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KHRS 2023
June 23(Fri.) - 24(Sat.), 2023
Grand Walkerhill Seoul, Korea
The 15th Annual Scientific Session of the Korean Heart Rhythm Society

Mapping & Ablation: Advanced Application of Mapping & Imaging

Clinical Application of ICE in EP Domain

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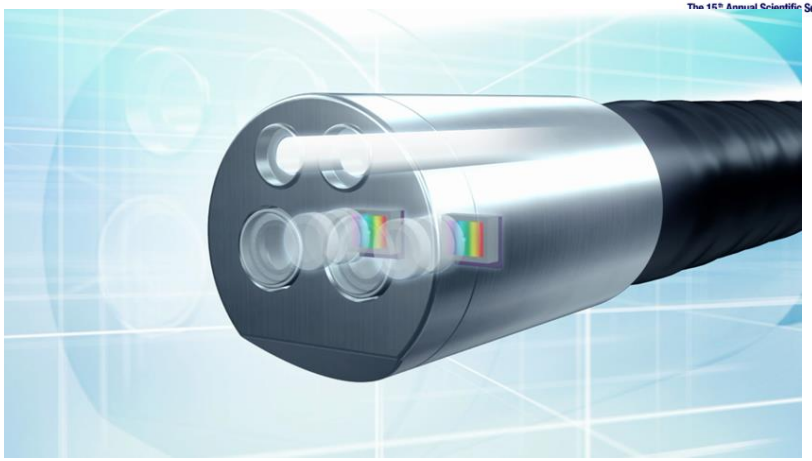
Open Surgery
= Correct Targeting (Visualize) + Tx. Delivery
Transformed into Minimally Invasive Procedure

The Anatomy Lesson

- 1632, Rembrandt Harmenszoon van Rijn
- Direct visualization of internal structures by Surgical dissection
- Surgical treatment has been performed by direct manipulation of organs or mass
- Accompanies pain & complications
- Effectively remove disease (mass or fluid)



Open Surgery Converted to **Minimally Invasive** Approach

- 1st thoracoscopic surgery in **1910**
- **CCD camera** played a critical role
- Gas inflation & small sized camera provided surgical views of intra-abdominal organs
- Almost all manipulations can be performed by laparoscope, endoscope or robotics – dissection, suture, hemostasis, etc.

Heart & Vessels are Filled with BLOOD

- **Ultrasound** or **X-ray** can visualize cardiovascular system
- **Fluoroscopy** – most widely used X-ray guiding instrument
- Source: Ionizing radiation
- Prompt visualization
- Virtually all **projection** angles ON **2D**
- Over the guidewire (OTW) system – anatomical translation by the wire location & bending
- Radiation hazards – direct or indirect, beyond dosage

Maria Sklodowska Curie

(1867~1934)

2 Nobel Prizes (Physics, Chemistry)

Died from unprotected radiation exposure (leukemia, aplastic anemia, myalgia, cataract, etc.)

How to Assess Procedural Outcomes by X-ray or US

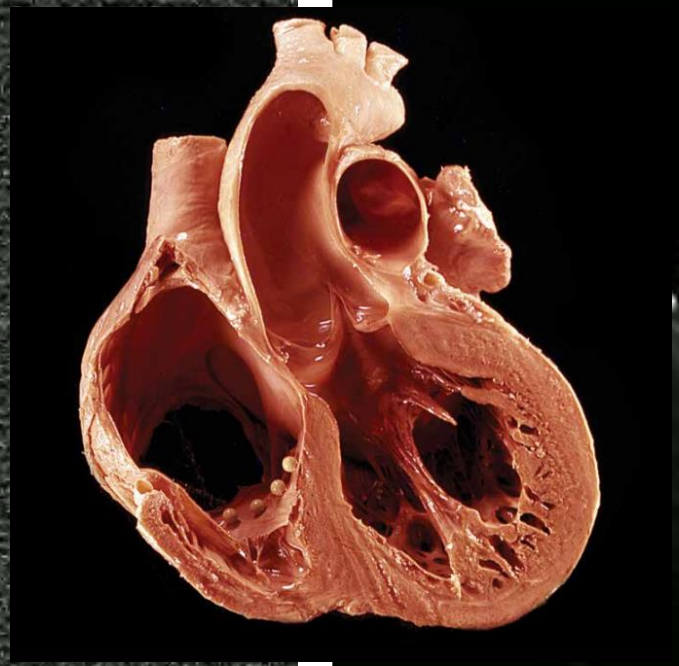
Advantages & Limitations

- **With X-ray**
  - Prolonged X-Ray exposure with higher resolution & power - helpful
  - Repeated angiography with large amount of contrast media - helpful
  - **Indirect** visualization, Imagine within operators' imagination - limited values

- **With Ultrasound (Echo – TTE, TEE, ICE)**
  - **Direct** visualization of structures within the US field – 'out-of-field issue'
  - Currently available 2D ICE requires substantial learning curves
  - In conjunction with 3D navigation system, operators' learning curves & understanding can be facilitated
  - Eliminate or minimize direct / indirect hazards of ionizing radiation exposure

Same Procedure, Different Imaging Modality (X-ray vs Ultrasound)

AF Ablation Guided by Fluoroscopy+3D Nav. vs. ICE



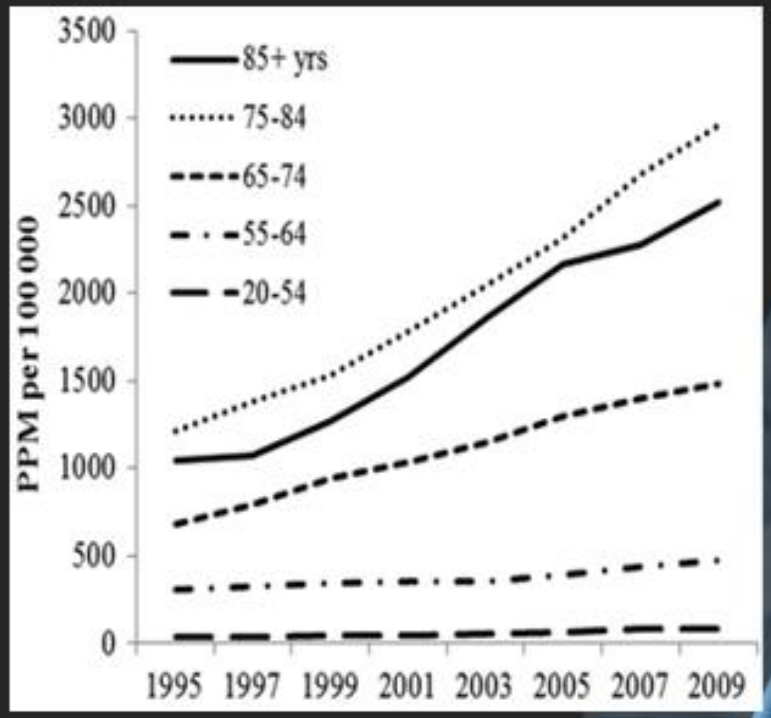
INDIRECT visualization
Detailed structures (valve leaflet, chordae, papillary muscle, atrial appendage, etc..) can**NOT** be visualized
Anatomical background knowledge required

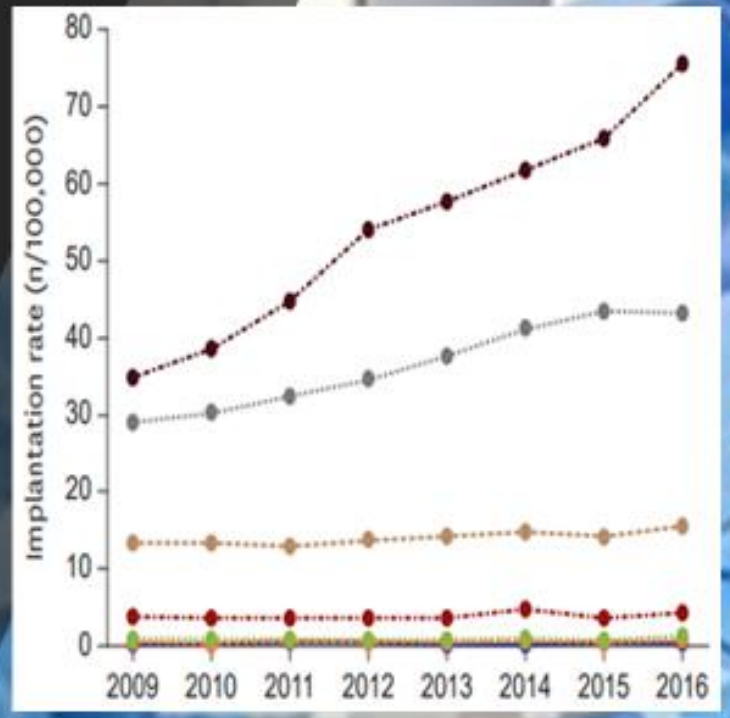
Direct visualization
Detailed structures (valve leaflet, chordae, papillary muscle, atrial appendage, etc..) can be visualized
Less anatomical background knowledge required

#2 Example of Switching Imaging Modality from X-ray to US

Pacemaker (PM) Implantation

Approx. 5,000 cases / year in Korea





Closest to radiation source (Tube)
Unprotected exposure of operator
Implantation number & rate increases
Shielding is difficult
Heavy protection wear → physical loading
Higher scatter exposure

Korean Circ J 49(9): 841-852 (2019).. Open Heart 1:e000177 (2014).

Fluoroscopy Associated Hazards is Not only direct radiation hazards but also indirect hazards!

- Small survey in Korean Heart Rhythm Society (n = 36), April 2021
- Clinical experience as an EP physician: 11.1 years [5~29]
- Male: 80.6 %
- Annual case using X-ray: 101~200 (41.7%), >200 (36.1%)
- Minimize radiation exposure (55.6%)
- Willingness to alternative imaging tool (16.7%)
- Lead Apron (100%), Goggle (69.4%), Facial shield (5.6%)
- Radiation exposure dosage awareness rate: 16.7%
- Correct dosimeter usage: 27.8%

SY Shin, unpublished data

Radiation Hazards Already Began (Survey results - Cont'd)

- Musculoskeletal pain (**88.2%**)
- Began **AFTER** working as an EP physician (81.3%)
- **Neck (51.5%), shoulder (57.6%), back (72.7%), knee (51.5%)**
- **Cataract (11.1%), Radiation dermatitis (15.4%)**
- Zero-fluoroscopic procedure attempt: AF ablation (**25%**)
  - Success rate: 41.7%, continue to use zero-fluoroscopic strategy: 12.5%
- Reasons for **NOT** using zero-fluoroscopic procedural strategy
  - Higher procedural complication rate
  - Lower success rate…

SY Shin, unpublished data

Dual Chamber Pacemaker Implantation with Intra-cardiac Echocardiography (ICE)

2021. 3. 3.

Operator: Seung Yong Shin, M.D., PhD.

Chung-Ang University Hospital, Seoul, KOREA

Procedure Time & Lead Parameters

	ICE (n=30)	X-Ray (n=235)	*P*-value
Total procedure time (min)	73 ± 22	81 ± 29	0.177
Conversion to X-ray (n, %)	5 (16.1)		
Lead Parameters			
Atrial Sensing (mV)	2.5 ± 1.1	2.7 ± 1.5	0.385
Atrial Pacing Threshold (V)	0.8 ± 0.3	1.0 ± 0.5	0.214
Atrial Impedance (Ohm)	454 ± 57	533 ± 125	< 0.001
Ventricular Sensing (mV)	8.7 ± 3.2	9.1 ± 4.1	0.630
Ventricular Pacing Threshold (V)	0.6 ± 0.2	0.7 ± 0.4	0.453
Ventricular Impedance (Ohm)	650 ± 122	687 ± 168	0.245

Reasons for Conversion to X-Ray

No	Age	Sex	Diag.	Mode	Reason for Conversion
1	82	M	SSS	DDDR	Tortuous Subclavian vein (GW to jugular vein)
2	78	F	SSS	VVIR	Markedly enlarged Aortic Root & Aneurysm (max. diameter: 69 mm) compressed RA
3	83	F	CAVB	DDDR	Tortuous Subclavian vein (GW to jugular vein)
4	80	F	SSS	VVIR	Echogenic shadow d/t tricuspid annuloplasty
5	73	M	CAVB	DDDR	Tortuous Subclavian vein

#1,3,5 cases were continued to perform ICE guided procedure after passing tortuous subclavian vein under fluoroscopic guidance (2~3 additional fluoroscopic usage) ➔ US-guided puncture!

#2 case: V lead implantation via PLSVC with ICE guided approach, but failed to implant RA lead because of collapsed RA compressed by aortic aneurysm

#4 case: RV lead was implanted under fluoroscopic guidance, then RA lead was implanted under ICE guidance

Radiation Exposure

	ICE (n=30)	X-Ray (n=235)	*P*-value
Fluoroscopic time (sec)	54 ± 93	566 ± 438	< 0.001
Dose Area Product (Gy-cm^2)	2.3 ± 4.4	27.2 ± 50.5	< 0.001
Total Air Kerma (mGy)	15.8 ± 32.6	340.6 ± 705.2	< 0.001

X-ray conversion cases were included in ICE group

Less than 10 % in time & exposure dosage!

- **Operator & workers' direct exposure – ZERO!**
- Enabled heavy protection wear free workplace!
- 2~4 fluoroscopy for lead redundancy & screw confirmation

→ **5 ~ 10 sec in usual cases**

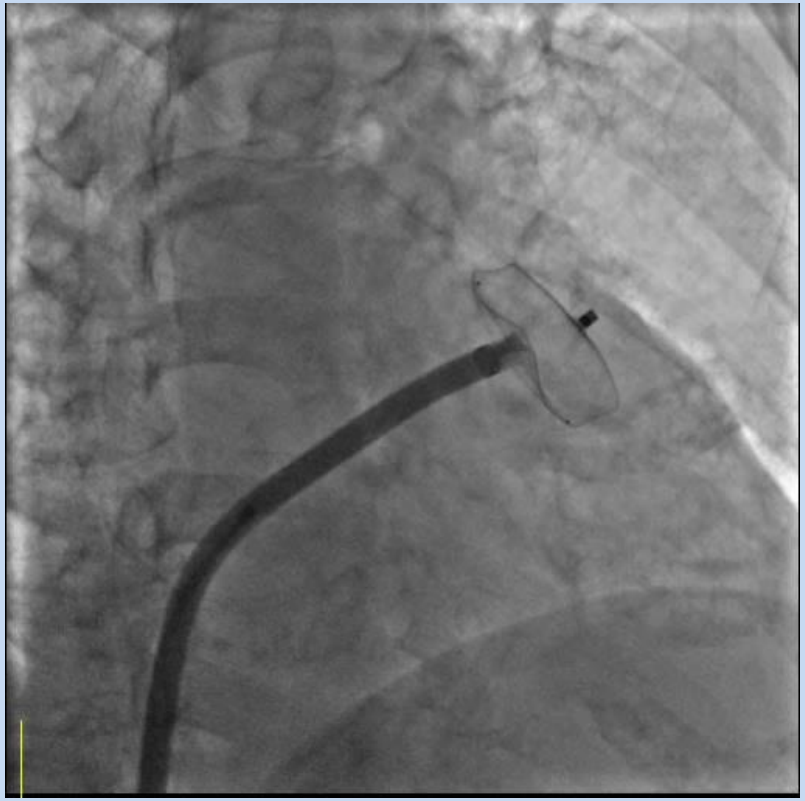
ESC
Onsit

Procedure Related Complications

	ICE (n=30)	X-Ray (n=235)	*P*-value
Death (n, %)	0 (0.0)	0 (0.0)	1.000
Pneumothorax (n, %)	0 (0.0)	2 (0.9)	1.000
Hemothorax (n, %)	0 (0.0)	0 (0.0)	1.000
Pocket infection (n, %)	0 (0.0)	0 (0.0)	1.000
Hematoma (n, %)	0 (0.0)	0 (0.0)	1.000
Cardiac perforation (n, %)	0 (0.0)	0 (0.0)	1.000
Atrial lead dislodgement (n, %)	0 (0.0)	1 (0.4)	1.000
Ventricular lead displacement (n, %)	0 (0.0)	2 (0.9)	1.000

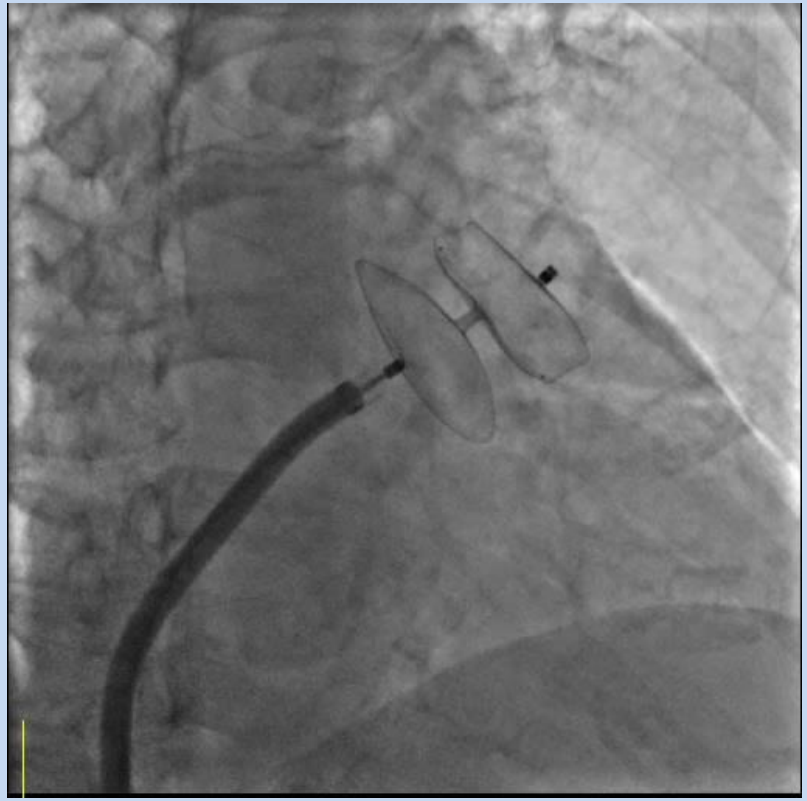
Percutaneous Closure of LAA with X-Ray

Atriography Measure



Land Lobe

- Check anchoring



Expand disc

- Tug test (3 times)

1st Challenge in 2014~2016

Intra-Procedural TEE & General Anesthesia → Fluoroscopy ONLY Feasible?

Left Atrial Appendage Occlusion (LAAO) Without Intra-procedural Trans-Esophageal Echocardiography (TEE), Is It Feasible Approach? Single Center Experience

Seung Yong Shin[1], Hong Euy Lim[2], Ju Hyun Song[1], Yong Hyun An[1], Jin-Seok Kim[2], Jeong-Min Kim[3], Kwang-Yeol Park[3], Moon Ki Jung[1], Young Kim[1], Iksung Cho[1], Hoyoun Won[1], Wang-Soo Lee[1], Kwang Je Lee[1], Sang Wook Kim[1], Tae Ho Kim[1], Chee Jeong Kim[1]

1 Cardiovascular and Arrhythmia Center, Chung-Ang University Hospital, Seoul, Korea. 2 Department of Cardiology, Korea University Guro Hospital, Seoul, Korea 3 Department of Neurology, Chung-Ang University Hospital, Seoul, Korea

BACKGROUND

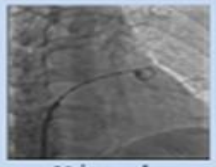
Left atrial appendage occlusion (LAAO) is frequently performed alternative antithrombotic treatment in patients with non-valvular atrial fibrillation who are intolerable to traditional oral anticoagulation. Because LAAO procedure is assisted by trans-esophageal echocardiography (TEE), general anesthesia is usually required. However, in high risk patients with multiple co-morbidities, who are not tolerable for general anesthesia, LAAO procedure without TEE under local anesthesia was tried and successfully performed without any serious complications.

OBJECTIVE

The aim of this study is to investigate the safety and feasibility of LAAO without TEE and to test the differences in long term results according to the intra-procedurally used imaging modalities.

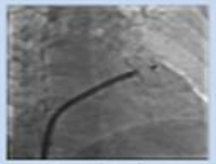
METHODS

Between May 2014 and November 2016, all consecutive patients who underwent LAAO in Chung-Ang University Hospital, were included and analyzed retrospectively. The procedures were performed using the Amplatzer cardiac plug or Amulet device (St. Jude). Pre-procedural TEE was performed in all patients and LAA anatomy was carefully examined.



Atriography

Measure



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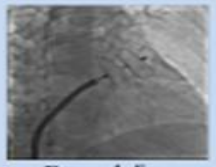

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Tug test (3 times)

According to the intra-procedurally used imaging modalities, patients were divided into 2 groups (group 1: with intra-procedural TEE, group 2: without intra-procedural TEE). Between two groups, baseline characteristics, procedure related complications, clinical outcomes were compared.

RESULTS

Forty one patients were enrolled and analyzed. Mean follow-up period was 310 ± 253 days.

Table 1. Baseline characteristics

Variables	With TEE (n = 10)	Without TEE (n = 31)	P value
Age (y)	72.3 ± 11.3	76.7 ± 6.4	0.266
Male (n, %)	3 (30.0)	13 (41.9)	0.712
Non-paroxysmal AF (%)	6 (60.0)	24 (77.4)	0.413
HF (n, %)	4 (40.0)	12 (38.7)	1.000
HTN (n, %)	10 (100.0)	30 (96.8)	1.000
DM (n, %)	3 (30.0)	4 (12.9)	0.332
Prior stroke or TIA (n, %)	3 (30.0)	15 (48.4)	0.467
Ischemic heart disease (n, %)	3 (30.0)	7 (22.6)	0.683
$CHADS_2$ score (points)	2.5 ± 1.6	2.8 ± 1.3	0.582
CHA_2DS_2-VASc score (points)	4.6 ± 1.8	4.9 ± 1.7	0.633
Major bleeding (n, %)	4 (40.0)	19 (61.3)	0.289
Liver disease (n, %)	0 (0.0)	2 (6.5%)	1.000
Chronic kidney disease (n, %)	5 (50.0)	16 (51.6)	1.000
eGFR (ml/min)	50.8 ± 36.8	57.4 ± 22.5	0.524
HASBLED score (points)	3.7 ± 1.9	3.8 ± 1.1	0.869
Echocardiography			
LVEF (%)	58.1 ± 7.8	57.4 ± 9.4	0.830
LA (mm)	45.1 ± 10.1	49.2 ± 7.4	0.175

Data are presented as mean ± SD (standard deviation). TEE: trans-esophageal echocardiography, AF: atrial fibrillation, HF: heart failure, HTN: hypertension, DM: diabetes mellitus, TIA: transient ischemic attack, $CHADS_2$: Congestive heart failure, Hypertension, Age>75, Diabetes mellitus, Stroke, CHA_2DS_2-VASc: Congestive heart failure, Hypertension, Age>75, Diabetes mellitus, Stroke, Vascular disease, Age 65-74, Sex category (female), eGFR: estimated glomerular filtration rate, HASBLED: Hypertension, Abnormal liver/kidney disease, Stroke or TIA, Bleeding, Labile INR, Elderly (age > 75), Drugs (aspirin, NSAIDs, etc.), LVEF: left ventricular ejection fraction, LA: left atrium.

Table 2. Procedure related outcomes

Variables	With TEE (n = 10)	Without TEE (n = 31)	P value
TEE			
LAA flow impairment (Grade 1–4)	1.9 ± 1.1	2.5 ± 6.8	0.141
SEC (Grade 0–4)	1.3 ± 1.6	1.7 ± 1.2	0.394
Device size			
Lobe size (mm)	25.1 ± 5.0	27.0 ± 2.5	0.198
Disc size (mm)	30.4 ± 6.0	32.9 ± 4.2	0.249
Total procedure time (min)	163.3 ± 39.8	142.2 ± 48.2	0.242
Net procedure time (min)	112.2 ± 30.8	98.6 ± 41.0	0.368
Fluoroscopy time (min)	26.9 ± 6.9	18.7 ± 11.7	0.067
Fluoroscopy dosage (mGy)	1369.9 ± 1152.4	2852.1 ± 9649.4	0.665
Any procedural complication (n, %)	0 (0.0)	2 (6.5)	1.000
Vascular complication (n, %)	0 (0.0)	1 (3.2)	
Pericardial effusion (n, %)	0 (0.0)	1 (3.2)	
Device migration (n, %)	0 (0.0)	0 (0.0)	
Stroke or TIA (n, %)	0 (0.0)	0 (0.0)	
Any follow up events (n, %)	1 (10.0)	4 (12.9)	1.000
Pericardial effusion (n, %)	0 (0.0)	3 (9.7)	
Device migration (n, %)	0 (0.0)	0 (0.0)	
Device thrombosis (n, %)	1 (10.0)	0 (0.0)	
Stroke or TIA (n, %)	0 (0.0)	1 (3.2)*	

Data are presented as mean ± SD (standard deviation). TEE: trans-esophageal echocardiography, LAA: left atrial appendage, flow: grade 1: > 50 cm/sec; 2: 30-50 cm/sec; 3: 10-30 cm/sec; 4: < 10 cm/sec, SEC (spontaneous echo contrast): 0: none; 1: mild; 2: moderate; 3: severe; 4: thrombus, *: 1 minor stroke at 3 months – might be related with incomplete endothelialization – follow-up TEE revealed no peridevice leakage

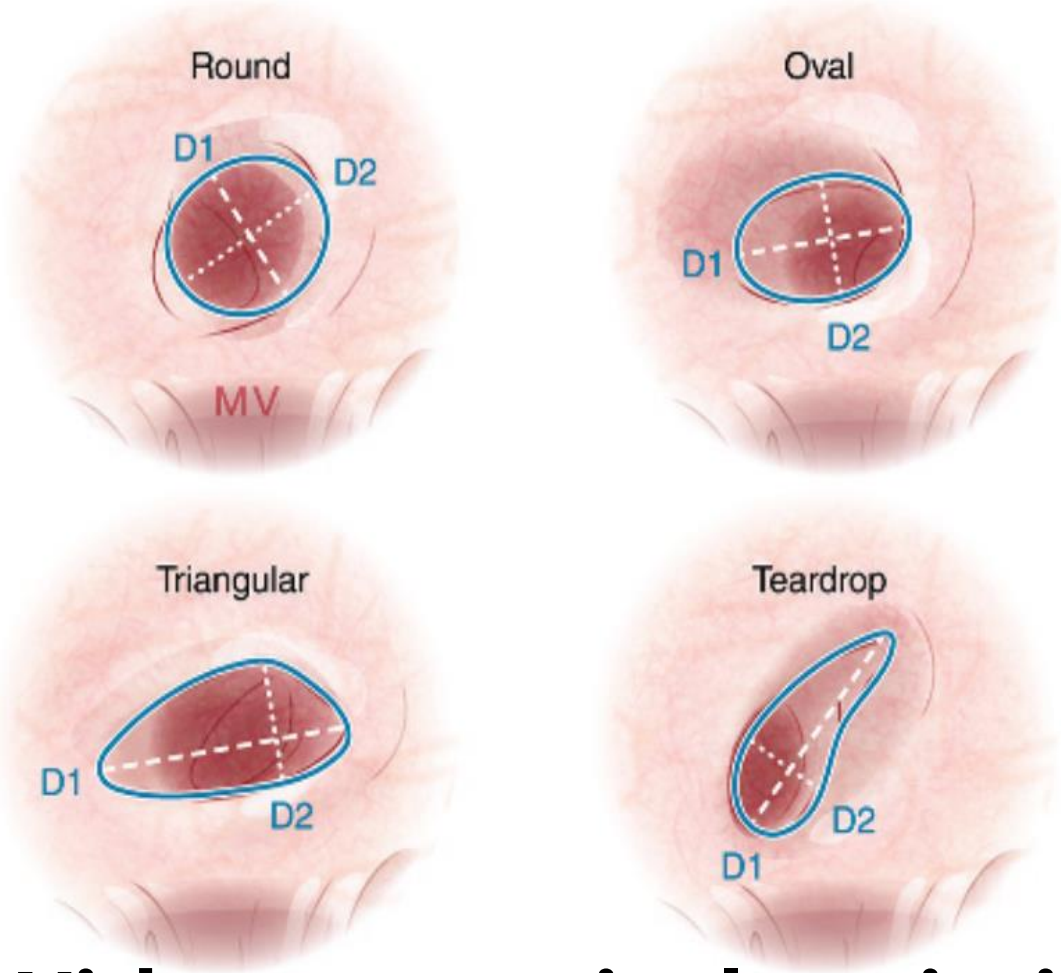
COUNCLUSION

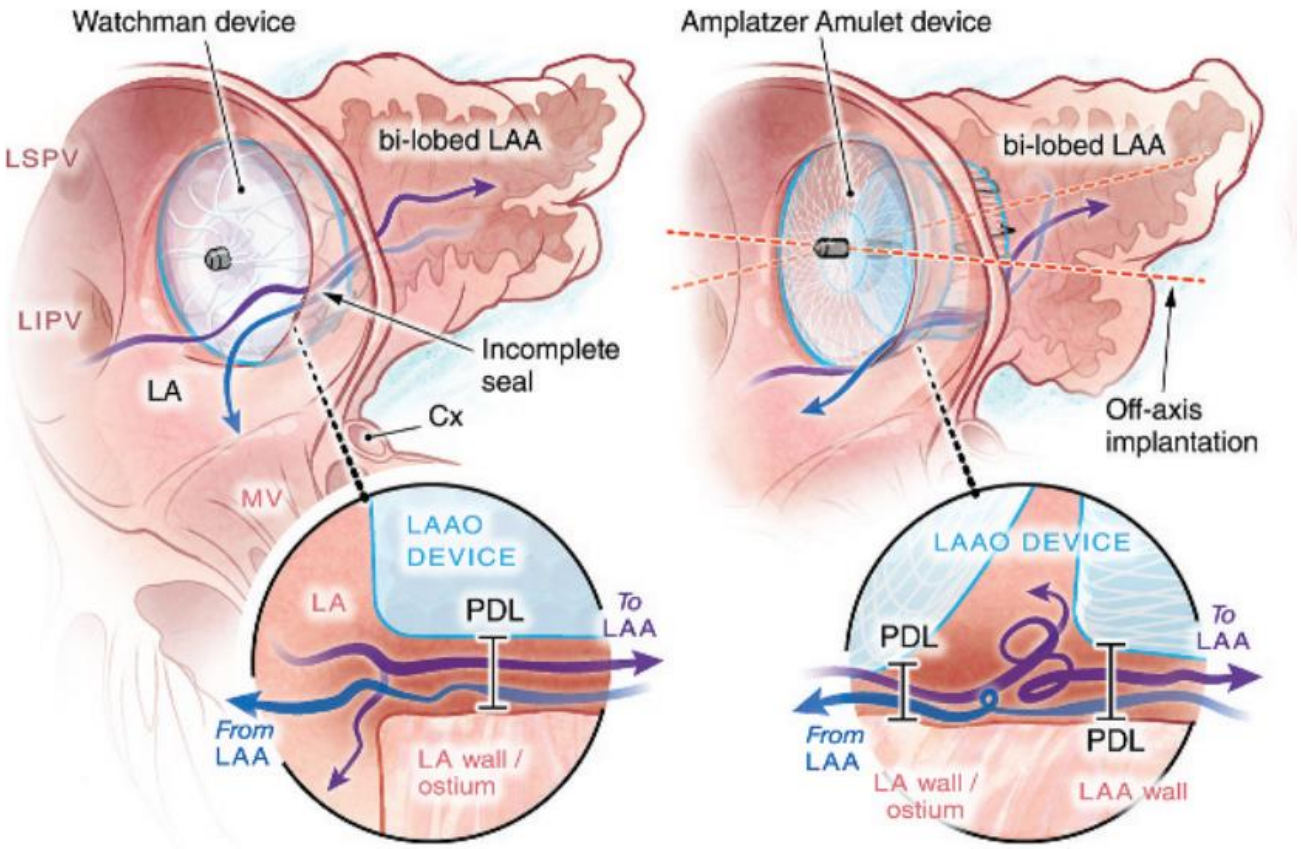
Without intra-procedural TEE, LAAO can be performed with safety similar to LAAO with intra-procedural TEE and procedure related outcomes and clinical outcomes are not inferior to LAAO with intra-procedural TEE. In addition, general anesthesia can be omitted in LAAO without intra-procedural TEE and complications related with general anesthesia can be avoided in elderly patients with high risk for general anesthesia.

LAA 18-19 November 2016- Frankfurt, Germany

Without TEE, device implantation – Feasible, But Peri-device Leakage (PDL) can be missed!

If PDL is Small, Is it acceptable?





Wide anatomical variation & Circular device ➔ PDL!

STRUCTURAL HEART 2020, 4(6):475–481. https://doi.org/10.1080/24748706.2020.1817642

Clinical Impact of PDL

- FDA approved **PDL < 5 mm accepted "sufficient LAA closure"**
- Re-categorized PROTECT-AF, PREVAIL, CAP2 participants' TEE at 45 days & 1 year ➔ **Absence of PDL vs. PDL < 5 mm**
- N = 1,054
- 404 (**38.3%**) PDL < 5 mm at 45 days TEE
- 272 (**27.7%**) **PDL < 5 mm at 1 year TEE** → increased 5 year stroke or SE risk (**adjusted HR 1.94**, 95% CI 1.15-3.29, P = 0.014)
- Mainly driven by **Non-fatal stroke**

J Am Coll Cardiol. 2022 Aug 2;80(5):469-483.

Peri-Device Leakage (PDL) is More Prevalent than Our Expectation

Table 1. Summary of definitions, frequency, modality for detection, and impact on outcomes of PDL in percutaneous LAAO studies.

Device	Year	Patients (n)	Definition and Timing of PDL	Presence of PDL or Leak (LARIAT)	Anticoagulation Regimen	Imaging	Impact of PDL on outcomes
WATCHMAN (Boston	2009	463	>5 mm, 45 days	14%[31]	See notes below	TEE	N/A
				%/<1%[30]		TEE	None
				%[20]		CT	N/A
				%[32]		TEE	None
				%[33]		CT	N/A
				59%[34]		TEE	N/A
				%[34]		CT	N/A
				e[35]		TEE	N/A
				%[20]		CT	N/A
				8%[36]		TEE	N/A
				%[21]		CT	N/A
				%[20]		CT	N/A
				%[33]		CT	N/A
				%[29]		TEE	None
				[37]		TEE	N/A
				%[32]		TEE	None
				e[38]		TEE	N/A
				5%[16]		TEE	None
				7%[39]		TEE	N/A
				%[40]		TEE	N/A
				[41]		TEE	N/A
				[42]		TEE	N/A
				e[43]		TEE	N/A
				12%/3%[44]		TEE	N/A
				[45]		N/A	N/A

?

Anticoagulation regimen in patients receiving LAAO by study:

[31] 45 days warfarin (until no PDL or PDL<5 mm), 75 mg clopidogrel + 81–325 mg aspirin (until 6 month follow-up), 81–325 mg aspirin (indefinitely)

[30] 45 days warfarin (until no PDL or PDL<5 mm), clopidogrel + aspirin (until 6 month follow-up), aspirin (indefinitely).

[20] "typically" aspirin + clopidogrel for 1–3 months, followed by aspirin alone indefinitely.

[32] Watchman: 45 days warfarin, oral antiplatelet agent for 6 months, continuation of either oral anticoagulants or antiplatelet agents "was left to the operator's discretion". Lariat: "oral anticoagulants and antiplatelet agents were discontinued immediately after the procedure in the majority and at 4–6 weeks in some. Subsequent continuation of these agents was left to the operator's discretion based on patient situation".

[33] Watchman: 45 days warfarin, dual-antiplatelet therapy for 6 months, single-antiplatelet therapy indefinitely.
ACP: dual-antiplatelet therapy for several weeks to months, and a single-antiplatelet drug or no medication thereafter.

[34] Oral anticoagulation for 45 days unless PDL >5 mm, clopidogrel up to 6 months, aspirin indefinitely.

[35] Dual anti-platelet therapy (aspirin 80 mg/day and clopidogrel 75 mg/day) for a minimum of three months followed by aspirin indefinitely.

[36] Following implantation, a loading dose (6[illegible] mg) of clopidogrel was administered, and treatment was started with 300 mg aspirin (ASA) on the first day and 100 mg daily thereafter. Clopidogrel was maintained for [illegible]6 months, barring hemorrhagic complications, and ASA for [illegible]12 months. If thrombus occurred, subcutaneous enoxaparin in a therapeutic dose was added for 2 weeks, clopidogrel was prolonged and the TOE was repeated to check for disappearance. If the result was negative, the decision to prolong the treatment for another week or hospitalize the patient and begin treatment with intravenous heparin was evaluated.

[21] Anticoagulation therapy was discontinued at discharge in all patients (one patient had thrombus treated with 3 weeks of LMWH).

[29] Antithrombotic therapy recommendation by the device manufacturer after LAA closure was aspirin [illegible] mg/day and clopidogrel [illegible] mg/day for 1 to 3 months, followed by aspirin [illegible] to 100 mg/day for at least another [illegible] months. However, the choice and duration of antithrombotic therapy were individualized on the basis of physician preference and recorded at admission and last follow-up visit

- Antithrombotic therapy use post–LAA closure was available in 255 patients; of these, 159 were on dual-antiplatelet therapy, 79 were on single-antiplatelet therapy, 16 were on OAC, and 1 was receiving no antithrombotic agent post–LAA closure.

[37] Discharged on a single-antiplatelet agent (23.0%), dual antiplatelets (54.3%) or an oral anticoagulant (18.9%).

[38] Patients with a contraindication to warfarin remained off warfarin. Patients with a CHADs-VASC score of 2 or higher who could tolerate warfarin (i.e., noncompliant or labile international normalized ratio level) were recommended to continue warfarin or a NOAC. Patients with a CHADS-VASC score of 1, anticoagulation was left to the discretion of the referring physician.

[16] Postprocedural medical therapy (including antithrombotic therapy) was prescribed according to the operator's preference

- 85% of patients were discharged on antithrombotic therapy: 50% on antiplatelet therapy (aspirin in 18%, clopidogrel in 2%, and dual-antiplatelet therapy in 30%) and 35% on OAC (warfarin in 26%, rivaroxaban in 5%, and dabigatran in 4%).
- At 6-month follow-up, [illegible]1% of patients were on OAC and [illegible]4% on antiplatelet therapy.
- At 12-month follow-up, [illegible]% were on OAC and 4[illegible]% on antiplatelet therapy. Patients were kept on OAC either because leaks were observed or because they underwent AF ablation procedures at follow-up.

[39] Anticoagulation was resumed after LAA exclusion in all patients except those with prohibitive bleeding (67.4%) and high fall risk (11.6%). The other 21% patients were on OAC at 6 weeks, and all of them were off OAC at 6, 12, and 24 months, unless they were found to have a thrombus on follow-up TEE (n ¼12) that required reinitiating of OAC.

[40] Clopidogrel [illegible] mg daily for [illegible] months then aspirin 100 mg daily indefinitely.

[41] Dual antiplatelet therapy with aspirin and clopidogrel for 3 months, followed by aspirin alone. At 1 month a relevant leak of ≥5 mm was observed in 3/60 (5%) patients, which persisted during 12- month follow-up. After its detection, antiplatelet therapy was switched to oral anticoagulation.

[42] 100 mg aspirin and 75 mg clopidogrel was recommended for 3 months

- 2 patients required warfarin for device thrombus and maintained INR > 2 until 3-month follow-up, then phenprocoumon.
- 2 patients required warfarin for device thrombus and maintained INR > 2 until 3-month follow-up, then phenprocoumon.

[43] Aspirin 81 mg/day and clopidogrel 75 mg/day for 3 months and single-antiplatelet therapy (usually aspirin) indefinitely.

[44] Most patients (~90%) were discharged on single or dual-antiplatelet therapy, whereas only 4% of patients received oral anticoagulation.

- 5 patients with device-related thrombosis received oral anticoagulation.
- 5 patients with device-related thrombosis received oral anticoagulation.

[45] Not reported.

Post-LAAO Anti-thrombotic regimens are not standardized!

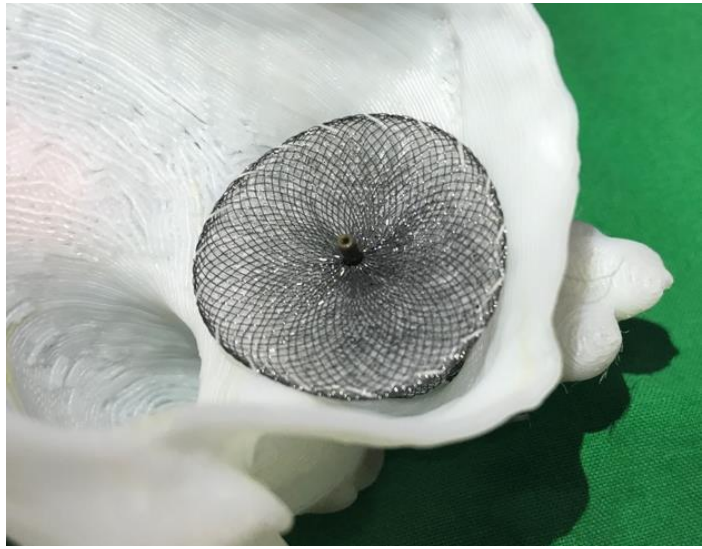
Should be individualized according to indication & procedural outcomes!

Notes. Abbreviations: PDL, peri-device leak; TEE, transes[illegible]

STRUCTURAL HEART 2020, 4(6):475–481. https://doi.org/10.1080/24748706.2020.1817642

Device Size Determination

- Every patient has his/her ***best fitting device*** (device size selection from pre-made device vs. manufactured device for his/her LAA anatomical characteristics)
- Repeated Trial increases **Risk** of Perforation/Embolization/Device damage



➔Discard or Disappoint?

1.8
devices/patient
in PROTECT-AF

3D Printing model based Pre-procedural simulation can Reduce Risk and Improve Outcomes!

Improving Left Atrial Appendage Occluder Size Determination by using 3-Dimensional Printing Model of Left Atrial Appendage

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Purpose

- The left atrial appendage(LAA) is the main source of thromboembolism in atrial fibrillation. Percutaneous left atrial appendage occluder(LAAO) has shown effectiveness in decreasing events without increasing bleeding risk.
- However, given the complexity of LAA structure, current 2D based LAAO device size prediction system using transesophageal echocardiography(TEE) has limitations.
- The aim of this study was to assess the accuracy of LAAO size determination method by implantation simulation using 3D printed model compared with conventional method based on TEE.

Methods

- We retrospectively reviewed 57 cases with percutaneous LAAO using Amplatzer Cardiac Plug and Amulet (St. Jude Medical, Inc.) from 2014 to 2018.
- We excluded cases without cardiac CT(21 cases) or with peri-device leakage or inappropriate position of the device on six months follow up TEE(6 cases), or with paroxysmal atrial fibrillation(2 cases).
- 29 cases with anatomically and physiologically properly implanted LAAO were finally included, using the device size as a standard for the size prediction.
- 3D printing models were generated from cardiac CT images using Dimension SST 768 (Stratsys Inc.) printer with fused deposition modeling P400 ABS material.
- LAAO size was determined with device implantation simulation using 3D printing model and occluder devices, and conventional 2D TEE measurements by 2 experienced cardiologists who were blinded to the size of the actually implanted device.

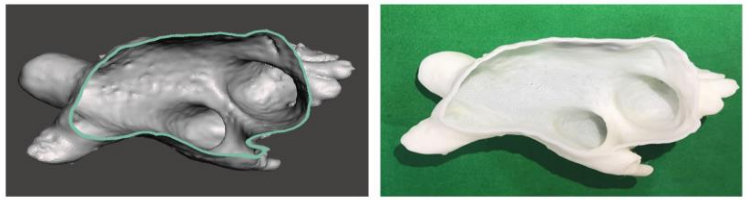


Figure 1. 3D printed model of left atrium

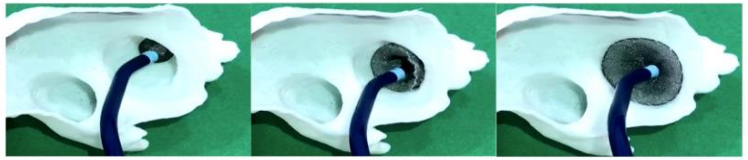
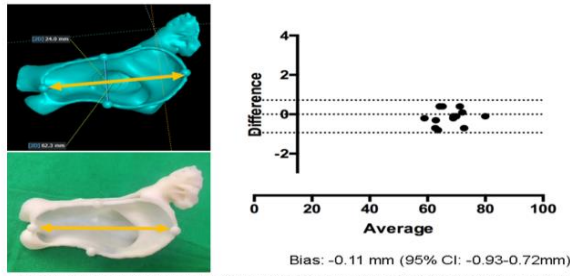


Figure 2. Implantation simulation using 3D printing model and occlude devices

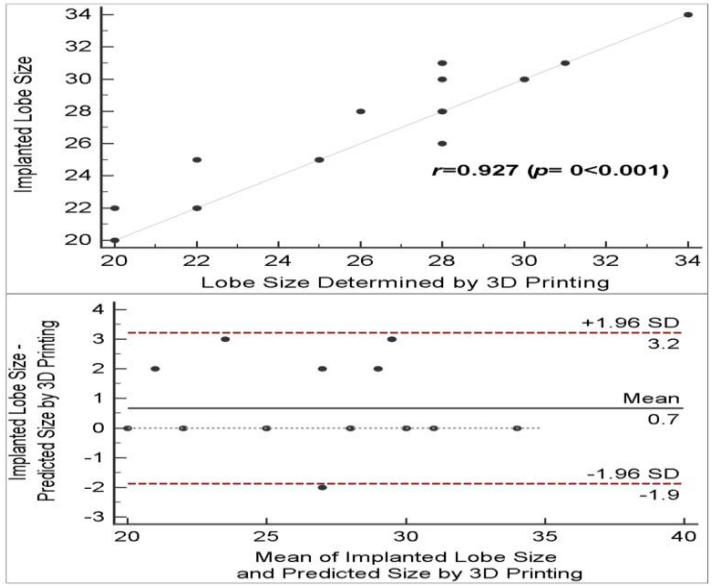
Results

- **Accuracy in size of printed 3D models compared with CT images**



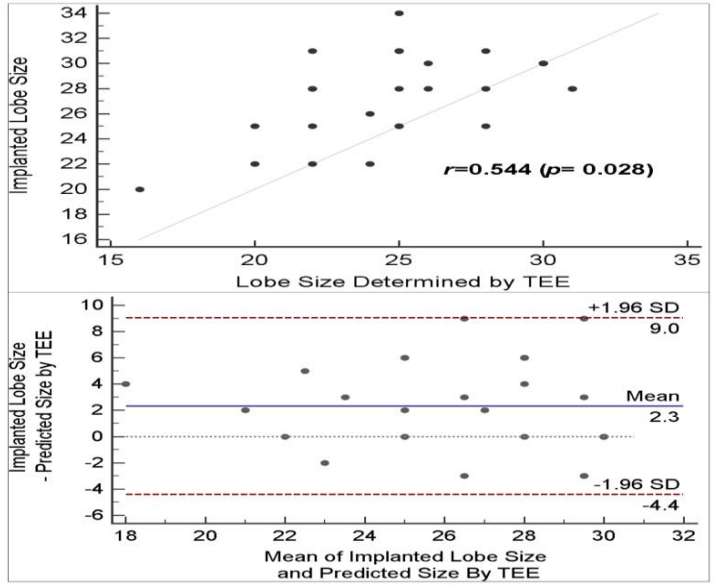
Minimal bias of [-0.11 mm] between 3D images and printed left atrium models.

- **LAAO sizing by simulation with 3D printing and actually implanted size**



Excellent agreement (r=0.927; bias=0.7±2.5) using implantation simulation with 3D printing model.

- **LAAO sizing by 2D TEE measurements and actually implanted size**



Poor agreement (r=0.544; bias=2.3±6.7) using implantation simulation with 3D printing model.

Conclusions

- Proper LAAO size prediction using 3D printing based device implantation method showed excellent accuracy.
- Prospective trials evaluating the clinical utility of this method are mandatory

Declaration of interest

- The authors have no financial conflicts of interest to disclose concerning the presentation.
- Relationships with commercial interests:
  - Grants/Research Support: None
  - Consulting Fees: None
  - Speakers Bureau/Honoraria: None
  - Other: None

Presented in ESC 2019, published in Scientific Report in 2022

More efficient ways using ICE?

CHORUS Minimalist Approach (MA)

- **C**omprehensive
- **H**ybrid
- **O**rganized
- **R**esources
- **U**tilization
- **S**trategy

* **Key Components for CHORUS MA**

- Pre-procedural device size determination ➔ **3DP Simulation**

- **ICE guide device delivery & verify PDL**

- No or minimized Intra-procedural LAA angiography & no touch device delivery (minimize the risk of (micro) thromboembolism)
- By using ICE, general anesthesia becomes unnecessary
- Intra-procedural steps are minimized

* **Advantages of CHORUS style minimalist approach**

- Harmony of improved efficiency & minimized risk
- Minimize redundant (imaging tools/personnel, other personnel – anesthesiologist and accompanying personnel, etc.)

CAUH's Experience

Minimalist approach vs. Conventional approach

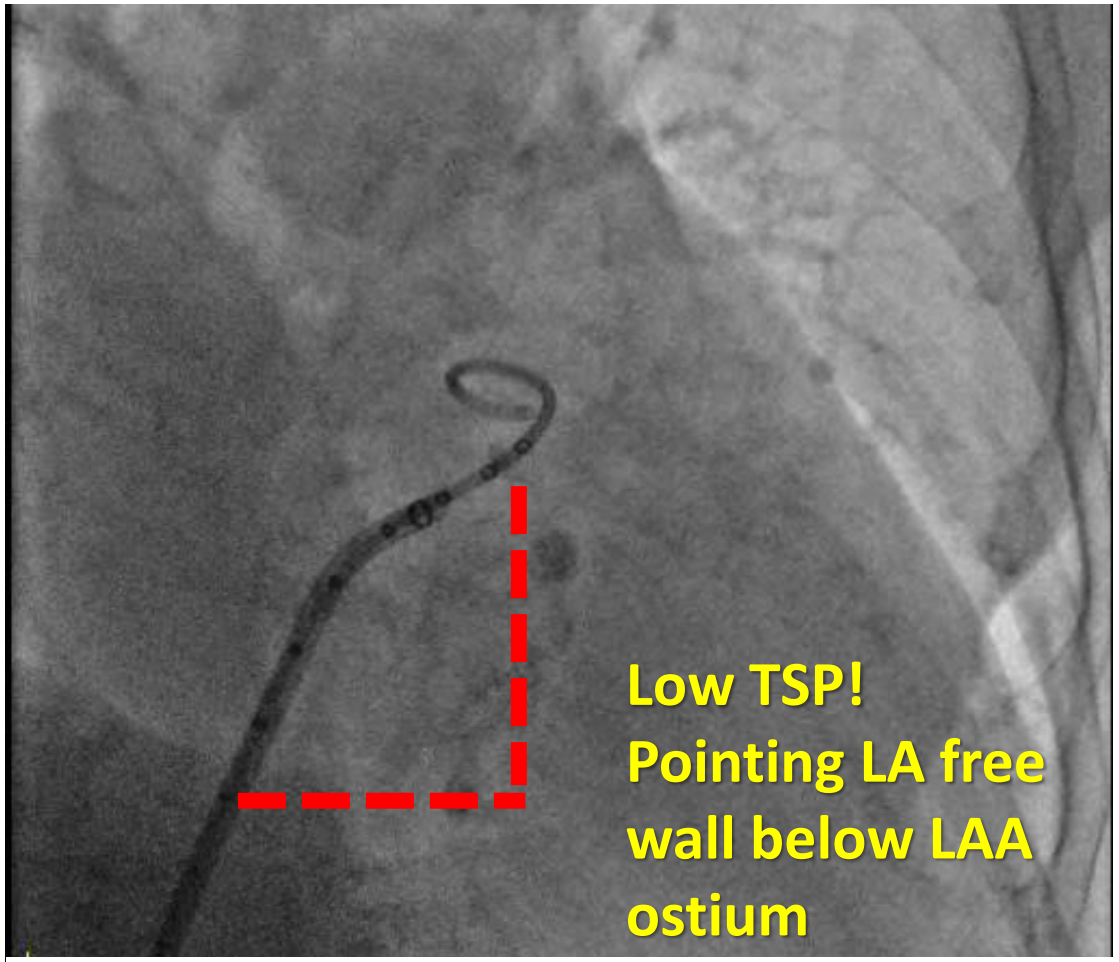
	Minimalist approach (n = 28)	**Conventional approach (n = 53)**	***P* value**
Age (years)	74.8 ± 9.5	75.4 ± 11.4	0.815
Male (n, %)	14 (50.0 %)	28 (52.8 %)	0.993
CHA_2DS_2-VASc score (pts)	4.5 ± 1.4	4.1 ± 1.6	0.500
Prior Ischemic Stroke	14 (50.0 %)	21 (39.6 %)	0.509
HAS-BLED score (pts)	3.9 ± 0.6	3.9 ± 0.8	0.751
Procedure-Related Outcomes			
Success rate	28 (100 %)	52 (98.1 %)	0.455

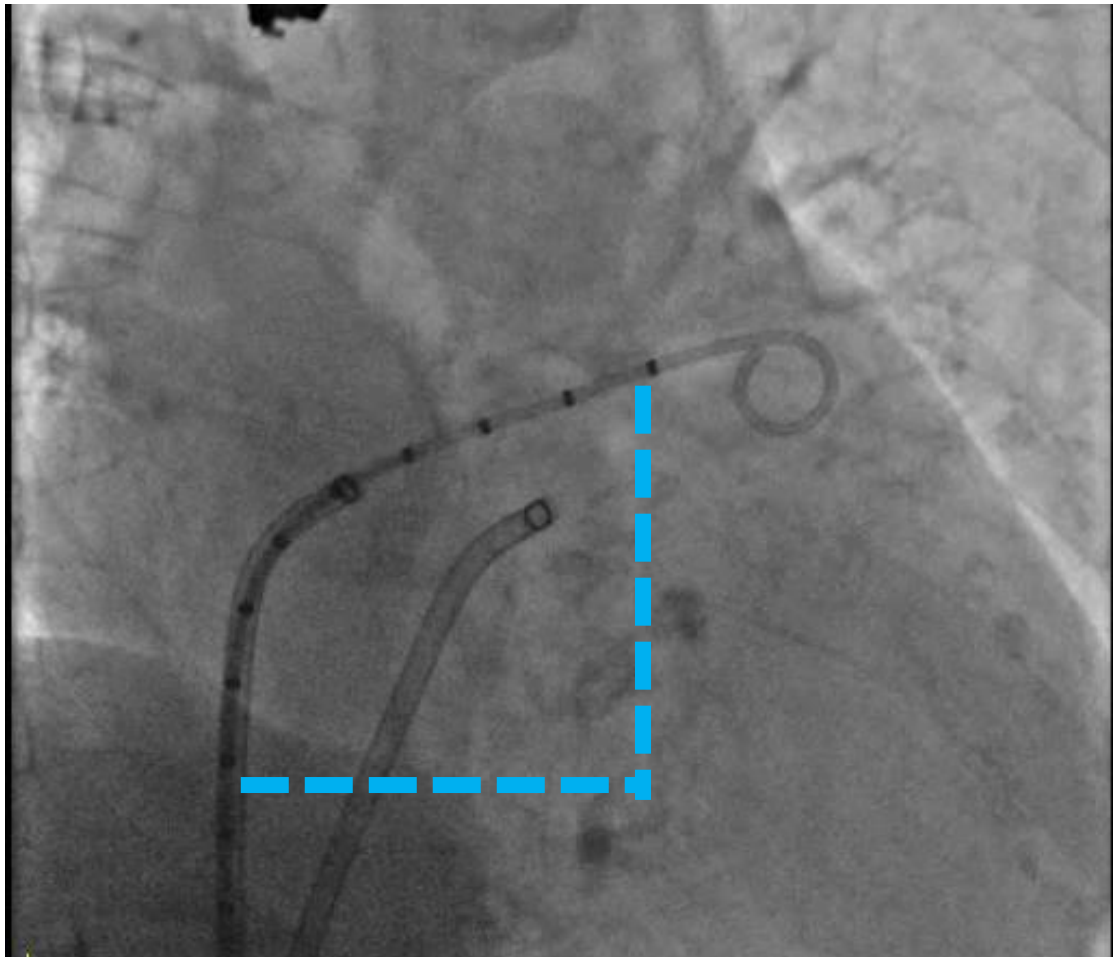
Poster Presentation in HRS 2023

	Minimalist approach (n = 28)	Conventional approach (n = 53)	*P* value
Procedure-Related Outcomes			
Procedure duration (min)	88.7 ± 62.1	108.0 ± 37.6	0.141
Fluoroscopy time (min)	10.2 ± 4.8	20.6 ± 9.8	< 0.001
Radiation exposure (DAP)	44.0 ± 48.3	131.9 ± 128.8	0.001
Contrast (mL)	150.9 ± 73.2	296.5 ± 155.8	0.002
Device size (mm)	26.8 ± 3.0	27.9 ± 3.7	0.443
# of Implantation Attempt	1.6 ± 0.9	2.8 ± 2.1	< 0.001
# of Angiography	2.0 ± 1.3	5.7 ± 4.7	< 0.001
Pericardial effusion	1 (14.3 %)	3 (6.8 %)	1.000
Peri-device leakage			0.935
Insignificant (< 3mm)	11 (39.2 %)	28 (59.6 %)	
Significant (≥ 3mm)	0	3 (5.7 %)	
Device embolization	0	1 (1.9 %) *	0.455
Peri-procedural Stroke	0	1 (1.9%) **	0.455

Improper Aiming vs. Correct Aiming

- Nearest puncture crossing point between IAS and ideal delivery path (straight line to the center of LAA ostium)



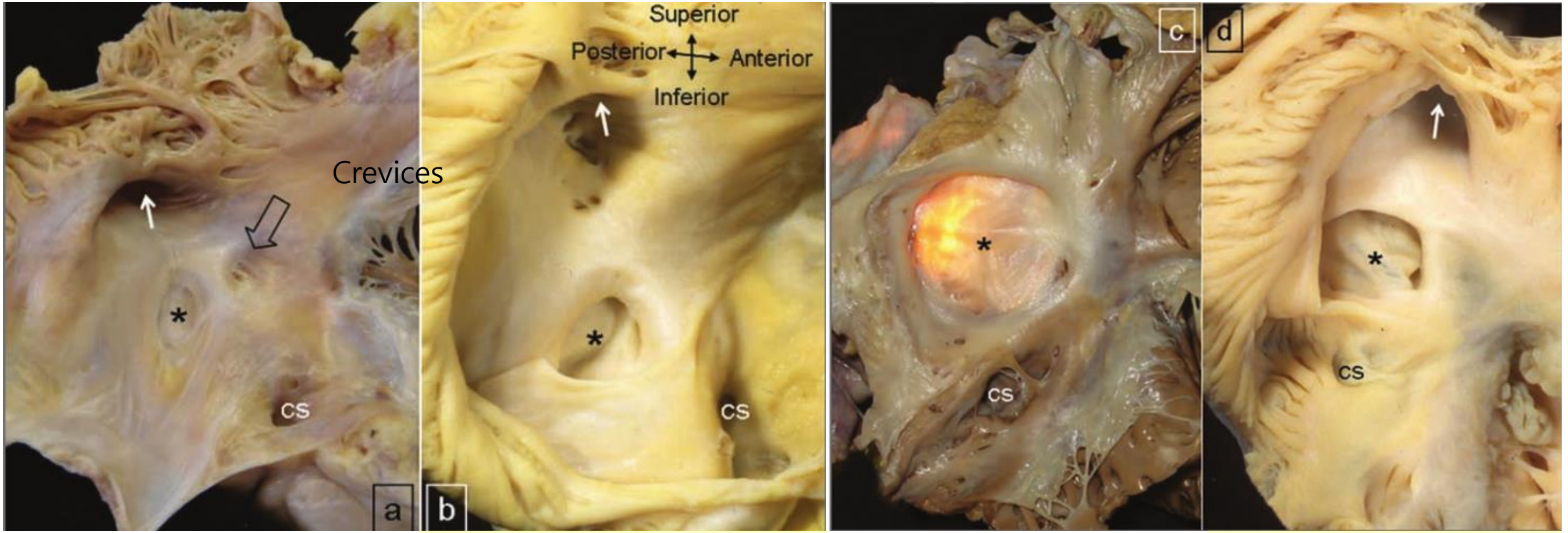


Perform another septal puncture **without** removing the 1st puncture

Guide Aiming on Target

Trans-septal puncture (TSP) is **NOT** merely entering LA **BUT** a way to correct delivery!!

Target of TSP: Fossa Ovalis (FO*)
Wide Anatomical Variations



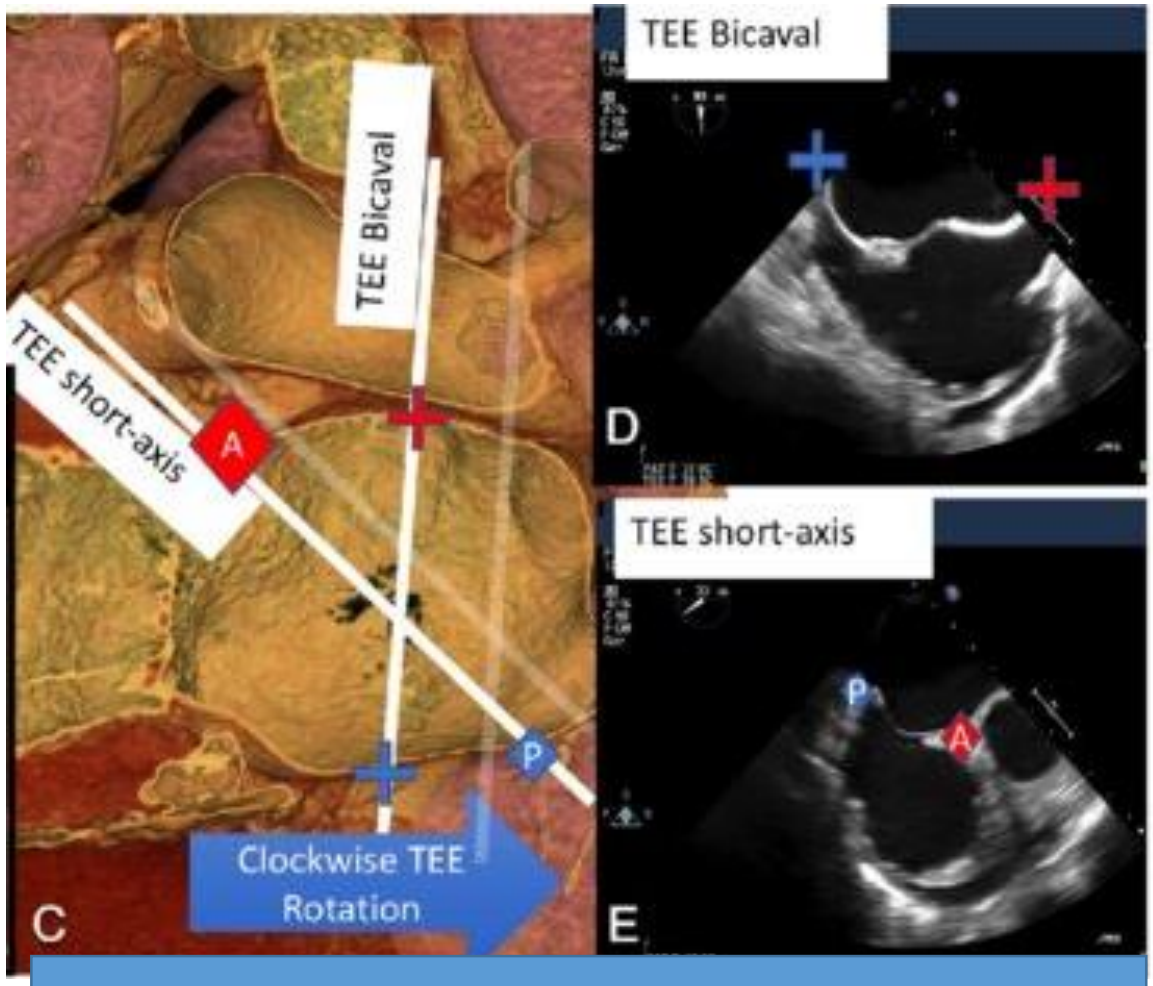
Small FO
Muscular rim is not distinctive

Muscular rim is promi-nent

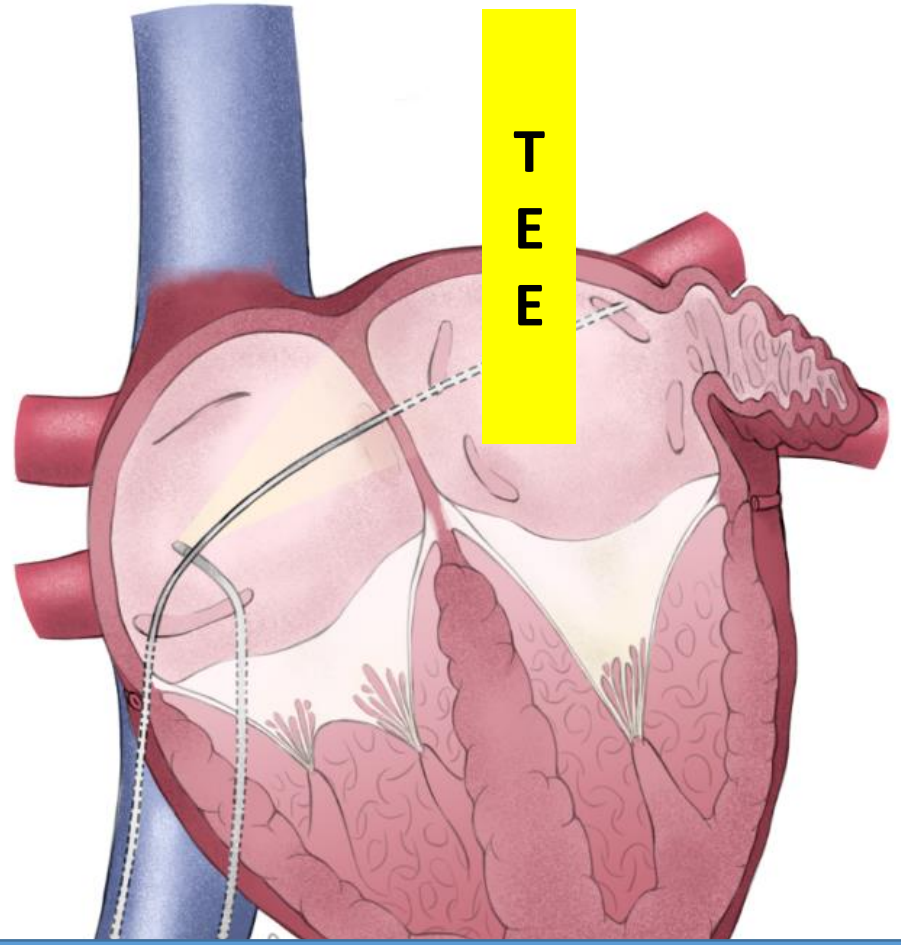
Large & Thin FO
Muscular rim is well defined

Aneurysmal FO, herniated into RA

Is TEE Sufficient?

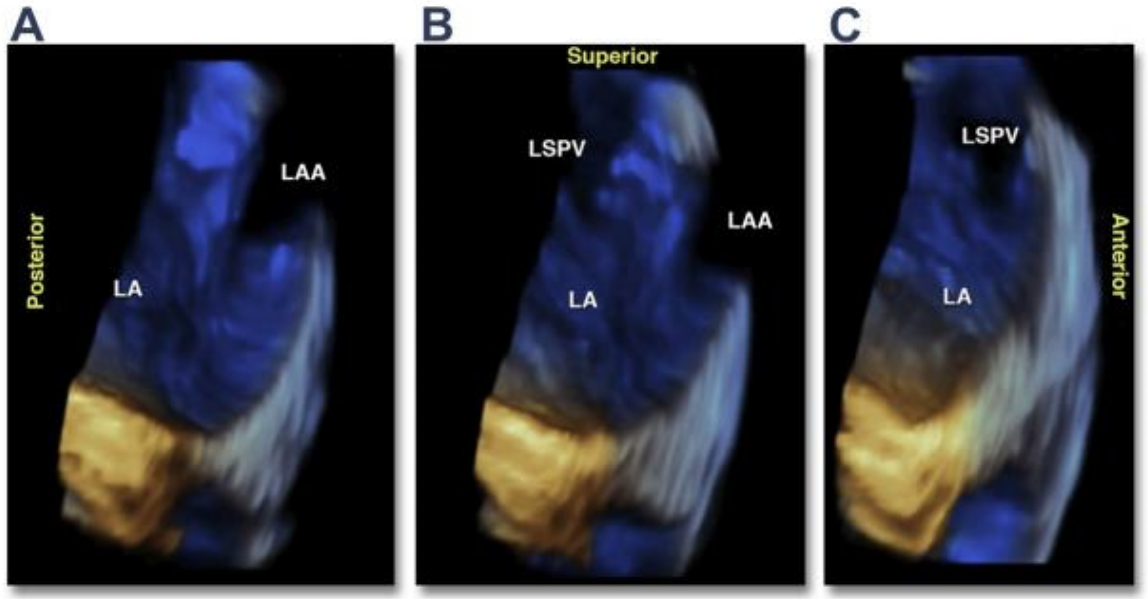


X-Plane in TEE



Straignt Line to Target

4D ICE (Real-time + 3D visualization)

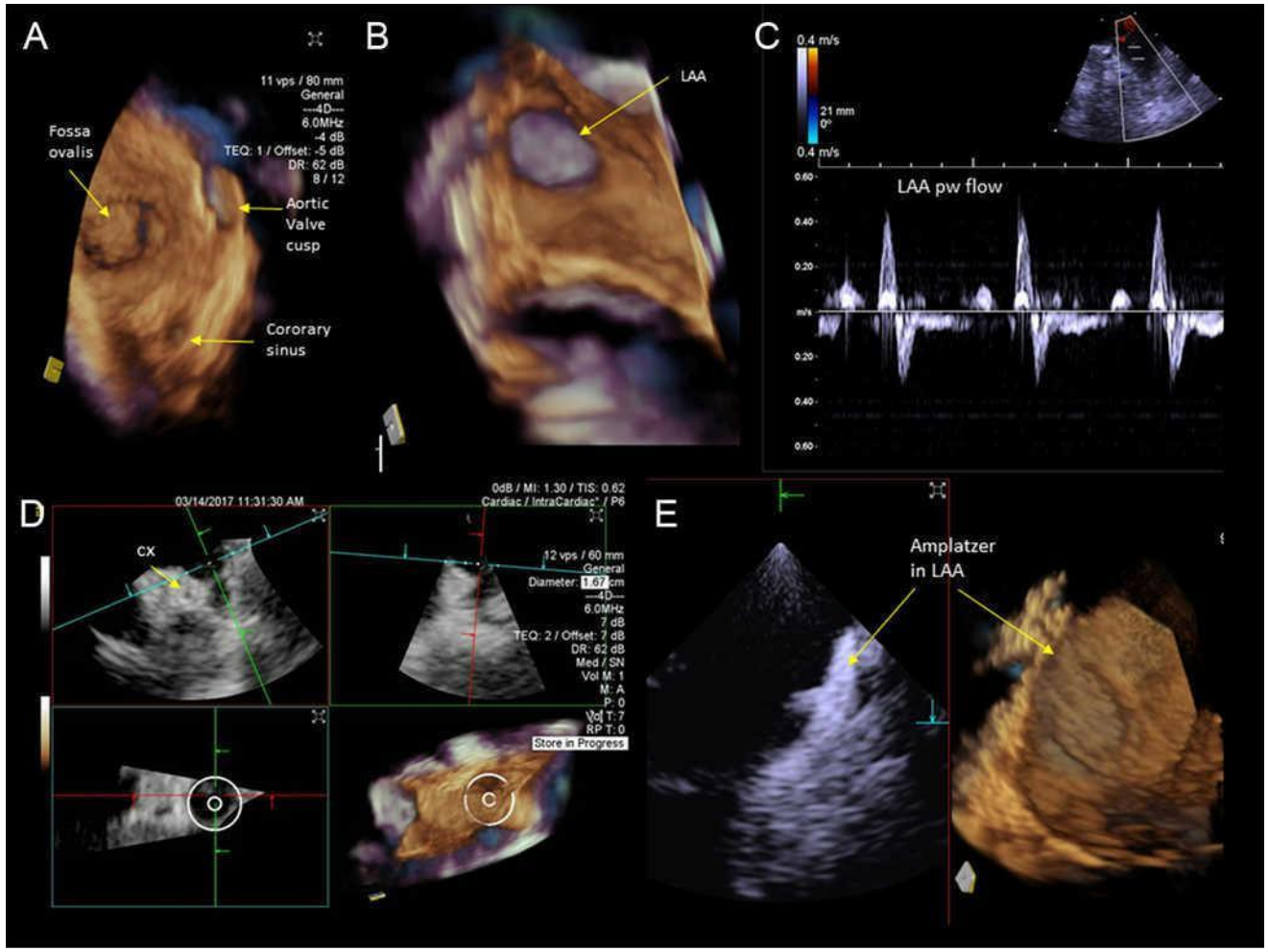


short elevation angle (maximum 90° x 24°), which limits its ability to view complete cardiac structures or devices.

Brysiewicz et al. JACC imaging 2014:7; 97 - 100

Narrow width → Improving!

90° x 24° 90° x 50°



Rev Esp Cardiol. 2018;71:293

ACUSON SC200 ultrasound system (Siemens Healthineers, Erlangen, Germany), the **ACUSON AcuNav Volume ICE technology** is a 12.5-Fr catheter, capable of obtaining a volume **of 90° x 50°** with a volume frame rate of **16 volumes per second**.

Role of ICE in EP Domain

- **Direct & real-time** visualization of internal structures
- **Higher resolution** (similar level to optical imaging with CCD) is necessary
- Ideally, **real-time 3D** visualization – available soon (fast moving structures i.e. valve leaflet)


Thank you
for
Your Attention
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