Journal of Cardiothoracic and Vascular Anesthesia ▮ (▮▮▮▮) ▮▮▮–▮▮▮

Contents lists available at ScienceDirect

Journal of Cardiothoracic and Vascular Anesthesia

journal homepage: www.jcvaonline.com

Original Article

Utility of Angle Correction for Hemodynamic Measurements with Doppler Echocardiography

Martin I. Sigurdsson, MD, PhD*,[1], Eun J. Eoh, MD*, Vinca W. Chow, MD*, Nathan H. Waldron, MD, MSc*, Jayne Cleve, BS, RDCS†, Alina Nicoara, MD, FASE*, Madhav Swaminathan, MD, FASE, FAHA*, for the Multidisciplinary Echo Research Group for Enhancing Discovery (MERGED) team

*Division of Cardiothoracic Anesthesiology and Critical Care Medicine, Department of Anesthesiology, Duke University Medical Center, Durham, NC

†Division of Cardiology, Department of Medicine, Duke University Medical Center, Durham, NC

Objectives: The routine application angle correction (AnC) in hemodynamic measurements with transesophageal echocardiography currently is not recommended but potentially could be beneficial. The authors hypothesized that AnC can be applied reliably and may change grading of aortic stenosis (AS).

Design: Retrospective analysis.

Setting: Single institution, university hospital.

Participants: During phase I, use of AnC was assessed in 60 consecutive patients with intraoperative transesophageal echocardiography. During phase II, 129 images from a retrospective cohort of 117 cases were used to quantify AS by mean pressure gradient.

Interventions: A panel of observers used custom-written software in Java to measure intra-individual and inter-individual correlation in AnC application, correlation with preoperative transthoracic echocardiography gradients, and regrading of AS after AnC.

Measurements and Main Results: For phase I, the median AnC was 21 (16-35) degrees, and 17% of patients required no AnC. For phase II, the median AnC was 7 (0-15) degrees, and 37% of assessed images required no AnC. The mean inter-individual and intra-individual correlation for AnC was 0.50 (95% confidence interval [CI] 0.49-0.52) and 0.87 (95% CI 0.82-0.92), respectively. AnC did not improve agreement with the transthoracic echocardiography mean pressure gradient. The mean inter-rater and intra-rater agreement for grading AS severity was 0.82 (95% CI 0.81-0.83) and 0.95 (95% CI 0.91-0.95), respectively. A total of 241 (7%) AS gradings were reclassified after AnC was applied, mostly when the uncorrected mean gradient was within 5 mmHg of the severity classification cutoff.

Conclusions: AnC can be performed with a modest inter-rater and intra-rater correlation and high degree of inter-rater and intra-rater agreement for AS severity grading.

Key Words: TEE; aortic stenosis; angle correction; grading

DOPPLER ULTRASOUND remains the principal method for noninvasive measurement of blood flow velocity. Application of Doppler principles constitutes the backbone of clinical hemodynamic assessment using transthoracic (TTE) and transesophageal (TEE) echocardiography. However, the

[1]*Address reprint requests to* Martin I. Sigurdsson, MD, PhD, Box 3094, Duke University Medical Center, Department of Anesthesiology, Erwin Rd, Durham, NC 27710.

E-mail address: martin.sigurdsson@duke.edu (M.I. Sigurdsson).

https://doi.org/10.1053/j.jvca.2018.04.020
1053-0770/

accuracy of calculated blood flow velocities can be affected by significant deviation of the interrogation angle between the ultrasound beam and blood flow.

Most ultrasound machines can perform angle correction (AnC), allowing the user to define a line parallel to the blood flow and then adjusting for the angle between that line and the trajectory of the ultrasound beam. The most recent consensus guidelines from the European Association of Cardiovascular Imaging and the American Society of Echocardiography for quantification of valvular stenosis do not recommend AnC, in part because of the potential for increasing error, given the unpredictability of the direction of the jet.[1] The previous guidelines on valvular stenosis assessment recommended that the angle of incidence not exceed 15 degrees,[2] and the American Society of Echocardiography guidelines on Doppler echocardiography do not recommend AnC but rather suggest that the angle of incidence not exceed 20 degrees.[3] These recommendations also do not provide guidance on the problem of approximating the velocity of jets with unpredictable directions using 2-dimensional imaging. However, if AnC is applied reliably and correctly, doing so might improve the accuracy of 2-dimensional blood velocity measurements, especially when image acquisition does not allow for a low incident angle. Although this certainly does not replace assessing valvular function and structure using multiple 2- and 3-dimensional views, AnC might improve the accuracy of some frequently used ultrasound measurements made using 2-dimensional imaging, if AnC can be performed reliably.

The authors considered that AnC potentially could be beneficial during routine echocardiographic hemodynamic measurements, such as the quantification of aortic stenosis (AS), in which its application might, alter the grading of AS severity based on the mean gradient. Furthermore, the intra-observer and inter-observer variability in the application of AnC is unknown. The authors therefore conducted a study to determine the incidence of any misalignment of the Doppler beam with blood flow and assess the distribution of applied AnC and the consistency and reliability of its application. Furthermore, to provide an example of its application, the authors evaluated how applying AnC might change the grading severity of AS if graded by the mean gradient. The authors hypothesized that (1) misalignment, defined as any incident angle, of ultrasound with blood flow frequently occurs in routine imaging; (2) AnC can be applied consistently and reliably to hemodynamic measurements with Doppler using TEE; and (3) applying AnC would change the AS severity grading by the mean gradient in a substantial number of patients presenting for aortic valve replacement surgery.

Methods

After Institutional Review Board approval, data were obtained from the Duke University Hospital intraoperative echocardiography database that collects all TEE examinations in real time dating to January 2000. The patient population comprised adult patients undergoing cardiothoracic surgery requiring intraoperative TEE. Patients were imaged based on a standard imaging protocol for intraoperative TEE for all cardiothoracic surgery patients. Demographic, clinical, and echocardiographic data were obtained from the Duke University Hospital intraoperative echocardiography database and individual chart review.

Patient Selection

The study was conducted in 2 phases involving 2 distinct study populations. Phase I was a pilot study conducted to quantify the number of patients requiring any AnC and the amount of AnC needed. In this phase, the authors prospectively included any examinations performed and included into their institutional database from September to November 2016. Clinicians performing examinations for adult patients requiring TEE for intraoperative monitoring during cardiothoracic surgery were asked to perform measurements of blood flow using pulsed-wave Doppler in the left ventricular outflow tract from the deep transgastric view with and without AnC. This was performed using the default image acquisition software on the machine. All images were performed during a routine assessment after the institutional TEE imaging protocol in the precardiopulmonary bypass period. Measurements were performed either by fellows under supervision in an advanced perioperative TEE training program or by cardiac anesthesiology faculty with advanced perioperative TEE certification. Velocity measurements with and without AnC were performed sequentially to minimize hemodynamic changes between measurements. The results from this data set were used to generate a hypothesis about how aortic valve gradient and AS grading would change after a theoretical application of the mean AnC.

In phase II, a convenience cohort was used, which included a subset of a larger database of 318 patients undergoing aortic valve replacement that was used previously in a prior study to compare TEE grading of AS by pressure gradient and valve area.[4] This database included 318 patients undergoing aortic valve replacement with or without concomitant coronary bypass procedure. Patients were required to have available measurement of the aortic valve pressure gradient via continuous wave Doppler, either from the transgastric long-axis or deep transgastric view. Per the inclusion criteria for the prior study using this database, patients were excluded if they underwent emergency surgery, prior sternotomy, ejection fraction less than 55%, more-than-mild mitral regurgitation, or severe aortic insufficiency.[4] In addition, individuals with a reported mean valve gradient more than 40 mmHg ($n = 127$) were excluded to ensure that application of AnC potentially could affect AS grading. Furthermore, individuals in whom static images used for grading were of inadequate quality (without clear view of septal wall and left ventricular outflow tract, $n = 66$) also were excluded. Finally, images from 8 patients could not be retrieved, leaving images from 117 patients for analysis. All images for phase II were exported without patient identifiers and stored in a secure, password-protected location in compliance with institutional regulations.

Please cite this article as: Sigurdsson MI, et al. (2018), https://doi.org/10.1053/j.jvca.2018.04.020