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Essential roles for CT and MRI in timing of therapy in tricuspid regurgitation

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ABSTRACT

The rapid development of transcatheter tricuspid valve intervention (TTVI) therapies has quickly provided the opportunity to improve patient selection and procedural planning for patients with significant tricuspid regurgitation (TR) considered at high surgical risk.

This review focuses on the contributions which both computed tomography angiography and cardiac magnetic resonance can provide in the better understanding of the natural history of TR, in the comprehensive anatomical and functional assessment of right heart involvement and in the timing and planning for TTVI. We also discuss areas of potential importance such as the quantification of response to TTVI, which will be informative for future trials.

Contents

Introduction

Severity of tricuspid regurgitation (TR), right ventricle (RV) remodeling and RV function all have a direct impact on long-term survival, especially in patients with chronic heart failure and left ventricular (LV) dysfunction.[1,2] The current guidelines for valvular heart disease lack class I indication for intervention in isolated severe TR, recommending only concomitant surgical tricuspid valve (TV) repair or replacement as class I indication in patients undergoing left-sided valve surgery with severe functional TR or with mild or moderate TR and severe dilation of the tricuspid annulus (TA).[3] While transcatheter TV interventions (TTVI) have emerged as an alternative therapeutic option to serve a high risk population of patients with severe symptomatic TR, most of these patients already present late with advanced comorbidities.

This review describes the role for CTA and CMR in understanding of the natural history of TR, improvement in the anatomical and functional assessment of right heart involvement and TTVI planning.

Abbreviations and acronyms: CMR, cardiac magnetic resonance; CT, computed tomography; CTA, computed tomography angiography; LV, left ventricle; RA, right atrial; RV, right ventricle; TA, tricuspid annulus; TR, tricuspid regurgitation; TTE, transthoracic echocardiography; TTVI, transcatheter tricuspid valve interventions.

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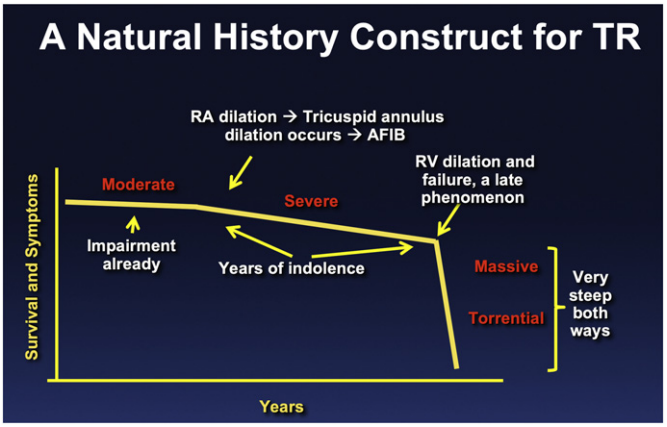

Fig. 1. Natural history construct for tricuspid regurgitation.

Anatomical changes and challenges in right heart involvement

Transthoracic echocardiography (TTE) is the first imaging modality for TR evaluation, but known to have important limitations on the accurate and reproducible assessment of TR severity, TV anatomy, and RV remodeling and function. Although societal guidelines promote the use of quantitative Doppler to assess TR severity,[4] in the majority of times qualitative, color Doppler jet area is actually the method used which leads to a consistent underestimation and under calling of the true TR severity. Furthermore, the complex RV geometry often leads to incomplete and inadequate visualization of the entire RV by 2D TTE again leading to underestimation of the true extent of cardiac damage. Symptomatology from severe TR is also non-specific which causes further delay in their presentation and referral to treatment.

With the progression of TR, dilation of the right atrium (RA) followed by dilation of the tricuspid annulus and eventually RV remodeling takes place. Using computed tomographic (CT) angiography (CTA), Nemoto et al. showed that even patients with mild TR already demonstrated significant biatrial and TA dilatation, when compared to patients with no or trace TR. As such RA and TA dilation are the first anatomical changes seen with significant TR. These changes tend to beget more atrial fibrillation which perpetuates further the cardiac damage. RV dilation and eventually dysfunction typically suggest a late phenomenon.[5]

The complexities in the imaging of the TV, RA/RV size, function and progressive symptomatology are captured in Fig. 1, which shows a conceptual framework construct for the natural history of TR.

Role of CTA for functional assessment of right-side and TTVI

Multiphasic, contrast-enhanced, retrospective cardiac-gated acquisition, encompassing the entire heart silhouette and proximal main vessels enables subsequent multiplanar reconstruction and comprehensive evaluation of the right heart.

Specific CT acquisition protocols focusing on the right-side should be followed to maximize image quality for analysis. New generation of CT scanners, with higher number of detectors enables shorter breath-hold, lower radiation and contrast utilization. Since atrial fibrillation is quite common in patients with significant TR, motion/misregistration artifacts can cause blurring, distortion and inadequate visualization of the cardiac structures. For such patients, higher temporal resolution dual-source CT scanners (preferably <80 ms) can improve image quality and analysis.[6] Reconstructing functional dataset based on the cardiac cycle timing in milliseconds, in addition to the traditional R-R interval percentage, can further improve misregistration artifacts potentially seen in patients with atrial fibrillation.

Anatomical changes of TA and quantification of right-side function and remodeling, including TA area and diameter, TV leaflet tethering height and area, anatomical regurgitant orifice area (Fig. 2), right atrial and ventricular volume and ejection fraction at baseline as well as

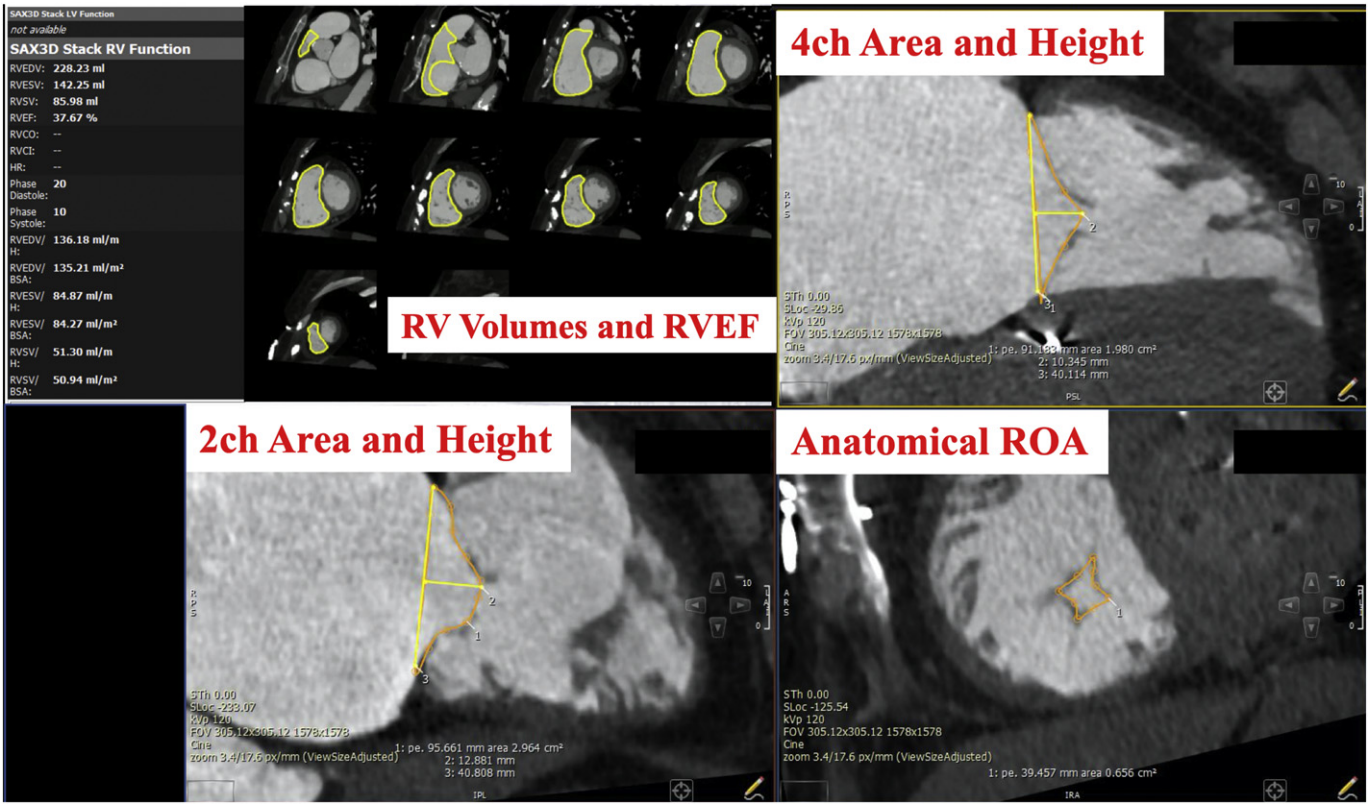

Fig. 2. Anatomical and functional measurements for tricuspid regurgitation.

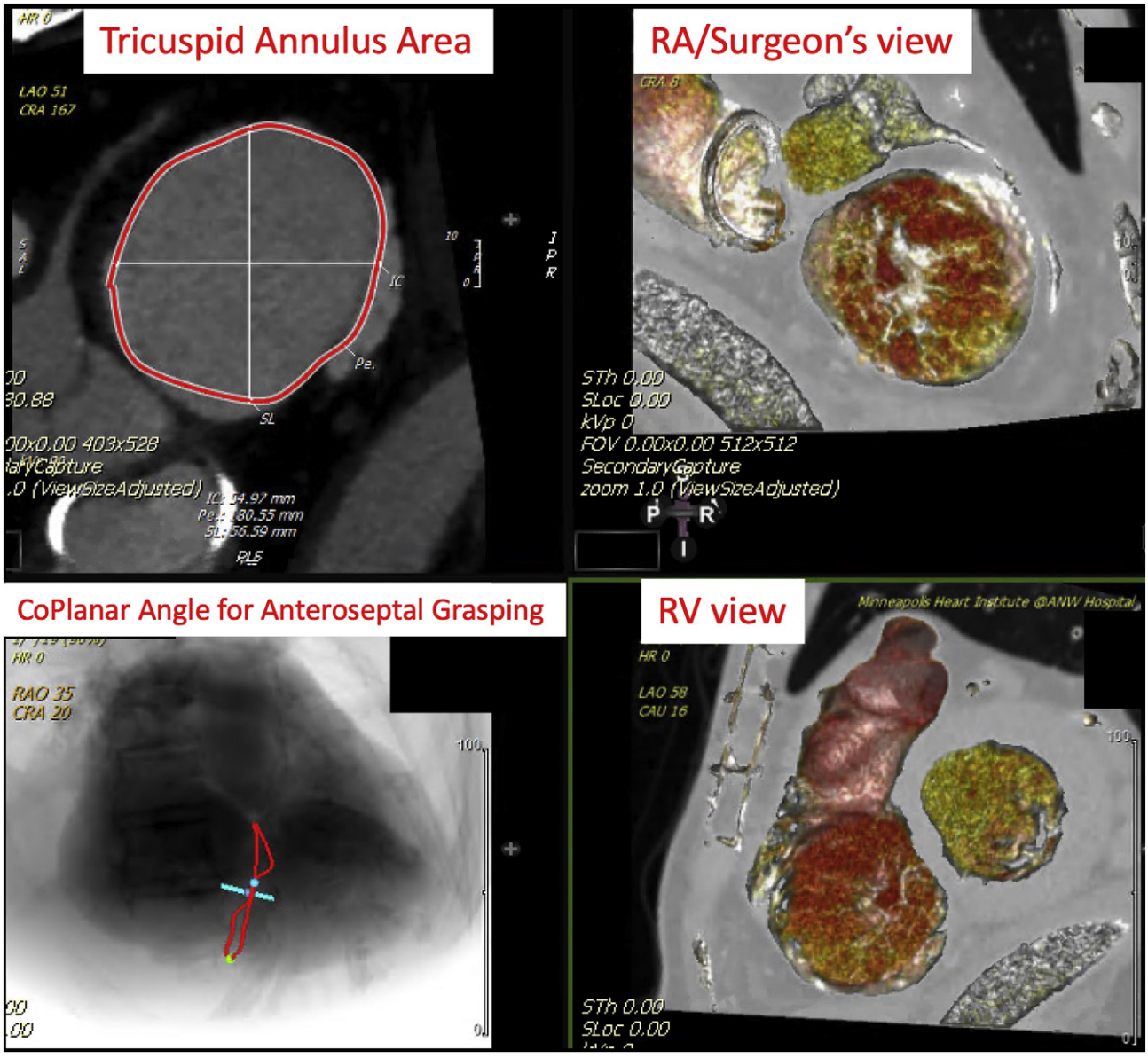

Fig. 3. Additional pre-procedural CTA planning for TriClip.

post-procedure are assessed.[7,8] The comprehensive assessment of right heart involvement could provide the appropriate evaluation for TR severity, risk stratification, planning for the TV therapy and assessing the response to TTVI.

The TTVI can be divided into 4 domains: caval implants, tricuspid annuloplasty, valve replacement and direct leaflet approximation. While other reviews have well covered the role of CTA in the first 3 domains,[9] the role of CTA for TriClip (Abbott Vascular, Menlo Park, CA) procedural planning has not been well described. In the growing experience of our center with TriClip device implantation, CTA has an essential tool to provide in addition to functional and remodeling quantification, also critical information regarding mechanism of TR, TV/leaflet anatomy, motion, visualization of the valve gap, best fluoroscopic angles for coplanar alignment and leaflet grasping strategy. (Fig. 3).

Emerging role for cardiac magnetic resonance in TR and TTVI

CMR has the advantage of assessing cardiac anatomy and function with excellent spatial resolution and without body habits limitations, ionizing radiation and need for contrast injection. Dedicated RV views from multiple planes allow for comprehensive assessment of the RV size and function.[7,8]

CMR can provide quantification of TR volume and TR fraction by both direct (using RV-LV stroke volume) and indirect methods (using phase-contrast imaging). However, CMR quantification of TR severity has been less established than for other regurgitant valvular lesions. Cardiac arrhythmias and presence of intracardiac leads (particularly implantable cardioverter defibrillator) can create significant artifacts which can compromise image quality and interpretation. Furthermore, there are no CMR-specific cutoff values for TR severity.[8,10]

Despite the imaging obstacles aforementioned, the CMR potential to evaluate interval response of TriClip device in patients with severe TR has been recently documented.[11] This is a promising area of future research and investigation in the upcoming Triluminate study (NCT03904147).

Data on the timing of TR intervention with CMR remains limited. Preoperative RV end-systolic volume index and RV ejection fraction assessed by CMR have been associated with all-cause and cardiac mortality in patients with TR who received surgical TV intervention.[12]

Further studies are needed to evaluate the utility of these CMR parameters, in addition to RV scar, in the prediction of timing and response to TTVI.

Conclusions

Multimodality cross-sectional imaging with CTA and CMR have an emerging and complementary use to echocardiography. They are key in the comprehensive evaluation of the right-sided unit. In the context of TTVI, their importance will continue to grow and inform us on the ideal timing, patient selection, procedural planning and response to therapies tackling TR.

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References

1. Neuhold S, Huelsmann M, Pernicka E, et al. Impact of tricuspid regurgitation on survival in patients with chronic heart failure: unexpected findings of a long-term observational study. Eur Heart J 2013;34:844-852Available at, https://doi.org/10.1093/eurheartj/ehs465.
2. Benfari G, Antoine C, Miller WL, et al. Excess mortality associated with functional tricuspid regurgitation complicating heart failure with reduced ejection fraction. Circulation 2019;140:196-206Available at, https://doi.org/10.1161/CIRCULATIONAHA.118.038946.
3. Nishimura RA, Otto CM, Bonow RO, et al. 2014 AHA/ACC guideline for the management of patients with valvular heart disease: executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol 2014;63:2438-2488Available at, http://www.ncbi.nlm.nih.gov/pubmed/24603192.
4. Zoghbi WA, Adams D, Bonow RO, et al. Recommendations for noninvasive evaluation of native valvular regurgitation. J Am Soc Echocardiogr 2017;30:303-371Available at, https://linkinghub.elsevier.com/retrieve/pii/S089473171730007X.
5. Nemoto N, Lesser JR, Pedersen WR, et al. Pathogenic structural heart changes in early tricuspid regurgitation. J Thorac Cardiovasc Surg 2015;150:323-330Available at, https://linkinghub.elsevier.com/retrieve/pii/S0022522315006959.
6. Lewis MA, Pascoal A, Keevil SF, Lewis CA. Selecting a CT scanner for cardiac imaging: the heart of the matter. Br J Radiol 2016;89:20160376Available at, https://doi.org/10.1259/bjr.20160376.
7. Khalique OK, Cavalcante JL, Shah D, et al. Multimodality imaging of the tricuspid valve and right heart anatomy. JACC Cardiovasc Imaging 2019;12:516-531Available at, http://www.ncbi.nlm.nih.gov/pubmed/30846125.
8. Hahn RT, Thomas JD, Khalique OK, Cavalcante JL, Praz F, Zoghbi WA. Imaging assessment of tricuspid regurgitation severity. JACC Cardiovasc Imaging 2019;12:469-490Available at, https://linkinghub.elsevier.com/retrieve/pii/S1936878X19300981.
9. Prihadi EA, Delgado V, Hahn RT, Leipsic J, Min JK, Bax JJ. Imaging needs in novel Transcatheter tricuspid valve interventions. JACC Cardiovasc Imaging 2018;11:736-754Available at, https://linkinghub.elsevier.com/retrieve/pii/S1936878X18301992.
10. Cavalcante JL, Lalude OO, Schoenhagen P, Lerakis S. Cardiovascular magnetic resonance imaging for structural and valvular heart disease interventions. JACC Cardiovasc Interv 2016;9:399-425Available at, https://linkinghub.elsevier.com/retrieve/pii/S1936879815018531.
11. Rommel K-P, Besler C, Noack T, et al. Physiological and clinical consequences of right ventricular volume overload reduction after transcatheter treatment for tricuspid regurgitation. JACC Cardiovasc Interv 2019;12:1423-1434Available at, http://www.ncbi.nlm.nih.gov/pubmed/31326430.
12. Park J-B, Kim H-K, Jung J-H, et al. Prognostic value of cardiac MR imaging for preoperative assessment of patients with severe functional tricuspid regurgitation. Radiology 2016;280:723-734Available at, https://doi.org/10.1148/radiol.2016151556.