

Liver Elastography for Complementary Assessment of Heart Failure

Diane Xavier de Ávila,^{1,2} Humberto Villacorta,¹ Evandro Tinoco Mesquita¹

Universidade Federal Fluminense,¹ Niterói, RJ – Brazil

Complexo Hospitalar de Niterói,² Niterói, RJ – Brazil

Abstract

Liver elastography (LE) assesses the systemic consequences of heart failure (HF). This method may help in the prognostic assessment of patients with HF. HF can secondarily affect the function of various organs and systems, especially the liver, through venous congestion. The purpose of this article is to provide a narrative review of the importance of LE in the complementary evaluation of HF. The hepatic consequences of cardiac disease are sometimes silent, without significant changes in physical examination and/or laboratory tests. In this context, LE has emerged as a recommended non-invasive method to measure liver damage caused by HF.

Introduction

Liver elastography (LE) provides information on the degree of hepatic fibrosis and steatosis as well as the consequences of venocapillary congestion due to heart failure (HF). LE may aid in the prognostic assessment of patients with HF. Finding methods to complement this evaluation in patients with HF is crucial, as it is a common disease, more prevalent in older patients, and one of the leading causes of hospitalization (2.6%) and death (6%) in Brazil, consuming 3% of the total public resources allocated to the Brazilian Unified Health System (SUS).¹⁻⁶

HF can secondarily affect the function of various organs and systems, especially the liver, through venous congestion.⁶⁻¹¹ The purpose of this article is to provide a narrative review of the importance of LE in the complementary assessment of HF.

What is LE?

LE allows for the assessment of biomechanical properties of tissues and can be considered a virtual palpation. Under stress, stiffer tissues exhibit less axial displacement and greater transverse displacement velocity, which implies the propagation of shear waves. Shear waves can be generated by applying mechanical stress externally to the body or by applying the

Acoustic Radiation Force Impulse (ARFI) of the ultrasound (US) beam directly to the body, which applies high concentrated energy to create tissue compression (stress) and generate shear waves. Shear wave elastography (SWE) describes any technique that generates shear waves and measures their velocity. This includes vibration controlled transient elastography (VCTE), ARFI, and magnetic resonance elastography. ARFI-SWE includes point SWE (pSWE) and 2D-SWE.¹²

The term shear wave LE refers to techniques based on both types of stress, namely VCTE and ARFI-based techniques. In the latter, shear wave velocity/stiffness is assessed at a single point (approximately 1 cc), as in pSWE, or using multiple ARFI lines, where it is possible to obtain quantitative color-coded images of elasticity, as in 2D-SWE.¹²

The FibroScan® device evaluates the elasticity of liver tissue using a 5 MHz US transducer. The device emits low-frequency vibrations (50 Hz), and the shear waves propagating through the tissue are detected and their velocity measured by US. The stiffer the liver parenchyma (i.e., the higher the degree of inflammation), the faster the vibrations propagate. This velocity represents the mean liver elasticity, measured in kilopascals (kPa).¹²⁻¹⁴ In addition to the standard transducer, there is a pediatric transducer (5 MHz) and an XL transducer (2.5 MHz) for obese patients. A success rate of more than 70% is required. The device also calculates the degree of hepatic steatosis as measured by the controlled attenuation parameter (CAP), which correlates well with liver biopsy findings. Steatosis is quantified as mild from 100 to 400 and as moderate to severe above 400.¹⁴

HF and liver changes

Liver changes caused by decompensated HF, in addition to neuroendocrine factors, lead to an increase in canalicular enzymes (e.g., alkaline phosphatase and gamma-glutamyl transpeptidase) and bilirubin and/or ischemia with elevation of transaminases, which may progress to so-called “cardiac cirrhosis”.⁶⁻¹²

There is a significant correlation between liver stiffness and markers of increased venocapillary pressure.^{8-10,15-19} Increased liver stiffness can be inferred from an increased systemic volume index.⁹ A high liver stiffness value at hospital admission is associated with increased mortality, cirrhosis and congestive HF, with a mortality rate of 20.8% in patients with values above 8.0 kPa in LE showing a statistically significant value.¹⁰ Liver stiffness is also a predictor of HF severity.¹⁶ Liver stiffness is associated with congestive states such as HF. There is no defined cutoff for liver stiffness, with studies varying between 8.0 and 14 kPa.²⁰

Gamma-glutamyl transpeptidase and direct bilirubin are laboratory tests that are frequently elevated in patients with HF, correlating with the degree of systemic congestion and greater

Keywords

Elasticity Imaging Techniques; Heart Failure; Liver Cirrhosis; Fatty Liver.

Mailing Address: Diane Xavier de Ávila •

Universidade Federal Fluminense. Rua Marques de Paraná, 303. Postal code: 24220-900. Niterói, RJ – Brazil

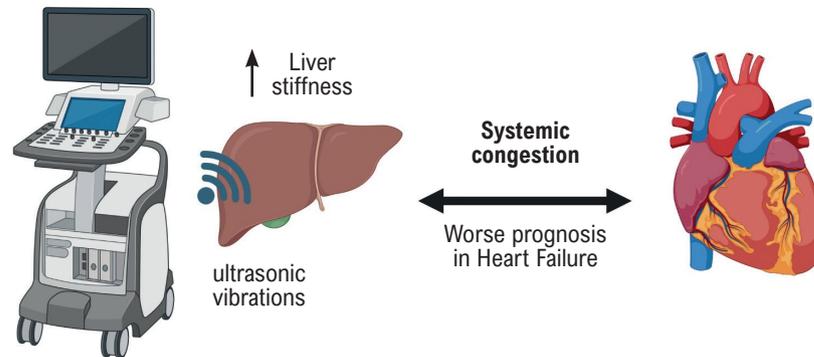
E-mail: dianeavilamed@gmail.com

Manuscript received June 14, 2024; revised June 14, 2024; accepted June 17, 2024

Editor responsible for the review: Marcelo Tavares

DOI: <https://doi.org/10.36660/abcimg.20240057i>

Central Illustration: Liver Elastography for Complementary Assessment of Heart Failure



Arq Bras Cardiol: Imagem cardiovasc. 2024;37(3):e20240057

severity.²¹⁻²³ This was confirmed in the Romanian Acute Heart Failure Syndromes (RO-AHFS) registry, where transaminases were higher in patients receiving higher doses of intravenous diuretics and in those using inotropes and vasopressors, and served as an independent predictor of worsening renal function and admission to intensive care.²⁰

Most patients with acute HF had elevated liver stiffness values above 7.65 kPa and NT-proBNP levels, which tended to decrease with clinical improvement.¹² The results showed a significant correlation between liver stiffness and markers of increased venocapillary pressure.¹⁰⁻¹³ Liver stiffness has previously been associated with clinical congestion and volume overload as assessed by bioimpedance and was not correlated with the degree of liver fibrosis on histopathologic examination.¹⁵ Besides, liver stiffness is considered a predictor of outpatient chronic HF severity.^{22, 23}

A recent meta-analysis confirmed that liver stiffness is associated with a worse prognosis in patients with acute decompensated HF.²⁴ When evaluating comorbidities in patients with metabolic liver disease and increased liver stiffness, these patients should be considered for more detailed cardiac evaluation due to the high cardiovascular risk in this setting.²⁵

In a study of 52 patients with acute decompensated HF, excluding those with associated liver disease, LE was performed to assess outcomes of left ventricular assist device (LVAD) use, heart transplantation, or death. Median liver elasticity was increased in patients who received an LVAD or heart transplant within 30 days compared with those who did not (median [IQR] = 55.6 [22.5-63.4] vs. 13.8 [9.5-40.3] kPa, $P = 0.049$). In addition, the risk of the composite outcome was higher in the third tertile (> 39.8 kPa vs. the first and second tertiles combined, HR 2.83, 95% CI 1.20-6.67, $P = 0.02$). Each 1 kPa increase in LSM was associated with a 1% increase in the incidence of readmission (IRR 1.01, 95% CI 1.00-1.02, $P = 0.01$), confirming LE as a useful tool for prognostic assessment.²⁶

Limitations of elastography

There are several limitations to LE testing. First, it is necessary to achieve a signal acquisition success rate. This success rate requires proper training and depends on patient-related factors. Besides, there is still no standardization in the evaluation of variables in patients with HF.

Literature indicates that although different LE techniques show a strong linear correlation with increasing stages of liver fibrosis, LSM values obtained with ARFI-SWE techniques are lower than those obtained with VCTE. This difference increases at more advanced stages of liver fibrosis. Besides, different US systems provide different LSMs in the same individuals; therefore, the cutoff points for accurate staging of fibrosis that mimic histologic classifications cannot be used interchangeably between US systems, and the same US system should be used for follow-up measurements in the same patient. Therefore, the US system used to measure liver stiffness should be reported.¹²

Prospects for elastography on other tissues

Each organ has its own elasticity, and this examination uses sound vibrations and the propagation of waves in tissue to provide measurements that can indicate tissue damage. Besides the liver, elastography is performed on the breast, thyroid, and heart to assess myocardial stiffness. Mechanical waves propagate along the heart wall at speeds related to stiffness and are associated with increased fibrosis, filling pressures and diastolic dysfunction. Because of the thin wall geometry of the heart and its complex material properties, a proper understanding of the various factors that influence wave propagation is still required to correctly interpret the results.²⁷ This technique has been successfully applied to diseases such as cardiac amyloidosis²⁸ and hypertrophic cardiomyopathy.^{28,29}

Renal elastography was also evaluated with the prospect of assessing fibrosis and potentially avoiding pretransplant renal biopsy, although more data are needed. There was a moderate correlation between renal stiffness measured by SWE and biopsy results.³⁰

Conclusion

LE may become an effective method for assessing congestion and may be useful for monitoring response to treatment and as a prognostic factor in HF. The hepatic consequences of cardiac disease often remain silent, without significant changes in physical examination and/or laboratory tests. In this context, elastography has emerged as a recommended non-invasive method to measure liver damage caused by HF.

Author Contributions

Conception and design of the research: Ávila DX, Villacorta H; acquisition of data, statistical analysis and writing of the manuscript: Ávila DX; analysis and interpretation of the data and critical revision of the manuscript for intellectual content: Ávila DX, Villacorta H, Mesquita ET.

References

- Ceia F, Fonseca C, Mota T, Morais H, Matias F, Sousa A, et al. Prevalence of Chronic Heart Failure in Southwestern Europe: The EPICA Study. *Eur J Heart Fail.* 2002;4(4):531-9. doi: 10.1016/s1388-9842(02)00034-x.
- Rohde LE, Montera MW, Bocchi EA, Clausell NO, Albuquerque DC, Rassi S, et al. Diretriz Brasileira de Insuficiência Cardíaca Crônica e Aguda. *Arq Bras Cardiol.* 2018;111(3):436-539. doi: 10.5935/abc.20180190.
- Bleumink GS, Knetsch AM, Sturkenboom MC, Straus SM, Hofman A, Deckers JW, et al. Quantifying the Heart Failure Epidemic: Prevalence, Incidence Rate, Lifetime Risk and Prognosis of Heart Failure The Rotterdam Study. *Eur Heart J.* 2004;25(18):1614-9. doi: 10.1016/j.ehj.2004.06.038.
- Albuquerque DC, Souza JD Neto, Bacal F, Rohde LE, Bernardes-Pereira S, Berwanger O, et al. I Brazilian Registry of Heart Failure - Clinical Aspects, Care Quality and Hospitalization Outcomes. *Arq Bras Cardiol.* 2015;104(6):433-42. doi: 10.5935/abc.20150031.
- Straus SM, Kors JA, de Bruin ML, van der Hooft CS, Hofman A, Heeringa J, et al. Prolonged QTc Interval and Risk of Sudden Cardiac Death in a Population of Older Adults. *J Am Coll Cardiol.* 2006;47(2):362-7. doi: 10.1016/j.jacc.2005.08.067.
- Jorge AJL, Rosa MLC, Fernandes LCM, Freire MDC, Rodrigues RC, Correia DMS, et al. Estudo da Prevalência de Insuficiência Cardíaca em Indivíduos Cadastrados no Programa Médico de Família - Niterói. Estudo Digitalis: Desenho e Método. *Rev Bras Cardiol.* 2011;24(5):320.
- Redfield MM, Jacobsen SJ, Burnett JC Jr, Mahoney DW, Bailey KR, Rodeheffer RJ. Burden of Systolic and Diastolic Ventricular Dysfunction in the Community: Appreciating the Scope of the Heart Failure Epidemic. *JAMA.* 2003;289(2):194-202. doi: 10.1001/jama.289.2.194.
- Nishi H, Toda K, Miyagawa S, Yoshikawa Y, Fukushima S, Kawamura M, et al. Novel Method of Evaluating Liver Stiffness Using Transient Elastography to Evaluate Perioperative Status in Severe Heart Failure. *Circ J.* 2015;79(2):391-7. doi: 10.1253/circj.CJ-14-0929.
- Taniguchi T, Ohtani T, Kioka H, Tsukamoto Y, Onishi T, Nakamoto K, et al. Liver Stiffness Reflecting Right-Sided Filling Pressure Can Predict Adverse Outcomes in Patients With Heart Failure. *JACC Cardiovasc Imaging.* 2019;12(6):955-64. doi: 10.1016/j.jcmg.2017.10.022.
- Lindvig K, Mössner BK, Pedersen C, Lillevang ST, Christensen PB. Liver Stiffness and 30-day Mortality in a Cohort of Patients Admitted to Hospital. *Eur J Clin Invest.* 2012;42(2):146-52. doi: 10.1111/j.1365-2362.2011.02571.x.
- Colli A, Pozzoni P, Berzuini A, Gerosa A, Canovi C, Molteni EE, et al. Decompensated Chronic Heart Failure: Increased Liver Stiffness Measured

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Sources of Funding

There were no external funding sources for this study.

Study Association

This study is not associated with any thesis or dissertation work.

Ethics Approval and Consent to Participate

This article does not contain any studies with human participants or animals performed by any of the authors.

- by Means of Transient Elastography. *Radiology.* 2010;257(3):872-8. doi: 10.1148/radiol.10100013.
- Ferraioli G, Barr RG, Berzigotti A, Sporea I, Wong VW, Reiberger T, et al. WFUMB Guideline/Guidance on Liver Multiparametric Ultrasound: Part 1. Update to 2018 Guidelines on Liver Ultrasound Elastography. *Ultrasound Med Biol.* 2024;50(8):1071-87. doi: 10.1016/j.ultrasmedbio.2024.03.013.
- Perazzo H, Veloso VG, Grinsztejn B, Hyde C, Castro R. Factors That Could Impact on Liver Fibrosis Staging by Transient Elastography. *Int J Hepatol.* 2015;2015:624596. doi: 10.1155/2015/624596.
- Scmillevitch J, Mincis R, Mincis, D. Atualização Tecnológica da Elastometria do Fígado. *Gastroenterol Endosc Dig.* 2016;35(1):36-9.
- Ambrosy AP, Gheorghide M, Bubenek S, Vinereanu D, Vaduganathan M, Macarie C, et al. The Predictive Value of Transaminases at Admission in Patients Hospitalized for Heart Failure: Findings from the RO-AHFS Registry. *Eur Heart J Acute Cardiovasc Care.* 2013;2(2):99-108. doi: 10.1177/2048872612474906.
- Alegre F, Herrero JJ, Iñárraiegui M, Gavira JJ, Pujol C, Montero A, et al. Increased Liver Stiffness Values in Patients with Heart Failure. *Acta Gastroenterol Belg.* 2013;76(2):246-50.
- Hopper I, Kemp W, Porapakham P, Sata Y, Condon E, Skiba M, et al. Impact of Heart Failure and Changes to Volume Status on Liver Stiffness: Non-invasive Assessment Using Transient Elastography. *Eur J Heart Fail.* 2012;14(6):621-7. doi: 10.1093/eurjhf/hfs044.
- Saito Y, Kato M, Nagashima K, Monno K, Aizawa Y, Okumura Y, et al. Prognostic Relevance of Liver Stiffness Assessed by Transient Elastography in Patients With Acute Decompensated Heart Failure. *Circ J.* 2018;82(7):1822-9. doi: 10.1253/circj.CJ-17-1344.
- Moher D, Shamseer L, Clarke M, Ghersi D, Liberati A, Petticrew M, et al. Preferred Reporting Items for Systematic Review and Meta-analysis Protocols (PRISMA-P) 2015 Statement. *Syst Rev.* 2015;4(1):1. doi: 10.1186/2046-4053-4-1.
- Chioncel O, Vinereanu D, Datcu M, Ionescu DD, Capalaneanu R, Brukner I, et al. The Romanian Acute Heart Failure Syndromes (RO-AHFS) Registry. *Am Heart J.* 2011;162(1):142-53. doi: 10.1016/j.ahj.2011.03.033.
- Mansur EM, Escosteguy CC, Meurer ML, Chaves MM, Roitman I, Reis L, et al. Marcadores Laboratoriais Hepáticos na Insuficiência Cardíaca Descompensada. *Rev SOCERJ.* 2008;21(5):297-304.

22. Ambrosy AP, Gheorghide M, Bubenek S, Vinereanu D, Vaduganathan M, Macarie C, et al. The Predictive Value of Transaminases at Admission in Patients Hospitalized for Heart Failure: Findings from the RO-AHFS Registry. *Eur Heart J Acute Cardiovasc Care*. 2013;2(2):99-108. doi: 10.1177/2048872612474906.
23. Ávila DX, Andrade TG, Mocarzel LOC, Gismondi RAOC, Cabrita CM, Mesquita ET, et al. Liver Stiffness as Measured by Transient Elastography is a Predictor of Outcomes in Patients with Chronic Heart Failure with Reduced, Mid-range, and Recovered Left-ventricular Ejection Fraction. *Am Heart J Plus*. 2021;11:100048. doi: 10.1016/j.ahjo.2021.100048.
24. Macerola N, Riccardi L, Di Stasio E, Montalto M, Gasbarrini A, Pompili M, et al. Prognostic Value of Liver Stiffness in Patients Hospitalized for Acute Decompensated Heart Failure: A Meta-analysis. *J Ultrasound*. 2024. doi: 10.1007/s40477-024-00873-0.
25. Boeckmans J, Sandrin L, Knackstedt C, Schattenberg JM. Liver Stiffness as a Cornerstone in Heart Disease Risk Assessment. *Liver Int*. 2024;44(2):344-56. doi: 10.1111/liv.15801.
26. Panchani N, Schulz P, van Zyl J, Felius J, Baxter R, Yoon ET, et al. Liver Stiffness and Prediction of Cardiac Outcomes in Patients with Acute Decompensated Heart Failure. *Clin Transplant*. 2022;36(3):e14545. doi: 10.1111/ctr.14545.
27. Caenen A, Bézy S, Pernot M, Nightingale KR, Vos HJ, Voigt JU, et al. Ultrasound Shear Wave Elastography in Cardiology. *JACC Cardiovasc Imaging*. 2024;17(3):314-29. doi: 10.1016/j.jcmg.2023.12.007.
28. Ihne-Schubert SM, Goetze O, Gerstendörfer F, Sahiti F, Schade I, Papagianni A, et al. Cardio-Hepatic Interaction in Cardiac Amyloidosis. *J Clin Med*. 2024;13(5):1440. doi: 10.3390/jcm13051440.
29. Fernandes F, Santorio NC, Pereira NM, Cafezeiro CRF, Alencar AC Neto, Bueno BVK, et al. Papel da Elastografia por Ondas de Cisalhamento na Avaliação da Rigidez Miocárdica nas Diversas Miocardiopatias. *Arq Bras Cardiol Imag Cardiol*. 2023;36(4):e20230108. doi: 10.36660/abcimg.20230108.
30. Filipov T, Teutsch B, Szabó A, Forintos A, Ács J, Váradi A, et al. Investigating the Role of Ultrasound-based Shear Wave Elastography in Kidney Transplanted Patients: Correlation between Non-invasive Fibrosis Detection, Kidney Dysfunction and Biopsy Results-a Systematic Review and Meta-analysis. *J Nephrol*. 2024. doi: 10.1007/s40620-023-01856-w.

