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Segmental Non-Occlusive Cryoballoon Ablation of Pulmonary Veins and Extra-Pulmonary Vein Structures: Best Practices III

Short title: *Aryana, et al., NOCA of PVs & Extra-PV Structures*

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Abstract

Although cryoballoon ablation of atrial fibrillation (AF) has been traditionally guided by pulmonary vein (PV) occlusion, there is evidence and growing interest in performing segmental, non-occlusive cryoballoon ablation to target not only large/common PVs, but extra-PV structures such as the left atrial (LA) roof and posterior wall in conjunction with PV isolation. To date, a number of studies have demonstrated improved clinical efficacy associated with non-occlusive cryoballoon ablation of the LA roof and posterior wall in addition to PV isolation, particularly in patients with persistent AF. Not only the cryoballoon can be utilized for targeting extra-PV structures through segmental, non-occlusive ablation, but the large size and durability of cryolesions coupled with the enhanced stability afforded through cryoadhesion render the cryoballoon an effective tool for such an approach. This manuscript reviews the rationale and the practical approach to segmental, non-occlusive cryoballoon ablation of large/common PV antra and the LA roof and posterior wall.

KEYWORDS: atrial fibrillation; catheter ablation; cryoablation; cryoballoon; intracardiac echocardiography; mapping; posterior wall; pulmonary vein isolation; roof

Introduction

Historically, cryoballoon ablation of atrial fibrillation (AF) has been guided by pulmonary vein (PV) occlusion.[1] This is supported by preclinical[2] and clinical[3] studies which have shown that the magnitude of PV occlusion is a significant determinant of PV isolation (PVI) durability. However, PV occlusion is not an absolute requirement for creating durable cryolesions.[4,5] Based on available data, myocardial cells are rendered electrically dormant (*i.e.*, reversible ion channel block) at +20°C to +25°C with irreversible, lethal effects achieved at temperatures of -20°C to -50°C.[6,7] Although PV occlusion likely augments the 'magnitude of the freeze', optimal tissue contact and not necessarily PV occlusion which in itself implies the same, is quintessential for creating durable cryolesions. This notion is further supported through finite element modeling data[8] and clinically corroborated when performing non-occlusive cryoballoon ablation (NOCA) to target large-sized PVs in a segmental approach as in the case of large, common PV ostia[9] and the left atrial (LA) roof ($NOCA_{ROOF}$)[10,11,12,13] and posterior wall (PW) ($NOCA_{LAPW}$)[14,15,16,17,18]. In fact, PV occlusion using the currently-available, fixed-diameter cryoballoons (23-/28-mm) is more likely to yield suboptimal results – namely, an ostial level PVI – when treating large-sized PVs or patients with persistent/long-standing persistent AF who typically exhibit large LA and PV antra.[19,20] This article will examine the procedural and practical aspects of a segmental, NOCA strategy for several LA structures, including large/common PVs as well as extra-PV structures such as the LA ridge, carina, roof and PW.

1. NOCA of Large/Common PV Ostia.

The level of PVI achieved using cryoballoon ablation has been the subject of controversy. First investigated by Reddy *et al*.[21], the level of isolation using a 23-mm cryoballoon was found to occur distally and predominantly at the PV ostia, whereas the PV antra were left largely intact/unablated. However, subsequent studies[22,23] examining the extent and level of PVI using a 28-mm cryoballoon found this to be more proximal in patients with paroxysmal AF and relatively normal-sized atria. Still, in those with marked LA enlargement or large/common PV ostia, PV occlusion using the currently-available, fixed-diameter cryoballoons can yield suboptimal/ostial PVI – even when using the larger 28-mm cryoballoon **(Figure 1-A).** As such, a segmental, NOCA strategy may be required in some cases. Not only can such an approach achieve an antral level PVI **(Figure 1-B),** but it can eliminate the need for contrast medium injection and possibly even reduce the risk of right phrenic nerve (PN) injury by avoiding distal placement of the cryoballoon into the PV ostia.[24] Arguably, this is one of the main reasons to account for a higher rate of PN injury using balloon-based versus point-by-point radiofrequency ablation (RFA) strategies.[24]

The initial step for ensuring a successful segmental, NOCA using any type of balloon catheter involves careful planning of the transseptal puncture. A posterior or a mid/high transseptal site can significantly impede the catheter reach to the desired locations on the lower segments of the LAPW and the inferior PVs. A low and anterior transseptal puncture is essential. In fact, some of the authors highly prefer crossing the interatrial septum at its utmost inferior (‘thicker’ and muscular) portion, adjacent to the inferior limbus for this approach **(Figure 2).** It is also believed that such a practice may reduce the incidence of post-ablation iatrogenic atrial septal defects,[25] which may otherwise persist in >⅓ of patients during long-term follow-up.[26]

Once the balloon is inserted via the delivery sheath into the LA, it is advanced over an inner-lumen circular mapping catheter (ILC) or a guide wire (GW), which is in turn positioned inside one of the PVs. Proper positioning of the ILC/GW is critical to the procedure as it is used as a rail to place the cryoballoon at the desired location. The ILC/GW is typically positioned in a superior PV for ablation of the superior antral segments and in an inferior PV for targeting the inferior segments. Initially, the ILC/GW may be placed distally in the desired PV to provide sufficient support and stability for the balloon, particularly when using the current-generation, short-tipped cryoballoons. Subsequent advancement or withdrawal of the ILC/GW directs the cryoballoon away or toward the targeted PV, respectively. The delivery sheath should also be deflected to point in the direction of the desired structure (*i.e.*, the inferior PVs, inferior LAPW). It is much easier to navigate the cryoballoon anteriorly or posteriorly once it has been inflated. The balloon should be guided and advanced at all times over the ILC/GW to avoid injury to the tissue by the tip of the balloon catheter. With the ILC/GW placed inside the left PVs, clocking the delivery sheath will result in a posterior balloon alignment, whereas a counterclockwise torque will steer the balloon anteriorly. Conversely, with the ILC/GW positioned in the right PVs, a clockwise torque will guide the balloon anteriorly and a counterclockwise rotation will direct it posteriorly. Positioning of the balloon can be further aided by intracardiac echocardiography (ICE) which in some systems can be integrated into the 3-D map (CartoSound; Biosense Webster, Irvine, CA) to allow direct visualization and recording of the balloon position **(Figure 3).** Though fluoroscopy may help validate an antral balloon placement, injection of contrast medium, itself, adds little value and is typically avoided during segmental NOCA. Once the balloon is placed at the desired location, ablation may begin. If suboptimal tissue contact is suspected, the operator may exploit cryoadhesion for incremental adjustments in the catheter position. This can be achieved by further clocking or counterclocking the catheter in the desired direction to improve the balloon–tissue contact. The balloon nadir temperature can prove particularly helpful in this regard, as reductions in nadir temperature correlate well with improvements in tissue contact during this procedure. This is also one of the inherent advantages of performing non-PV occlusive applications using the cryoballoon versus other similar tools. Although a comparable strategy can be employed using the RFA balloon (HelioStar; Biosense Webster), to not only achieve wide-area, antral PVI but also PW isolation (PWI),[27] in our experience, catheter stability afforded through cryoadhesion provides the cryoballoon a slight advantage for such an approach.

Perhaps, the main limitation of NOCA as compared to a conventional PV occlusion-guided method has to do with the current lack of lesion quality and durability markers. Although a great deal of data has been acquired and published over the last decade regarding the value of procedural and biophysical markers of cryoballoon ablation (*e.g.*, time-to-PVI, balloon cooling rate and thaw time) in guiding cryo-dosing and assessing lesion quality and durability,[1,3] these were all investigated in the context of PV occlusion and therefore, do not reliably apply when performing NOCA. As such, currently, most operators simply deliver a series of overlapping 120-sec cryoapplications at each balloon location.

2. NOCA of the LA Ridge and Carina.

The LA ridge and carina are sites that are frequently spared during PV-occlusive cryoballoon applications. However, both can be effectively targeted using NOCA in a similar manner as described for ablation of large PV antra. When ablating the LA ridge, the ILC/GW is placed in either the left PV (superior or inferior, depending on the PV anatomies and orientation) or the LA appendage. The balloon is then exposed over the ILC/GW. Upon inflation, the balloon and sheath are counterclocked (with the ILC/GW inside a PV) or clocked (with the ILC/GW in the appendage), to position the balloon along the ridge. Once again, ICE can prove helpful when positioning the balloon. If the operator chooses the LA appendage as the anchor site for the ILC/GW, care should be taken to avoid injury of this structure using the balloon tip. As such, the balloon should always be advanced over an ILC/GW. In addition, knowledge of the LA appendage depth and morphology, as determined by ICE or angiography, is critical for safe practices. With respect to the duration of applications, some of the authors favor prolonged cryoapplications in this area (*e.g.*, 180–240 sec) to create transmural lesions and to modify the Ligament of Marshall.

For ablation of the LA carina between the right superior and inferior PVs, the ILC/GW is inserted initially distally into one of the right PVs (most commonly, the superior) for stability. Then, with a clockwise torque, the sheath and the inflated balloon are positioned anteriorly along the carina. A similar strategy can be employed when targeting the anterior antral region of the right inferior PV by placing the ILC/GW into this vein. Once again, the key to ensuring optimal catheter maneuverability and to easily and successfully complete NOCA at this location is a low, anterior transseptal puncture. It should also be emphasized that although NOCA is believed to carry an overall lower likelihood of PN injury,[24] the anterior carina represents a site where PN suppression/injury might occur during NOCA owing to its relative proximity to the right PN. Thus, standard PN monitoring techniques[28] (*e.g.*, high-output pacing) are warranted when targeting this region. Moreover, cryoapplications at these locations are typically minimized to 120–180 sec. Post-ablation, wide-area, antral PVI and successful ablation of the LA ridge and carina should be validated through detailed mapping, preferably using a high-density mapping catheter (*e.g.,* Pentaray; Biosense Webster, Advisor™ HD Grid; Abbott), as well as high-output pacing to illustrate absence of local pacing capture. If any gaps are identified, ICE and specifically ICE image integration may be used for targeting these sites **(Figure 4-A).**

3. NOCA of Extra-PV Structures: Rationale.

Cryolesions created using the current-generation cryoballoons are typically large,[29,30,31,32] continuous[31,32] and durable[4,5,33] which render it an attractive tool for ablation of extra-PV substrates. A study[29] comparing lesion characteristics and clinical outcomes associated with catheter ablation of AF using the hot balloon (SATAKE HotBalloon; Toray Industries, Inc, Tokyo, Japan) versus the current-generation cryoballoon (Arctic Front Advance; Medtronic, Minneapolis, MN) found that lesions created using the latter were significantly larger (38±12 cm^2 *versus* 24±8 cm^2). Another study[30] investigating the extent of LA isolation using the laser balloon (HeartLightTM, CardioFocus, Inc, Marlborough, MA) versus cryoballoon (Arctic Front Advance; Medtronic), discovered that total (42±15 cm^2 *versus* 57±14 cm^2) and antral (54±10% *versus* 65±8%) areas of isolation were both greater using the latter. Similar studies examining the sizes of ablation lesions and the areas of isolation using the cryoballoon versus force-sensing RFA have shown the lesions to be significantly wider (16.7±5.1 mm *versus* 5.3±2.3 mm)[31] and more contiguous with fewer gaps[32] using cryoballoon. Though much of the published literature pertains to the Arctic Front Advance cryoballoon (Medtronic), early experiences with the Polar-X cryoballoon catheter (Boston Scientific, Marlborough, MA) suggests at least a similar or an improved level of efficacy owing to the compliance of the latter catheter.[34]

Moreover, despite the weak level of evidence, some have also considered the cryoballoon a safer tool for this approach. For instance, several studies have found a lower incidence of adverse events using cryoballoon versus point-by-point RFA, including a reduced rate of perforation and tamponade[35,36] and with the exception of the PN, some have even suggested a higher degree of safety with respect to collateral structures[37,38]. Along these lines, a comparative study by Ripley, *et al.*[37] found smaller esophageal lesions with cryoballoon versus point-by-point RFA. Additionally, cryoballoon was associated with a lower incidence of partial- and full-thickness esophageal ulcerations. Similarly, in a multicenter study of 376 patients with AF, Squara, *et al.*[38] compared the outcomes of cryoballoon versus force-sensing RFA and observed a lower incidence of severe complications including esophageal injury using cryoballoon.

4. NOCA of Extra-PV Structures: The LA Roof.

In most patients, $NOCA_{ROOF}$ can be effectively achieved through a series of sequential, non-occlusive, overlapping 120–180 sec applications. This is also a relatively common site for AF termination during NOCA in patients with persistent AF.[14] In several studies, this approach when performed using the cryoballoon in conjunction with PVI, has been shown to offer favorable outcomes in patient with persistent AF.[10,11,12,13] This location is also the site of the main autonomic ganglionic plexi related to the LA dome (*i.e.*, the superior LA ganglionated plexus) which is believed to modulate extrinsic cardiac innervation and facilitate the occurrence of AF in a hyperactive autonomic state.[39] As such, catheter ablation at this site is believed to greatly attenuate the input of these plexi to the PVs and interrupt the vago-sympathetic input to the ligament of Marshall and the inferior left ganglionated plexus which are both highly implicated in the pathogenesis of AF.[39]

Meanwhile, the LA roof is a location where adequate tissue contact using the cryoballoon can be readily achieved and catheter maneuverability is relatively unimpeded. For this, the ILC/GW is typically anchored in one of the superior PVs (most commonly, the left). With the ILC/GW anchored, its progressive advancement farther and farther into the vein, displaces the inflated balloon outward, farther and farther along the roof, away from the PV. This allows the operator to systematically ablate the LA roof using serial, overlapping cryoapplications **(Figure 5).** Once again, ICE can prove quite helpful, particularly in the setting of image integration which allows direct visualization of the cryoballoon locations within the 3-D map **(Figure 3)** and to target any remaining gaps **(Figure 4-B).** Typically, between 3 and 5 applications are required to achieve block across the LA roof. With the ILC/GW inside the left superior PV, slight clockwise rotation of the sheath and balloon can improve contact with the posterior aspect of the roof, whereas a counterclockwise rotation will guide the balloon anteriorly. The converse of this is true when the ILC/GW is anchored in the right superior PV. That is, the operator will need to counterclockwise rotate the sheath and the balloon to target the posterior segments of the roof, whereas a clockwise torque will guide the balloon anteriorly. Using the right superior PV as the anchor point is sometimes helpful when attempting to complete the right segments of the roof lesion set. In fact, in some instances, the right superior PV may be selected preferentially if the left superior PV exhibits an acutely superior takeoff **(Supplementary Material 1)**. In such a situation, the cryoballoon may not be aligned coaxially with the ILC/GW, thereby, compromising optimal tissue contact and balloon positioning along the roof.

Post-ablation, complete block across the LA roof can be verified through a delay in conduction across the roof >120 msec when pacing adjacent to the line/ablated area and an ascending activation over the LAPW.[40] Acute success in achieving block across the roof using the current-generation cryoballoons ranges between 88–92%.[10,11,12,13] Compared to PVI alone, not only this approach does not result in higher incidences of complications or recurrent atrial arrhythmias, this strategy is in fact associated with a lower incidence of arrhythmia recurrences during long-term follow-up (24.4% *versus* 43.0%; P=0.01).[12] Moreover, in a multivariate analysis, $NOCA_{ROOF}$ has emerged as a significant predictor of freedom from recurrent atrial arrhythmias (hazard ratio: 2.13; P<0.01).[12] Nonetheless, block across the roof must always be validated post-ablation to avoid the possibility of iatrogenic roof flutters/tachycardias.[4,13] Rapid ventricular pacing at 350–500 msec (titrated to a systolic blood pressure >70 mmHg) is an effective strategy practiced by some of the authors to improve cryolesion formation at this site and to enhance $NOCA_{ROOF}$. In a prior study, this approach has been shown to increase the success of block across the LA roof through significant reductions in the balloon nadir temperature during $NOCA_{ROOF}$.[41]

5. NOCA of Extra-PV Structures: The LAPW.

As with $NOCA_{ROOF}$, $NOCA_{LAPW}$ has been a recent subject of growing interest and attention, particularly in patients with persistent AF. Although a definitive role for empiric PWI has not yet been established,[42] it seems plausible in those with persistent AF given that persistent AF is generally considered not a triggered, but a substrate-based arrhythmia. Not only cryoballoon PVI+PWI within the region of the PV component (*i.e.*, the LAPW segment lying between the PVs)[39] represents an extended form of wide-area, antral PVI, which in itself has been shown to be superior to ostial PVI strategies,[43] but there is anatomic[39,44] and electrophysiologic[45,46] evidence to suggest that this region of the LAPW may contribute to the genesis and maintenance of AF **(Supplementary Material 2)**. Meanwhile, several studies have illustrated that cryoballoon PVI+PWI is of superior efficacy compared to PVI alone in patients with persistent AF.[14,15,16,17,18] A multicenter, retrospective study[14] first analyzed this outcome and found that acute PWI using this approach was feasible in >⅔ of the patients, yielding significantly greater LAPW (77% *versus* 41%) and total LA (53% *versus* 36%) isolation as compared to PVI alone with also a higher incidence of AF termination/conversion. Adverse events were similar between the two strategies. However, recurrence of AF was significantly reduced with PVI+PWI at 12 months of follow-up (~20% further reduction as compared to PVI alone).[14] In a Cox regression analysis, PVI+PWI also emerged as a significant predictor of freedom from recurrent atrial arrhythmias (hazard ratio: 2.04; P=0.015).[14] Similar results have been reported in subsequent retrospective analyses[15,16] and another study[17] also found this approach to be highly effective in patients undergoing repeat ablation for recurrent AF, in whom it yielded an 85% freedom from recurrent atrial arrhythmias at 1 year. More recently, these findings were echoed by a multicenter, prospective, randomized-controlled trial (ClinicalTrials.gov #NCT03057548)[18] which similarly showed that in patients with persistent AF, PVI+PWI was associated with a ~20% reduction in AF recurrence at 12 months over and beyond PVI alone (25.5% *versus* 45.5%; P=0.028). Furthermore, PVI+PWI once again emerged as a significant independent predictor of freedom from recurrent AF during long-term follow-up (odds ratio: 3.67; P=0.006).[18]

As for the approach, $NOCA_{LAPW}$ is practically similar to performing $NOCA_{ROOF}$. In addition to incorporating this strategy **(Figure 5),** the approach also includes NOCA of the inferior segments of the PW **(Figure 6)** to directly ablate and eliminate all electrical activity within the PV component. To target the lower segments of the LAPW, the inferior PVs are typically used to anchor the ILC/GW – most commonly, the right inferior PV which often exhibits a posterior takeoff. As with ablation of the roof, this is performed using sequential, overlapping 120–180 sec applications by progressively advancing the ILC/GW deeper and deeper into the right inferior PV, with each application. This in turn allows for gradual progression of the balloon away from the right inferior PV, along the inferior PW segments. Depending on the LA size, between 8 and 14 cryoapplications are typically required to complete

PWI. The Cine recordings of the typical cryoballoon maneuvers for PWI are depicted in **Figure 7.** Although complete PWI can be successfully achieved using a 28-mm cryoballoon without the need for adjunct point-by-point cryo/RFA,[15,47,48] in some studies this has been shown to be necessary in ≥⅓ of the patients,[4,14,18] particularly in those with an LA diameter >48 mm[4]. A gap, if present, is normally encountered along the mid portion of the inferior PW **(Figure 8).** As with NOCA of other related structures, ICE and specifically ICE image integration (CartoSound; Biosense Webster) can prove remarkably helpful at identifying gaps among the lesion sets and to complete the procedural endpoint while minimizing the need for adjunct RFA **(Figure 4).**

Similar to $NOCA_{ROOF}$, block across the PW is critical when attempting PWI. As illustrated by Nanbu, *et al.*[13] the 1-year incidence of freedom from recurrent arrhythmias was significantly greater in those with versus without complete roof/PW block (78% *versus* 45%). In another study,[4] the authors found that incomplete PWI was associated with a high rate of atypical roof/PW flutters and virtually every patient with LAPW reconnection exhibited such an arrhythmia, either clinically or inducible at electrophysiology study. The authors also found PWI using NOCA to be durable in 67/81 patients (82.7%) during 18±4 months of follow-up.[4] LA diameter emerged as a significant predictor for the need for adjunct RFA, particularly in those with an LA diameter >48 mm (assessed in parasternal long-axis view). Additionally, patients with LAPW reconnection were found to exhibit larger LA, such that 71% of those with PW reconnection exhibited an LA diameter >48 mm (negative predictive value=89.7%).[4] Given these findings, when performing $NOCA_{LAPW}$, we strongly recommend that the operator always validate this endpoint through detailed high-density 3-D mapping (*e.g.*, Pentaray, Advisor™ HD Grid, etc) as well as high-output pacing illustrating absence of pacing capture, to avoid iatrogenic atrial arrhythmias.

Lastly, due to the close proximity of LAPW to the esophagus, one must also consider the possibility of increased risk of esophageal injury. Though to date, an increased risk of atrioesophageal fistula has not been described with $\text{NOCA}_{\text{ROOF}}$/$\text{NOCA}_{\text{LAPW}}$, the reported experience remains limited.[14,15,16,17,18] However, a study evaluating the outcomes of $\text{NOCA}_{\text{LAPW}}$ has found that interruption of cryoapplications at a luminal esophageal temperature >15°C is associated with absence of esophageal thermal lesions.[48] This recommendation seems tangible as it is consistent with findings from a prior study which reported the same when examining the risk of esophageal injury in the setting of cryoballoon PVI.[49]

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Figure 1. Cryoballoon ablation of PVs and extra-PV structures. 3-D electroanatomic voltage maps (scar voltage cutoff: 0.05 mV) depicting suboptimal, ostial PVI **(A),** antral PVI **(B),** antral PVI with $NOCA_{ROOF}$ **(C)** and PVI+PWI **(D)** performed using the cryoballoon. *LAA=left atrial appendage; LIPV=left inferior PV; LSPV=left superior PV; RIPV=right inferior PV; RSPV=right superior PV.*

Figure 2. Suitable transseptal puncture site for NOCA. ICE images illustrating a low and anterior needle position (yellow arrows) at the fossa ovalis **(A, B),** followed by puncture **(C)** and insertion of a cryoballoon sheath **(D)** through the most inferior segment of the interatrial septum, adjacent to the inferior limbus, most suitable for NOCA. *RA=right atrium; TSS=transseptal.*

Figure 3. ICE-guided NOCA. Shown, are positions of 10 serial cryoballoon applications **(A–J)** delivered antrally, outside the PVs along the roof and the PW, visualized using ICE image integration (CartoSound; Biosense Webster). After creating an LA shell using ICE, the position of the cryoballoon can be directly recorded within the 3-D map by creating an ICE contour of the balloon at each location (turquoise represents the distal and yellow the proximal hemi-surfaces of the cryoballoon to ensure proper balloon alignment with desired locations).

Figure 4. ICE image integration to target gaps and to complete LA roof and PW isolation. **(A)** After cryoballoon PVI, a small gap/unablated area anterior to the right superior PV and a roof-associated PV branch (arrows) are detected on the post-ablation high-density voltage map (left panel). By positioning the cryoballoon directly over each site under the guidance of ICE and 3-D mapping (middle panels), each location is successfully ablated using a single

cryoapplication. **(B)** Following PVI with $NOCA_{LAPW}$, a small gap/unablated area is detected on the LA roof (arrows) on the post-ablation voltage map. By directly positioning the cryoballoon at this location, guided by ICE and 3-D mapping, the site of interest is targeted using NOCA. **(C)** After completion of wide-area, antral PVI with $NOCA_{ROOF}$, PWI is performed using a series of additional cryoapplications guided by ICE image integration and direct visualization in the 3-D map. **(D)** After completion of PVI using a conventional PV-occlusive strategy, the PV component of the LAPW is subsequently ablated using a series of overlapping cryoapplications guided by ICE image integration and 3-D mapping **(E)** Shown, are the cryoballoon positions within a 3-D map as recorded on ICE to achieve wide-area, antral PVI and PWI within the PV component.

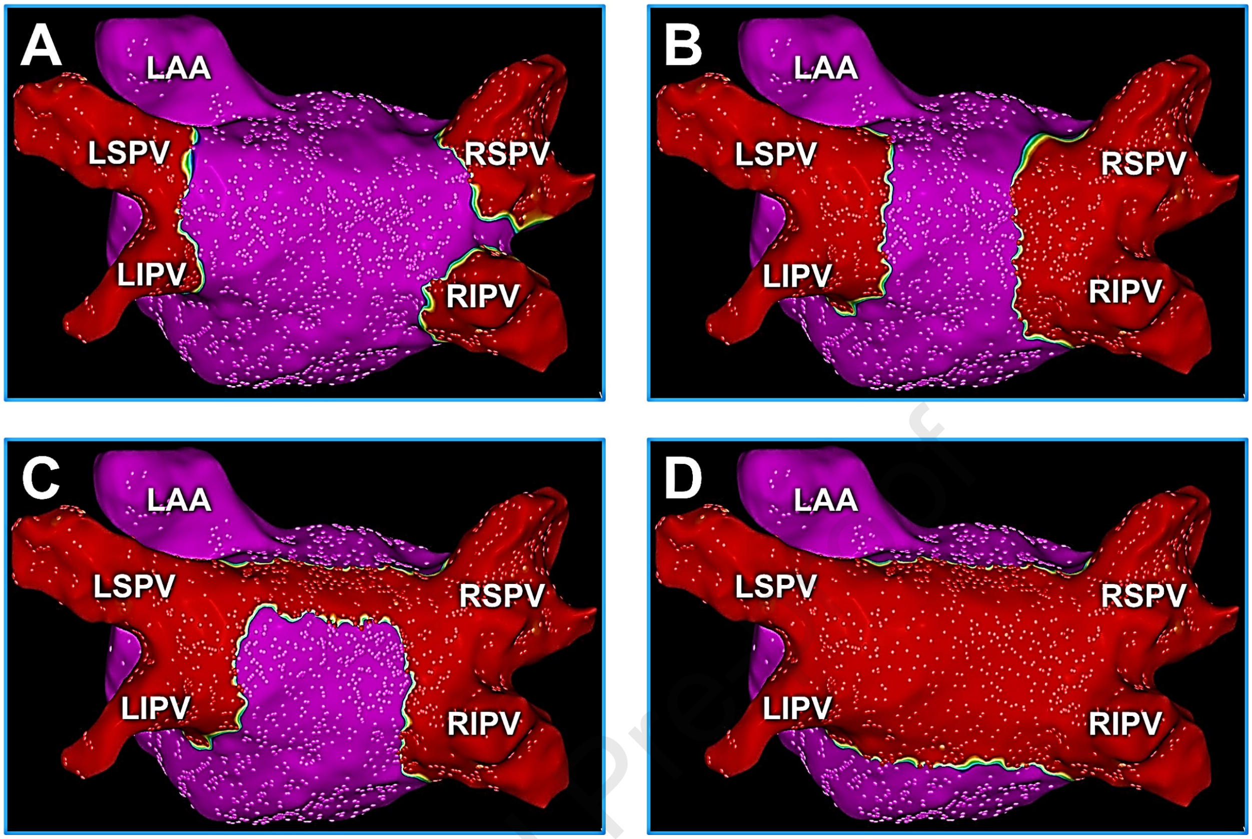
Figure 5. Cryoballoon positions for $NOCA_{ROOF}$. Shown, are the typical positions of cryoballoon applications (1–5) on the roof, individually **(A–E)** and collectively **(F),** to complete $NOCA_{ROOF}$. *MV=mitral valve.*

Figure 6. Cryoballoon positions for NOCA of the inferior segments of the PW. Shown, are the positions of serial cryoballoon applications (1–7) along the inferior segments of the PW, individually **(A–G)** and collectively **(H),** to complete $NOCA_{LAPW}$.

Figure 7. Cine images of the cryoballoon for performing PVI+PWI. Shown in the top row, are Cine locations of the cryoballoon placed over an ILC for NOCA of the left **(A)** and right **(D)** superior PV antra, the left **(B),** mid **(C)** and right **(E)** roof segments, and the mid portion of the roof/PW **(F).** Shown in the bottom row, are the cryoballoon Cine positions for NOCA of the left

(G) and right **(H)** inferior PVs and the inferior **(I, J)** and mid **(K, L)** segments of the PW. *CB=cryoballoon; CS=coronary sinus.*

Figure 8. Incomplete isolation of the PW using NOCA. Incomplete PWI using $NOCA_{LAPW}$ may be observed in ~⅓ of patients when performed using a 28-mm cryoballoon, sometimes requiring adjunct RFA for completion. Shown, are variations in gaps detected following such a procedure **(A–C).** When present, these gaps are typically encountered/most prominent along the mid portion of the inferior PW (arrows).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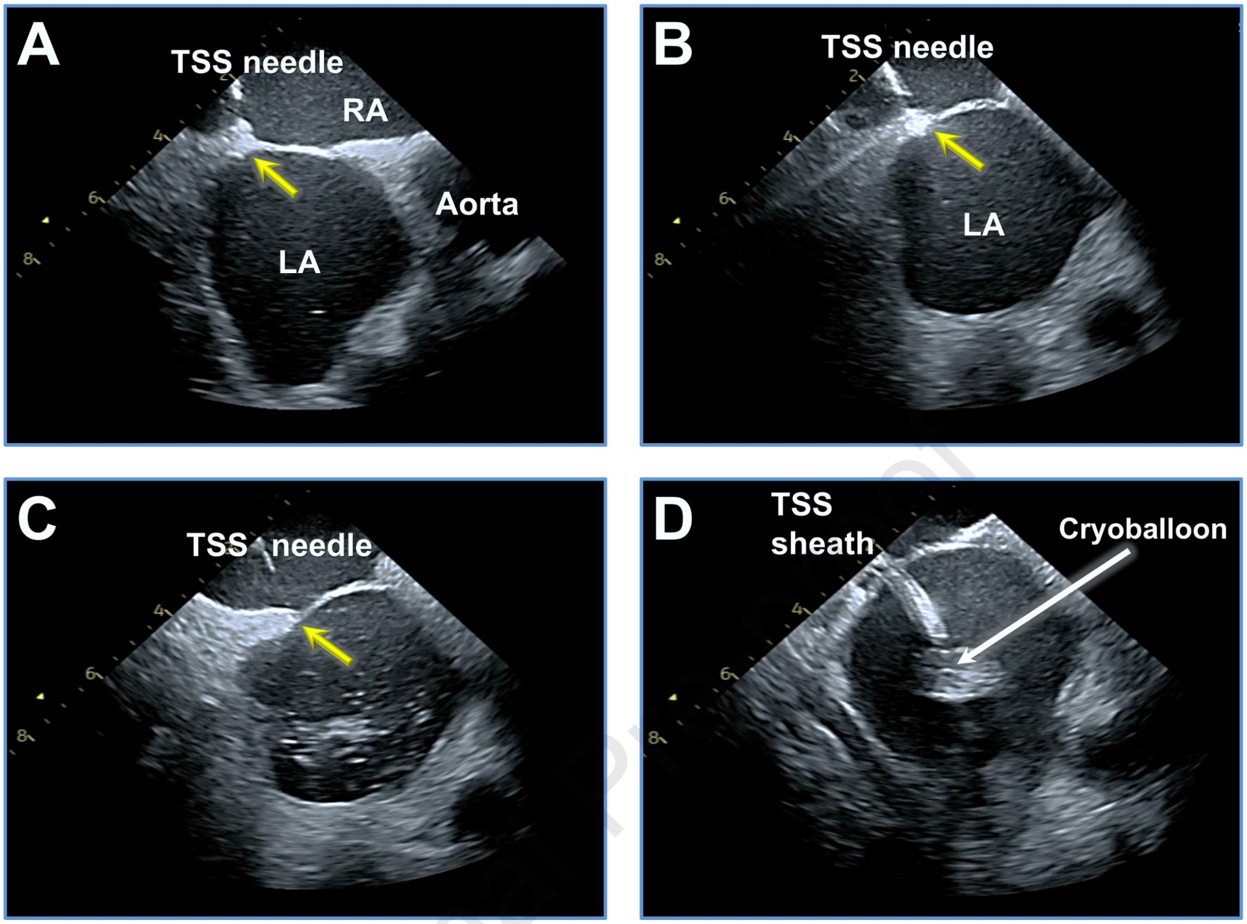
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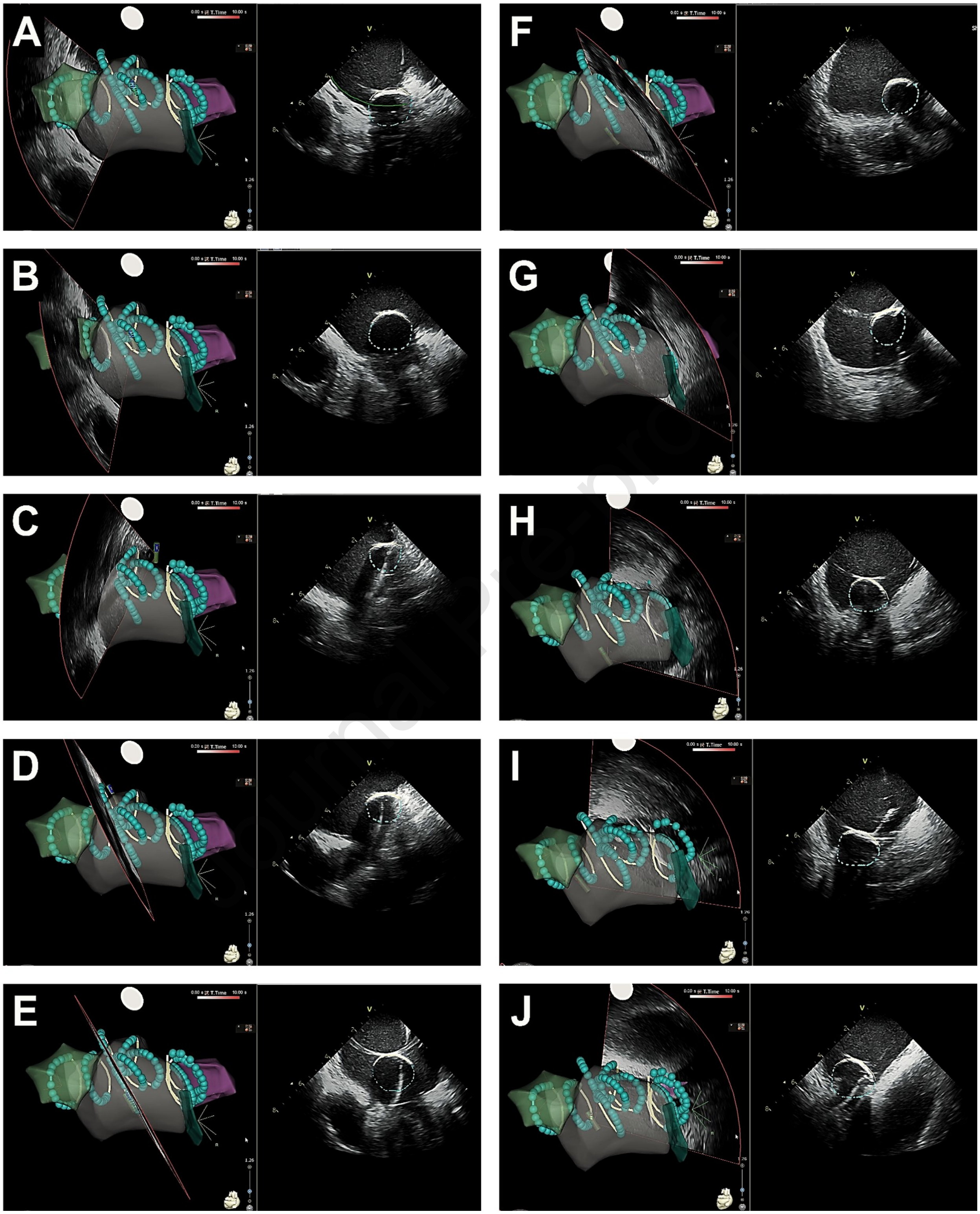
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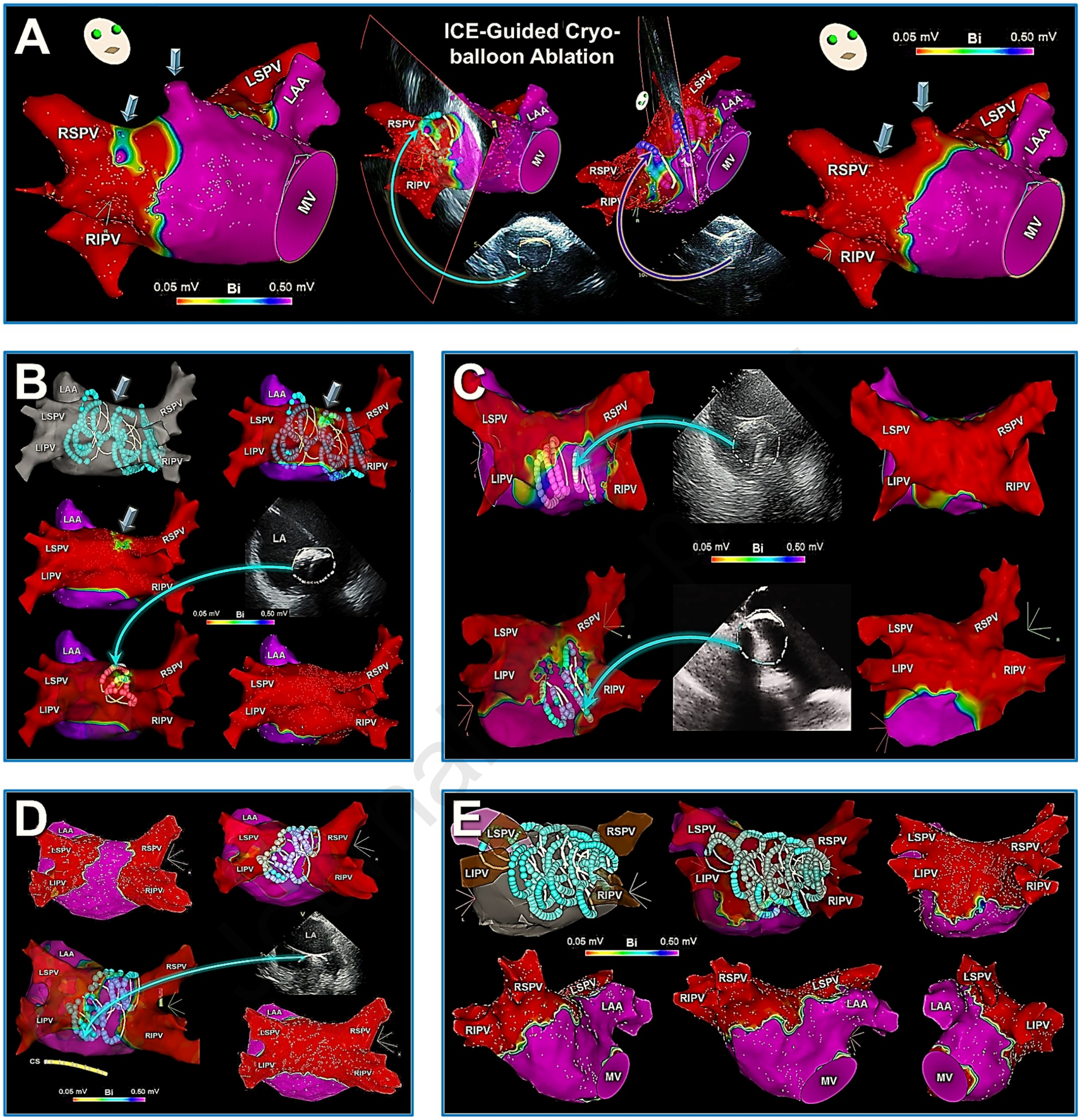
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ICE-Guided Cryo-balloon Ablation
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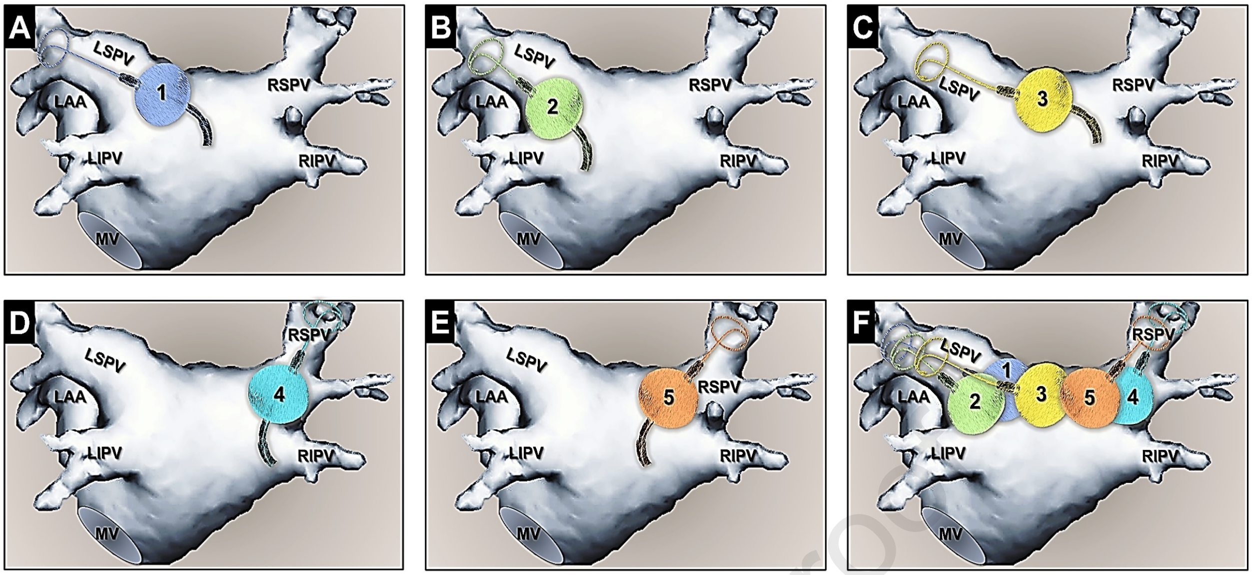
MV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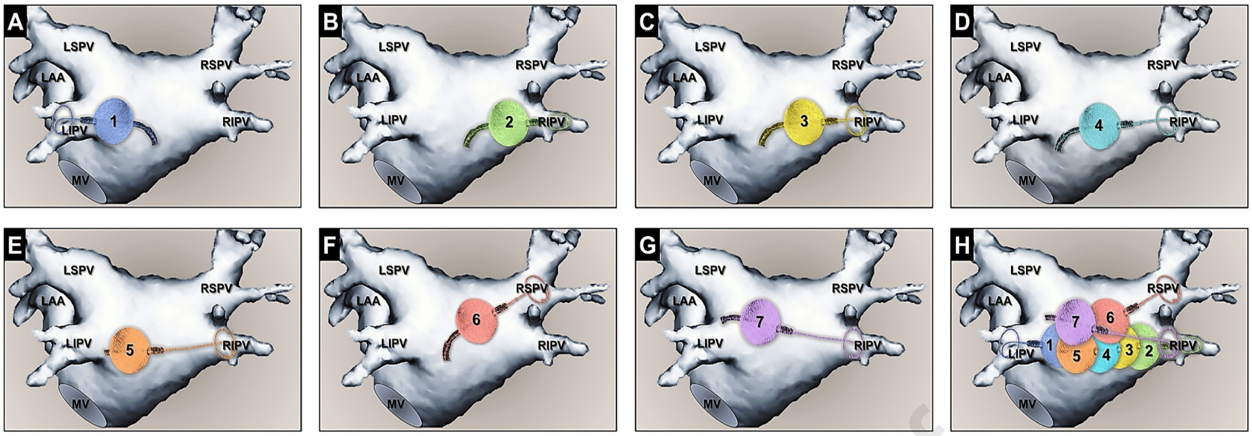
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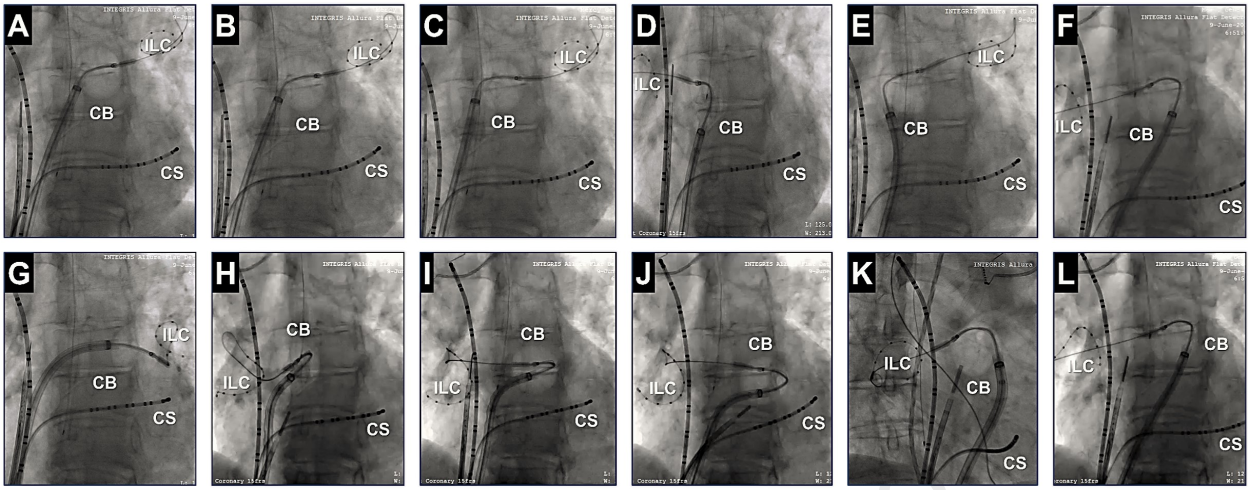
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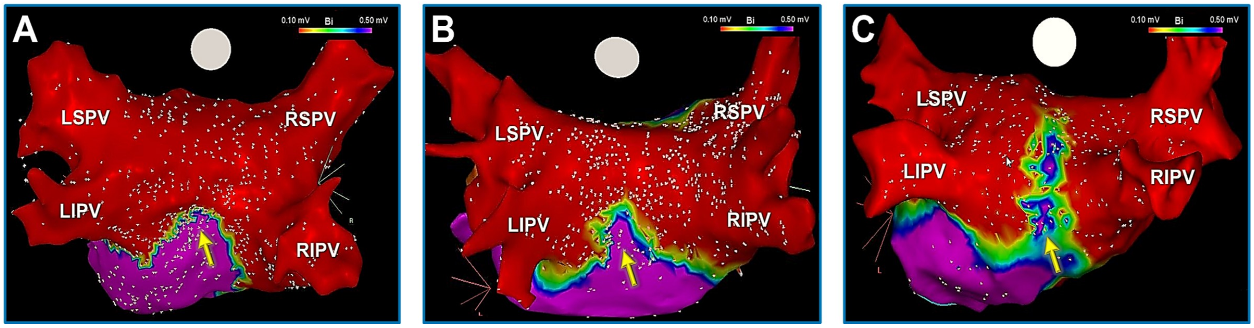
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