Kidney Medicine

Echocardiogram Assessment of Left Ventricular Mass for Hemodialysis Patients

Dou Huang and Benjamin S. Wessler

Risk prediction has a central role in the clinical care of patients at risk for cardiovascular disease. Patients with end-kidney disease receiving maintenance hemodialysis are at particularly high risk for cardiovascular events, in part because of the high prevalence of traditional risk factors,[1] and improved risk stratification is needed. There is substantial interest in identifying novel risk predictors, as well as evaluating whether traditional metrics are reliable and can improve risk prediction (and ultimately patient care). It is in this context that we view the work by Kristensen et al[2] in this issue of *Kidney Medicine*. These investigators demonstrate that for hemodialysis patients with large fluid fluctuations, left ventricular (LV) mass (LVM) determined using 1-dimensional (1D) methods are less reliable than LVM estimated using 2-dimensional (2D) methods and suggest that the latter be incorporated into clinical risk assessment for these patients, especially if echocardiographic imaging is acquired around the time of large fluid fluctuations.

Related article, p. 579

LVM has long been recognized as an independent predictor of coronary disease, cardiovascular death, and all-cause mortality in patients with and without pre-existing cardiac disease. The Framingham Heart Study group demonstrated a relative risk of 1.67 in men and 1.60 in women for a coronary event per each 50-g/m increase in LVM.[3] Koren et al[4] later showed increased risk for cardiovascular events, cardiovascular death, and all-cause mortality in patients with LVM > 125 g/m^2. Furthermore, reducing LVM with treatment of hypertension or aortic stenosis is associated with lower cardiovascular and mortality risk.[5,6]

Although LVM is an important predictor of adverse events, it is not measured directly. Instead, this parameter is calculated by multiplying an estimate of myocardial volume by the density of myocardial tissue (1.05 g/mL). In contemporary practice, myocardial volume can be estimated using linear/1D echocardiographic methods, 2D echocardiographic methods, real-time 3-dimensional (3D) imaging, or cardiovascular magnetic resonance.[7]

The 1D echocardiographic method for assessing LVM is the historical reference standard because of its simplicity and wide availability.[8] One of the earliest methods (Teichholz), which assumed that the left ventricle was a sphere, was prone to error because of this assumption about ventricular shape. The Devereux and Reichek cube formula and the Penn Convention formula (Fig 1) improved on this original method and are instead based on the assumption that the left ventricle has a prolate ellipsoid shape. In the study by Kristensen et al, linear measurements (1D) of the end-diastolic interventricular septum, LV internal diameter, and inferolateral LV wall thickness were obtained in standard fashion by direct evaluation of 2D images and then LVM was calculated using these formulas (Fig 1).[9]

Despite major prognostic studies focused on 1D LVM determinations,[10] there are technical reasons to reassess the accuracy of these estimates. During transthoracic echocardiography, wall thickness and LV internal diameter must be measured perpendicular to the long axis of the left ventricle, and even small variations can have significant effects on LVM because the formulas raise linear measurements to the power of 3. Although the linear method provides a fair estimation of LVM when the left ventricle is normally shaped, its accuracy abates in the presence of dilated ventricles or asymmetric hypertrophy of the left ventricle.[7] As effectively demonstrated by Kristensen et al, the large fluid shift of hemodialysis causes a statistically significant difference in end-diastolic LV internal diameter, subsequently affecting LVM calculations by linear methods.[2]

Conversely, 2D echocardiographic methods for assessing LVM are more robust and accurate (and time consuming) because they require the imager to measure the total LV area and LV cavity area at the midpapillary level and divide the left ventricle long axis at the point of the widest short-axis view, allowing common changes in LV geometry to be accounted for. The commonly used formulas for 2D LVM assessment include the truncated ellipsoid and area-length methods (Fig 1).

Predictably, with fewer simplifying assumptions, 2D methods allow for partial correction of left ventricle shape distortions. The drawbacks to 2D methods include the requirement for better imaging windows, improved quality of endocardial and epicardial border definition (often not available in the data presented by Kirstensen et al), and a lack of studies that assess the prognostic value of 2D-derived LVM compared with the linear methods.[9] Moreover, as opposed to the state-of-the-art 3-dimensional method that measures LV volumes directly, 2D methods are still affected somewhat by abnormal features or changes to cavity shape.

Regardless of the method used, there are several caveats to using LVM for risk assessment and prognostication. LVM varies based on age, sex, height, and body surface area, and because of the high variability among individuals, it has been difficult to define the normal range of values. The currently recommended reference ranges were derived

1D Methods:

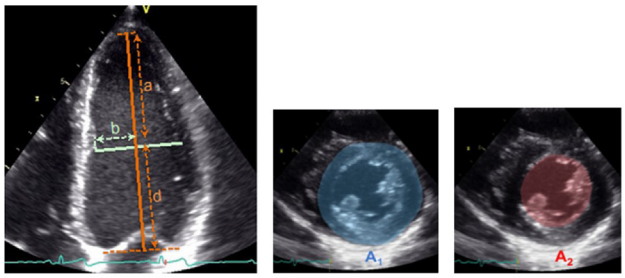
Devereux and Reichek cube formula

$$LVM = 0.8 \times 1.04 \times \left[(IVS_d + LVID_d + PWT_d)^3 - LVID_d{}^3\right] + 0.6$$

Penn Convention

$$LVM = 1.04 \times \left[(IVS_d + LVID_d + PWT_d)^3 - LVID_d{}^3\right] - 13.6$$

2D Methods:



Truncated Ellipsoid Method

$$LVM = 1.05\{(b+t)^2\left[\frac{2}{3}(a+t) + d - \frac{d^3}{3(a+t)^2}\right] - b^2\left[\frac{2}{3}a + d - \frac{d^3}{3a^2}\right]\}$$

Area-Length Method

$$LVM = 1.05\{\left[\frac{5}{6}A_1(a+d+t)\right] - \left[\frac{5}{6}A_2(a+d)\right]\}$$

Figure 1. The 1-dimensional (1D) linear and 2D methods for left ventricular (LV) mass (LVM) measurements. Abbreviations: IVS_d, end-diastolic interventricular septum; $LVID_d$, end-diastolic LV internal diameter; PWT_d, end-diastolic inferolateral LV wall thickness. Adapted from Armstrong and Ryan.[8]

from nondialysis populations and therefore it may not be appropriate to apply these values to dialysis patients given different pathophysiologic changes seen in dialysis patients as compared with the general population.

Beyond measurement accuracy, there are 3 important clinical questions that are raised by the current work. The first is whether an accurate assessment of LVM (likely by 2D or more mature 3D methods) is predictive of adverse clinical events because previous work has focused largely on 1D methods.[11] Second, because reproducible cardiac imaging requires technical acquisition expertise, as well as access to echocardiographers, it will be important to evaluate whether this marker offers benefit (ie, improved prediction) over standard (and routinely collected) clinical predictors. Last, it is essential that investigators work to identify the clinical decisions that might be informed by this variable and test whether decisions (and outcomes) can be improved for dialysis patients, who are among the highest cardiac risk population.

ARTICLE INFORMATION

Authors' Full Names and Academic Degrees: Dou Huang, MD, and Benjamin S. Wessler, MD, MS.

Authors' Affiliations: Department of Medicine (DH), Cardiovascular Center (BSW), and Predictive Analytics and Comparative Effectiveness (PACE) Center (BSW), Tufts Medical Center, Boston, MA.

Address for Correspondence: Benjamin S. Wessler, MD, MS, Tufts Medical Center, Cardiovascular Center, Predictive Analytics and Comparative Effectiveness (PACE) Center, 800 Washington St., #32, Boston, MA 02111. E-mail: bwessler@tuftsmedicalcenter.org

Support: Dr Wessler is supported by National Institutes of Health grant K23AG055667.

Financial Disclosure: The authors declare that they have no relevant financial interests.

Peer Review: Received July 31, 2020, in response to an invitation from the journal. Direct editorial input by the Editor-in-Chief. Accepted in revised form August 18, 2020.

REFERENCES

1. Longenecker JC. Traditional cardiovascular disease risk factors in dialysis patients compared with the general population: the CHOICE Study. *J Am Soc Nephrol*. 2002;13:1918-1927.
2. Kristensen CB, Steensgaard-Hansen F, Myhr KA, et al. Left ventricular mass assessment by 1- and 2-dimensional echocardiographic methods in hemodialysis patients: changes in left ventricular volume using echocardiography before and after a hemodialysis session. *Kidney Med*. 2020;2(5):579-589.
3. Levy D, Garrison RJ, Savage DD, Kannel WB, Castelli WP. Left ventricular mass and incidence of coronary heart disease in an elderly cohort. *Ann Intern Med*. 1989;110:101-107.
4. Koren MJ, Devereux RB, Casale PN, Savage DD, Laragh JH. Relation of left ventricular mass and geometry to morbidity and mortality in uncomplicated essential hypertension. *Ann Intern Med*. 1991;114:345-352.
5. Verdecchia P, Schillaci G, Borgioni C, et al. Prognostic significance of serial changes in left ventricular mass in essential hypertension. *Circulation*. 1998;97:48-54.
6. Hatani T, Kitai T, Murai R, et al. Associations of residual left ventricular and left atrial remodeling with clinical outcomes in patients after aortic valve replacement for severe aortic stenosis. *J Cardiol*. 2016;68:241-247.
7. Mizukoshi K, Takeuchi M, Nagata Y, et al. Normal values of left ventricular mass index assessed by transthoracic three-dimensional echocardiography. *J Am Soc Echocardiogr*. 2016;29:51-61.
8. Armstrong WF, Ryan T. *Feigenbaum's Echocardiography*. Lippincott Williams & Wilkins; 2010.
9. Lang RM, Badano LP, Victor MA, et al. Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. *J Am Soc Echocardiogr*. 2015;28:1-39.e14.
10. Armstrong AC, Gidding S, Gjesdal O, Wu C, Bluemke DA, Lima JAC. LV mass assessed by echocardiography and CMR, cardiovascular outcomes, and medical practice. *JACC Cardiovasc Imaging*. 2012;5:837-848.
11. Paoletti E, Specchia C, Di Maio G, et al. The worsening of left ventricular hypertrophy is the strongest predictor of sudden cardiac death in haemodialysis patients: a 10 year survey. *Nephrol Dial Transplant*. 2004;19:1829-1834.