) occurring during the first 90 days. 93.2% of surviving patients had no MR with decrease in heart failure hospitalizations. The improvement in symptoms at 1 year (88.5% NYHA functional class I or II) was sustained to 2 years (81.6% NYHA functional class I or II) [54].

Key points

Mitral valve interventions

- ➢ Transcatheter edge-to-edge repair (TEER) is now supported by ACC/AHA and ESC/EACTS guidelines for primary and functional MR.
- ➢ TEER mortality today is 4.6% at 30 days and the average length of stay is one day.
- ➢ Sustained 3-year TEER outcomes in patients with secondary MR.
- ➢ Sustained 2-year outcomes with the PASCAL system in patients with primary or functional MR.
- ➢ Creatinine, gender, diabetes, KCCQ-OS score, atrial fibrillation and COPD affect the outcomes of TEER in patients with functional MR.
- ➢ TEER in post-MI MR may be an alternative to surgery.
- ➢ TEER can be safely performed with moderate conscious sedation and with same-day discharge.
- ➢ Promising results of transseptal SAPIEN 3 implantation for mitral valve-in-valve or valve-in-ring in high-risk patients with failed bioprosthesis or surgical annuloplasty rings.
- ➢ Sustained 2-year outcomes with the TENDYNE device.

1.3. Tricuspid valve interventions

Currently there are no FDA-approved transcatheter modalities for the management of tricuspid valve disease. In Europe PASCAL and TriClip are CE certified. They are both clip-based devices designed for right heart interventions.

A single-center database analysis (n:80) compared the PASCAL versus MitraClip-XTR for the treatment of tricuspid regurgitation. Reduction in TR severity by at least one grade at 30 days was achieved in 91% and 96% respectively with similar 30-day mortality (5.0% vs 5.0%) [55].

1-year outcomes of the TRILUMINATE trial (observational, n:85) found the TriClip to be safe and effective in patients with moderate or greater TR. TR was reduced to moderate or less in 71% of subjects while the overall major adverse event rate and all-cause mortality were both 7.1% at 1 year [56].

In the first 30-day report of the CLASP TR (observational, n:34) in the US, the PASCAL device performed as intended, with substantial TR reduction, low MAE rate (5.9%), no mortality or re-intervention, and significant improvements in functional status, exercise capacity, and quality of life [57].

12-month outcomes from the multicenter compassionate-use experience with the PASCAL System (n:30) demonstrated survival of 93% and achievement of NYHA functional class I or II in 90% of the patients with improved 6-min walk distance. There was no stroke, endocarditis, or device embolization during the follow-up [58].

The Cardioband tricuspid system is designed to reduce functional TR through annular reduction. Via a steerable catheter the Cardioband implant is secured to the tricuspid annulus with stainless steel anchors. A size-adjustment tool enables controlled annular reduction to achieve optimal TR improvement.

In the 30-day report of the TriBAND study (n:61), Cardioband demonstrated favorable outcomes at discharge and 30 days (all-cause mortality 1.6% and 19.7% at discharge and 30-days) in patients with symptomatic severe functional TR [59].

This first-in-human experience evaluating a percutaneous tricuspid valve (EVOQUE TTVR) in 25 patients demonstrated high technical success (92%), acceptable safety (30-day mortality 0%, 96% TR grade $\leq$ 2+, major bleeding 12% and 8% pacemaker implantation requirement) and significant clinical improvement [60].

Key points

Tricuspid valve interventions

- ➢ PASCAL and MitraClip-XTR showed reduction in TR severity by at least one grade at 30 days in 91% vs 96% respectively with similar 30-day mortality (5.0% vs 5.0%)
- ➢ TriClip reduced TR to moderate or less in 71% of patients with 1-year all-cause mortality 7.1%.
- ➢ First US experience with the PASCAL device: substantial TR reduction, low MAE rate (5.9%), no mortality or re-intervention, and significant improvements in functional status, exercise capacity, and quality of life.
- ➢ Cardioband demonstrated favorable outcomes at discharge and 30 days (all-cause mortality 1.6% and 19.7% at discharge and 30-days).
- ➢ First-in-human experience with the EVOQUE TTVR demonstrated high technical success (92%), acceptable safety (30-day mortality 0%, 96% TR grade $\leq$ 2+, major bleeding 12% and 8% pacemaker implantation requirement) and significant clinical improvement.

1.4. Percutaneous left atrial appendage occlusion

4-year outcomes from the PRAGUE-17 trial (RCT, n: 402) comparing left atrial appendage closure (LAAO) (Watchman or Amulet) with NOACs (95% apixaban) in non-valvular AF patients with a history of cardio-embolism, LAAO remains non-inferior to NOACs for preventing major cardiovascular, neurological or bleeding events [61].

A meta-analysis of 16 studies comprising 1428 patients suggested that LAAO combined with AF ablation is an effective and safe strategy. The long-term freedom rate from atrial arrhythmia was 66%, long-term successful rate sealing of LAAC 100%, and ischemic stroke/transient ischemic attack/systemic embolism during follow-up was 1%. Peri-procedural adverse event rate (phrenic nerve palsy, intracoronary air embolus, device embolization, and periprocedural death) was 0%, procedure-related bleeding 3% and pericardial effusion 0% [62].

Another meta-analysis of 42 studies showed that intra-cardiac echocardiography (ICE) guided implantation is feasible and safe while it reduces exposure to general anesthesia and associated potential risks [63].

The next-generation Watchman FLX device approved by FDA in August 2020, is fully recapturable and repositionable with shorter device length and an atraumatic closed distal end. The PINNACLE FLX study (n:400) achieved primary effectiveness end point in 100%. Device-related thrombus was reported in 7 patients, no patients experienced pericardial effusion requiring open cardiac surgery, and there were no device embolizations [64].

A real-life analysis of the NCDR LAAO Registry (n: 49,357) suggested that women have a significantly higher risk of any in-hospital adverse events after LAAO (6.3% vs 3.9%, $P < 0.001$), major adverse event (4.1%vs 2.0%; $P < 0.001$) owing to pericardial effusion requiring drainage (1.2% vs 0.5%) or major bleeding (1.7% vs 0.8%). Women were also more likely than men to experience a hospital stay longer than 1 day (16.0% vs 11.6%; $P < 0.001$) or death (0.3% vs 0.1%; $P < 0.001$) [65].

In the Amulet IDE trial (RCT, n: 1878) Amulet was non-inferior to Watchman for the primary safety end point (14.5% versus 14.7%; $P < 0.001$ for non-inferiority). Major bleeding and all-cause death were similar between groups (10.6% versus 10.0% and 3.9% versus 5.1%, respectively). Procedure-related complications were higher for the Amulet occluder (4.5% versus 2.5%), largely related to more frequent pericardial effusion and device embolization. LAA occlusion was higher for the Amulet occluder than for the Watchman device (98.9% versus 96.8%; $P < 0.001$ for non-inferiority; $P = 0.003$ for superiority) [66].

Two retrospective studies suggested that LAAO can be safely

performed with moderate conscious sedation and with same-day discharge [67,68].

Key points
Left atrial appendage occlusion ➢ LAAO is non-inferior to NOACs in patients with AF and history of cardioembolism. ➢ ICE-guided LAAO is safe. ➢ Combined LAAO and AF ablation is safe and effective. ➢ LAAO may carry higher risk in women. ➢ The next-generation Watchman FLX device demonstrates improved outcomes. ➢ Amulet in non-inferior to the Watchman device. ➢ LAAO can be safely performed with moderate conscious sedation and with same-day discharge.

2. Discussion

Although the COVID-19 pandemic dominated public health headlines in 2021, important research progressed on the structural cardiology field. The most highlighted issues were the establishment of TAVR efficacy and safety in low risk, younger and cancer patients, and with the use of alternative access, the deeper understanding of the subclinical leaflet thrombosis, the advancement of TEER as a preferred therapy for selective patients, the newer data on TMVR and TTVR and the expansion of LAAO and PFO closure technologies.

Declaration of Competing Interest

Nothing to disclose.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijcard.2022.04.023.

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