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CASE REPORT

CLINICAL CASE SERIES

Tricuspid Valve Leaflets–Lead Interaction

Adjunctive Role of Functional Cardiac Computed Tomography for Clinical Decision Making

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ABSTRACT

The diagnostic approach toward the management of cardiac implantable electronic device–related tricuspid regurgitation is challenging and undefined. Functional cardiac computed tomography angiography provides a complementary role to echocardiography in the evaluation of lead-leaflet interaction which can help the clinical decision-making process, as presented in this case series. (J Am Coll Cardiol Case Rep 2024;29:102372) © 2024 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Emerging data regarding the prevalence and prognostic role of cardiac implantable electronic device (CIED)-related tricuspid regurgitation (TR) have supported its clinical relevance.[1,2] Although CIED-related TR diagnosis has improved recently, specific anatomical and causal relationships between TR and CIEDs are complex to determine. However, addressing this question may be of pivotal importance, particularly considering novel transcatheter edge-to-edge valve repair (TEER) and transcatheter valve (TV) replacement therapies, as it relates to procedural lead management.[3]

LEARNING OBJECTIVES

- To understand how cardiac CT can improve our diagnostic approach to patients with severe TR.
- To consider the role of cardiac CT in the evaluation of TV lead-leaflet interaction and TV remodeling.
- To identify how cardiac CT evaluation may help to predict the feasibility of a future invasive treatment for lead-induced TR.

Although 2-dimensional and 3-dimensional transesophageal echocardiography (TEE) is essential to understand the CIED-TR relationship, suboptimal imaging can arise (eg, from a horizontal heart or from an acoustic shadowing of nearby structures). The following clinical case series reports our initial experience of 3 patients with severe TR and CIEDs who underwent time-resolved (functional) 4-dimensional cardiac computed tomography angiography (4D-CTA). We demonstrate the adjunctive

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ABBREVIATIONS AND ACRONYMS

CIED = cardiac implantable electronic device

PM = permanent pacemaker

SL = septal leaflet

TEER = transcatheter edge-to-edge valve repair

TR = tricuspid regurgitation

TV = transcatheter valve

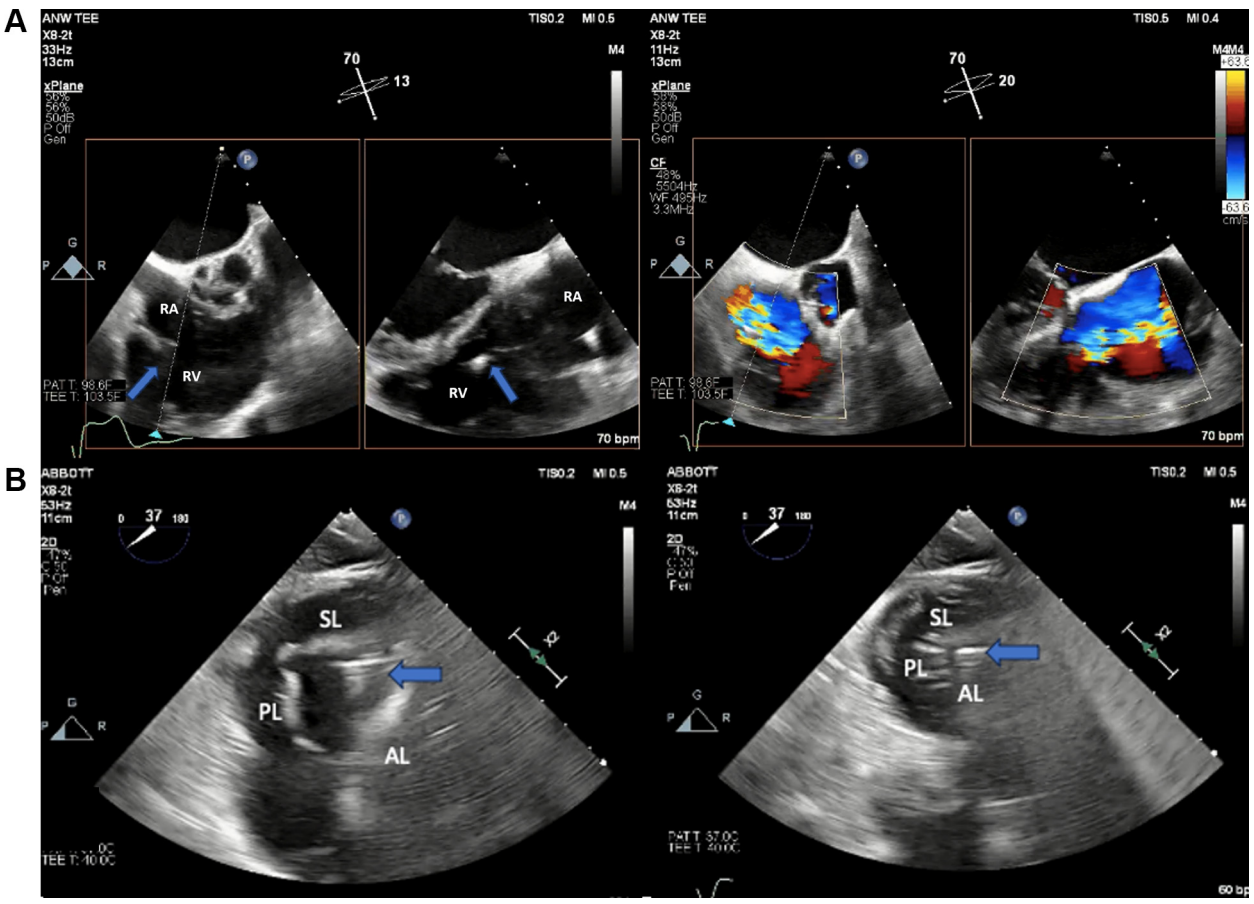
imaging by 4D-CTA may contribute to clinical decision making by better evaluating the lead-leaflet anatomical interaction, anticipating its potential feasibility and/or the complications of invasive procedures.

PATIENT 1

An 82-year-old woman with a history of chronic kidney disease, a dual-chamber permanent pacemaker (PM) implanted in 2008, and severe TR known since 2018, experienced worsening right-sided congestive heart failure. On admission, the patient described exertional dyspnea (NYHA functional class III), and physical examination demonstrated bilateral lower extremity edema. Jugular venous distension could not be assessed.

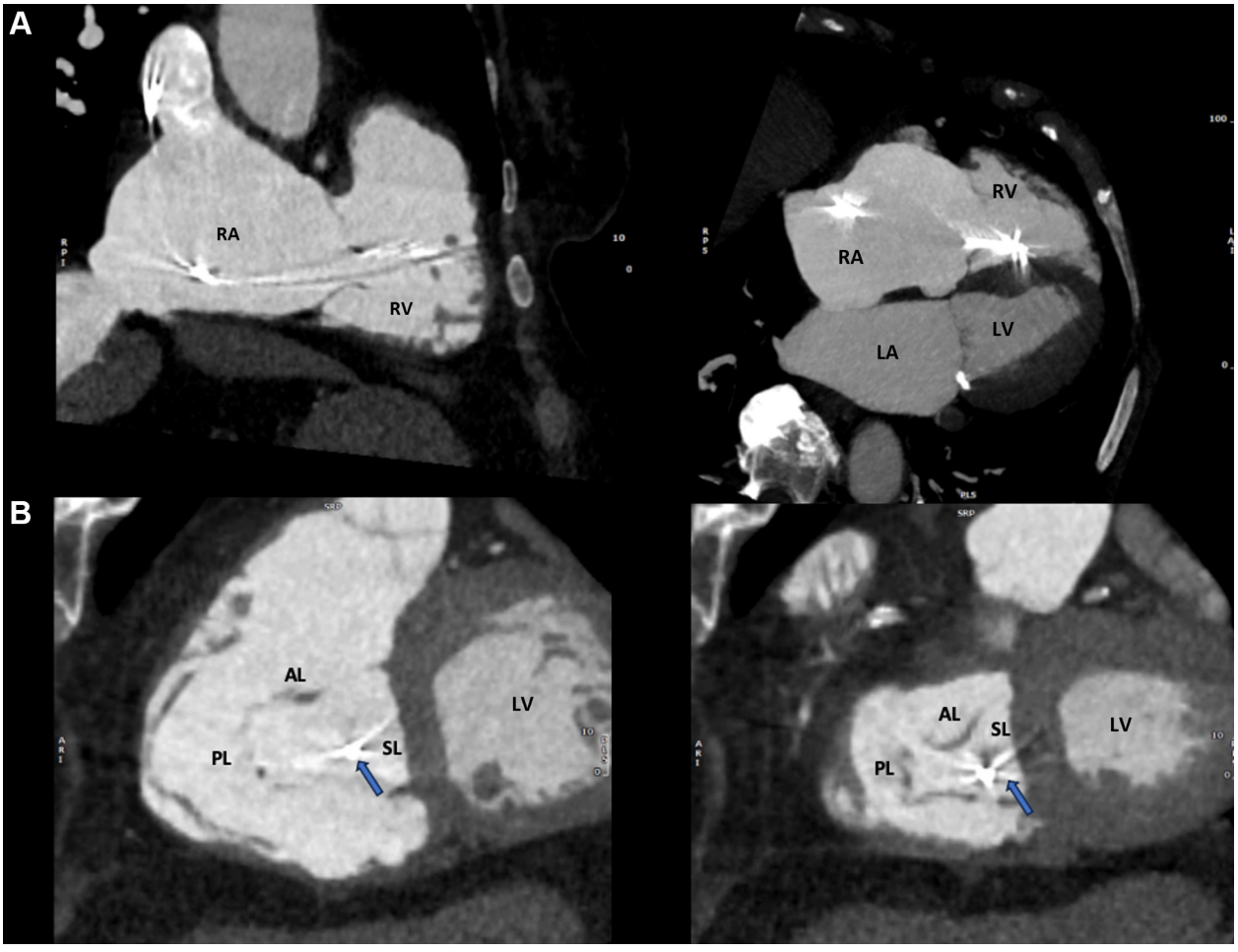
Echocardiography showed severe TR, and potential impingement of the septal leaflet (SL) was suspected; however, the acoustic window was suboptimal even with transesophageal echocardiography (**Figure 1**). The transgastric views were poor, and 3-dimensional images were not obtainable. By contrast, 4D-CTA allowed identification of an adhesion of the lead with the SL, without impingement or significant fibrotic remodeling of the leaflet in a patient with a 4-leaflet tricuspid valve and a large central coaptation gap (10 mm) (**Figure 2**, Videos 1 and 2). Taking all of this into account, along with her high surgical risk, and following tricuspid annular measurements, the patient was considered eligible for laser lead extraction and subsequently for transcatheter VR with an Intrepid 48-mm prosthesis (Medtronic). At her 1-year follow-up visit, the patient was in NYHA functional

FIGURE 1 Transesophageal Echocardiogram of Patient 1



(A) Inflow-outflow view with the lead across the valve. (B) Transgastric short-axis view showing, despite suboptimal acoustic window, the lead close to the septal leaflet. Blue arrows point to the lead. AL = anterior leaflet; PL = posterior leaflet; RA = right atrium; RV = right ventricle; SL = septal leaflet.

FIGURE 2 **Cardiac Computed Tomography of Patient 1**



(A) Inflow-outflow (left) and 4-chamber (right) views showing the lead adhering to the septal leaflets. (B) Short-axis view confirming the anatomical relationship between the lead and the septal leaflet. Blue arrows point to the lead. LA = left atrium; LV = left ventricle; other abbreviations as in **Figure 1**.

class I, and both echocardiography and 4D-CTA confirmed stability of the prosthesis, with trivial intraprosthetic regurgitation (Video 3).

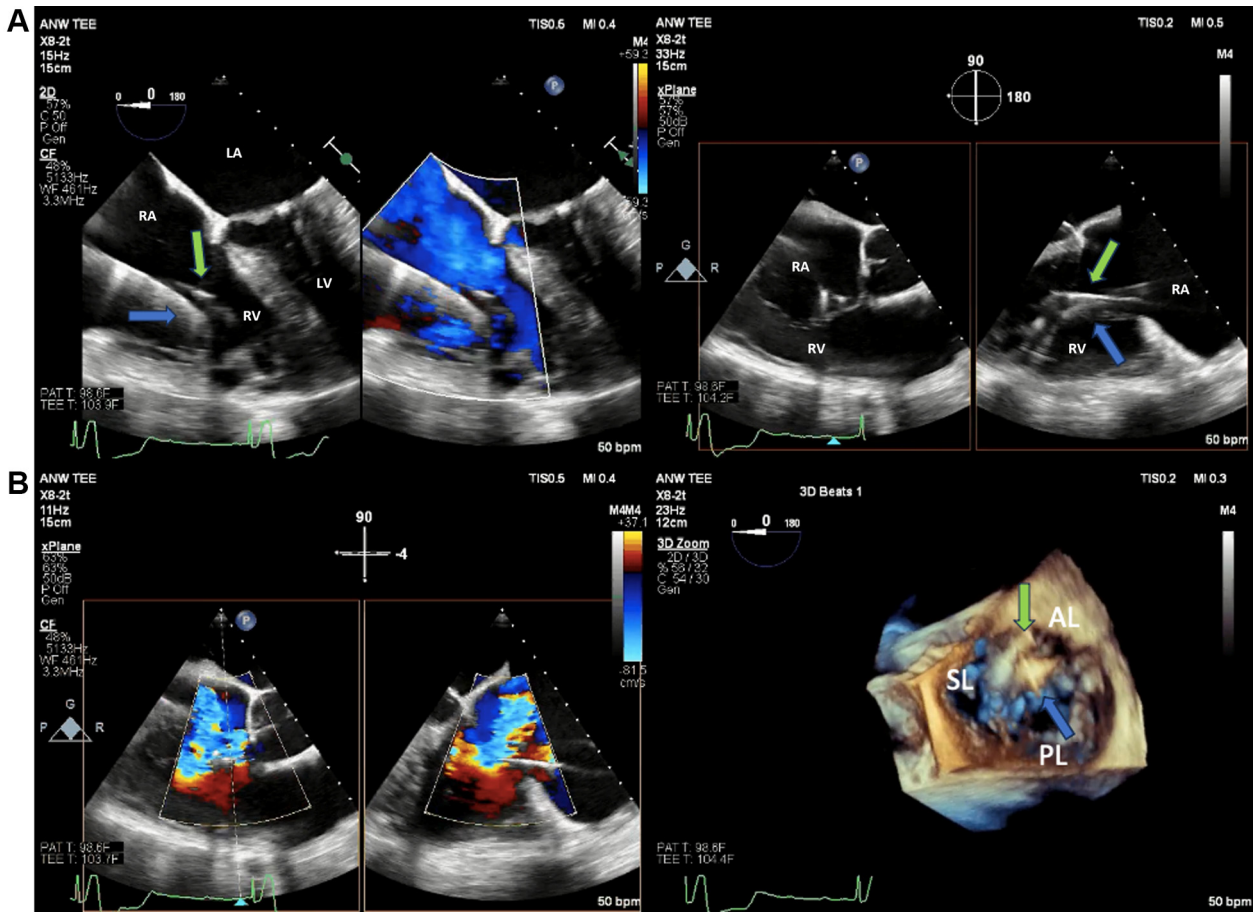
PATIENT 2

An 80-year-old man had carried a single-chamber PM since 1985; however, after lead fracture, its ventricular portion was abandoned in the cavity, and a second lead was implanted in 2011. He had been experiencing severe functional TR since 2017. At clinical evaluation he was in NYHA functional class II, without signs of systemic venous congestion.

Transesophageal echocardiography confirmed massive TR in the presence of 2 leads crossing the TV: however, the precise relationship of each lead with the TV apparatus was difficult to assess (**Figure 3**, Video 4).

Evaluation with 4D-CTA characterized the specific role of each lead: the older lead crossed the anterosuperior part of the right atrium with atypical curvature and crossed the TV, remaining fixed in the anteroseptal commissure with SL impingement (**Figure 4**, Videos 5 and 6). The newer lead presented adequate excursion, without interaction with TV leaflets, thereby acting as a bystander with regard to TR development. Nonetheless, owing to the patient's high surgical risk and the double lead crossing the TV, 1 fixed and causing leaflet impingement, it was decided not to attempt lead extraction or TEER, and the patient was discharged with optimized medical therapy. At the 1-year follow-up visit, the TR

FIGURE 3 Transesophageal Echocardiogram of Patient 2



(A) 4-chamber (left) and inflow-outflow (right) views showing the 2 leads crossing the tricuspid valve. (B) Severe tricuspid regurgitation is shown on the left, and the 3D transgastric view (right) shows both leads. Blue arrow points to the newer lead, the green arrow to the older. Abbreviations as in **Figures 1 and 2**.

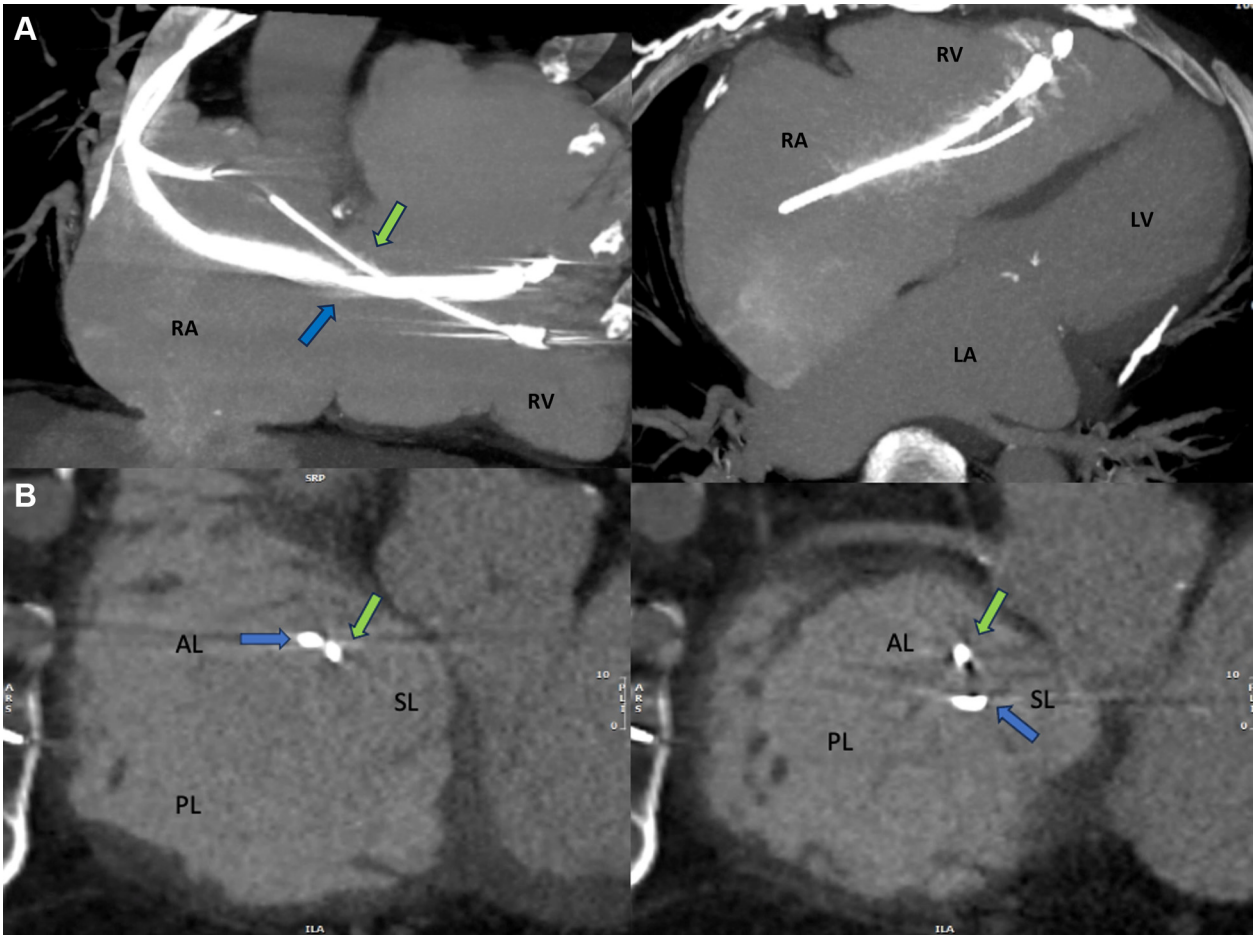
remained severe, but no episode of AHF had occurred.

PATIENT 3

An 83-year-old woman with a history of mitral valve replacement in 2007, paroxysmal atrial fibrillation, and a dual-chamber PM implanted in 2007 presented for evaluation of progressive heart failure symptoms. On clinical evaluation she was in NYHA functional class III, with moderate bilateral lower extremity edema and mild jugular venous distention.

TEE, despite suboptimal imaging related to the mitral valve prosthesis, demonstrated massive TR and the lead at the anteroseptal (AS) commissure with systolic interaction with the SL, creating a coaptation gap (**Figure 5**, Video 7). 4D-CTA identified 3 additional important findings. First, the PM lead in the anteroseptal commissure also caused restricted systolic excursion of the anterior leaflet. Second, both the anterior leaflet and the SL presented discrete low-attenuation regional thickening at the sites with direct contact with the PM lead, suggesting fibrotic changes—a finding that might have had implications for lead extraction and for the long-term durability of leaflet grasping after TEER. Finally, an additional coaptation gap was described involving the posteroseptal zone of the valve (8 mm) (**Figure 6**, Videos 8 and 9). These extreme complexities for transcatheter intervention yielded a decision for surgical

FIGURE 4 Cardiac Computed Tomography of Patient 2



(A) 2-chamber (left) and 4-chamber (right) views showing the courses of the 3 leads in the right atrium and across the tricuspid valve. (B) Short-axis views showing the position of the 2 leads. Blue arrow points to the newer lead, the green arrow to the older. Abbreviations as in Figures 1 and 2.

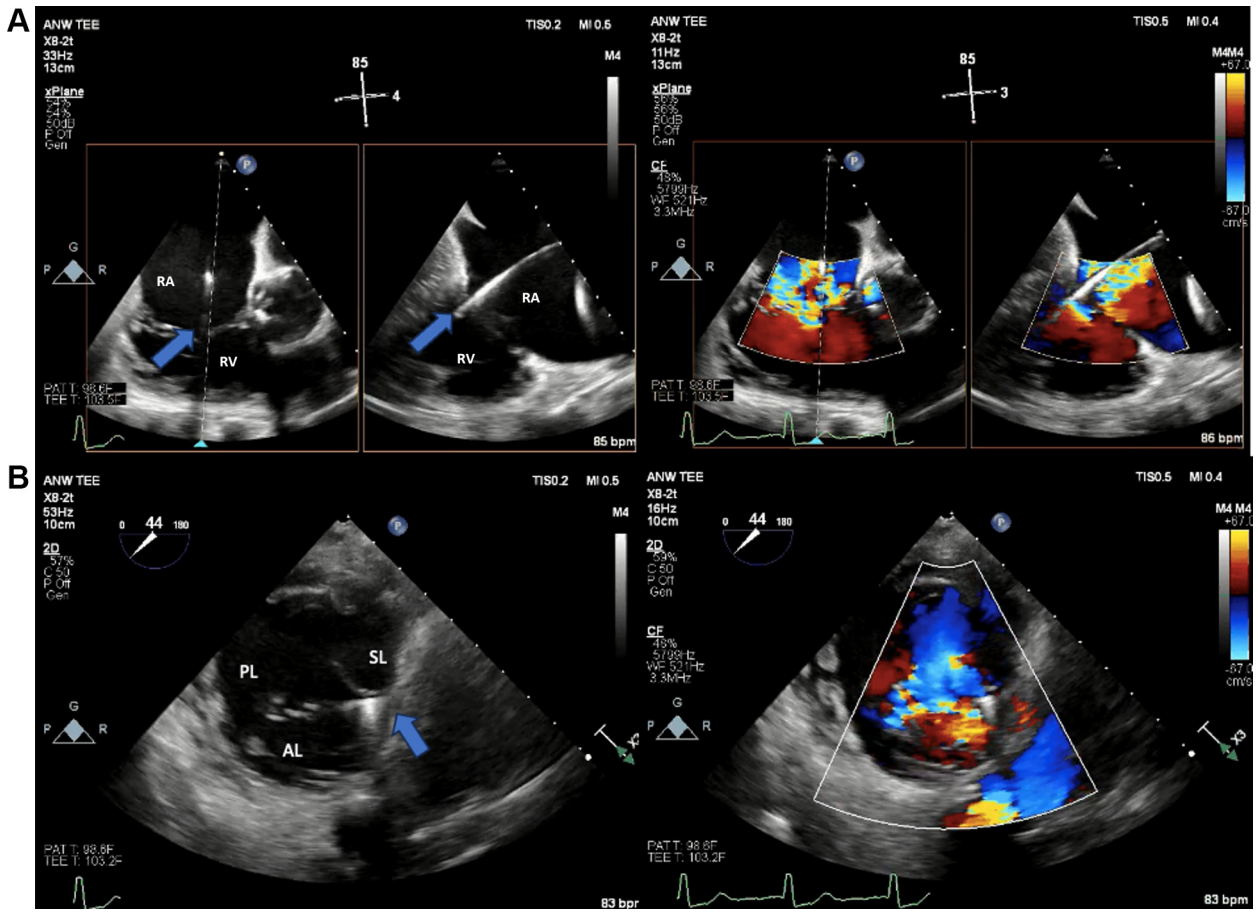
treatment, which was successfully performed with TV replacement with a 29-mm Abbott Epic bioprosthesis.

DISCUSSION

Although increasing attention from the scientific community has been provided to CIED-related TR lately, the diagnostic approach to fully clarify the lead-leaflet relationship is still uncertain. In this context, echocardiography is the most often used imaging technique[2] because of its wide availability and portability. However, intrinsic diagnostic limitations may halt the evaluation of crucial aspects for the treatment of patients with CIED-related TR.

When 4D-CTA is performed with proper acquisition protocol, including an ECG-gated retrospective acquisition covering the whole cardiac cycle without dose modulation, proper right-sided contrast material enhancement, and dedicated post-processing software to reconstruct and provide a systematic analysis, it could play a pivotal complementary role to define the nature of lead-leaflet interaction,[1,4] as shown in this case series. Of particular importance for improved 4D-CTA imaging is to have high temporal resolution from dual-source system scanners, which also allow for absolute millisecond reconstructions mitigating motion and streak artifacts, commonly seen in these patients with CIED-related TR.

FIGURE 5 Transesophageal Echocardiogram of Patient 3



(A) Inflow-outflow view with the lead located close to the septal leaflet. (B) Transgastric short-axis views with the lead in the anteroseptal commissure. Blue arrow points to the lead. Abbreviations as in Figures 1 and 2.

Accordingly, if TEER is considered, leaflet impingement, coaptation gap, and its proximity to the lead can be measured, possibly predicting the success of invasive treatments. Moreover, the assessment of lead and/or leaflet fibrosis, lead adhesion to central venous structures, and perforation may help to avoid eventual complications during transvenous lead extraction.[2] The prediction of potential futility/eligibility for interventional treatments (patient 1), the evaluation, even in case of multiple leads, of the lead's trajectory, slack (or lack thereof) and potential mobilization (patient 2), and identification of leaflet fibrotic remodeling, impingement, and different coaptation gap zones (patient 3), are all essential pieces of information that show the complementary adjunctive role of 4D-CTA in the multimodality imaging evaluation of CIED-related TR.

CONCLUSIONS

Four-dimensional CTA has a potential role in the multimodality diagnosis of, and guidance on, the therapeutic approach to patients with severe TR in the presence of a CIED, by accurately determining the anatomical and functional implications of the transvalvular lead.

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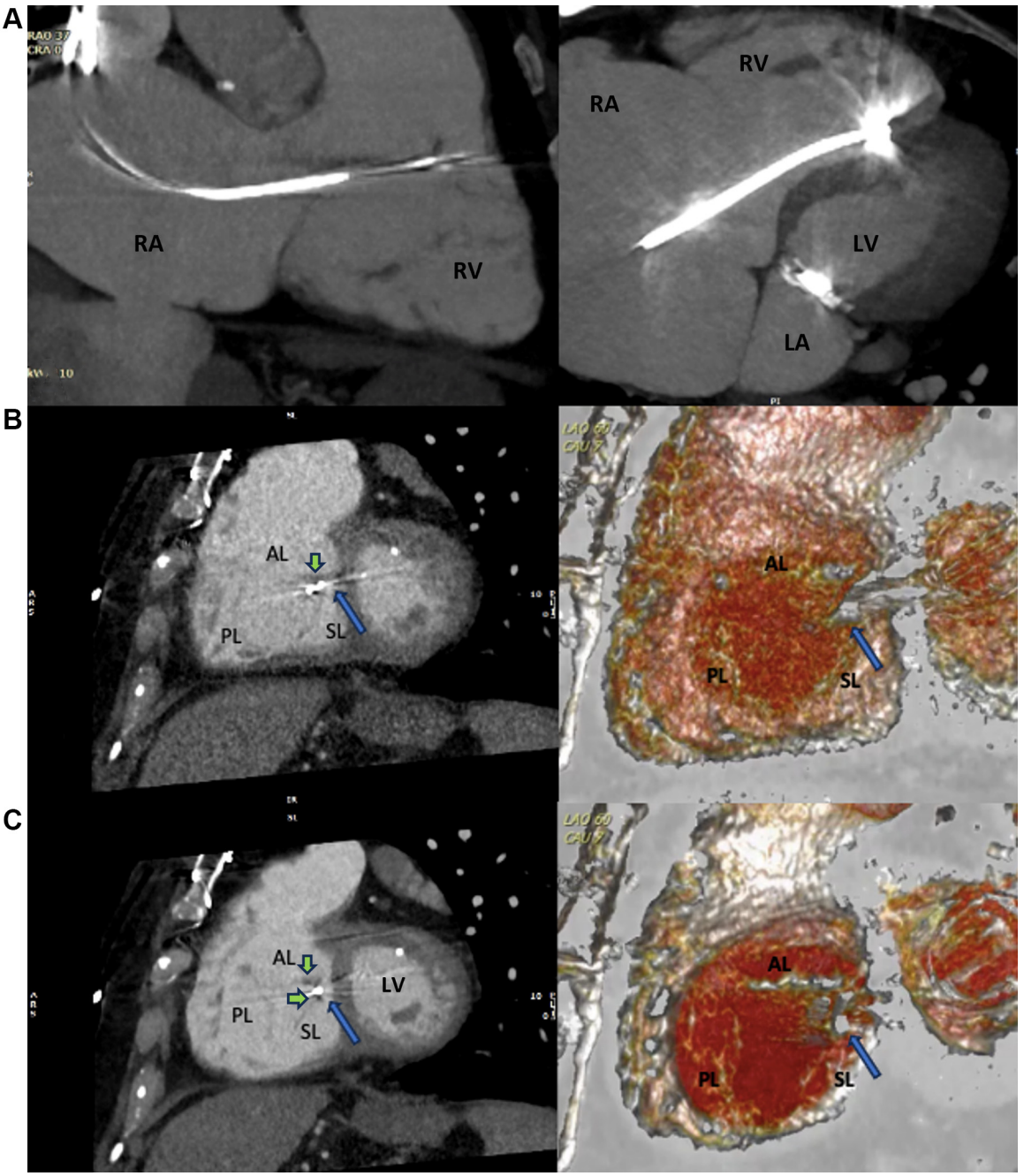
Dr Enriquez-Sarano has received consulting fees from CryoLife, Edwards Lifesciences, HighLife, and ChemImage. Dr Sorajja has received consulting fees from 4C Medical, Abbott Structural, Anteris, Boston Scientific, Edwards Lifesciences, Evolution Medical, Foldax, GLG, Medtronic, Philips, Siemens, Shifamed, W.L. Gore & Associates, VDyne, and xDot Medical; and has received institutional research grant support from Abbott Structural, Medtronic, and Boston Scientific. Dr Bapat has received consulting fees from Abbott Structural, Medtronic,

FIGURE 6 **Cardiac Computed Tomography of Patient 3**



(A) Inflow-outflow view (left) and 4-chamber view (right) showing the trajectory of the lead and its close relationship with the septal leaflet. Short-axis views of the lead in the anteroseptal commissure, causing fibrosis and limited excursion of the AL and SL, both in 2-dimensional view (B) and in 3-dimensional view zoomed (C). Blue arrows point to the lead, green arrowhead to the low-attenuation thickening surrounding the lead, a marker of fibrosis. Abbreviations as in Figures 1 and 2.

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KEY WORDS cardiac computed tomography, cardiac implantable electronic device, tricuspid regurgitation

APPENDIX For supplemental videos, please see the online version of this paper.