Perioperative Transesophageal Echocardiographic Assessment of the Right Heart and Associated Structures: A Comprehensive Update and Technical Report

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IMAGING OF THE RIGHT HEART is an important aspect of perioperative transesophageal echocardiographic assessment. Experienced clinicians are well aware of the value of intraoperative right-heart assessment to guide fluid and vasoactive drug therapy, ventilation, and successful separation from cardiopulmonary bypass. Many familiar nonstandard views have been included in the cardiac anesthesiologist's repertoire to assist in right-heart assessment.

This article discusses the functional anatomy of the right heart and associated structures, with emphasis on new insights offered by recently published work. The authors also review the two-dimensional transesophageal echocardiographic (2D TEE) assessment of the right heart by the application of the relevant ASE/SCA standard and nonstandard views. Methods of image acquisition and the application of these views in functional assessment are discussed. The authors also introduce and describe previously unevaluated views of right-heart structures. The feasibility of reliable capture of these views is assessed by the frequency of acquisition in a small case series of 30 subjects. The anatomy pertinent to the understanding of how these views are attained also is discussed and presented in conjunction with video and diagrammatic guides.

While the development of real-time three-dimensional transesophageal echocardiography shows great promise in adding further detail to right-heart assessment, its application in the operating room environment remains limited and will not be addressed in this article.

FUNCTIONAL ANATOMY OF THE RIGHT HEART

Pulmonary artery catheter monitoring provides important information on right-heart preload, afterload, and cardiac output; however, interpretation of its data still is subject to confounders. TEE can assist by confirming impressions suggested by invasive monitoring and adding further detail to guide fluid management and inotropic support, such as dynamic valvular assessment and indices of right ventricular (RV) systolic and diastolic function. An understanding of the various normal right atrial (RA) remnants will assist in the identification of right atrial masses. New insights into the shape of the tricuspid annulus in health and disease can guide surgical intervention.

RIGHT VENTRICLE

The RV is a V-shaped tubular chamber, with the tricuspid annulus and pulmonary annulus forming the tips of the "V". The free wall, septum, and apex of the RV delineate the anterior, posterior, and inferior margins of its wider midsection. The anatomic divisions of the right ventricle are the inflow region, free wall, outflow region, and septum (Fig 1), with the free wall further subdivided into inferior, anterior, and lateral segments based on commonly used echocardiographic views[1] (Fig 2). The irregular shape of the RV has made assessment of its volumes and systolic function difficult with simple uniplanar and geometric methods. The heavily trabeculated interior of the RV also creates problems in defining the endocardial border.

Akin to peristalsis, RV contraction is sequential. Contraction begins with vertical shortening of the inflow region, followed by motion of the free wall toward the septum. Outflow tract contraction is the last to be initiated, generated by increased tension at the junctions of the free wall and outflow tract fibers to the interventricular septum.[2] The multidirectional orientation of myocardial muscle fibers in the RV results in a complex contractile pattern. Most fibers lie in a base-to-apex orientation in the subendocardial layer.[3] The remainder lie in the superficial myocardium, run circumferentially in an approximately perpendicular direction, and are responsible for free wall contraction.[4] Unlike the LV, the RV does not possess a middle myocardial layer consisting of circumferential muscle fibers,[5] and, hence, longitudinal contraction contributes most to RV systolic motion.[6] This explains the utility of tricuspid annular plane systolic excursion (TAPSE) and tricuspid annular systolic myocardial velocities (S') as indices of RV systolic function. Assessment of RV wall thickening is difficult because of its thin myocardium and subtlety of thickening.[7] Doppler and speckle-tracing derived strain and strain-rate techniques are alternative methods in quantifying RV wall thickening, but these techniques can be

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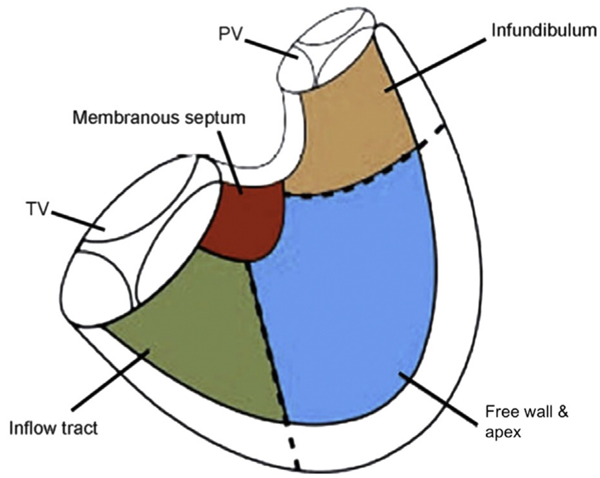

Fig 1. Inflow, free wall, and outflow segments of the right ventricle. TV, tricuspid valve, PV, pulmonary valve. Reproduced in part with permission from Haddad F, et al: Right ventricular function in cardiovascular disease, part I: Anatomy, physiology, aging, and functional assessment of the right ventricle. Circulation 117:1436–1448, 2008. (Color version of figure is available online.)

tedious, do not have normal values established,[8] and are only validated in small samples.

Ventricular interdependence refers to the impairment of function of one ventricle when the primary problem lies with the other. A significant proportion of RV function is dependent on septal contraction[9] as the muscle fibers of the left ventricle (LV) and RV are in continuity at the septum,[2] and RV free wall contraction relies on tension at its anterior and posterior attachments to the septum. In turn, LV preload and perfusion of the systemic and coronary circulation are dependent on RV output. RV hypertrophy also causes an inward "bowing" of the septum toward the LV, impairing LV diastolic function.[5]

The RV tolerates volume loading well compared with the LV, because of its greater compliance.[10] This increased compliance, however, makes the RV more susceptible to compression, severely reducing diastolic filling during exposure to high intrathoracic pressures. The lower contractility of the thin-walled RV compared with the LV also means that acute increases in afterload are poorly tolerated. These factors explain the phenomenon of pulsus paradoxus and hemodynamic effects of the valsalva maneuver and why echocardiographic indices of diastolic and systolic function of the RV are highly load-dependent. With a smaller myocardial mass, favorable coronary perfusion pressure, and lower stroke work indices and loading conditions than the LV, the RV has a greater reserve at times of ischemia.[5]

The low resistance, high capacitance pulmonary circulation that is responsible for the majority of RV afterload is the reason why the thin-walled, compliant RV is able to match the cardiac output of the LV. This low afterload state creates a situation in which small changes in RV pressure trigger the opening and closing of the pulmonary valve (PV), and, hence, isovolumic

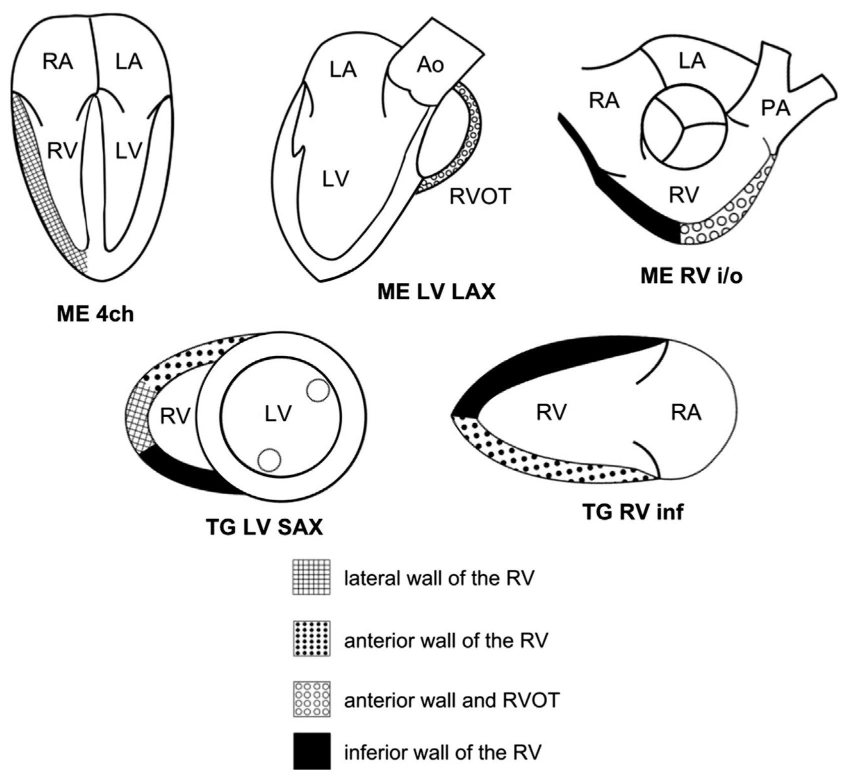

Fig 2. Segmental divisions of the RV free wall as seen in 2D TEE. LA, left atrium; RA, right atrium; LV, left ventricle; RV, right ventricle; Ao, aorta; PA, pulmonary artery. Reproduced in part with permission from Haddad F, et al: Right ventricular function in cardiovascular disease, part I: Anatomy, physiology, aging, and functional assessment of the right ventricle. Circulation 117:1436–1448, 2008.