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Original Article

Vendor-Neutral Right Ventricular Strain Measurement

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Objective: To test the feasibility and reliability of using a vendor-neutral platform to evaluate right ventricular (RV) strain. Reliability was determined by comparing intra- and inter-observer variability between RV strain assessments. The secondary objective was to assess strain's correlation with conventional RV functional parameters to evaluate its feasibility as a RV systolic functional assessment tool.
Design: This is a retrospective study.
Setting: Tertiary hospital.
Participants: A total of 15 patients who underwent elective coronary artery bypass graft surgery were selected for inclusion.
Interventions: None.
Measurements and Main Results: Images obtained during routine, intraoperative, two-dimensional transesophageal echocardiography (2D TEE) were assessed for longitudinal strain (LS) and conventional parameters, including fractional area change (FAC), tricuspid annular plane systolic excursion (TAPSE), Doppler tissue imaging (DTI)-derived tricuspid lateral annular systolic velocity wave (S'), and RV dimensions using vendor-neutral software. There was good to excellent intra- and inter-observer reproducibility (intraclass correlation coefficient [ICC] from 0.75 to 1.00) with the exception of basal free wall longitudinal strain (FWLS) (for intra- and inter-observer reproducibility, ICC = 0.670 and 0.749, respectively). FWLS and global longitudinal strain (GLS) showed moderate to strong positive correlation with FAC, TAPSE, and S' (correlation coefficients from 0.667 to 0.721).
Conclusion: It is feasible to assess RV strain across multiple platforms in a reproducible and reliable fashion. Furthermore, RV strain demonstrated good correlation with conventional RV functional parameters, suggesting its feasibility as a sensitive RV function assessment tool.

Key Words: inter-observer; intra-observer; reproducibility; correlation; strain; right ventricular function

STRAIN IS DEFINED AS the relative length changes of individual myocardial fibers at systole and diastole, and is considered a functional parameter for early detection of myocardial dysfunction.[1] Strain assessment is a functional assessment technique that has recently found application in the clinical realm and involves speckle tracking estimates of the motion velocity of small fractions of the heart muscle. Strain can detect subtle functional changes often not appreciated with visual qualitative evaluation. Specifically, strain recently has displayed value in right ventricular (RV) functional assessment.[2] Due to the unique shape and contractility of the RV, conventional two-dimensional (2D) imaging precludes a comprehensive quantitative RV functional assessment. Because strain evaluation is derived from the relative change

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in length from the original length, it overcomes many of the limitations of the conventional parameters.[3,4] Initial evidence regarding RV longitudinal strain (LS) has demonstrated correlation with RV functional assessment with cardiac magnetic resonance imaging.[5] Further studies have demonstrated that RV LS is a more sensitive measurement for RV functional assessment when compared to the other conventional parameters.[6] Despite widespread availability and use, there is a lack of inter-vendor compatibility of strain assessment software with a subsequent lack of standardization.[7,8] This is a practical hurdle in its widespread adoption and use as a routine RV functional assessment tool.

Lack of uniform standards across various platforms impedes the development of normative data and universal guidelines for RV strain assessment, limiting the applicability of existing data.[9] Therefore, a universal, vendor-neutral platform with the ability to evaluate strain would be an important tool to achieve standardization. Similar limitations in three-dimensional (3D) imaging have been addressed and resolved with the availability of vendor-neutral applications for geometric analyses of 3D data.[10–12] Vendor-neutral applications are now commercially available for strain assessment across platforms. However, their feasibility and reliability, including intra- and inter-observer reproducibility, have not been evaluated systematically.[13] Therefore, the authors conducted this study to evaluate the feasibility and reliability of RV strain assessment across multiple ultrasound platforms with commercially available, vendor-neutral software. The secondary objective of this study was to assess strain's correlation with conventional RV functional parameters to evaluate its feasibility as a RV functional assessment tool.

Materials and Methods

This study was conducted as part of the authors' Institutional Board Review-approved protocol with a waiver of informed consent for post-acquisition analysis of intraoperative echocardiographic data. The analyzed echocardiographic data were selected from transesophageal echocardiographic (TEE) studies conducted between October 1, 2017, and December 31, 2017. Patients undergoing elective coronary artery bypass graft surgery were selected for inclusion in this study. Criteria for inclusion were sinus rhythm, normal bi-ventricular size and function, absence of any valvular abnormality, and patients in whom a satisfactory focused RV view was acquired.

Two-Dimensional Echocardiography

All TEE examinations were performed after induction of general anesthesia in the operating room prior to the start of the surgical procedure. The comprehensive intraoperative TEE examination was conducted prior to the initiation of this study according to the guidelines[14] and during a brief period of apnea and lack of patient motion. These exams were then accessed and reviewed retrospectively to confirm eligibility for inclusion in the study and acquisition of suitable RV views. A focused RV view was defined as a mid-esophageal 4-chamber view with visualization of the entire lateral mitral and the tricuspid annulus, left ventricular (LV) apex, entire RV free wall, and mitral and tricuspid valves without any significant artifacts. A single expert (F.M.) confirmed the image quality of the focused RV view with a satisfactory spatial resolution and frame rate (50-92 frames per second).

After acquisition, all data were copied on digital media—Universal Serial Bus (USB) drive in the Digital Imaging and Communications in Medicine (DICOM) format for off-line access and analysis. The USB was accessed on a desktop workstation with commercially available strain analysis software EchoInsight (Epsilon Imaging, Ann Arbor, MI).

For the purpose of this study, multiple ultrasound platforms were used for acquisition of intraoperative TEE data. Fifteen patients with 5 patients per ultrasound system were selected for this study. The ultrasound systems used were a Philips iE33 ultrasound machine with an X7-2t TEE transducer (Philips Medical Systems, Andover, MA), a Siemens ACUSON SC2000 ultrasound machine with an XM-5 TEE transducer (Siemens Medical Systems, Mountainview, CA), and a General Electric Vivid E95 TEE ultrasound machine with a 6VD-T transducer (General Electric Corporation, Boston, MA).

Parameters Analyzed

The values of RV strain were calculated by EchoInsight for global longitudinal strain (GLS), free wall longitudinal strain (FWLS), septal longitudinal strain (SLS), basal free wall longitudinal strain (basal FWLS), mid free wall longitudinal strain (mid FWLS), apical free wall longitudinal strain (apical FWLS), basal septum longitudinal strain (basal SLS), mid septum longitudinal strain (mid SLS), and apical septum longitudinal strain (apical SLS). Additional parameters analyzed automatically by the software included RV fractional area change (FAC), tricuspid annular plane systolic excursion (TAPSE), Doppler tissue imaging (DTI)-derived tricuspid lateral annular systolic velocity wave (S'), and RV dimensions (RV basal diameter, RV mid diameter, and RV longitudinal diameter).

1. GLS: Defined as the relative change in the length of the global RV myocardium.
2. FWLS: Defined as the relative change in the length of the myocardium of the RV free wall. It includes basal FWLS, mid FWLS, and apical FWLS.
3. SLS: Defined as the relative change in the length of the myocardium of the RV septum. It includes basal SLS, mid SLS, and apical SLS.
4. FAC: Defined as the percentage change in RV area between end-diastole and end-systole.
5. TAPSE: Defined as the distance of systolic excursion of the RV annular plane toward the apex.
6. S': Defined as the longitudinal velocity of excursion of tricuspid annular motion.

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