Utility of intracardiac echocardiography (ICE)

Hye Bin Gwag, M.D.
Division of Cardiology, Department of Internal Medicine, Heart Vascular Stroke Institute, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Republic of Korea
Outline

• Introduction of ICE catheter
  – Structures, catheter types, manipulation
  – Basic views of ICE imaging

• Clinical applications of ICE

• Our experiences

• Remaining issues & summary
Structure of ICE catheter

- Piezoelectric crystals are arranged in circumferential fashion (radial) or linear fashion (phased array) in the transducer.

- It functions as a transmitter and a receiver of ultrasound by alternating electrical current to ultrasound and vice versa.

*EuroInterv.2006;1:454-464*
• Phased-array systems use a linear array of crystals parallel to the catheter body to produce a sector scan parallel to the long axis of the catheter.

• A **phased-array** ultrasound-tipped catheter is preferable, especially in catheter-based ablation procedures because of sector imaging, flexibility in changing the frequency, and full Doppler capabilities.

The arced sector from a phased array 2-D echocardiogram

The arced sector imaged with phased array scanners.
Radial ICE: A crystal rotates providing cross-sectional images in a 360° radial plane. 3-D reconstruction of the anatomy can be obtained by pulling the catheter within the heart.
Commerially available ICE catheters

- **ACUSON AcuNav™ ultrasound catheter (Siemens-Acuson)**
  - 8 or 10 Fr catheter; 90 cm; 4-way steering to 160 degree
  - Phased array & 64 elements
  - 15cm penetration; sector image of 90 degree
  - Provides Doppler imaging capabilities

- **Soundstar catheter**: with location sensor, 3D reconstruction using CartoSound system
• ACUSON AcuNav™ ultrasound catheter compatibility

- **GE**
  - Vivid™ i
  - Vivid™ q
  - Vivid™ iq

- **Siemens**
  - Sequoia™
  - Cypress™
  - ACUSON X300™
  - ACUSON X700™
  - ACUSON SC2000™

- **GE 2-D imaging Frequencies**
  - 11.5 / 10.0 / 9.0 / 8.0 / 6.0 / 4.5MHz
  - 11.5 / 10.0 / 9.0 / 8.0 / 6.0 / 4.5MHz
  - 11.5 / 10.0 / 9.0 / 8.0 / 6.0 / 4.5MHz

- **Siemens 2-D imaging frequencies**
  - 10.0 / 8.5 / 7.5 / 5.5MHz
  - 7.0 / 6.0MHz
  - 8.9 / 6.7 / 5.0MHz
  - 1.0 ~ 17.0MHz
  - 5.0 ~ 10.0MHz
Swift Link Connection
• **ViewFlex™ Xtra ICE Catheter (Abbott)**
  
  – Single-handed, self-locking steering
  
  – 64 element phased array
  
  – 9 F catheter size; 10 F introducer; 90 cm insertable length
  
  – Four-way tip deflection
  
  – 20 degree tip deflection
- ULTRA ICE™ PLUS (Boston)

Rotating Drive Shaft  Clear Acoustic Window  Radiopaque Tip  

Single Large Aperture 9 MHz Transducer

ULTRA ICE™ PLUS Catheter 360° view

VS.

Phased Array Catheter Pie-Shaped Wedge View
Catheter manipulation

- Clockwise/counterclockwise rotation
- Advance/withdraw
- Anterior/posterior or left/right tilt using the handle
Basic views

- From the mid right atrium

*EuroInterv.2006;1:454-464*
12:00-3:00
① Home View
② Aorta & PA
③ LAA

3:00-6:00
④ IAS
⑤ Left PVs
⑥ Esophagus

6:00-7:00
⑦ Right PVs

10:00-11:00
⑧ Crista terminalis
Clinical application of ICE

• The first ICE transducers were described in the 1960s with one of the first descriptions of use within the cardiac catheterization laboratory in 1981 by Glassman and Kronzon.

• It provides the real-time, high-resolution images of intracardiac anatomy and physiology necessary to guide structural heart disease interventions.

• Rapid increase in complex ablation procedures within the past decade; particularly for atrial fibrillation, ventricular tachycardia, and congenital heart disease

• ICE has helped to meet the growing need for real-time monitoring of patient anatomy, catheter location, and surveillance of intraprocedural complications, such as pericardial effusion or thrombus formation
• ICE is exclusively indicated for procedural guidance **competing with** 2-D and real-time 3-D **trans-esophageal echocardiography (TEE)**.
  
  – TEE requires moderate sedation or general anesthesia; sedation risk, compromised airways, or oral/esophageal abnormality
  
  – Possible complications of TEE: oropharyngeal trauma, esophageal perforation, aspiration pneumonitis
  
  – TEE can interrupt fluoroscopic views.
  
  – TEE requires additional physician.

• It help to **reduce procedural and fluoroscopy times** and decrease overall **radiation exposure** during adult congenital heart disease catheter-based interventions.

• High resolution SoundMap
• ICE can be **concomitantly used with other imaging tools** by being overlaid on existing electroanatomical maps or imaging scans.

• Relevant **reference structures** vary according to the procedures.
  
  — Atrial fibrillation (AF): both atrium, fossa ovalis, aorta, pulmonary veins, left atrial appendage (LAA)
  
  — Ventricular tachycardia (VT): mitral/ aortic valves, papillary muscles, scars and aneurysms, sinus of Valsalva, coronary ostium, pericardial space
  
  — Congenital heart disease: each chamber, baffles/ shunts, scars

• Procedures

- Electrophysiologic (EP) procedures: 3D mapping & radiofrequency ablation, transseptal puncture, etc.

- Other procedures: ASD/PFO closure, left atrial appendage closure, transcatheter aortic valve replacement (TAVR), lead extraction, MitraClip implantation, mitral valvulopasty, closure of paravalvular leak, etc.

• Role of ICE during procedures

- Visualization of anatomy (anatomical 3D mapping, transseptal puncture, closure devices) and tissue-catheter contact; ↑efficacy and accuracy of procedures

- Monitoring before/during procedures (intracardiac thrombus, pericardial effusion); ↑ safety by continuous monitoring for complications
Utility of Intracardiac Echocardiography for Catheter Ablation of Complex Cardiac Arrhythmias in a Medium-Volume Training Center

David Filgueiras-Rama, M.D., Ph.D.,*†1 Fernando de Torres-Alba, M.D.,*1 Sergio Castrejón-Castrejón, M.D.,* Alejandro Estrada, M.D.,* Jorge Figueroa, M.D.,* Óscar Salvador-Montañés, M.D.,* Teresa López, M.D.,* Mar Moreno-Yanguela, M.D.,* José L. López Sendón, M.D., Ph.D.,* and José L. Merino, M.D., Ph.D.*

*Department of Cardiology, La Paz University Hospital, Madrid, Spain; and †Atherothrombosis, Imaging and Epidemiology Department, National Center for Cardiovascular Research (CNIC), Madrid, Spain

- Prospective, observational study
- 102 patients, 110 ablation procedures

<table>
<thead>
<tr>
<th>Types</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VTs</td>
<td></td>
</tr>
<tr>
<td>- Ischemic</td>
<td>15 (13.6)</td>
</tr>
<tr>
<td>- Non-ischemic</td>
<td>1 (0.9)</td>
</tr>
<tr>
<td>- Epicardial</td>
<td>3 (2.7)</td>
</tr>
<tr>
<td>- Others (OTVT or PVC)</td>
<td>6 (5.5)</td>
</tr>
<tr>
<td>AF/AFL</td>
<td></td>
</tr>
<tr>
<td>- Paroxysmal</td>
<td>48 (43.6)</td>
</tr>
<tr>
<td>- Persistent</td>
<td>13 (11.8)</td>
</tr>
<tr>
<td>- Left AFL</td>
<td>18 (16.4)</td>
</tr>
<tr>
<td>Others (WPW, AT, ANRT)</td>
<td>6 (5.5)</td>
</tr>
</tbody>
</table>

*Echocardiography 2015;32:660–670
Experiences in SMC

• Between Nov 2017 and May 2018
• Total 136 ablation procedures

<table>
<thead>
<tr>
<th>Types</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VT or VPC</td>
<td>33 (24.3%)</td>
</tr>
<tr>
<td>- RVOT</td>
<td>14</td>
</tr>
<tr>
<td>- LVOT</td>
<td>4</td>
</tr>
<tr>
<td>- Other ventricular chambers</td>
<td>15</td>
</tr>
<tr>
<td>AF/AFL</td>
<td>103 (75.7%)</td>
</tr>
</tbody>
</table>
1. Ablation procedures

- The development of an ICE catheter integrated into a 3D mapping system was a major technological advance. The ICE catheter with a location sensor and 3-D module allows bridging the between the anatomy and electrophysiologic targets.

- It is especially useful for the complex structures like papillary muscle, false tendon, mitral valve insertion, or other anatomic variants.
3D reconstruction of papillary muscle

Prominent Eustachian ridge in cavotricuspid isthmus

3D reconstruction of moderator band and anterior papillary muscle of RV
• Accurate anatomical confirmation is possible; aortic cusps, VTs originating from pulmonary artery myocardium

Vertically orientated aortic valve and sinus of Valsalva in patients with thoracic aorta aneurysm
Visualization and tagging of the important structures help to avoid complications; coronary artery ostium, esophagus, etc.

*Echocardiography 2007;24:533–400*
Echogenic lesion contiguous to the esophageal anterior in a patient with post-procedural LA-esophageal fistula
• ICE helps to guide **trans-septal puncture**. It is especially useful for patients with **abnormal interatrial septum** (thick, double membrane or aneurysmatic floppy septum; patent foramen ovale or atrial septal defect; lipomatous hypertrophy of the septum; previous cardiac surgery with distorted anatomy or thickened septum; after device closure of an atrial septal defect)

• ICE helps to guide the subxyphoid/subcostal *pericardial puncture*.
  
  – Rapid identification of unexpected needle puncture passing through the ventricle
  
  – Monitoring of catheter tip position and lesion morphologic change

*Echocardiography 2007;24:533–400*
• It can provide ablation target by **localizing substrate** like scar or areas of wall motion abnormality.

**M/74, ischemic VT**
The voltage mapping shows that electrical scar area matches the left ventricular septal aneurysm.
M/64, ischemic VT

Scar area marked by yellow lines at LV posterior wall near posteromedial papillary muscle

Hypokinetic LV wall with bright scar area noted by ICE
• ICE can provide imaging of **lesion morphologic changes** (swelling, dimpling, crater formation, accelerated bubbles before popping-crater like lesion development, and increased echogenicity) → titration of energy power/duration to control lesion formation and to prevent overheating

• The **catheter-tissue contact** can be monitored.

*Echocardiography 2007;24:533–400*
• Doppler color flow imaging has been effectively used for monitoring **pulmonary vein ostial narrowing** during focal AF ablation.

• A flow velocity change of $>100\text{cm/sec}$ warrants a more proximal approach to lesion deployment if possible.

• Monitoring ostial flow velocity during repeated ablation at previously ablated pulmonary veins is critical.

• One of the important roles of ICE imaging is in the early diagnosis and prevention of potential complications during ablation procedures.

• ICE has proven an effective real-time monitoring tool to enhance early detection of pericardial effusion in transseptal catheterization.

• ICE can typically detect
  – <20 cc of pericardial fluid at baseline assessment; no echo-free space or less than 1 to 2 mm of echo-free space seen posteriorly only during systole
  – Small amount (50 to 80cc); 2-5 mm of echo-free space
  – Easy to differentiate clot from fluid; more sensitive to detect small amount of pericardial effusion with greater resolution.

• The short dwell time of foreign material within the slow flow area of the left atrium is sufficient for thrombus formation.

• The thrombi are usually single, linear, and mobile, and are typically attached to a catheter or sheath.

Thrombus attached to the circular mapping catheter

Thrombus attached to the tip of transseptal sheath

2. Left atrial appendage (LAA) occlusion

- Visualization of LAA
  - Detailed scanning of the LAA from the right atrium is usually not possible due to intervening structures like septum, aorta, and pulmonary artery.
  - Clear visualization requires ICE placement adjacent to LAA; coronary sinus, right ventricular outflow tract, or pulmonary artery or imaging from left atrium.

• Role of ICE in LAAO

- LAA size measurement: good correlation between ICE-measured ostium size and landing zone measurements and angiographic measurements (ICE from RA or coronary sinus)
limited echo views: The view from the right atrium or coronary sinus can sometimes be suboptimal for LAA assessment, especially in the enlarged left atria.

- Limitations of ICE in LAAO
  - Invasiveness (additional venous access), learning curve for ICE use, and cost
  - ICE may be comparable to TEE for the guidance of LAAO.

3. Lead extraction

- Phased-array ICE increases the diagnostic yield of lead-related endocarditis compared with TEE. It is an ideal tool to evaluate the tissue-lead interface in the cardiac chambers and superior vena cava.

- Useful in lead extraction
  - Continuous monitoring; yield time for rescue intervention
  - Identification of lead-adherent echodensities and lead binding site; embolization of echodensities to pulmonary artery
  - Stratification of extraction risk by assessing lead-tissue interface
  - Watching lead-tissue interaction during extraction; plan for next tool

The presence of lead binding, as noted by increased echogenicity at the lead-tissue interface, correlates with the difficulty of the extraction.

ICE may be a more sensitive than the presence of hinge points on fluoroscopy.

*Heart Rhythm 2017;14:1779–1785*
Binding site at SVC

Binding site at tricuspid annulus

Binding site at right ventricular wall

*Heart Rhythm 2017;14:1779–1785
Pseudotamponade

4. Cryoablation of pulmonic veins

- Doppler from ICE provides a relatively simple and effective method of assessing for leaks without the need for radiocontrast or fluoroscopy.

Angiographic confirmation of LSPV occlusion

Gap between balloon and pulmonary vein detected by ICE

- 338 occlusions of 107 PVs; loss of echocontrastographic back-flow to the left atrium after saline injection
- High level of agreement with the angiographic diagnosis of occlusion
- PV occlusion during cryoablation can be effectively predicted by intracardiac saline echocontrastography. This reduces procedural time, radiological exposure and iodinated contrast use.

Our experiences

AF
VT x3
LAAO
AF case

- **Before the adoption of ICE**: pulmonary venography + anatomical mapping using catheter touch + cardiac CT
• After the adoption of ICE: pulmonary venography + non-contact mapping using ICE + cardiac CT
• **Mapping with ICE**
  
  – Respiratory synchronization: ICE catheter in hepatic vein
  
  – ECG synchronization
    
    • Sinus rhythm: end of P wave
    
    • AF: end of T wave
  
  – Helpful locations for anatomical merge: roof, posterior wall, carina, LA-LAA ridge
Respiration synchronization; ICE catheter in the hepatic vein

Anatomic mapping using ICE image (right pulmonary vein carina)
Visualization of LAA ridge from RVOT or RV base
• Monitoring for pericardial effusion during and after the ablation
VT case 1

- M/40, Recurrent outflow tract VPCs
ICE-guided anatomic mapping of outflow tract

Aortic cusp

RVOT
3D activation mapping merged with ICE imaging
Ablation from both outflow tract

RVOT

Opposing LV side
VT case2

- M/74, ischemic VT
ICE-guided anatomic mapping of LV
VT case 3

- M/63, idiopathic VT
• TTE: normal LV cavity size and function; dilated aortic root and ascending aorta

Enlarged aortic root compressing TV area
Vertically oriented aortic valve
Mitral annulus
Aortic valve
LAAO case

- From RA
• From LA
LAAO deployment

Doppler imaging
Tug test

Well visualized LAAO
Remaining issues

• **Cost**: single use; not authorized for re-sterilization

• Large sheathes are needed occasionally; vascular complication and thrombus formation

• Transient arrhythmia by catheter contact

• Further advances in ICE would increase the feasibility of ICE
  – Higher resolution and frequency agility; 3D and real-time 3D (4D) imaging
  – Miniaturization, improvement in steering mechanisms
Summary

(1) The recent advance of the real time ICE with Doppler capabilities and integration into the 3D mapping system provides the ability to directly image cardiac anatomy and intracardiac events during various procedures.

(2) The use of ICE facilitates procedural efficacy and potentially reduces complications.
Thank you