REVIEW | OPEN ACCESS

Medical Science

Features of the diagnostic tools utilized by emergency physician to identify acute heart failure; systematic review

Mazi Mohammed Alanazi[1], **Ahmad Khalid Alsaif**[2], **Mohammed Mubarak Alswoaiegh**[3]

To Cite:
Alanazi MM, Alsaif AK, Alswoaiegh MM. Features of the diagnostic tools utilized by emergency physician to identify acute heart failure; systematic review. *Medical Science* 2025; 29: e55ms3552
doi: https://doi.org/10.54905/disssi.v29i158.e55ms3552

Authors' Affiliation:
[1]Saudi Board Emergency Medicine, Head of Emergency Research Unit, Emergency Department, First Health Cluster, Riyadh, Saudi Arabia
[2]Saudi Board Emergency Medicine Resident, Emergency Department, Second Health Cluster, Prince Mohammed Bin Abdulaziz Hospital, Riyadh, Saudi Arabia
[3]Saudi Board Emergency Medicine Resident, Emergency Department, First Health Cluster, King Saud Medical City, Riyadh, Saudi Arabia

Peer-Review History
Received: 09 November 2024
Reviewed & Revised: 13/November/2024 to 29/March/2025
Accepted: 03 April 2025
Published: 07 April 2025

Peer-review Method
External peer-review was done through double-blind method.

Medical Science
pISSN 2321–7359; eISSN 2321–7367

DISCOVERY SCIENTIFIC SOCIETY

ABSTRACT

Background: AHF is one of the most frequent diagnosis in ED hospitalized patients. AHF diagnosis in ED patients is difficult, and the condition's show high frequency in the emergency room. This study's aim to systematically review the operational characteristics of the diagnostic tools used by emergency physicians diagnose AHF. *Method:* We conducted a systematic review of studies that examined the characteristics of the tests utilized by emergency physicians to diagnose AHF in patients who present with dyspnea in the ED. The systematic review was conducted according to the Preferred Reporting Items for Systematic Review and Meta-analyses (PRISMA) standards. PubMed, Scopus, and EMBASE were used to search the medical literature between January 2016 and October 2024. *Result and conclusion:* Five publications were included in this systematic review. ADHF is better diagnosed using natriuretic peptides. Low-cost methods for identifying ADHF include BIA and IVCu, particularly in older patients with renal failure. BNP testing can accurately diagnose heart failure, but it has no discernible effect in diagnosing patients with dyspnea. The creation of BNP nomograms that are modified for HF history, age, gender, and ethnicity may increase the usefulness of BNP in the emergency department. AHFS-related acute dyspnea and pulmonary-related acute dyspnea may be distinguished with more accuracy with LCI integrated ultrasonography than with other techniques. Although LCI integrated ultrasonography is helpful for quickly evaluating acute dyspnea in the emergency department, more study is needed to determine how it affects diagnosis and decision-making.

Keywords: Emergency physician, acute heart failure, diagnosis

1. INTRODUCTION

Acute heart failure (AHF) patients commonly visit emergency department (ED) with dyspnea (Adams et al., 2005). AHF characterized by decline in heart failure symptoms that requires immediate medical attention. In the United States, more than one million ED visits are attributed to an AHF main diagnosis (Storrow et al., 2014). Even though AHF is quite common in the ED, it can be difficult to diagnose in patients with undifferentiated dyspnea, particularly if they have advanced age and other medical conditions (Hawkins et al., 2009). No single physical examination, radiography, electrocardiogram (ECG), or history can accurately identify or rule out AHF as the cause of dyspnea. In 44% of cases Januzzi et al., (2005), ED diagnosis of AHF depend on the history, physical examination, chest x-Ray (CXR), and ECG accuracy was low as it differs from the final discharge diagnosis in one out of four cases (Bayés-Genís et al., 2004).

Natriuretic peptide (NP) testing is now a standard part of the workup of AHF patients and reduces diagnostic ambiguity for individuals who are acutely dyspneic (Januzzi et al., 2005). Nevertheless, the misdiagnosis rate stays between 14% and 29% even when NP testing is included in the clinical workup for acute dyspnea (Collins et al., 2006). Although their further clinical usefulness has not yet been thoroughly described, alternative diagnostic modalities such bedside echocardiography Huang et al., (2006), lung ultrasonography (US) Al-Deeb et al., (2014), and bioimpedance Piccoli et al., (2012) have been demonstrated to aid in differentiating AHF from other main causes of dyspnea. This systematic review aimed to find the best available data on the diagnostic accuracy of index tests that could be used to distinguish AHF from other clinical conditions in patients who present to the ED with dyspnea.

2. METHOD

We carried out a comprehensive analysis of research that looked at the features of the operative tests that emergency physicians (EPs) employ to diagnose AHF in patients who arrive at the ED with dyspnea. We follow the Preferred Reporting Items for Systematic Review and Meta-analyses (PRISMA) criteria in the conduct of the systematic review. From January 2016 and October 2024, PubMed, Scopus and EMBASE were used to search the medical literature. The search terms used include (heart failure, dyspnea, sensitivity and specificity, predictive value of tests, physical examination, history taking, electrocardiography, ultrasonography, natriuretic peptide, ultrasonics, bioelectrical impedance, and echocardiography). Relevant studies were found by searching the references of review papers found by these searches.

The search results for each relevant diagnostic modality were separately filtered by two authors. Studies that addressed the diagnosis of AHF in the ED population were eligible to be included in the systematic review. Additionally, only English-language human studies were included in the search. Two authors independently selected articles for each index test from the combined database search for full text review. Each reviewer selected research that could be eligible on their own before the two writers decided on the list of publications for full text examination. Disagreements on study selection, were solved through discussion. After reviewing the methods sections of the full-text versions of the studies that would be appropriate for inclusion, each author utilized the designated inclusion and exclusion criteria to choose which publications to include in the systematic review.

Articles from the combined database search for full text review were separately chosen by two or more writers for each index test. Before both authors agreed on the list of papers for full text evaluation, each reviewer individually chose studies that may be qualified. Consensus was reached to settle differences in study selection. Each author used the specified inclusion and exclusion criteria to choose which papers to include in our systematic review after reading the methods sections of the full-text versions of the studies that would be suitable for inclusion. Consensus was reached via debate and decision-making. We collected data from the included studies using a predesigned data collection form, collected information include (study design, study population, methods, key diagnostics, intervention, tests outcomes and main findings).

3. RESULTS

In this study we included 5 articles (Figure 1). The studies by Gil-Martínez et al., (2016) and Lokuge et al., (2010) show the significance of biomarkers in diagnosing acute decompensated heart failure (ADHF). Natriuretic peptides (e.g., NT-proBNP) are used commonly, and according to Gil-Martínez et al., (2016) these markers are not sufficient for a definitive diagnosis. Age, renal function, and other comorbidities must be considered for interpretation. Bioelectrical impedance analysis (BIA) and IVCu were found to be non-expensive techniques that can be used with natriuretic peptides, mainly in elderly patients with renal impairment. Lokuge et al., (2010) study,

examined the utility of BNP testing in heart failure diagnosis, they found that BNP's diagnostic accuracy did not affect the clinical decision in the ED for patients presenting with dyspnea.

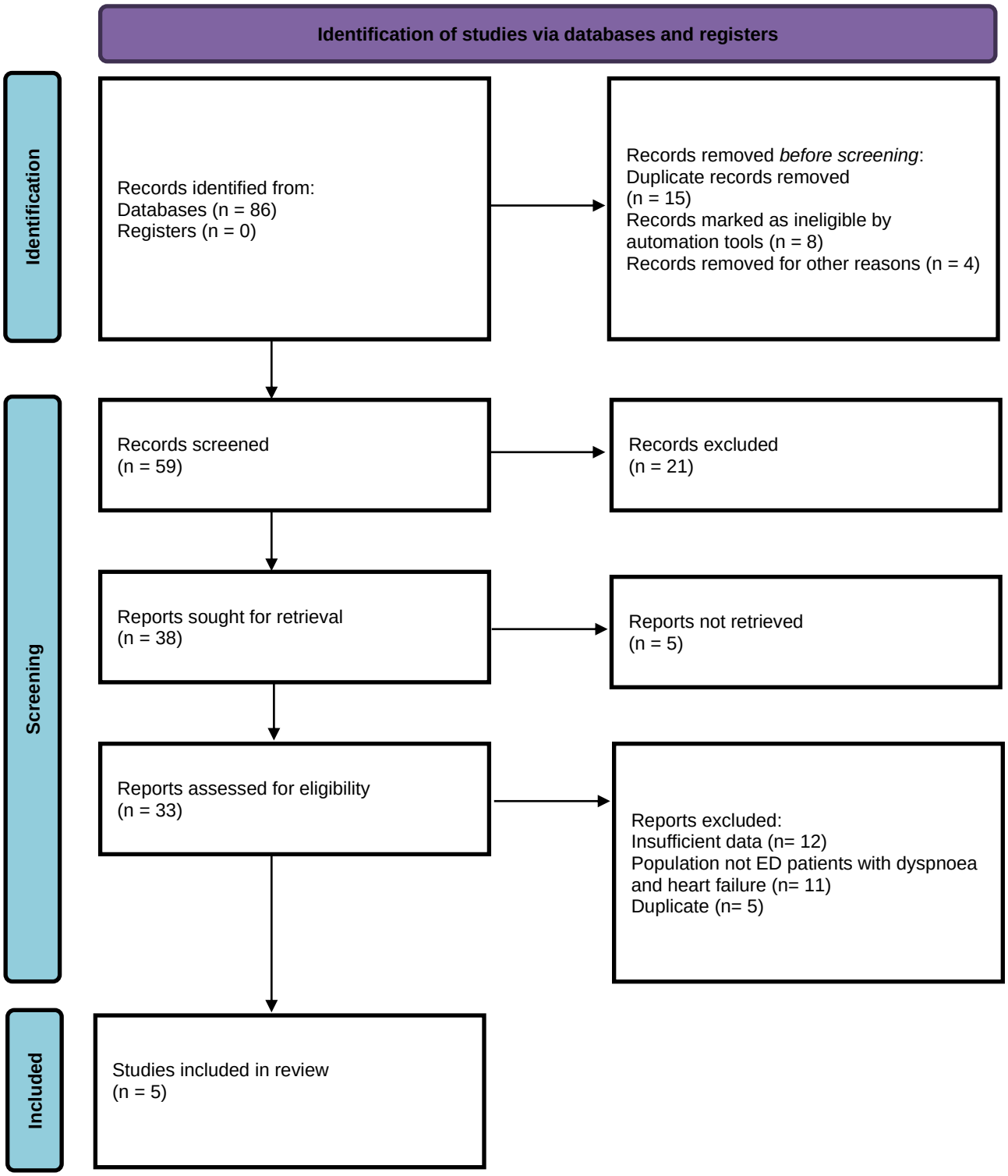

Figure 1 PRISMA consort chart of studies selection

Incorporating advanced imaging techniques into clinical practice is another important aspect of diagnosing ADHF, as seen in the findings from (Hacıalioğulları et al., 2021; Kajimoto et al., 2012). Hacıalioğulları et al., (2021) used lung ultrasound (LUS) to assess B-lines and IVC diameters, which proved to be more effective than BNP and echocardiographic measurements of ejection fraction (EF) in diagnosing pulmonary edema secondary to ADHF. The integration of IVC measurements with B-lines was especially useful in making decisions about patient hospital admission and discharge from the ED. This method provide accurate diagnosis, improving clinical decision and patient outcomes. Kajimoto et al., (2012) show the advantages of LCI integrated ultrasound, which combines lung ultrasound with IVC assessments.

This combination provides difference between AHFS-related acute dyspnea and pulmonary-related acute dyspnea in relation to other diagnostic approaches, such as BNP testing alone. Jobs et al., (2020) research aims to explore IVC assessments addition to clinical evaluations and its effect to improve patient outcome, by enhancing the NT-proBNP as a diagnostic tool. In addition to the emphasis on biomarkers and imaging techniques, there help in developing more accurate diagnostic approaches. This includes the promise for BNP nomograms designed to specific variables such as age, gender, ethnicity, and HF history, as suggested by Lokuge et al., (2010) Such adjustments could make BNP testing more reliable in diagnosing heart failure in the ED. Methodology of the included studies presented in (Table 1), and main findings presented in (Table 2).

Table 1 Methodology of the included studies

Study	Study Design	Study Population	Methods	Key Diagnostics	Intervention/Tests	Outcomes
Hacıalioğulları et al., 2021	Prospective cohort study	Patients with symptoms consistent with ADHF presenting to the ED	Clinical assessment, LUS, IVCUS, CXR, and lab tests	LUS, IVCUS, CXR, BNP, and other biomarkers	No direct intervention, observational use of ultrasound as diagnostic tool	Final diagnosis (discharge or hospital admission) and diagnosis accuracy based on ED physician decisions
Jobs et al., 2020	Randomized controlled trial	Patients with ADHF at 15 trial sites	IVC ultrasound, clinical assessment	Ultrasound-guided decongestion therapy, NT-proBNP levels, clinical assessment	Primary endpoint: NT-proBNP reduction	Change in NT-proBNP levels from baseline to discharge
Lokuge et al., 2010	Prospective randomized controlled study	Dyspneic patients in ED	Randomized to BNP testing or non-BNP testing group	BNP test, ECG, CXR, TTE	BNP levels tested for the BNP group only	Sensitivity, specificity, diagnostic accuracy, ROC curve analysis for BNP and ED physicians' HF probability
Kajimoto et al., 2012	Prospective cohort study	Patients with acute dyspnea	Lung, cardiac, and IVC ultrasound (Vscan), blood	Rapid lung, cardiac, and IVC ultrasound	Diagnosis based on integrated ultrasound and BNP levels	Sensitivity, specificity, ROC curve for BNP, diagnostic

			tests, CXR			accuracy for AHFS
Gil-Martínez et al., 2016	Prospective observational study	Patients with dyspnea in the ED	BIA, IVC ultrasound, NT-proBNP test	BIA, IVC ultrasound, NT-proBNP levels	Diagnosis of ADHF or non-ADHF based on clinical judgment	Diagnostic accuracy based on BIA, IVC ultrasound, and NT-proBNP compared to final diagnosis

Table 2 Main findings of the included studies

Study	Diagnostic Tools & Efficiency for Heart Failure
Gil-Martínez et al., 2016	NT-proBNP is effective in ADHF diagnosis. Elevated levels are inversely related to eGFR. MaxIVC, MinIVC, CIx, Rz/h, and Xc/h, had diagnostic efficiency, which distinguish ADHF from non-ADHF with statistical significance.
Lokuge et al., 2010	BNP Testing had a high specificity for diagnosing heart failure, with sensitivity of 66% and specificity of 90%. BNP > 500 pg/mL. BNP < 100 pg/mL indicate low diagnostic efficiency.
Jobs et al., 2020	IVC assessment effective for monitoring decongestion and assessing heart failure, especially in ADHF patients. NT-proBNP combined with IVC measurements, NT-proBNP improves diagnostic accuracy for decongestion status and heart failure evaluation.
Hacıalioğulları et al., 2021	BNP Levels significantly higher in ADHF patients, show diagnostic value for heart failure. LUS & B-Lines showed diagnostic utility in evaluating lung congestion, contribute in the diagnosis of heart failure, especially in respiratory distress.
Kajimoto et al., 2012	ECG is effective for differentiating cardiogenic from non-cardiogenic causes of dyspnea, contributing to heart failure diagnosis. BNP used with ECG and imaging tools, increasing diagnostic efficiency in identifying heart failure. CXR is effective for distinguishing between cardiac and pulmonary causes of heart failure.

4. DISCUSSION

In this systematic review study we included 5 articles aimed to assess the diagnostics method emergency physicians used to diagnose heart failure in ED, method used in the included articles were (NT-proBNP, BIA, BNP levels, Clinical examination, LUS, IVC diameters, EF, Urinary Output, and Lung-Cardiac-Inferior Vena Cava (LCI) integrated ultrasound) (Gil-Martínez et al., 2016; Hacıalioğulları et al., 2021; Jobs et al., 2020; Kajimoto et al., 2012; Lokuge et al., 2010). The most common cause of mortality and hospitalization globally is acute decompensated heart failure, a clinical condition with symptoms including congestion, pleural effusion, tiredness, and dyspnea (Muniz et al., 2018). It is one of the most prevalent symptoms among patients who come to EDs and the underlying cause of dyspnea in up to 40% of older individuals (Pivetta et al., 2019).

It can be difficult to diagnose ADHF, and several investigations needed. Due to their insensitivity, the existing recommendations' suggested procedures for diagnosing ADHF (a physical examination, a CXR examination, and a BNP measurement) may cause treatment delays and higher fatality rates (Yancy et al., 2017). The limited effectiveness of current diagnostic techniques has led to a recent surge in the usage of innovative diagnostic techniques for ADHF (Peacock et al., 2010). Point-of-care US is a bedside, real-time, radiation-free diagnostic tool that has become an essential tool for EDs and has been used more and more in emergency medicine practice. It allows for quick narrowing of the differential diagnosis list as well as early diagnosis and treatment among patients who present to the ED (Daffos et al., 2019).

The study by Kajimoto et al., (2012) showed that rapid evaluation by LCI integrated ultrasound, either alone or in conjunction with plasma BNP assay, has a higher diagnostic accuracy for distinguishing acute dyspnea caused by AHFS from pulmonary acute dyspnea (including COPD, asthma, pulmonary fibrosis, and ARDS). According to these results, LCI integrated ultrasonography has emerged as

a key diagnostic tool for acute dyspnea patients and for choosing early therapy in an emergency situation. Despite the fact that the BNP test had a high degree of accuracy for diagnosing HF and that BNP values were significantly higher in patients with a final diagnosis of HF, the accuracy of the disposition diagnosis of HF in the real-world setting was not significantly increased by adding the BNP test to clinical judgment (Lokuge et al., 2010).

One of the characteristics of ADHF is congestion, which has prompted the development of innovative methods to enhance ADHF diagnostics. There have been several studies in the past years that have compared NPs with either BIA or IVC Goonewardena et al., (2010), Stawicki et al., (2009), some of which include the use of pulmonary ultrasonography (Anderson et al., 2013). Hemodynamic analysis show a strong relationship between IVC parameters and right atrial pressure readings. Left ventricular filling pressures in the majority of patients are correlated with right chamber pressure and, as a result, with pressure in the IVC area.

Age, higher NT-proBNP, left atrial size, pulmonary arterial pressure, atrial fibrillation, and tricuspid regurgitation are other variables linked to increased IVC diameter (Gil-Martínez et al., 2016). When compared to NT-proBNP and a clinical congestion score, the metric that most closely linked with higher left ventricular filling pressures in patients with congestive HF was Max IVC Goonewardena et al., (2008), Pellicori et al., (2013), which has been shown to be helpful in diagnosing ADHF in dyspneic patients (Goonewardena et al., 2010).

5. CONCLUSION

Natriuretic peptides improve the diagnosis of ADHF. BIA and IVCu are low-cost techniques for diagnosing ADHF, especially in elderly patients with renal impairment. BNP testing is accurate in diagnosing HF but does not significantly improve diagnosis in dyspneic ED patients. Development of BNP nomograms adjusted for age, gender, ethnicity, and HF history may improve BNP's utility in the ED. LCI integrated ultrasound provides better accuracy for differentiating AHFS-related acute dyspnea from pulmonary-related acute dyspnea than other methods. LCI integrated ultrasound is useful for rapid evaluation of acute dyspnea in the ED but requires further research to assess its impact on diagnosis and decision-making.

List of abbreviations

AHF: Acute Heart Failure
ADHF: Acute Decompensated Heart Failure
BNP: B-type Natriuretic Peptide
BIA: Bioelectrical Impedance Analysis
CXR: Chest X-ray
ECG: Electrocardiogram
ED: Emergency Department
eGFR: Estimated Glomerular Filtration Rate
IVC: Inferior Vena Cava
IVCu: Inferior Vena Cava Ultrasound
LCI: Lung-Cardiac-Inferior Vena Cava
LUS: Lung Ultrasound
NT: proBNP, N-terminal Pro B-type Natriuretic Peptide
ROC: Receiver Operating Characteristic
TTE: Transthoracic Echocardiography

Ethical approval

Not applicable.

Informed consent

Not applicable.

Funding
This study has not received any external funding.

Conflict of interest
The authors declare that there is no conflict of interests.

Data and materials availability
All data sets collected during this study are available upon reasonable request from the corresponding author.

REFERENCES

1. Adams KF Jr, Fonarow GC, Emerman CL, LeJemtel TH, Costanzo MR, Abraham WT, Berkowitz RL, Galvao M, Horton DP; ADHERE Scientific Advisory Committee and Investigators. Characteristics and outcomes of patients hospitalized for heart failure in the United States: rationale, design, and preliminary observations from the first 100,000 cases in the Acute Decompensated Heart Failure National Registry (ADHERE). Am Heart J 2005; 149(2):209-16. doi: 10.1016/j.ahj.2004.08.005
2. Al-Deeb M, Barbic S, Featherstone R, Dankoff J, Barbic D. Point-of-care ultrasonography for the diagnosis of acute cardiogenic pulmonary edema in patients presenting with acute dyspnea: a systematic review and meta-analysis. Acad Emerg Med 2014; 21(8):843-52. doi: 10.1111/acem.12435
3. Anderson KL, Jenq KY, Fields JM, Panebianco NL, Dean AJ. Diagnosing heart failure among acutely dyspneic patients with cardiac, inferior vena cava, and lung ultrasonography. Am J Emerg Med 2013; 31(8):1208-1214. doi: 10.1016/j.ajem.2013.05.007
4. Bayés-Genís A, Santaló-Bel M, Zapico-Muñiz E, López L, Cotes C, Bellido J, Leta R, Casan P, Ordóñez-Llanos J. N-terminal probrain natriuretic peptide (NT-proBNP) in the emergency diagnosis and in-hospital monitoring of patients with dyspnoea and ventricular dysfunction. Eur J Heart Fail 2004; 6(3):301-8. doi: 10.1016/j.ejheart.2003.12.013
5. Collins SP, Lindsell CJ, Peacock WF, Hedger VD, Askew J, Eckert DC, Storrow AB. The combined utility of an S3 heart sound and B-type natriuretic peptide levels in emergency department patients with dyspnea. J Card Fail 2006; 12(4):286-292. doi: 10.1016/j.cardfail.2006.01.012
6. Daffos Q, Hansconrad E, Plaisance P, Pateron D, Yordanov Y, Chauvin A. Methodological characteristics of randomized controlled trials of ultrasonography in emergency medicine. Am J Emerg Med 2019; 37(2):338-343. doi: 10.1016/j.ajem.2018.11.017
7. Gil-Martínez P, Mesado Martínez D, Curbelo García J, Cadiñanos-Loidi J. Amino-terminal pro-B-type natriuretic peptide, inferior vena cava ultrasound, and biolectrical impedance analysis for the diagnosis of acute decompensated CHF. Am J Emerg Med 2016; 34(9):1817-1822. doi: 10.1016/j.ajem.2016.06.043
8. Goonewardena SN, Blair JE, Manuchehry A, Brennan JM, Keller M, Reeves R, Price A, Spencer KT, Puthumana J, Gheorghiade M. Use of hand carried ultrasound, B-type natriuretic peptide, and clinical assessment in identifying abnormal left ventricular filling pressures in patients referred for right heart catheterization. J Card Fail 2010; 16(1):69-75. doi: 10.1016/j.cardfail.2009.08.004
9. Goonewardena SN, Gemignani A, Ronan A, Vasaiwala S, Blair J, Brennan JM, Shah DP, Spencer KT. Comparison of hand-carried ultrasound assessment of the inferior vena cava and N-terminal pro-brain natriuretic peptide for predicting readmission after hospitalization for acute decompensated heart failure. JACC Cardiovasc Imaging 2008; 1(5):595-601. doi: 10.1016/j.jcmg.2008.06.005
10. Hacıalioğulları F, Yılmaz F, Yılmaz A, Sönmez BM, Demir TA, Karadaş MA, Duyan M, Ayaz G, Özdemir M. Role of Point-of-Care Lung and Inferior Vena Cava Ultrasound in Clinical Decisions for Patients Presenting to the Emergency Department with Symptoms of Acute Decompensated Heart Failure. J Ultrasound Med 2021; 40(4):751-761. doi: 10.1002/jum.15447
11. Hawkins NM, Petrie MC, Jhund PS, Chalmers GW, Dunn FG, McMurray JJ. Heart failure and chronic obstructive pulmonary disease: diagnostic pitfalls and epidemiology. Eur J Heart Fail 2009; 11(2):130-139. doi: 10.1093/eurjhf/hfn013
12. Huang CH, Tsai MS, Hsieh CC, Wang TD, Chang WT, Chen WJ. Diagnostic accuracy of tissue Doppler echocardiography for patients with acute heart failure. Heart 2006; 92(12):1790-1794. doi: 10.1136/hrt.2006.089516

13. Januzzi JL Jr, Camargo CA, Anwaruddin S, Baggish AL, Chen AA, Krauser DG, Tung R, Cameron R, Nagurney JT, Chae CU, Lloyd-Jones DM, Brown DF, Foran-Melanson S, Sluss PM, Lee-Lewandrowski E, Lewandrowski KB. The N-terminal Pro-BNP investigation of dyspnea in the emergency department (PRIDE) study. Am J Cardiol 2005; 95(8):948-54. doi: 10.1016/j.amjcard.2004.12.032
14. Jobs A, Vonthein R, König IR, Schäfer J, Nauck M, Haag S, Fichera CF, Stiermaier T, Ledwoch J, Schneider A, Valentova M, Von-Haehling S, Störk S, Westermann D, Lenz T, Arnold N, Edelmann F, Seppelt P, Felix S, Lutz M, Hedwig F, Borggrefe M, Scherer C, Desch S, Thiele H. Inferior vena cava ultrasound in acute decompensated heart failure: design rationale of the CAVA-ADHF-DZHK10 trial. ESC Heart Fail 2020; 7(3):973-983. doi: 10.1002/ehf2.12598
15. Kajimoto K, Madeen K, Nakayama T, Tsudo H, Kuroda T, Abe T. Rapid evaluation by lung-cardiac-inferior vena cava (LCI) integrated ultrasound for differentiating heart failure from pulmonary disease as the cause of acute dyspnea in the emergency setting. Cardiovasc Ultrasound 2012; 10(1):49. doi: 10.1186/1476-7120-10-49
16. Lokuge A, Lam L, Cameron P, Krum H, De-Villiers S, Bystrzycki A, Naughton MT, Eccleston D, Flannery G, Federman J, Schneider HG. B-type natriuretic peptide testing and the accuracy of heart failure diagnosis in the emergency department. Circ Heart Fail 2010; 3(1):104-110. doi: 10.1161/CIRCHEARTFAILURE.109.869438
17. Muniz RT, Mesquita ET, Souza Junior CV, Martins WA. Pulmonary Ultrasound in Patients with Heart Failure - Systematic Review. Arq Bras Cardiol 2018; 110(6):577-584. doi: 10.5935/abc.20180097
18. Peacock WF, Braunwald E, Abraham W, Albert N, Burnett J, Christenson R, Collins S, Diercks D, Fonarow G, Hollander J, Kellerman A, Gheorghiade M, Kirk D, Levy P, Maisel A, Massie BM, O'Connor C, Pang P, Shah M, Sopko G, Stevenson L, Storrow A, Teerlink J. National Heart, Lung, and Blood Institute working group on emergency department management of acute heart failure: research challenges and opportunities. J Am Coll Cardiol 2010; 56(5):343-351. doi: 10.1016/j.jacc.2010.03.051
19. Pellicori P, Carubelli V, Zhang J, Castiello T, Sherwi N, Clark AL, Cleland JG. IVC diameter in patients with chronic heart failure: relationships and prognostic significance. JACC Cardiovasc Imaging 2013; 6(1):16-28. doi: 10.1016/j.jcmg.2012.08.012
20. Piccoli A, Codognotto M, Cianci V, Vettore G, Zaninotto M, Plebani M, Maisel A, Peacock WF. Differentiation of cardiac and noncardiac dyspnea using bioelectrical impedance vector analysis (BIVA). J Card Fail 2012; 18(3):226-232. doi: 10.1016/j.cardfail.2011.11.001
21. Pivetta E, Goffi A, Nazerian P, Castagno D, Tozzetti C, Tizzani P, Tizzani M, Porrino G, Ferreri E, Busso V, Morello F, Paglieri C, Masoero M, Cassine E, Bovaro F, Grifoni S, Maule MM, Lupia E; Study Group on Lung Ultrasound from the Molinette and Careggi Hospitals. Lung ultrasound integrated with clinical assessment for the diagnosis of acute decompensated heart failure in the emergency department: a randomized controlled trial. Eur J Heart Fail 2019; 21(6):754-766. doi: 10.1002/ejhf.1379
22. Stawicki SP, Braslow BM, Panebianco NL, Kirkpatrick JN, Gracias VH, Hayden GE, Dean AJ. Intensivist use of hand-carried ultrasonography to measure IVC collapsibility in estimating intravascular volume status: correlations with CVP. J Am Coll Surg 2009; 209(1):55-61. doi: 10.1016/j.jamcollsurg.2009.02.062
23. Storrow AB, Jenkins CA, Self WH, Alexander PT, Barrett TW, Han JH, McNaughton CD, Heavrin BS, Gheorghiade M, Collins SP. The burden of acute heart failure on U.S. emergency departments. JACC Heart Fail 2014; 2(3):269-277. doi: 10.1016/j.jchf.2014.01.006
24. Yancy CW, Jessup M, Bozkurt B, Butler J, Casey DE, Colvin MM, Drazner MH, Filippatos GS, Fonarow GC, Givertz MM, Hollenberg SM, Lindenfeld J, Masoudi FA, McBride PE, Peterson PN, Stevenson LW, Westlake C. 2017 ACC/AHA/HFSA focused update of the 2013 ACCF/AHA guideline for the management of heart failure: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines and the Heart Failure Society of America. J Am Coll Cardiol 2017; 70(6):776–803. doi: 10.1016/j.jacc.2017.04.025