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Left atrial appendage occlusion in COVID-19 times

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The coronavirus disease 2019 pandemic is having a major impact on healthcare systems worldwide. Several months after the COVID-19 outbreak, waiting lists of non-urgent structural heart (SH) interventions continue to increase. Limitations in terms of ICU beds and anesthesiology represent a major limitation to conduct non-urgent SH interventions and are a valid reason to move towards less invasive approaches. The field of left atrial appendage occlusion (LAAO) reflects this challenging situation perfectly. The aim of this paper is to describe the possibilities for pre-procedural LAA assessment, performance of the LAAO procedure and post-procedural surveillance in these challenging times.

Introduction

The coronavirus disease 2019 (COVID-19) pandemic is having a major impact on healthcare systems worldwide. Non-urgent procedures, including structural heart (SH) interventions, have been postponed to avoid unnecessary patient exposure to COVID-19 as well as to preserve capacity of intensive care units (ICUs) and anaesthesiology teams.[1] Six months after the COVID-19 outbreak, waiting lists of non-urgent SH interventions continue to increase, while the pandemic is not yet under control. In addition, some of the previously deferred patients have worse cardiac symptoms, especially those patients with heart valve disease, precluding any other delay in their treatment. Limitations in terms of ICU beds and anaesthesiology represent a major limitation to conduct non-urgent SH interventions and are a valid reason to move towards even less invasive approaches for transcatheter SH interventions.

The field of left atrial appendage occlusion (LAAO) reflects this challenging situation perfectly. While not being an urgent SH intervention, patients waiting for LAAO will be exposed to an increased risk for thromboembolic or bleeding events in case they would stop or continue their OAC treatment, respectively. Despite some reference centres have already moved to a less invasive LAAO approach without general anaesthesia and with use of intracardiac echocardiography (ICE) or micro-transoesophageal echocardiography (TOE) before the current crisis, most of the centres performing LAAO are still using general anaesthesia and conventional TOE guidance for their LAAO procedures.[2,3] The COVID-19 pandemic is an opportunity for these centres to move towards a less invasive LAAO approach. The aim of this article is to describe the possibilities for pre-procedural LAA assessment, performance of the LAAO procedure, and post-procedural surveillance in these challenging COVID-19 times—knowing that this approach may as well become the standard in non-COVID times.

Pre-procedural imaging with cardiac computed tomography angiography

Traditionally, imaging and sizing of the LAA have relied on TOE. However, in parallel with the acceptance of cardiac

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computed tomography angiography (CCTA) as the 'gold standard' imaging tool to prepare for transcatheter aortic valve implantation, CCTA is also increasingly recognized as a valuable pre-procedural imaging modality to prepare for percutaneous LAA closure.[4,5]

The LAA is a complex three-dimensional (3D) structure with often multiple lobes in different planes; a detailed and accurate 3D assessment of this cardiac structure helps in obtaining a solid pre-procedural plan.[6,7] Whereas 3D multi-planar reconstruction (MPR) is a standard option in all CCTA analysis software packages, this information is much harder to acquire and interpret on TOE imaging.

One of the important steps in the pre-procedural planning for LAAO is the measurement of the LAA ostium and landing zone dimensions.[4] As the LAA is most often an elliptical structure, accurate measurement of the LAA dimensions should be made on 3D double-oblique images, which can be easily provided by CCTA-based 3D-MPR; however, this may not be easily acquired by TOE.[6] This also explains why CCTA-based measurements are typically more reproducible and accurate.[8,9] In contrast, the main limitation of this imaging modality is the need of contrast media in patients with renal insufficiency, which is not infrequent in subjects undergoing LAAO.

Another advantage of using cardiac CCTA is that 3D volume-rendered CT images are easier to compare and link to the fluoroscopic images obtained during the intervention. Pre-procedural CCTA analysis allows to predict the optimal C-arm angle for LAA closure device implantation—typically the operator favours an implantation angle in which the LAA ostium and/or landing zone are aligned. This angle is not only the best projection to assess device compression but is also helpful in verifying coaxial alignment with the LAA structure. This is of importance, as off-axis LAA closure device implantation has been reported to be associated with a higher risk of peri-device leakage. Also, the location of the transseptal puncture can impact the possibility to obtain coaxial alignment between the delivery sheath and the LAA central axis—determining the optimal transseptal puncture site is also possible on cardiac CT and dependent on the LAA position and orientation.[9]

The use of CCTA-fluoroscopy fusion imaging is also finding its first applications in LAA closure procedures.[10] Cardiac computed tomography angiography-generated markers can be placed at the fossa ovalis, LAA ostium, and/or landing zone; the use of these markers can be helpful to reduce procedure time, radiation dose, and the use of contrast dye. In addition, overlay imaging may help to ensure correct device positioning.

Another promising CCTA-based application is computational modelling, which allows the simulation of different types and/or sizes of LAA closure devices at different implant depths within a patient-specific LAA anatomy.[11] The computational model generates information on LAAO device compression and device-wall apposition, aiming to optimize procedural safety and efficacy. A randomized controlled trial comparing standard planning with computational model-assisted planning of LAA closure procedures is underway.[12]

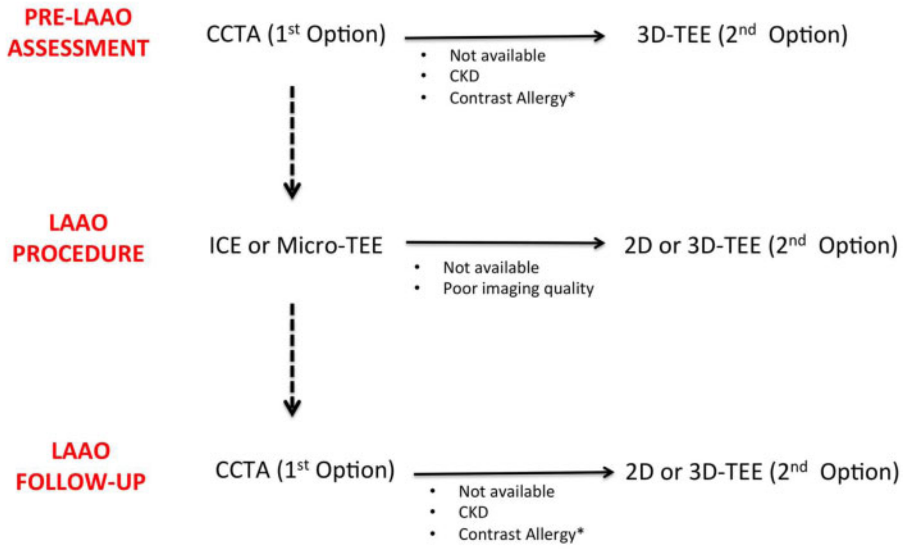
Finally, as use of cardiac CCTA allows a comprehensive and accurate pre-procedural planning, it also opens up on the possibility to perform percutaneous LAA closure in local anaesthesia and by intra-procedural guidance with ICE or micro-TOE. Avoidance of pre-procedural TOE and general anaesthesia are clear advantages in these COVID-19 period and justify that CCTA should be the preferred pre-procedural imaging modality in these times (*Figures 1* and *2*).

Left atrial appendage occlusion with intracardiac ecocardiography

Intracardiac echocardiography is widely used to guide transeptal puncture in cardiac electrophysiology procedures and transcatheter closure of defects in the interatrial septum. More recently, ICE is being used in other SH interventions like LAAO.[13] The LAA can be visualized from different positions in the right heart (right atrium, right ventricle outflow track , pulmonary artery, and coronary sinus), but direct imaging from the LA provides superior image quality and has become the standard for ICE to guide LAAO. A single transseptal puncture is adequate to allow advancement of both the device delivery sheath and the ICE catheter into the LA. Three standard positions of the tip of the ICE probe inside the LA are used to visualize the LAA: LUPV ostium (long-axis view), mid-LA (view corresponding to the 45° TOE view), and supra-mitral (view corresponding to the 135° TOE view). Intracardiac echocardiography from these sites provides high-resolution near-field images to guide positioning of the delivery sheath and optimal landing of the LAAO device and to assess device stability, device compression, and peri-device leaks. The 9-Fr ViewFlex (Abbott) and the 8 Fr (or 10 Fr) AccuNav (Siemens) are currently the ICE catheters that are used for LAAO. Both feature 64-element phased-array 2D-monoplane imaging with ultrasound frequencies between 4.5 and 10 MHz providing tissue penetration up to 21 cm. The tip of the catheters is four-way steerable (A/P; L/R) and both catheters have colour Doppler features. Two-dimensional ICE cannot be recommended for device sizing due to the limitation of monoplane imaging and ICE-guided LAAO should therefore always be combined with pre-procedural imaging (preferable cardiac CT) for planning and device sizing.

The major advantage of ICE is that the procedure can be carried out in local anaesthesia (*Figure 3*). Then, standard TOE or micro-TOE that are aerosol-generating procedures with an associated risk of virus transmission can be avoided. An anaesthesia team and TOE operator are not required facilitating logistics and saving of in-room time. Moreover, patient discomfort and risks associated with general anaesthesia and a post-anaesthesia recovery period are also avoided. Patients are awake and cooperating, and LA loading conditions are not influenced by anaesthesia. Patients with gastro-oesophageal disorders contraindicated for TOE are obvious candidates for an ICE-guided approach.

Intracardiac echocardiography has been compared with TOE in non-randomized observational studies showing ICE to be feasible, efficacious, and safe to guide LAAO.[2] Together, the studies show that procedural success, procedure time, fluoroscopy time, contrast use, and seal are about the same for ICE and TOE, whereas the in-room time



* Previous severe reaction to contrast

Figure 1 Proposed ideal workflow for coronavirus disease 2019 and non- coronavirus disease 2019 times. CKD, chronic kideny disease.

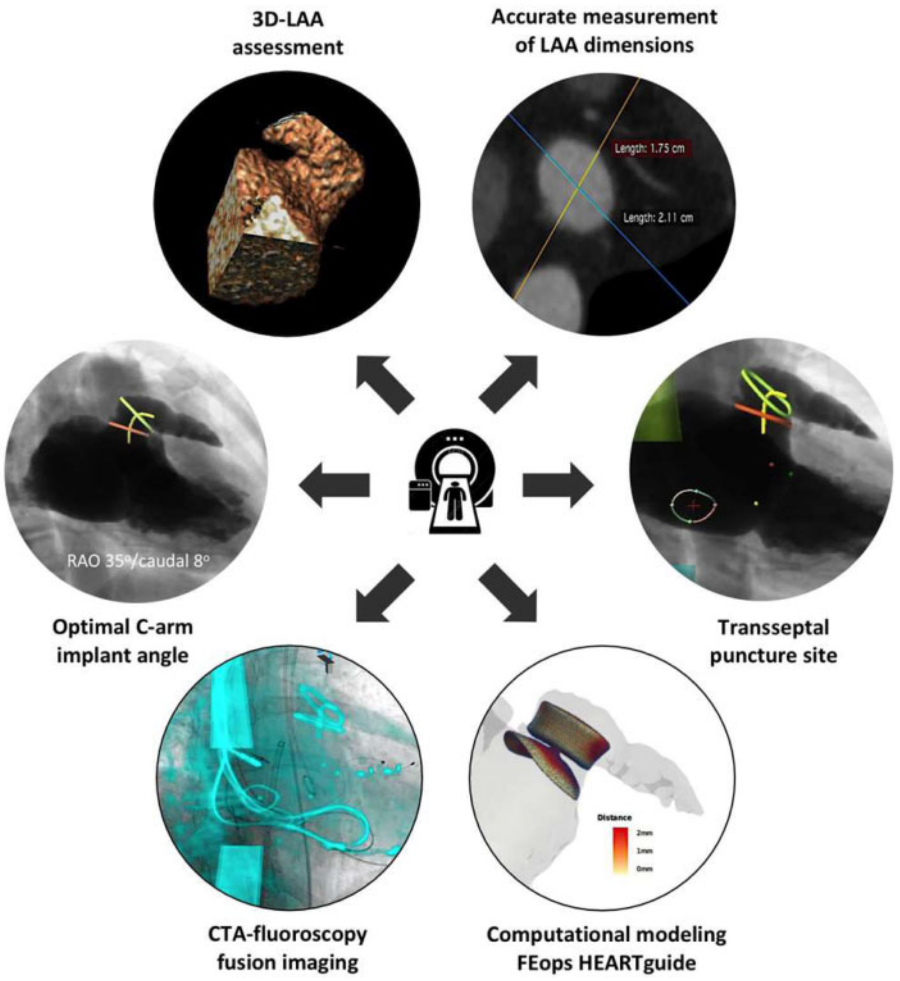
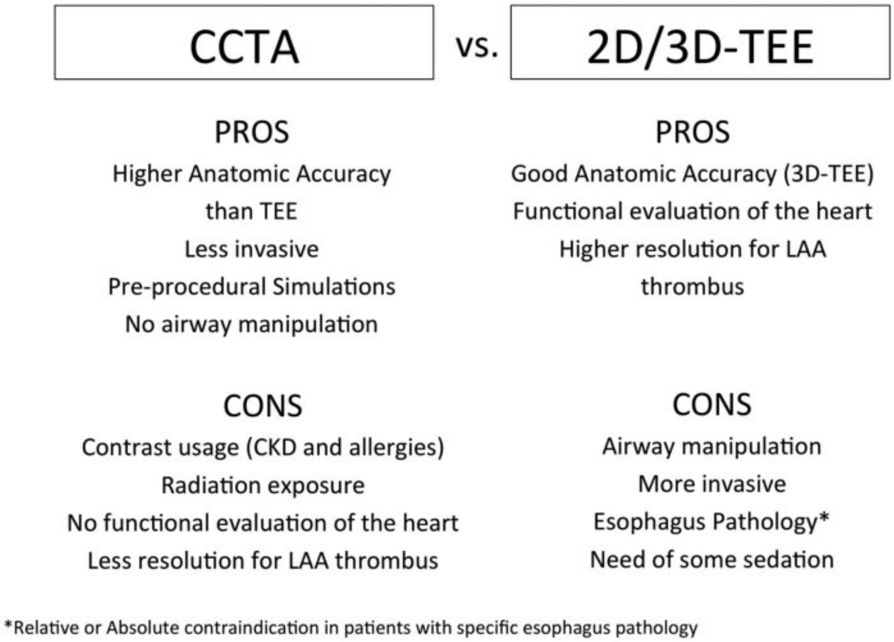


Figure 2 Preprocedural cardiac computed tomography angiography.



CCTA vs.	2D/3D-TEE
PROS	**PROS**
Higher Anatomic Accuracy than TEE	Good Anatomic Accuracy (3D-TEE)
Less invasive	Functional evaluation of the heart
Pre-procedural Simulations	Higher resolution for LAA thrombus
No airway manipulation	
CONS	**CONS**
Contrast usage (CKD and allergies)	Airway manipulation
Radiation exposure	More invasive
No functional evaluation of the heart	Esophagus Pathology*
Less resolution for LAA thrombus	Need of some sedation

*Relative or Absolute contraindication in patients with specific esophagus pathology

Figure 3 Pros and Cons of cardiac computed tomography angiography vs. transoesophageal echocardiography for pre-procedural left atrial appendage assessment. CKD, chronic kideny disease.

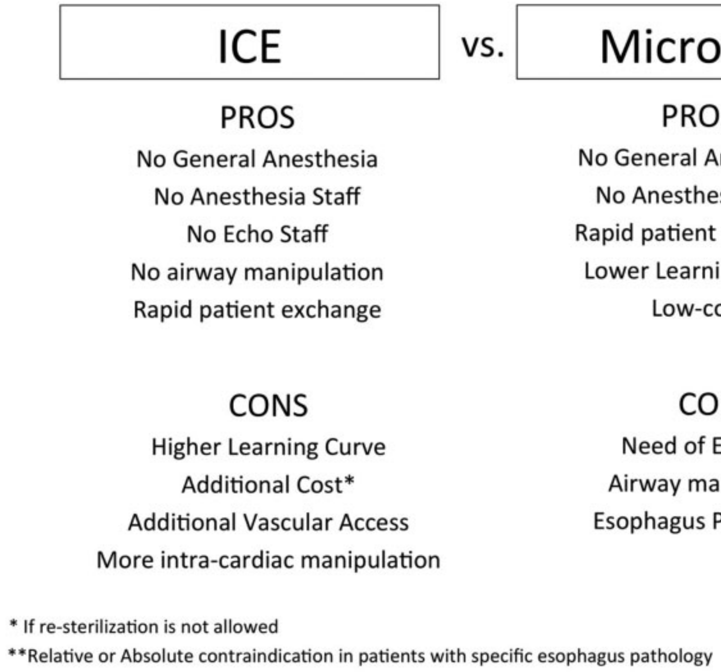
is much shorter for ICE.[14] The main limitations of the ICE are the higher cost of the echo-catheter, the potential learning curve, and the need of additional vascular access and probe manipulation within the heart with the subsequent risk of complications. Nonetheless, in some health systems, the higher cost of the ICE might be compensated by the reduced overall costs of the LAAO process.[15] In addition, ICE catheters can be re-sterilized several times without loss of image quality.

Major technological improvements in ICE catheters are expected in the near future. Recently, the first-in-human LAAO procedure guided by real-time 3D ICE using a Siemens AcuNav V volume ICE catheter (sector view of 24° × 70°) was reported.[16] Philips has presented preliminary data on a 3D real-time ICE probe with even larger sector views and omni-plane imaging, similar to TOE probes.

Left atrial appendage occlusion with micro-transoesophageal echocardiography

As previously mentioned, percutaneous LAAO requires continuous echocardiographic monitoring for accurate and safe transseptal puncture, optimal device deployment, and confirmation of LAA sealing.[4] In fact, for most operators, conventional TOE remains as the preferred imaging modality for LAAO guidance. In this setting, general anaesthesia is usually required during LAAO because of the relatively large shaft and tip of current standard TOE transducers, which are poorly tolerated when using only sedation, especially in case of long procedures. However, general anaesthesia is associated with increased overall procedure complexity and cost, together with potential serious complications.[17] Similar to ICE guidance, the recent availability of miniaturized TOE probes (micro-TOE) represents an innovative alternative to conventional TOE monitoring during LAAO, by allowing to perform the procedure without general anaesthesia. The novel multi-plane micro-TOE probe (Philips Healthcare and General Electrics) is currently the smallest cardiac imaging transducers, initially dedicated for neonatal patients, and subsequently used also for structural cardiac procedures in adult patients. Currently, micro-TOE probes allow multi-plane 2D and Doppler-colour but not 3D imaging. For instance, the Phillips probe measures only 7.5 and 5.2 mm in tip and shaft diameter as compared with the 16.6 mm and 9.5 mm in tip and shaft of the standard probe.

Although limited by small sample sizes, several reports have demonstrated that LAAO with micro-TOE guidance under local anaesthesia and conscious sedation was safe and feasible, with excellent procedural and mid-term outcomes.[3] The use of micro-TOE was well tolerated by most patients without significant airway complications. Although these encouraging preliminary results need to be confirmed in larger series of patients, potential advantages of micro- TOE over conventional TOE guidance during LAAO are numerous and include reduction in procedural time and cost, local anaesthesia, faster patient recovery, increased patient satisfaction, and improved cathlab workflow (*Figure 4*). As compared to ICE guidance, micro-TOE offers comparable image quality with a marked increased field of view. The learning curve is faster since the operator will use the same projections as for conventional TOE. Moreover, micro-TOE does not require an additional vascular access and the procedure is less costly than ICE since the micro-TOE probe is reusable. Importantly, as compared to conventional TOE, the micro-TOE has a lower spatial resolution (due to a smaller number of elements) and suboptimal image quality can result from inadequate contact between the probe and the oesophagus wall. As a consequence, LAA measurements on images obtained by micro-TOE have less accuracy than standard TOE measurements



ICE	Micro-TEE
PROS	**PROS**
No General Anesthesia	No General Anesthesia
No Anesthesia Staff	No Anesthesia Staff
No Echo Staff	Rapid patient exchange
No airway manipulation	Lower Learning Curve
Rapid patient exchange	Low-cost
CONS	**CONS**
Higher Learning Curve	Need of Echo staff
Additional Cost*	Airway manipulation
Additional Vascular Access	Esophagus Pathology**
More intra-cardiac manipulation	

* If re-sterilization is not allowed

**Relative or Absolute contraindication in patients with specific esophagus pathology

Figure 4 Pros and Cons of intracardiac echocardiography vs. micro-transoesophageal echocardiography for procedural left atrial appendage occlusion guidance.

with the potential to underestimate LAA dimensions, increasing the risk of device under-sizing.[4] Although micro-TOE provides sufficient image quality for procedural guidance, we would strongly recommend performing device sizing based on pre-procedural 3D imaging modalities (CT or 3D TOE).[4] Future large registries and randomized trials are needed to confirm the safety and benefits of micro-TOE guidance under local anaesthesia for LAAO.

Clinical and imaging follow-up after left atrial appendage occlusion

In light of the widespread diffusion of COVID-19 throughout Europe, not only for procedural but also for surveillance aspects, a fundamental goal consists in minimizing the risk of COVID-19 exposure while simultaneously preserving hospital resources. Even though in-hospital follow-up is crucial for patients following LAAO device implantation, multiple visits to hospitals should be avoided at the present time to minimize the risk of viral transmission among inpatients, outpatients, and healthcare personnel. Typically, surveillance is both clinical and imaging-based. However, dedicated centres should explore, whenever possible, the feasibility of remote follow-ups through telephone calls and computerized telemedicine.[18] Patients usually undergo TOE or CCTA within 45 days and after 1 year. In view of the COVID-19 pandemic, it seems reasonable and safe to postpone the first imaging examination 4–6 months.[19] Imaging must address four key points: (i) check the correct position of the device and exclude migration or embolization, (ii) exclude erosion of the surrounding anatomical structures, (iii) exclude the presence of leaks or possibly define their entity if present, and (iv) exclude thrombosis of the device. Because COVID-19 is transmitted via particulate aerosols, post-procedural follow-up TOE should be limited. For this reason, surveillance with CCTA may be the preferred alternative. Indeed, CCTA provides assessment of the position and function of LAA device comparable or superior to TTE, with the added advantage of non- invasiveness. Cardiac CCTA appears to be superior to TOE for determining off-axis device positions, adequate compression, and ostial peri-device LAA gaps. This highlights the challenges with TOE in representing 3D structures, such as the LAA.[8]

Moreover, measurement of the CCTA linear attenuation coefficient (degree of attenuation, Hounsfield) allows the detection of residual flow (patency) into the LAA distal to the device by comparing contrast density to that of surrounding cardiac chambers. Available data indicate that cardiac CCTA is more sensitive than TOE for the detection of PDL,[19,20] even though the clinical significance of residual leaks remains unclear. In order to avoid suboptimal images at CCTA, a dedicated acquisition protocol should be used.[9] Finally, the CT radiation dose received by the patient using such a protocol is low and acceptable (5-6 mSv).

Conclusions

Left atrial appendage occlusion procedures have been directly impacted by the COVID-19 pandemic. Movements towards less invasive strategies would allow a more regular workflow for this indication. Cardiac computed tomography angiography should be the preferred imaging modality for pre-procedural LAA assessment not only for the absence of airway manipulation but also for the higher accuracy in LAA assessment. Procedural guidance with ICE and micro-TOE are currently the most used non-invasive techniques that allow rapid and safe interventions without general anaesthesia. Finally, clinical and imaging follow-up of LAAO patients should also move to telematics medicine and CCTA surveillance (*Figure 1*).

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