Left Ventricular End Diastolic Loading: Comparison of Cardiac MR with Echocardiography

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Research Article

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Abstract

Purpose

In a prior publication, loss of myocardial bounce was highly associated with systolic and diastolic dysfunction. The bounce is the rapid change in LV volume at the end of diastole during atrial contraction just prior to systolic ejection. This study attempts to determine if bounce is associated with diastolic dysfunction determined by echocardiography.

Methods

135 patients with an echocardiogram and a cardiac MR were selected with 38% of those paired of studies within three months of each other. The bounce was graded by 3 blinded observers into categories of 0=none, 1=minimal/reduced, and 2=normal bounce.

Results

Inter-reader agreement was summarized using the intraclass correlation coefficient (ICC) and ratings was moderate [ICC 0.60, 95% confidence interval (0.51-0.68)]. The sensitivity and specificity of lack of bounce (grade 0 or 1) as a screen for diastolic dysfunction on echo were 89% and 47%, respectively.

Conclusion

The simple observation of a normal myocardial bounce in MRs was predictive of normal diastolic function and lack of was highly associated with dysfunction determined via echocardiography. Systolic function remains normal in some of these patients and this finding may represent diastolic dysfunction. Further studies examining the relationship between bounce with different types of diastolic function is needed. This updated study confirms myocardial bounce seen on various cardiac imaging modalities may be a simple useful tool for detecting cardiac dysfunction.

Introduction

The prevalence of heart failure in the U.S. is increasing, and it is expected that more than 8 million patients will develop heart failure within the next decade. Echocardiography remains the study of choice for the evaluation of heart failure, and the evaluation of diastolic function in particular depends upon Doppler evaluation including waveforms taken at the mitral valve [1–3].

The mechanics of myocardial contraction and relaxation are well known [4]. The more the myocardium stretches during diastole [5], the more it contracts during systole [6–8]. In our prior study, we estimated that the ventricular wall stretch or loading that occurs at end diastole accounts for 15 to 20% of ejection volume [9].

It is helpful to separately consider the events of early and late diastole. In early diastole, the ventricle continues to achieve relaxation, and any slowing of that process will affect early filling. By late diastole, relaxation of the ventricle is complete, and filling is determined by the stiffness of the myocardium and vigor of the atrial contraction. Diastolic dysfunction can affect either or both parts of diastole. Doppler echocardiography of the transmitral flow demonstrates an early diastolic flow called the E wave and a late flow called the A wave, caused by atrial contraction. In normal functioning hearts, the E wave is of greater velocity than A wave, indicating that atrial contraction contributes a smaller amount of filling to the left ventricle compared to that which occurs early. There are other measures of diastolic function obtained at echocardiography, one of the most popular being the ratio of the E wave velocity to the mitral annular velocity (e’), or the E/e’ ratio [12–15].

The interpretation of cardiac MR has generally not paid much attention to diagnosing diastolic dysfunction [16]. We have repeatedly observed that healthy adult hearts demonstrate a definite myocardial bounce seen as a rapid change in LV volume at the end of diastole that occurs secondary to atrial contraction just prior to systolic ejection. Given its simplicity, the purpose of this study attempts to determine if the simple observation of the myocardial bounce can be utilized as a screening tool for diastolic dysfunction when compared with echocardiographic report as the standard of disease detection.

Materials And Methods

Following IRB approval, study #STUDY0000327, a search of the echocardiography and cardiac MR databases were undertaken from January 2010 through July 2020 to determine the number of patients that underwent both exams. These were further refined using the following inclusion criteria: Age over 17 years, diastolic function assessments at echocardiography including E/e’ and E/A ratios, and a cardiac MR that included a short axis stack. The study excluded echocardiograms where diastolic function was not assessed, those with a mass, thrombus, myocardial infarct, arrhythmias including atrial fibrillation, the presence of a significant congenital defect, pulmonary venous mapping or MR aortic studies. All patients had echocardiographic reports and charts were reviewed for correlation.

All MR images were obtained on Philips Achieva 1.5T (Amsterdam, Holland). The short axis stack and four chamber views were reviewed. The MR protocol was as follows: Slices total: 12, Slice orientation: Short axis, 4 Chamber Technique: bFFE, Acquisition mode: CARTESIAN, Fat suppression: None, Total scan duration: 00:32.0, Act. TR/TE (shifted) (ms): 2.7 / 1.37, Scan time / BH:00:10.7, FOV MPS (mm): 300 x 300, ACQ matrix M x P: 200 x 200, TFE factor: 14, TFE shots: 3, TFE dur. shot / acq (ms): 38.3 / 38.3, TFE shot interval (ms): 38.3, Act. Phase acq (%): 69.6, Local torso SAR: < 92%, Whole body SAR / level: < 2.3 W/kg / 1st level.

The diastolic loading is defined as the rapid change over a time period of 100 to 120 ms in LV volume that occurs at the end of diastole secondary to atrial contraction just prior to systolic ejection. All images were reviewed by 3 blinded graders, one with 15 years of experience performing cardiac MR, one medical student with 1 year experience, and one with no experience. After the first round of independent review of 10 cases with discrepant reads (5 grade 0, 1 grade 1, 4 grade 2), they were revisited by two readers (CR, TJD) who viewed the cine loop together and to ensure consensus. An echo report that listed diastolic function as normal was interpreted as normal, an echo report that commented on diastolic dysfunction, increased filling pressures, impaired ventricular relaxation, or reduction in ventricular compliance were all scored as presence of diastolic dysfunction.

Consistency of individual bounce ratings was assessed using the intraclass correlation coefficient (ICC). The ICC command in Stata version 16 [33] was used to estimate the ICC using a two-way mixed effects model, which corresponds to ICC (3,1) in [34].

Results

135 patients' cardiac MR and echocardiography exams met the inclusion criteria and were graded as following: 0 = no bounce; 1 = minimal/reduced bounce; 2 = strong/normal bounce. At time of exam, patient characteristics and other variables are presented in (**Table I**). Clinical indications for the cardiac MR included: shortness of breath, dyspnea on exertion, or chest pain. The cohort included 68 females, 67 males, age ranged from 18–82 (Median: 53), E/A ratio ranged from 0.45–8.4 (Mean: 1.65) and E/e' ranged from 2.2–34.06 (Mean: 13.07). Sensitivity 0.89, specificity 0.47, PPV 0.70, NPV 0.75 for bounce grades 0 or 1 (screen positive for diastolic dysfunction) versus 2 (screen negative for diastolic dysfunction) compared to standard of diastolic dysfunction determination by echocardiography report.

E/A and E/e' distributions versus degree of bounce are shown in Figs. 1 and 2. There was no significant change difference in the E/A or E/e' ratios related to the degree of bounce.

Inter-reader agreement

Inter-reader agreement is summarized in (**Table 2**), using the ICC. Overall agreement was moderate with ICC = 0.60 (95% CI: 0.51–0.68).

Bounce grade vs. summary report from echocardiography

The distribution for bounce grade vs the final impression of all the data in the echocardiography report is summarized in (Table 3).

Bounce Grade as Screening Test vs. Echo Report Diastolic Dysfunction as Standard of Disease State

The sensitivity and specificity of bounce grading as a screening test are summarized in (Table 4). Bounce grades of 0 or 1 as a positive screen for diastolic dysfunction, with Bounce 2 as negative screen for diastolic dysfunction. Echo report as standard for diastolic dysfunction adjudication (disease state).

Discussion

Our data indicates that the end diastole myocardial bounce is reliably appreciated between three blinded observers. Overall agreement was moderate with ICC = 0.60 (95% CI: 0.51–0.68).

This study examined whether the presence, reduction or absence of the myocardial bounce seen during atrial contraction at end diastole seen on one mid-ventricular slice on cardiac MR corresponds to diastolic dysfunction determined on echocardiography report. Very few studies have been performed that compare cardiac MR to echocardiography directly [17–19]. We obtained reasonable sensitivities for diastolic dysfunction when grade 0 and 1 were combined and compared to grade 2. Late filling contributes to preload while a decrease can also indicate increased left ventricular stiffness or atrial dysfunction. Loss or decrease in myocardial bounce would make sense if there is decreased late filling. If there is slowed relaxation, which is another representation of diastolic function, that would primarily affect early diastole, and can even cause increased late filling.

In most of the prior publications on the evaluation of diastolic dysfunction with cardiac MR, no evaluation of heart filling such as we have outlined was discussed. Studies of diastolic function with echocardiography have concluded that in patients with HF, there is evidence of both systolic and diastolic dysfunction [23, 24]. Although little has been reported on myocardial bounce seen on cardiac MR and echocardiography, several recent studies have discussed using geometric changes in hearts and its relationship to cardiac function. Ramos et al. and Mordi et al. concluded extracellular volume (ECV) [25, 26] and global longitudinal strain (GLS) were associated with HFpEF [27]. Chen used native T1 relaxation times to evaluate the hemodynamics of pulmonary hypertension [28]. De Jesus measured myocardial elastography in patients with mitral regurgitation to predict post-surgical repair outcomes [29]. Kim and Zeng evaluated left ventricular geometry to predict response to percutaneous mitral valve repair [30, 31]. While elegant, these highly advanced MR techniques require additional scanning and processing time. The observation of the presence or absence of the end diastolic myocardial bounce can be made readily after minimal training in every case without any extra MR sequences.

This study has several limitations. We initially attempted to correlate bounce score with direct quantitative measures from echocardiography but ran into obstacles. Not every parameter was reported on every patient's echocardiogram, hence the differing total numbers of patients for E/A and E/e' in our data. E/A and E/e' ratio can be abnormal when elevated or low [32]. In particular, E/A can be either increased or decreased depending on the type of diastolic dysfunction. Both values can change as the heart adapts and it sometimes becomes necessary to perform a Valsalva maneuver to determine if these are truly normal or pseudo-normal in the setting of known HF. At this time, Valsalva is not part of our cardiac MR protocol, or routinely part of the echo protocol. While lack of bounce was highly associated with abnormal diastolic function parameters, a large number of cases with normal E/A and E/e' showed abnormal bounce. We suspect this occurs because of the divergence of abnormalities depending on the type of diastolic dysfunction and because not every parameter on echocardiography will necessarily be abnormal in patients with heart failure and diastolic dysfunction. If one looks at the final echocardiography reports, which are dependent on all of the parameters rather than just the ones we have evaluated in this manuscript, much better specificities are obtained (Table 4). Long term follow up will be necessary to observe the outcomes in these patients. Unfortunately, not every MR was performed within a few weeks of the echocardiogram with some being delayed by over a year. Lastly, we acquired images at 26 frames per second, but there is evidence that acquiring images at higher frame rates improves the evaluation of diastolic function [19].

Conclusion

The observation whether myocardial bounce is present or absent is easy to make, requires no advanced MR sequences, and can be implemented in every case if a four-chamber view and a short axis stack are obtained. Reduced or absent myocardial bounce during atrial contraction at end diastole on cardiac MR corresponds to diastolic dysfunction. Our findings suggest the assessment of myocardial bounce in cardiac MR could become a simple and useful tool for diagnosis of early diastolic dysfunction. Additional studies with long term outcomes in cases with normal echocardiographic measurements are needed to determine the potential utility of myocardial bounce in the detection of isolated diastolic dysfunction.

Declarations

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Competing interests

The authors have no relevant financial or non-financial interests to disclose.

Author Contributions

All authors contributed to the study conception and design. Material preparation and data collection were performed by Theodore J. Dubinsky, Christopher Rumer, and Erica Qiao. Statistical analysis were performed by Theodore J. Dubinsky. The first draft of the manuscript was written by Christopher Rumer and Erica Qiao, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript

Ethics Approval

This research study was conducted retrospectively from data obtained for clinical purposes. Ethical approval to report this study was obtained via IRB approval study #STUDY0000327 at the University of Washington.

Consent to participate

All information in this publication is anonymized and does not include images that may identify a person.

Consent to publish

All information in this publication is anonymized and does not include images that may identify a person.

References

1. Amano, M., Izumi, C., Kim, Y. J., Park, S. J., Park, S. W., Tanaka, H., Hozumi, T., Ling, L. H., Yu, C. M., Fukuda, S., Otsuji, Y., Song, J. K., & Sohn, D. W. (2020). Changes of echocardiographic parameters in primary mitral regurgitation and determinants of symptom: an assessment from the Asian Valve Registry data. *Heart and Vessels*, *35*(4), 555-563. https://doi.org/10.1007/s00380-019-01514-x
2. Aquila I, Fernández-Golfín C, Rincon LM, et al. Fully automated software for mitral annulus evaluation in chronic mitral regurgitation by 3-dimensional transesophageal echocardiography. Medicine. 2016 Dec;95(49):e5387. DOI: https://doi.org/10.1097/md.0000000000005387. PMID: 27930514; PMCID: PMC5265986.
3. Aruta P, Muraru D, Guta AC, Mihaila S, Ruozi N, Palermo C, Elnagar B, Iliceto S, Badano LP. Comparison of mitral annulus geometry between patients with ischemic and non-ischemic functional mitral regurgitation: implications for transcatheter mitral valve implantation. Cardiovasc Ultrasound. 2018 Oct 12;16(1):27. doi: https://doi.org/10.1186/s12947-018-0145-8. PMID: 30314517; PMCID: PMC6186037.
4. Abel FL. Pmax, end systolic elastance, and Starling's law of the heart. Shock (Augusta, Ga.). 2001 Jan;15(1):56-59. DOI: https://doi.org/10.1097/00024382-200115010-00009. PMID: 11198358.
5. Baan J, van der Velde ET, Steendijk P. Ventricular pressure-volume relations in vivo. *Eur Heart J*. 1992;13 Suppl E:2-6. doi: https://doi.org/10.1093/eurheartj/13.suppl_e.2
6. Giuliodori, M. J., Lujan, H. L., Briggs, W. S., Palani, G., & DiCarlo, S. E. (2009). Hooke's law: applications of a recurring principle. *Advances in physiology education*, *33*(4), 293–296. https://doi.org/10.1152/advan.00045.2009
7. Babu, A., Sonnenblick, E., & Gulati, J. (1988). Molecular basis for the influence of muscle length on myocardial performance. *Science (New York, N.Y.)*, *240*(4848), 74–76. https://doi.org/10.1126/science.3353709
8. BRAUNWALD, E., FRAHM, C. J., & ROSS, J., Jr (1961). Studies on Starling's law of the heart. V. Left ventricular function in man. *The Journal of clinical investigation*, *40*(10), 1882–1890. https://doi.org/10.1172/JCI104412
9. Brady A. J. (1966). Onset of contractility in cardiac muscle. *The Journal of physiology*, *184*(3), 560–580. https://doi.org/10.1113/jphysiol.1966.sp007931
10. Uretsky, S., Aldaia, L., Marcoff, L., Koulogiannis, K., Argulian, E., Lasam, G., & Gillam, L. (2020). Concordance and Discordance of Echocardiographic Parameters Recommended for Assessing the Severity of Mitral Regurgitation. *Circulation. Cardiovascular imaging*, *13*(5), e010278. https://doi.org/10.1161/CIRCIMAGING.119.010278

11. Peteiro, J., Barriales-Villa, R., Larrañaga-Moreira, J. M., Bouzas-Mosquera, A., Martinez-Veira, C., Castro-Dios, D., Fernández-Fernández, X., Monserrat, L., & Vazquez-Rodriguez, J. (2021). Value of a comprehensive exercise echocardiography assessment for patients with hypertrophic cardiomyopathy. *Journal of cardiology*, *77*(5), 525–531. https://doi.org/10.1016/j.jjcc.2020.11.017
12. Nabati, M., Salehi, S., Bagheri, B., & Nouraei, M. (2016). Abnormal left ventricular relaxation and symptoms of heart failure. *Journal of echocardiography*, *14*(3), 113–119. https://doi.org/10.1007/s12574-016-0287-3
13. Nasser, R., Van Assche, L., Vorlat, A., Vermeulen, T., Van Craenenbroeck, E., Conraads, V., Van der Meiren, V., Shivalkar, B., Van Herck, P., & Claeys, M. J. (2017). Evolution of Functional Mitral Regurgitation and Prognosis in Medically Managed Heart Failure Patients With Reduced Ejection Fraction. *JACC. Heart failure*, *5*(9), 652–659. https://doi.org/10.1016/j.jchf.2017.06.015
14. Ngiam, J. N., Chew, N., Teng, R., Kochav, J. D., Kochav, S. M., Tan, B. Y., Sim, H. W., Sia, C. H., Kong, W., Tay, E., Yeo, T. C., & Poh, K. K. (2020). Clinical and echocardiographic features of paradoxical low-flow and normal-flow severe aortic stenosis patients with concomitant mitral regurgitation. *The international journal of cardiovascular imaging*, *36*(3), 441–446. https://doi.org/10.1007/s10554-019-01735-1
15. Topilsky, Y., Rozenbaum, Z., Khoury, S., Pressman, G. S., Gura, Y., Sherez, J., Man, A., Shimiaie, J., Edwards, S., Berookhim, J., Le Tourneau, T., Halkin, A., Biner, S., Keren, G., & Aviram, G. (2017). Mechanisms of Effort Intolerance in Patients With Heart Failure and Borderline Ejection Fraction. *The American journal of cardiology*, *119*(3), 416–422. https://doi.org/10.1016/j.amjcard.2016.10.026
16. Capron, T., Cautela, J., Scemama, U., Miola, C., Bartoli, A., Theron, A., Pinto, J., Porto, A., Collart, F., Lepidi, H., Bernard, M., Guye, M., Thuny, F., Avierinos, J. F., & Jacquier, A. (2020). Cardiac magnetic resonance assessment of left ventricular dilatation in chronic severe left-sided regurgitations: comparison with standard echocardiography. *Diagnostic and interventional imaging*, *101*(10), 657–665. https://doi.org/10.1016/j.diii.2020.04.014
17. Rigolli, M., Anandabaskaran, S., Christiansen, J. P., & Whalley, G. A. (2016). Bias associated with left ventricular quantification by multimodality imaging: a systematic review and meta-analysis. *Open heart*, *3*(1), e000388. https://doi.org/10.1136/openhrt-2015-000388
18. Rosa, I., Marini, C., Stella, S., Ancona, F., Spartera, M., Margonato, A., & Agricola, E. (2016). Mechanical dyssynchrony and deformation imaging in patients with functional mitral regurgitation. *World journal of cardiology*, *8*(2), 146–162. https://doi.org/10.4330/wjc.v8.i2.146
19. Zhang, J., Chen, J., Cheong, B., Pednekar, A., & Muthupillai, R. (2019). High frame rate cardiac cine MRI for the evaluation of diastolic function and its direct correlation with echocardiography. *Journal of magnetic resonance imaging : JMRI*, *50*(5), 1571–1582. https://doi.org/10.1002/jmri.26791
20. DiBello, V., Bianchi, A. M., Caputo, M. T., Santoro, G., Panichi, V., Parrini, M., Giusti, C., & Palla, R. (1990). Fractional shortening/end-systolic stress correlation in the evaluation of left ventricular contractility in patients treated by acetate dialysis and lactate haemofiltration. *Nephrology, dialysis,*

transplantation : official publication of the European Dialysis and Transplant Association - European Renal Association, *5 Suppl 1*, 115–118. https://doi.org/10.1093/ndt/5.suppl_1.115

21. Earley J. J. (1991). Simple harmonic motion of tropomyosin: proposed mechanism for length-dependent regulation of muscle active tension. *The American journal of physiology*, *261*(6 Pt 1), C1184–C1195. https://doi.org/10.1152/ajpcell.1991.261.6.C1184
22. Wijnker, P. J., Sequeira, V., Foster, D. B., Li, Y., Dos Remedios, C. G., Murphy, A. M., Stienen, G. J., & van der Velden, J. (2014). Length-dependent activation is modulated by cardiac troponin I bisphosphorylation at Ser23 and Ser24 but not by Thr143 phosphorylation. *American journal of physiology. Heart and circulatory physiology*, *306*(8), H1171–H1181. https://doi.org/10.1152/ajpheart.00580.2013
23. Casas-Rojo, E., Fernández-Golfín, C., Moya-Mur, J. L., González-Gómez, A., García-Martín, A., Morán-Fernández, L., Rodríguez-Muñoz, D., Jiménez-Nacher, J. J., Martí Sánchez, D., & Zamorano Gómez, J. L. (2016). Area strain from 3D speckle-tracking echocardiography as an independent predictor of early symptoms or ventricular dysfunction in asymptomatic severe mitral regurgitation with preserved ejection fraction. *The international journal of cardiovascular imaging*, *32*(8), 1189–1198. https://doi.org/10.1007/s10554-016-0904-2
24. Kishiki, K., Singh, A., Narang, A., Gomberg-Maitland, M., Goyal, N., Maffessanti, F., Besser, S. A., Mor-Avi, V., Lang, R. M., & Addetia, K. (2019). Impact of Severe Pulmonary Arterial Hypertension on the Left Heart and Prognostic Implications. *Journal of the American Society of Echocardiography : official publication of the American Society of Echocardiography*, *32*(9), 1128–1137. https://doi.org/10.1016/j.echo.2019.05.008
25. Zeng, M., Qiao, Y., Wen, Z., Liu, J., Xiao, E., Tan, C., Xie, Y., An, J., Zhang, Z., Fan, Z., & Li, D. (2017). The Association between Diffuse Myocardial Fibrosis on Cardiac Magnetic Resonance T1 Mapping and Myocardial Dysfunction in Diabetic Rabbits. *Scientific reports*, *7*, 44937. https://doi.org/10.1038/srep44937
26. Zhang, Y., Zeng, W., Chen, W., Chen, Y., Zhu, T., Sun, J., Liang, Z., Cheng, W., Wang, L., Wu, B., Gong, L., Ferrari, V. A., Zheng, J., & Gao, F. (2019). MR extracellular volume mapping and non-contrast T1ρ mapping allow early detection of myocardial fibrosis in diabetic monkeys. *European radiology*, *29*(6), 3006–3016. https://doi.org/10.1007/s00330-018-5950-9
27. Arques, S., Ambrosi, P., Roux, E., Sbragia, P., Gelisse, R., Pieri, B., & Luccioni, R. (2008). Tissue Doppler echocardiography for the diagnosis of new-onset heart failure with normal ejection fraction: influence of serum protein concentration on clinical interpretation in elderly patients. *Archives of cardiovascular diseases*, *101*(5), 343–350. https://doi.org/10.1016/j.acvd.2008.04.002
28. Chen, Y. Y., Yun, H., Jin, H., Kong, H., Long, Y. L., Fu, C. X., Yang, S., & Zeng, M. S. (2017). Association of native T1 times with biventricular function and hemodynamics in precapillary pulmonary hypertension. *The international journal of cardiovascular imaging*, *33*(8), 1179–1189. https://doi.org/10.1007/s10554-017-1095-1

29. De Jesus, T., Alashry, M. M., Padang, R., Pislaru, S. V., Nkomo, V. T., Pellikka, P. A., & Pislaru, C. (2021). Intrinsic cardiac elastography in patients with primary mitral regurgitation: predictive role after mitral valve repair. *European heart journal. Cardiovascular Imaging*, *22*(8), 912–921. https://doi.org/10.1093/ehjci/jeaa117
30. Kim, J., Alakbarli, J., Palumbo, M. C., Xie, L. X., Rong, L. Q., Tehrani, N. H., Brouwer, L. R., Devereux, R. B., Wong, S. C., Bergman, G. W., Khalique, O. K., Levine, R. A., Ratcliffe, M. B., & Weinsaft, J. W. (2019). Left ventricular geometry predicts optimal response to percutaneous mitral repair via MitraClip: Integrated assessment by two- and three-dimensional echocardiography. *Catheterization and cardiovascular interventions : official journal of the Society for Cardiac Angiography & Interventions*, *93*(6), 1152–1160. https://doi.org/10.1002/ccd.28147
31. Zeng, D., Wu, J., Wu, S. S., Lin, H. H., & Chen, H. (2020). Three-dimensional echocardiographic comparison of left ventricular geometry and systolic function between dilated cardiomyopathy and mitral regurgitation with similar left ventricular dilation. *Journal of clinical ultrasound : JCU*, *48*(1), 29–37. https://doi.org/10.1002/jcu.22775
32. Teraguchi, I., Hozumi, T., Takemoto, K., Ota, S., Kashiwagi, M., Shimamura, K., Shiono, Y., Kuroi, A., Yamano, T., Yamaguchi, T., Matsuo, Y., Ino, Y., Kitabata, H., Kubo, T., Tanaka, A., & Akasaka, T. (2019). Assessment of decreased left ventricular longitudinal deformation in asymptomatic patients with organic mitral regurgitation and preserved ejection fraction using tissue-tracking mitral annular displacement by speckle-tracking echocardiography. *Echocardiography (Mount Kisco, N.Y.)*, *36*(4), 678–686. https://doi.org/10.1111/echo.14290
33. StataCorp. 2019. Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC
34. Shrout, P. E., & Fleiss, J. L. (1979). Intraclass correlations: Uses in assessing rater reliability. Psychological Bulletin, 86(2), 420–428. https://doi.org/10.1037/0033-2909.86.2.420

Tables

Table 1 Patient demographics (N=135).

Variable		Value
Sex	Female	68 (50.4%)
	Male	67 (49.6%)
Age	Age range	18 - 82
	Age mean MR	51
	Age mean Echo	52
Race and Ethnicity	White	102
	Black or African American	8
	Asian	11
	Native Hawaiian or Other Pacific Islander	1
	American Indian or Alaska Native	4
	Unknown	9
Echo Parameters	E/A mean	1.65
	E/A standard deviation	1.03
	E/A range	0.45 - 8.4
	E/e' mean	13.07
	E/e' standard deviation	5.28
	E/e' range	2.20 - 34.06
Time between modalities 38% of exams were within 3 months from each other	Median time between MR and Echo exams (days)	233
	Mean time between MR and Echo exams (days)	360
	Time range between MR and Echo exam (days)	0 - 1309

E/A: Ratio of Early vs. late (atrial) ventricular filling

E/e': Ratio of early mitral valve inflow velocity to mitral annular early diastolic velocity

Table 2 Number of cases and percentile within each bounce category graded by each reader and Inter-reader agreement during the first round.

N=134 (1 patient missing due to no 4-chamber view on MR)

Bounce Grade	**Readers**			**Agreement**	
	CR	**EQ**	**TD**	**ICC**	**(95% CI)**
0: no bounce	57 (43)	58 (43)	62 (46)	0.60	(0.51 – 0.68)
1: minimal bounce	65 (48)	66 (49)	52 (39)		
2: normal	12 (9)	10 (8)	20 (15)		

Table 3 Bounce Grade vs. Normal and Abnormal Diastolic Function per echocardiogram report.

Bounce Grade	**Normal Diastolic Function** N=57
0: No Bounce	11/57 (19.3%)
0 and 1: Minimal Bounce	30/57 (52.6%)
1: Minimal Bounce	19/57 (33.3%)
2: Normal Bounce	27/57 (47.3%)

Bounce Grade	**Abnormal Diastolic Function** N=78
0: No Bounce	33/78 (42.3%)
0 and 1: Minimal Bounce	69/78 (88.5%)
1: Minimal Bounce	36/78 (46.2%)
2: Normal Bounce	9/78 (11.5%)

Table 4 Bounce Grade vs. Diastolic function per echocardiogram report

Screening Result	Abnormal Diastolic Dysfunction	Normal Diastolic Dysfunction	Total
Abnormal Bounce Grade 0 or 1	69	30	99
Normal Bounce Grade 2	9	27	36
Total	78	57	135

Sensitivity: 0.89, **Specificity:** 0.47

Figures

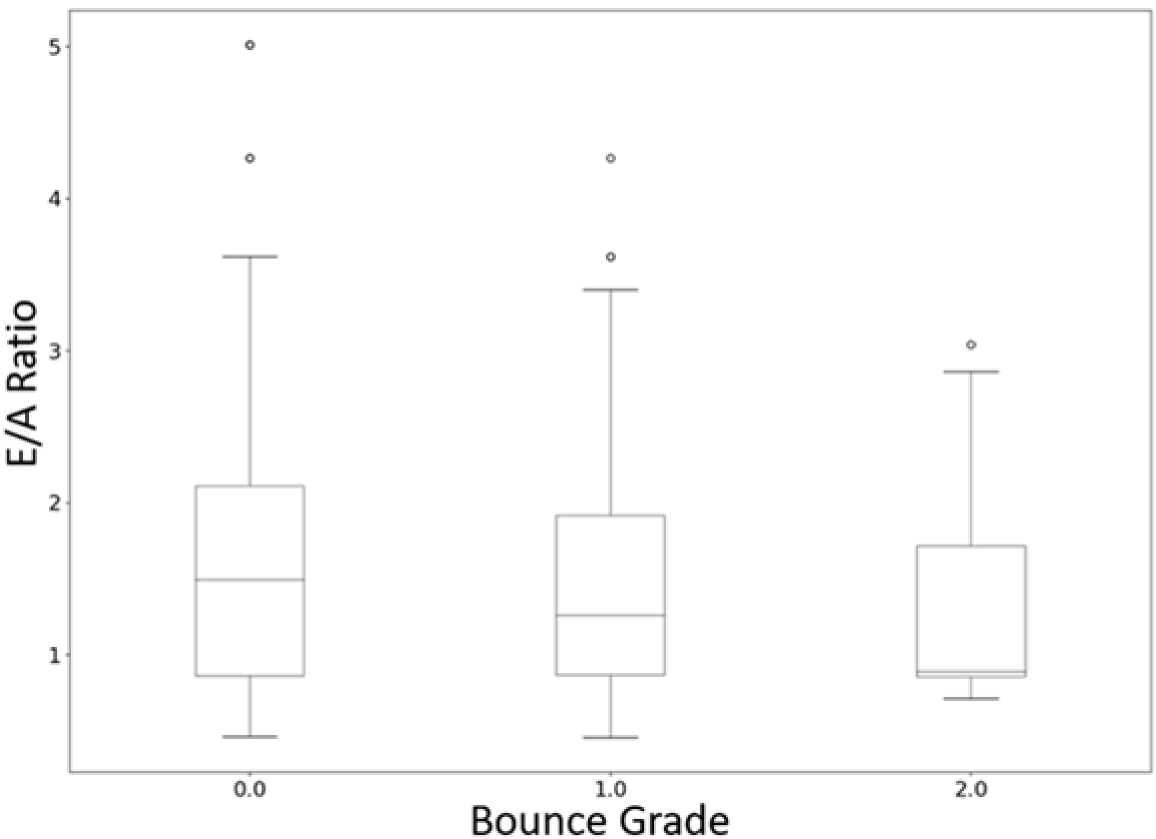

Figure 1

Box and whisker plots showing the distribution of E/A ratios per bounce grade

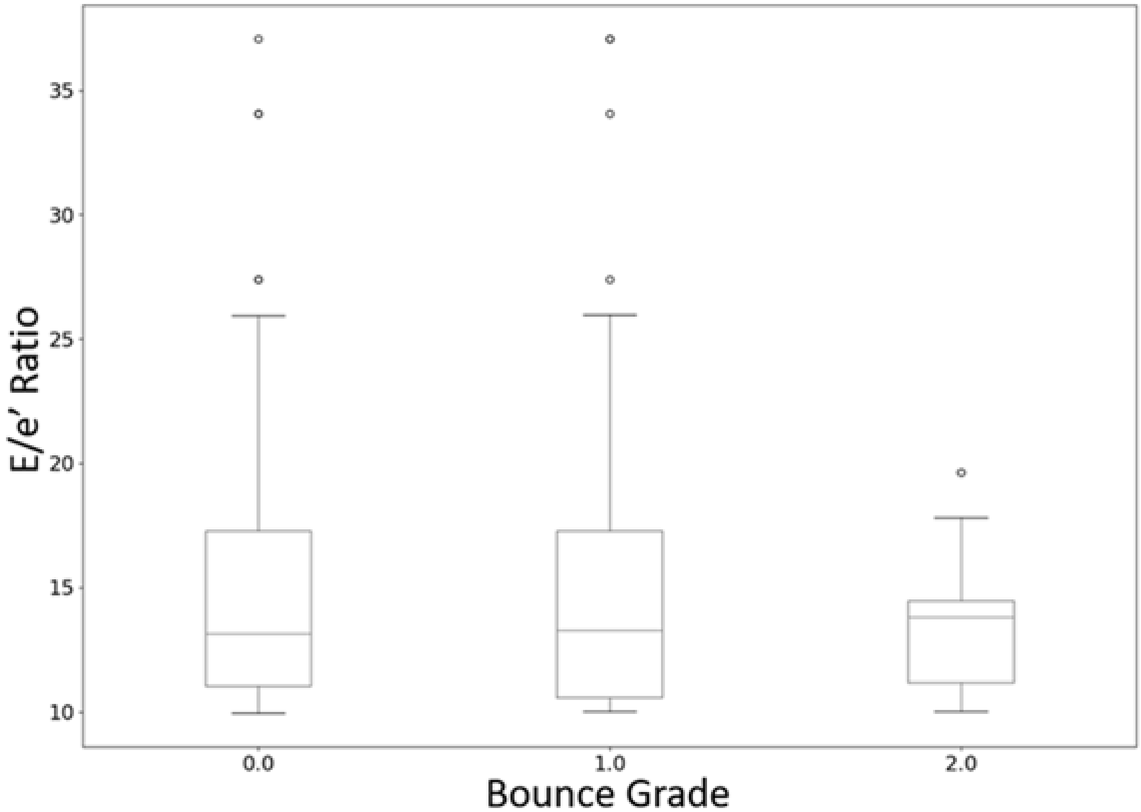

Figure 2

Box and whisker plots showing the distribution of E/e' ratios per bounce grade

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