Title

Correlation of Inferior Vena Cava Diameter via Point-of-Care Ultrasound and N-terminal pro-B-type Natriuretic Peptide Level in Heart Failure

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Correlation of Inferior Vena Cava Diameter via Point-of-Care Ultrasound and N-terminal pro-B-type Natriuretic Peptide Level in Heart Failure

A dissertation submitted in partial satisfaction of the

requirements for the degree

Doctor of Nursing Practice

by

Christina Light Craigo

2024

ABSTRACT OF THE DISSERTATION

Correlation of Inferior Vena Cava Diameter via Point-of-Care Ultrasound and N-terminal pro-B-type Natriuretic Peptide Level in Heart Failure

by

Christina Light Craigo

Doctor of Nursing Practice

University of California, Los Angeles, 2024

Professor Holli A. DeVon, Chair

Background: Heart Failure (HF) affects 6.2 million people annually. Despite improved survival, one in five HF patients is readmitted within 30 days. Pulmonary congestion is a risk factor for readmission and can manifest weeks before symptoms occur. Point-of-care ultrasound (POCUS) is a portable tool that enables immediate visualization of the inferior vena cava (IVC) and lungs. **Purpose:** To examine the correlation between IVC diameter via POCUS and N-terminal pro-B-type natriuretic peptide (proBNP) level in HF patients seen in a post-discharge clinic. The secondary aim was to assess for the presence of pleural effusions with POCUS. The tertiary objective was to establish correlation between IVC non-collapsibility and volume overload.

Methods: A convenience sample of adults with HF were seen in a nurse practitioner (NP)-led post-discharge clinic within 12 days of hospitalization. The setting was a large tertiary care hospital. Inclusion criteria were patients with Medicare and HF diagnosis, recently hospitalized. Medical records were reviewed for relevant patient outcomes. The NP measured IVC diameter, determined IVC collapsibility, and examined pleural cavities to assess for effusion. A proBNP level was drawn during the visit. Data were analyzed descriptively and using Spearman correlation. **Results:** The sample included 21 patients with mean age of 78.1; 52.4% female, and 42.9% Caucasian. The population had extensive co-morbidities: 85.7% with hypertension, 23.8% diabetes, 61.9% chronic kidney disease. Heart failure with preserved left ventricular function comprised 66.7% of the sample. Median proBNP level was 4095 pg/mL. Normal value for proBNP levels is less than 125 pg/mL for patients under 75 years old, and less than 450 pg/mL for people over age 75. Mean estimated glomerular filtration rate (GFR) was 46mL/min. The normal range for GFR is 90-120 mL/min. There was no correlation between IVC diameter and proBNP, $r = 0.034$, $p=0.884$). Pleural effusions were identified in three patients (14.3%) with POCUS and referred for thoracentesis. IVC was non-collapsible in 5 (23.8%) patients; each of these patients required diuresis for volume overload. **Conclusions:** Inferior vena cava diameter as measured by POCUS was not correlated with proBNP levels in a small sample. Point-of-care ultrasound can be utilized by NPs to identify patients with pleural effusions who may benefit from thoracentesis. Inferior vena cava non-collapsibility may be a predictor for volume overload in HF. **Implications:** POCUS equips NPs with an extra tool to effectively manage HF.

The dissertation of Christina Light Craigo is approved.

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This dissertation is dedicated to my children Madison and Carter and my husband, Chris for their unwavering support and encouragement of my continued education. This project is in honor of my parents Marc and Candy who instilled a strong work ethic and desire to continue learning and who provided exceptional patient care throughout their careers.

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CHAPTER ONE: INTRODUCTION

Every year, heart failure (HF) affects approximately 6.2 million people (Centers for Disease Control and Prevention [CDC], 2023). While advancements in pharmacologic and device therapies have improved survival, the current challenge lies in the increasing rate of hospitalizations. Readmissions for HF significantly impact the prognosis and quality of life of affected individuals and represent a new epidemic in healthcare. Despite a national initiative to reduce readmissions, one in five HF patients is readmitted within 30 days of discharge (Khera et al., 2020). With Medicare's transition towards bundled payments, hospitals have a strong financial incentive to reduce readmission rates. This development has prompted a strategic shift in priorities, compelling healthcare systems to adopt a value-based approach.

Persistent congestion in HF is a significant risk factor for rehospitalization (Girerd et al., 2018). Patients with residual congestion at discharge face a higher risk of cardiovascular mortality and rehospitalization within 90 days (Zisis et al., 2022). Congestion resulting from elevated intracardiac pressure manifests several days to weeks before a patient experiences HF symptoms such as weight gain and dyspnea (Khan et al., 2020). The 2022 American College of Cardiology (ACC) and American Heart Association (AHA) guidelines recommend the utilization of brain natriuretic peptide (BNP) or N-terminal pro-B-type natriuretic peptide (proBNP) to support a diagnosis or exclusion of HF (Heidenreich et al., 2022). However, BNP levels cannot be unequivocally attributed to cardiac etiology alone. Obesity is linked with decreased levels of BNP and proBNP, diminishing their diagnostic sensitivity. Given the limitations inherent in the current diagnostics, a pressing need exists for a robust tool capable of reliably evaluating volume status in patients with HF.

Assessing fluid status in patients is challenging, and there is an estimated 50% accuracy when relying solely on physical examination to establish a correlation with a patient's volume status (Khan et al., 2020). Echocardiography-based assessment of IVC diameter, collapsibility, and pleural cavities may help to identify patients at risk for HF exacerbation and subsequent admission (Gundersen et al., 2016). However, two-dimensional (2D) echocardiography is time-consuming and costly. Point-of-care ultrasound (POCUS) has emerged as a portable and cost-effective alternative to traditional echocardiography that enables immediate visualization of the IVC and lungs. Existing literature supports the effectiveness of POCUS as both a diagnostic and therapeutic tool in the context of HF. A meta-analysis by Szabo et al. (2023) demonstrated that this technology significantly reduces diagnosis and treatment time compared to conventional methods. Point-of-care ultrasound has shown promise as a predictive tool for identifying lung congestion in chronic HF patients at risk of impending decompensation, as exemplified in a study by Picano et al. (2018).

Inferior vena cava diameter and collapsibility can serve as indicators of volume overload and congestion. Increasing IVC diameter, greater than 2 centimeters, is associated with an increased risk of HF hospitalization (Khandwalla et al, 2017). Inferior vena cava collapse of greater than 50% with or without inhalation suggests normal right atrial pressure (Kaptein & Kaptein, 2021). Whereas IVC non-collapsibility, defined as IVC collapsibility less than 50%, is associated with volume overload (Al-Saray & Ali, 2023). Point-of-care ultrasound assessment of the lung cavities can identify pleural effusions resulting in subsequent referral thoracentesis. In summary, POCUS is a valuable tool to evaluate volume status in HF patients and may function as an alternative indicator of BNP level to identify those patients at risk for readmission.

Improving the accuracy of physical assessment through POCUS may expedite the treatment of HF patients and reduce avoidable hospital readmissions.

Problem Statement

The current challenge in HF is the rising rate and cost of readmissions. The total cost for HF was estimated to be $31 billion in 2012; projections indicate a substantial rise in the cost of HF to $70 billion by 2030 (Virani et al., 2020). Recurrent hospitalizations for HF impose a substantial burden on the healthcare system and significantly impact the quality of life for affected patients. It is crucial to thoroughly investigate the potential of utilizing POCUS as a predictive tool to identify impending HF exacerbation and subsequent readmission. By comprehensively studying and understanding its application, healthcare providers may significantly improve outcomes for HF patients.

Clinical Question: Population-Intervention-Comparison-Outcome-Time (PICOT)

The PICOT question for this Doctor of Nursing Practice (DNP) scholarly project is: In adult patients with HF (P), how does the utilization of POCUS (I) to assess the diameter of the IVC compared with physical examination alone (C) correlate with a proBNP blood level in a post-discharge clinic over 3 months (T)?

Purpose and Objectives

The objective of this DNP scholarly project was to evaluate the correlation between IVC diameter and proBNP blood level, an established marker of HF. The secondary objective was to assess the effectiveness of POCUS in identifying pleural effusion and the need for thoracentesis. The tertiary objective was to establish the correlation between IVC non-collapsibility and volume overload. A long-term goal is to increase the number of nurse practitioners (NP) who utilize this technology for HF patients.

CHAPTER TWO: THEORETICAL FRAMEWORK

The Plan, Do, Study, Act (PDSA) model is a quality improvement framework rooted in Edward Deming's Plan, Do, Check, Act cycle and quality theory. This model facilitates swift and successive changes in two consecutive cycles. Effective communication among team members is crucial in healthcare settings to promote safety and quality. Deming's theory of quality emphasizes the importance of education and retraining, providing team members with updated information to adapt to evolving processes (Butts & Rich, 2018). The PDSA model allows for testing changes, analyzing results, and adjusting as necessary, enabling healthcare organizations to enhance their processes and outcomes. See Appendix A for a visual depiction of the PDSA model.

The PDSA model is a structured approach that consists of four sequential steps: plan, do, study, and act. The "plan" step focuses on improving a particular process and identifying the necessary steps for execution. This involves the incorporation of POCUS into the post-discharge clinic setting. The "do" step involves implementing the proposed change on a small scale, allowing for a trial run. The subsequent "study" step involves a comprehensive evaluation of the implemented change, including discussing the lessons learned and assessing whether the desired goals were achieved. In practice, the study phase may occur simultaneously with the “do” step, as ongoing analysis and assessment are crucial. This entails the utilization of POCUS followed by evaluation, adaptation, and repetition. In the event of unforeseen challenges, adjustments can be implemented. Finally, during the "act" step, the intervention is thoroughly evaluated, and a decision is made regarding whether to maintain the change, modify it, or discard it altogether. In this phase, the effectiveness of the POCUS intervention in identifying impending HF exacerbation and preventing subsequent readmission is assessed. The act step also sets the

direction for the next PDSA cycle, guiding subsequent improvement efforts (McQuillan et al., 2016). The PDSA model allows for the rapid implementation of change and the acquisition of valuable knowledge through iterative cycles. Often, multiple cycles are required to fully implement and refine a change (Coury et al., 2017). Each cycle generates results that inform and guide the subsequent cycle, gradually leading to attaining the desired goal. The PDSA model, like other quality improvement frameworks, necessitates collaboration among team members and may present procedural challenges that need to be addressed.

The PDSA model was highly suitable for integrating POCUS into a post-discharge HF clinic, particularly as an NP provider was learning the technology and creating a new workflow. Given the dynamic nature of incorporating POCUS into clinical practice, it was imperative that the NPs and HF team consistently revisit and reassess the workflow to ensure its effective implementation and ongoing refinement. Utilizing the PDSA model, the HF team systematically introduced and evaluated changes, enabling continuous improvement in patient care, safety, and operational processes. The iterative nature of the model facilitated the acquisition of knowledge and the optimization of interventions, ultimately enhancing outcomes and the quality of care provided.

CHAPTER THREE: REVIEW OF LITERATURE

Evidence Search

An extensive literature search was conducted across PubMed, Cumulative Index to Nursing and Allied Health Literature (CINAHL), and Excerpta Medica Database (EMBASE). The initial search in PubMed provided baseline statistics and an overview of the scope of the problem of HF and readmissions. Subsequently, the project goals shifted towards identifying intervention strategies to reduce readmissions, requiring expanding search terms to encompass

various combinations of HF, readmission, pharmacy, pharmacist, the transition of care, ambulatory care, nurse, nurse practitioner, and nurse practitioner-led clinic. PubMed produced several comprehensive articles, offering insights into diverse strategies for addressing readmissions. However, CINAHL yielded the most information on specific nursing interventions, particularly highlighting the utilization of NP-led transitional care clinics.

Finally, an examination of a specific approach for reducing readmissions: the utilization of POCUS in a post-discharge clinic became the focus. Initially, EMBASE yielded the most information with the search terms ultrasound and handheld, linking the technology to the physical assessment, fluid status, and prognosis. The search terms POCUS and point-of-care ultrasound produced the most substantial literature on HF and hospital admissions. By combining the aforementioned search terms with HF and readmission, relevant studies exploring the utility of POCUS in a post-discharge setting were identified.

Efficacy of POCUS

Laffin et al. (2018) aimed to investigate the potential of daily POCUS imaging in hospitalized patients. The researchers enrolled 82 patients diagnosed with HF admitted to an academic teaching hospital in Chicago. Seventy patients were included in the analysis. Subjects were excluded if they required renal replacement therapy or intensive care. The imaging was obtained by medical residents not directly involved in patient care on the day of admission and daily thereafter. The primary endpoint of the study was to assess readmission within 30 days. Throughout the hospitalization, the researchers observed a reduction in the size of the IVC, indicating improved fluid management. Residents were blinded to all clinical data; management decisions were not prescribed based on the imaging results.

Sixty-two percent of patients were discharged with at least one abnormal physical finding of elevated jugular venous pressure, edema, or crackles on auscultation. At discharge, only 50% of patients were estimated to have a low or normal right atrial pressure by IVC assessment. The analysis demonstrated that IVC collapsibility and improvement in dyspnea were the only significant variables to predict subsequent readmission and emergency department visits. Additionally, the study findings showed that many patients were discharged with persistent fluid overload. The researchers concluded that IVC imaging obtained with POCUS might help to identify patients at risk of rehospitalization (Laffin et al., 2018).

Rattarasarn et al. (2022) conducted a single-center observational prospective study at a university hospital in Bangkok that utilized POCUS on a cohort of 126 HF patients before hospital discharge. Researchers evaluated the presence of B-lines and assessed the size of the IVC within a 24-hour timeframe preceding discharge. B-lines, also known as lung comets, are vertical artifacts that extend from the pleural line into the lung parenchyma and are indicative of certain pathological conditions, including pulmonary edema, interstitial lung disease, and pneumonia. The researchers subsequently examined the rehospitalization rate within six months. They found a notable difference between patients with significant B-lines (greater than or equal to 12) and those with non-significant B-lines. In six months, 54.76% of subjects experienced an HF event. The presence of greater than 12 B-lines before discharge was an independent predictor of cardiovascular hospitalization or mortality at six months. Furthermore, a non-significant number of B-lines was identified as indicative of a subgroup with a lower risk of rehospitalization for HF. This suggests residual pulmonary edema detected through POCUS is a prognostic factor for rehospitalization due to HF within six months (Rattarasarn et al., 2022).

Zsis et al. (2022) evaluated the ability of HF nurses to perform a predischarge lung and IVC assessment (LUICA) and evaluate its predictive value for 90-day outcomes. This prospective observational study took place across multiple sites. HF nurses performed scans on 240 hospitalized patients with acute decompensated HF using a 9-zone LUICA protocol. Patients were hospitalized in the intensive care unit, internal medicine, or cardiology ward in public hospitals in Tasmania. Based on a B-line cut-off of 10, patients were classified as congested or non-congested. At 90 days, 37% of congested patients experienced HF readmission or mortality compared to 14% of non-congested patients.

The analysis showed that pulmonary congestion independently increased the odds of HF readmission and mortality at 30 days by 3.3- to 4.2-fold ($p< 0.01$), adjusting for demographics, HF characteristics, comorbidities, and event risk score. Over 90 days, congested patients spent fewer days alive outside of the hospital. Researchers concluded that LUICA assessment could be a valuable tool for detecting pre-discharge residual congestion. This study examined POCUS use by nurses without prior ultrasound imaging experience. The favorable outcomes achieved with minimal training underscore the potential applicability of POCUS as a diagnostic modality that can deliver effective results without requiring specialized physician expertise (Zsis et al., 2022).

Khandwalla et al. (2017) conducted a retrospective analysis on a cohort of HF patients in an ambulatory setting over 17 months at a large academic institution in Los Angeles. The study aimed to assess the association between serial measurements of IVC dimension and the risk of HF admission. The cohort comprised 355 patients with systolic and diastolic HF, New York Heart Association (NYHA) class II-IV HF, or class I, with two prior outpatient visits to manage volume status the previous year. Throughout the study, 32.4% of patients required hospitalization. Patients who experienced at least one hospital admission had a higher mean IVC

than those who did not require admission (2.0cm vs. 1.8cm). For every 0.5cm increase in the mean IVC dimension, there was a 38% increase in the risk of HF admission. The risk of HF admission was also significantly elevated in patients with an IVC dimension measuring 2.0 to 2.49cm and those with an IVC dimension greater than 2.5cm compared to those less than 2.0cm (Khandwalla et al., 2017). Researchers concluded that increasing IVC diameter is associated with a risk of HF hospitalization, and POCUS may provide valuable clinical insight into managing HF.

Pellicori et al. (2019) conducted a study to assess the prevalence and clinical significance of congestion in outpatients with chronic HF. The researchers examined various clinical and ultrasound parameters related to congestion. A total of 342 patients participated in the study, most classified as NYHA class I or II. A physical exam was performed before echocardiography. Patients were assigned a congestion score based on physical assessment. Two-dimensional echocardiography was performed by an experienced practitioner assessing lung B-lines, IVC diameter, and the diameter of the internal jugular vein before and after a Valsalva maneuver (JVD ratio). Seventy-one percent exhibited at least one congestion indicator through clinical assessment or ultrasound findings. A subset of patients deemed free of congestion by physical examination still demonstrated signs of fluid overload based on objective measures. There was a positive association between each clinical and ultrasound measure of congestion and an increased risk of adverse outcomes. However, in multivariable models, only higher levels of proBNP, larger IVC diameter, and lower JVD ratio were significantly associated with the composite outcome. The researchers concluded that many patients diagnosed with chronic HF, even those experiencing minimal symptoms, exhibit objective evidence of congestion, which predicts an unfavorable prognosis (Pellicori et al., 2019).

Curbelo et al. (2018) conducted a study to investigate the application of POCUS in patients with chronic HF. This prospective cohort study used POCUS to measure the IVC collapse index (IVCCI) in 95 patients attending routinely scheduled follow-up visits in Madrid. Consensus statements suggest the degree of IVC collapse is less than 50% for diagnosing acutely decompensated HF. The patients were followed for one year and monitored for worsening HF, hospital admissions for HF, HF mortality, and all-cause mortality. The relationship between IVC parameters and other variables was examined. Findings indicated that worsening HF occurred in 70.9% of patients with an IVCCI value below 30%, compared to 39.1% with an IVCCI value above 50%. 45.3% of patients with an IVCCI below 30% required admission, whereas only 5.9% of patients with an IVCCI above 50% required hospitalization. Mortality rates were higher in the IVCCI <30% group, with 25.7% experiencing all-cause mortality and 18.6% experiencing HF-related mortality, compared to 13% and 4.7%, respectively, in the IVCCI >50% group. However, these differences did not reach statistical significance. Subsequent analysis showed that IVCCI was not superior to that of BNP or proBNP for any of the studied outcomes. Researchers concluded that IVC ultrasonography was a valuable tool in monitoring patients with chronic HF, enabling the identification of individuals at a heightened risk of worsening HF and hospitalization. However, its utility was not superior to that of proBNP (Curbelo et al., 2018).

Gundersen et al. (2016) explored nurses utilizing POCUS in an outpatient HF clinic and the impact on diuretic dosing. The study included 62 patients with a mean age of 73 years who were seen as outpatients at a non-university hospital in Norway. The patients were divided into two groups: one examined by a team with POCUS and the other by a team without ultrasound. For every study visit, the patients underwent a dual examination process. First, one of the nurses performed the initial assessment, either with or without ultrasound, based on the randomized

sequence. The same patient was examined by the second nurse, who examined the patients in reverse order compared to the first nurse. The two nurses involved in the study were blinded to the other's assessments. The ultrasound imaging assessed the IVC and pleural cavity. Based on the findings, the nursing team and cardiologist determined the adjustment of diuretic dosing. In 75 out of 119 examinations (63%), the nurses agreed with the volume assessment, suggesting moderate inter-rater reliability of examination findings.

Interestingly, the analysis demonstrated that POCUS imaging of the IVC and pleural cavity was significantly more effective than other factors, such as edema, changes in the NYHA classification status, creatinine levels, or proBNP levels, in predicting the need for diuretic dosing adjustment. This finding suggests that clinical signs such as lower extremity swelling may lack reliability and validity in accurately assessing congestion and volume status, or there may be a delay in time between physiologic changes and the manifestation of symptoms. This study demonstrated the potential benefits of incorporating POCUS devices into nursing practice in an outpatient HF clinic.

Prognostic Value

Cuthbert et al. (2021) established that in patients at risk for HF, subclinical signs of congestion (defined as at least one positive ultrasound marker of congestion) are common. Rattarasarn et al. (2022) focused on utilizing POCUS to assess B-lines and IVC size before discharge. Researchers found that 12 or more B-lines identified with POCUS predicted higher rehospitalization rates for HF within six months, while a non-significant number of B-lines indicated a lower risk of rehospitalization. This study highlights the prognostic value of POCUS in detecting residual pulmonary edema and its association with future HF readmissions. Zisis et al. (2022) also evaluated patients just before discharge. These researchers demonstrated that

pulmonary congestion detected by LUICA was associated with a higher risk of HF readmission or mortality at 30 and 90 days. Arvig et al. (2022) conducted a comprehensive meta-analysis comprising 24 studies, in which seven studies reported that a decline in B-lines or IVC size or an increase in IVC collapse index, exhibited a significant reduction in mortality, readmissions, and length of stay when linked to a single ultrasound measurement. Khandwalla et al. (2017) conducted a retrospective analysis focusing on the IVC dimension measured serially by POCUS in ambulatory HF patients. Researchers found that an increased IVC dimension was associated with a higher risk of HF admission. The study demonstrated that measuring the IVC dimension using POCUS in the outpatient setting provides valuable information for predicting HF admission risk. The preponderance of evidence suggests that POCUS is a dependable tool for assessing congestion and predicting risk.

POCUS Operator

The literature has established nurses as reliable users of this technology. Zisis et al. (2022) conducted a study that broadened the implementation of POCUS by involving nurses with limited training. The findings confirmed that nurses could obtain LUICA images and provide diagnostic reports that hold predictive value for acute decompensated HF outcomes. Laffin et al. (2018) investigated the potential of daily POCUS imaging by medical residents with minimal training not involved in the care of hospitalized HF patients. This study demonstrated that IVC collapsibility and dyspnea were significant predictors of subsequent readmission and emergency department visits, corroborating POCUS's utility in assessing fluid management and identifying patients at risk of readmission.

Gundersen et al. (2016) also explored the use of POCUS by nurses in an outpatient HF clinic. They found that ultrasound imaging of the IVC and pleural cavity was more effective in

predicting the need for diuretic dosing adjustment than other factors, including physical exam findings. This study emphasizes the potential benefits of incorporating POCUS into outpatient care, enhancing the assessment of congestion and volume status. Gunderson et al. (2016) showed that POCUS improved the clinician's ability to assess congestion and volume status, providing valuable insights for diuretic dosing decisions. By utilizing POCUS, nurses could complement and enhance their clinical assessment, resulting in a more accurate evaluation of patients with HF. The findings of this research contribute to the growing body of evidence supporting the integration of POCUS as a valuable tool in improving patient care and management in outpatient settings (Gundersen et al., 2016). A common theme throughout the literature review is the ease of use of POCUS devices, particularly by nurses. As this technology becomes more prevalent, it may directly impact nursing practice.

Recommendations

The 2022 ACC/AHA guidelines for managing HF acknowledge that POCUS is a useful tool for evaluating cardiac function, assessing volume status, and detecting pulmonary congestion (Heidenreich, et al., 2022). Moreover, the European Society of Cardiology recommends POCUS as a primary diagnostic tool for assessing pulmonary congestion in suspected cases of acute HF (McDonagh et al., 2021). The American Society of Echocardiography (ASE) recognizes that POCUS offers rapid diagnosis and early therapeutic intervention for critical cardiovascular conditions, a practice increasingly embraced across diverse clinical environments. The ASE issued guidelines in 2020 with recommendations for POCUS training and supervision (Kirkpatrick et al., 2020). These guidelines and consensus statements underscore the significance of integrating POCUS in clinical practice to enable a more comprehensive evaluation of patients with HF.

Synthesis of Literature Review

The literature review established an association between the diameter of the IVC, fluid status, and prognosis. Ciozda et al. (2017) conducted a meta-analysis of clinical studies that compared sonographic evaluation of IVC diameter and collapsibility to the gold standard measurements of central venous pressure (CVP) and right atrial pressure (RAP). Despite variations in the methods used for measurements and patient characteristics, a majority showed moderate positive correlations between the measurements of IVC diameter and collapsibility (the degree of IVC constriction during respiration) and CVP or RAP. The researchers concluded that the sonographic measurement of IVC diameter and collapsibility are reliable for estimating CVP and RAP. A seminal work by Pellicori et al. (2013) demonstrated that increasing IVC diameter (on 2D echocardiogram) was associated with an adverse outcome in individuals with chronic HF. Khandwalla et al. (2017) corroborated that increasing IVC dimension, measured by POCUS, is associated with a heightened risk of HF admission.

The literature review consistently highlights the value of POCUS in assessing congestion and fluid status and predicting outcomes in HF patients. Researchers acknowledge the limitations of the physical examination in accurately assessing volume status and emphasize the convenience and cost-effectiveness of POCUS. Moreover, nurses can be trained quickly to utilize this technology, further supporting its widespread adoption. The highlighted studies contribute to the growing body of evidence supporting the integration of POCUS as an effective tool in managing HF, especially when symptoms are absent.

Gaps in Literature

The evidence supports POCUS to evaluate a patient's volume status, particularly in HF. While much of the research on POCUS has focused on its utility in the hospital setting, exploring

its potential benefits in the ambulatory care setting is crucial. This setting presents unique challenges, such as medication and dietary noncompliance and failure to follow up. It has been established that POCUS can guide therapy and help predict outcomes in both inpatient and outpatient settings. However, further studies are needed to determine correlations between POCUS imaging, subsequent therapy adjustments, and patient outcomes. Arvig et al. (2022) conducted a meta-analysis of 24 studies in which they found no articles that examined the difference between two ultrasound measurements and primary outcomes. It is also essential to acknowledge that most existing literature lacks a direct and comprehensive head-to-head comparison between POCUS and physical examination or BNP to assess congestion. Such a comparative analysis would be pivotal in discerning these two diagnostic approaches' relative effectiveness and clinical implications, particularly regarding patient outcomes and readmission rates. Finally, most studies reviewed enrolled small samples and may have been underpowered. The existing body of literature also does not address the use of POCUS within the context of a clinic led by NPs. This knowledge gap is significant, considering NPs' increasingly pivotal roles in delivering comprehensive healthcare services to HF patients. Given the potential advantages of POCUS, such as its portability, real-time imaging capabilities, and potential to enhance diagnostic accuracy, exploring its integration and utilization within NP-led clinics holds substantial promise.

Although this DNP scholarly project does not encompass a direct head-to-head comparison of POCUS and physical assessment, it aims to investigate the application of POCUS in a post-discharge NP-led ambulatory clinic. By undertaking this analysis, the project will help shed light on the potential impact of POCUS on HF patients in an ambulatory care setting, thus contributing insight to the existing body of knowledge in the field.

CHAPTER FOUR: METHODS

Ethical Considerations

Institutional Review Board (IRB) approval was obtained prior to patient recruitment. Participation was voluntary as indicated in the consent for participation (Appendix B).

Project Design

This single-center project aimed to assess the correlation between IVC diameter (measured by POCUS) and proBNP level during a post-discharge clinic visit at an academic medical center. The secondary objective was to assess the effectiveness of POCUS in identifying pleural effusion and the need for subsequent thoracentesis. The tertiary aim sought to determine the relationship between IVC non-collapsibility and volume overload. Refer to Appendix C for a visual depiction of the POCUS device.

Population Sample and Setting

A convenience sample of adults with HF (N=21) was seen in an NP-led post-discharge clinic within 12 days of hospitalization. The setting for the project was an outpatient ambulatory clinic at a large tertiary care hospital. Inclusion criteria were patients with Medicare diagnosed with HF, recently admitted to the hospital. The hospitalization did not need to be related to HF. Patients who were not seen in person in the post-discharge clinic were not eligible for the study.

Intervention

Patients were approached during the visit with an introductory flyer (Appendix D). Medical records were reviewed for relevant patient outcomes. Every morning, the registered nurse received a reminder about a patient's eligibility for the project and anticipated blood draw, provided the patient gave consent. During the post-discharge visit, the NP utilized POCUS to measure IVC diameter, evaluate for IVC non-collapsibility and examined pleural cavities to

assess for pleural effusion. A proBNP level was drawn during the visit. The team employed the PDSA cycle to evaluate project efficiency and identify areas that may benefit from improvement.

Data Collection and Instruments

During the clinic visit, an image of the IVC and its diameter measurement was obtained and uploaded into the patient's medical record. A proBNP blood level was drawn. The presence or absence of a pleural effusion measured by POCUS was assessed during the clinic visit and served as a secondary outcome measure. If the patient had a pleural effusion, this image was uploaded into the medical record. IVC non-collapsibility was recorded as a tertiary outcome.

Additional confounding variables including age, sex, HF with reduced left ventricular (LV) function or HF with preserved LV function, and co-morbidities, including hypertension, diabetes, and renal disease were recorded. Researchers also documented whether patients were maintained on angiotensin receptor/neprilysin inhibitor (ARNI), and sodium-glucose linked transporter-2 (SGLT2) inhibitors. These data were obtained from the patient’s electronic medical record and by interviews with patients during the time of medical assessment.

Data Analysis

Demographic and clinical characteristics were analyzed using descriptive statistics. The degree of association between IVC diameter and proBNP level was measured using the Spearman correlation coefficient. The alpha level was set at <0.05 for all tests. The presence or absence of pleural effusion was recorded along with referral to thoracentesis and the outcome of the pleural fluid extraction. Additionally, IVC collapsibility or non-collapsibility was recorded for each patient. Data was analyzed using IBM SPSS Statistical Software.

CHAPTER FIVE: RESULTS

This scholarly project aimed to identify if there is a correlation between IVC diameter and proBNP level. The secondary aim was to evaluate the efficacy of POCUS in detecting pleural effusion and the need for thoracentesis. The tertiary aim was to examine the relationship between IVC non-collapsibility and volume overload in HF patients.

Participant Characteristics

The sample included 21 patients with mean age of 78.1 (±11.8) years who were: 52.4% female, and 42.9% Caucasian. The mean body mass index (BMI) of the cohort was 24.51 kg/m^2. Table 1 displays the frequency counts for comorbid conditions. The population had extensive co-morbidities. The majority (85.7%) of the cohort were treated for hypertension. Fewer patients (23.8%) were diagnosed and treated for diabetes. Over half (61.9%) of the cohort was diagnosed with chronic kidney disease, and three patients (14.3%) were dialysis dependent. Heart failure with preserved left ventricular function included 66.7% of the sample while the remaining 33.3% had HF with reduced LV function.

Table 1: ***Demographic and Clinical Characteristics of the Sample***

Condition	*n*	%
Age	78.1±11.8	
Female (%)	11	52.4%
Male (%)	10	47.6%
Caucasian (%)	10	47.6%
Mean Body Mass Index (kg/m^2)	24.51	

HTN	18	85.7%
Diabetes	5	23.8%
Chronic Kidney Disease	14	66.7%
Heart Failure with Preserved LV Function	14	66.7%

There was no correlation between IVC diameter and proBNP (r = 0.034, p=0.884) in this cohort. See Figure 1.

Figure 1: ***IVC Diameter and proBNP Levels***

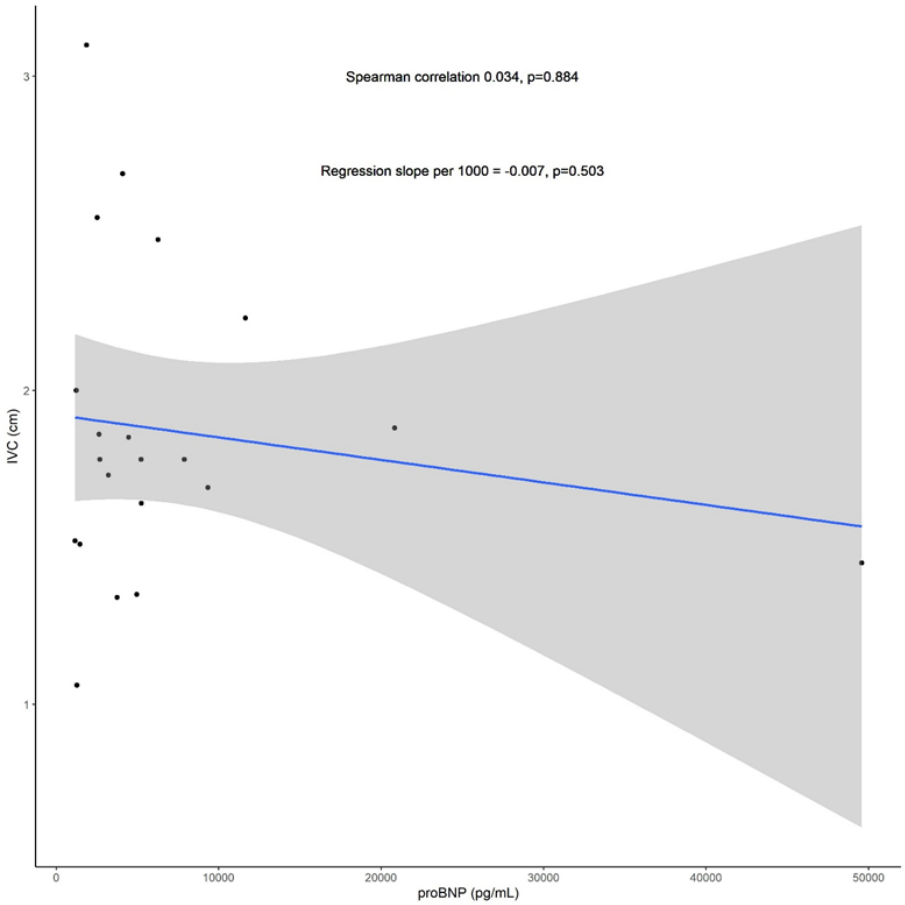

Table 2 displays the variables of interest for the sample. The average IVC diameter was 1.82cm. The median proBNP level was 4095. (Normal value for proBNP levels is less than 125 pg/mL for patients under 75 years old, and less than 450 pg/mL for people over age 75). The mean eGFR was 46ml/min. (The normal range for GFR is 90-120 mL/min.) Pleural effusion was identified in three patients (14.3%) with POCUS and referred for thoracentesis. Among the three patients referred for thoracentesis, one had 900cc of pleural fluid drained, while the other two subjects each had 1200cc removed.

The tertiary aim of this project was to examine the relationship between IVC non-collapsibility and volume overload. Inferior vena cava was non-collapsible in five (23.8%) of patients. Of the five patients with non-collapsible IVC, three patients (14.3%) required diuresis with intravenous Lasix administration in the clinic, one patient was instructed to up-titrate oral diuretic therapy and one patient was instructed to proceed with dialysis the following day. Four patients (19%) were readmitted to the hospital within 30 days. Two of these patients were readmitted for HF. One of the patients was admitted for evaluation of chest pain; one patient was admitted for elective mitral valve replacement.

Table 2: ***Clinical Variables of Interest***

Outcome Variable	*n*	
Average IVC (cm)		1.82cm
Median proBNP (IQR)		4095 (range 2520, 6260)
Mean eGFR (SD)		46.0±25.4
Pleural Effusion/Referred for Thoracentesis	3	14.3%

Non-Collapsible IVC (%)	5	23.8%
IVC Diuresis (%)	3	14.3%
Readmitted within 30 Days	4	19%

CHAPTER SIX: DISCUSSION

Many health systems have created initiatives to reduce preventable readmissions in HF patients, particularly in the context of Medicare's shift from fee-for-service to bundle-based payments. Persistent congestion is a significant risk factor for recurrent hospitalizations and negatively impacts patients' quality of life. Subclinical signs of congestion, defined as at least one positive ultrasound marker of congestion, are common in patients at risk for HF (Cuthbert et al., 2021). Clinicians have several options to evaluate volume status and manage patients with HF. Brain natriuretic peptide and proBNP assays are commonly utilized to ascertain the presence and severity of HF. The utilization of POCUS to measure IVC diameter and assess for non-collapsibility is increasing in popularity and is another tool at the disposal of clinicians.

A correlation was not established between IVC diameter and proBNP level suggesting that these two markers are unrelated. This finding is corroborated by Haag et al. (2023) who also did not identify a correlation between the congestion markers of IVC diameter and proBNP level, or other quantitative congestion markers including dyspnea using visual analogue scale and a clinical congestion score. It is possible that there were methodological issues in the studies, the sample sizes were insufficient, or there is genuinely no relationship between these biological markers of HF and symptoms.

Both measures have provided independent prognostic information for HF exacerbation. Low proBNP values have a high negative predictive value for HF. N-terminal pro-B-type natriuretic peptide has good sensitivity and specificity, however values are less accurate in the elderly population. The study population had a mean age of 76 years and extensive co-morbidities including hypertension, diabetes, and renal impairment. While proBNP levels offer important information, these assays should not be relied upon as a solitary test. Concentrations of proBNP are most effectively understood as a valuable marker of HF and lung congestion, taking into consideration renal function and body mass index.

The 2022 ACC/AHA guidelines for managing HF acknowledge that POCUS is a useful tool for evaluating cardiac function, assessing volume status, and detecting pulmonary congestion (Heidenreich et al., 2022). This project did establish that POCUS is efficacious in identifying pleural effusion and need for subsequent thoracentesis. Furthermore, by recognizing the non-collapsibility of the IVC, the NP identified important volume overload and recommended management including intravenous diuretics and other therapies. Incorporating POCUS in a post-discharge clinic setting can complement a clinician's physical examination and provide early indications of volume overload, enabling prompt intervention.

Point-of-care ultrasound facilitates rapid evaluation of volume status, though it might pose challenges in cases of obesity and poorly visualized IVC. The mean BMI of the cohort was 24.51kg/m^2; some individuals who were seen in the post-discharge clinic were excluded from the study due to poor IVC visualization in the setting of obesity. Perhaps the optimal utility is realized when proBNP level is used in conjunction with other diagnostic tools such as the POCUS assessment of IVC. Integrating these tools into a post-discharge clinic workflow offers

benefits, complementing a clinician's physical examination and offering early indications of congestion, thus enabling timely intervention.

Technical Logistics

The literature has established nurses as reliable and competent users of POCUS, however developing skills takes time and practice. During the six months preceding project implementation, the NP project lead secured a POCUS device and acquired the skills to visualize the IVC and pleural cavities. This required shadowing a clinical physician mentor, participating in continuing education, and refining skills through hands-on practice with a model at a national conference. It was not until three months into this period that the project lead felt at ease using the device. The project lead relied heavily on her clinical mentor and supervising physicians to validate both the measurement of the IVC and diagnosis of pleural effusion. It was crucial for the HF team to continually revisit and reassess the clinic workflow to ensure effective integration of POCUS and ongoing refinement. By utilizing the PDSA model, the HF team systematically introduced and evaluated changes, allowing for continuous improvement in operational processes.

As this technology advances, it paves the way for clinical trials to explore how these devices can complement current therapies and ultimately improve patient outcomes. Nurses and advanced practice providers will play a critical role in the widespread dissemination of this knowledge, potentially encouraging more institutions to adopt the integration of handheld devices and proBNP measurement into post-discharge clinic workflow. In the future, there will be a necessity to establish standardized education programs on POCUS to ensure both quality and consistency across practices.

Long-term Implications

There are considerable prospects for expanding the utilization of POCUS within the broader healthcare system. For one, the potential benefits of utilizing POCUS extend beyond clinical settings, encompassing environments such as a patient's home or skilled nursing units, where the presence of a clinician is limited for patient evaluation and phlebotomy. The use of POCUS by home health nurses may provide substantial benefits for patients who do not have regular access to advanced imaging. In a feasibility study conducted by Pratzer et al. (2023), it was observed that patients successfully obtained interpretable lung ultrasound examinations in over 90% of remotely supervised sessions within the comfort of their homes. These promising results indicate the potential for remotely guided lung ultrasound to detect early HF decompensation outside of the acute environment. The future of this technology holds promise as advancements and expanded applications continue to facilitate rapid and cost-effective diagnoses at the patient's bedside.

The POCUS market is projected to experience continued growth due to increasing demand across healthcare settings. The ongoing evolution of this technology has created a promising landscape wherein advanced artificial intelligence software and machine learning algorithms can support less-experienced operators, optimizing diagnostic effectiveness and providing valuable clinical feedback in real time. Currently, artificial intelligence can guide non-clinicians to acquire images in third-world countries, allowing cardiologists to diagnose rheumatic heart disease remotely (Francis, 2021). This has implications for increased access to care. Integrating POCUS into more settings may expedite care delivery in developed regions' urgent or less acute settings and has the potential to improve health access and reduce disparities worldwide.

Limitations

The project has several limitations. First, the sample size was small and lacked the statistical power to identify a correlation between IVC diameter and proBNP level if it existed. The project's duration was also limited to three months. Two of the subjects had a poorly visualized IVC, posing challenges in determining IVC diameter. Several patients were ineligible for the study because of our inability to visualize the IVC in the setting of obesity. Two of the study candidates were not eligible because proBNP levels could not be drawn. Selection bias must be acknowledged given the convenience sample of 21 was recruited in the same post-discharge cardiology clinic.

Serial measurements of IVC and proBNP were not conducted nor was information gathered on medication administration during hospitalization which could potentially affect both natriuretic peptides and IVC size. Additionally, proBNP is affected by other factors, including age, sex, creatinine clearance, and body mass index, which could influence findings. A larger prospective study should be conducted to explore trends in IVC diameter, non-collapsibility, and proBNP levels from the time of discharge to the time of first post-discharge follow up. Patients with advanced renal failure were not excluded from this study, resulting in several outliers within the study cohort.

CONCLUSION

This project offers insights into the management of HF patients immediately post-discharge. In a sample of 21 patients, no correlation was found between IVC diameter as measured by POCUS and proBNP level. Measuring proBNP level improves diagnosis but must be interpreted in the context of the comprehensive clinical picture. POCUS is an effective tool that allows for rapid assessment of volume status but may be difficult to employ in the setting of

obesity and poorly visualized IVC. Both measures provide valuable insights and offer independent prognostic information. To comprehensively manage HF patients, it is useful to employ both approaches.

This project demonstrated that POCUS can be utilized by NPs to identify patients with pleural effusions who may benefit from thoracentesis. In addition, it was found that IVC non-collapsibility may be a marker of volume overload in HF patients who need intravenous diuresis or other interventions. Widespread dissemination of this knowledge could encourage more institutions to adopt POCUS technology to enhance diagnostic accuracy in HF. These findings add to the literature supporting NPs utilizing POCUS in an ambulatory clinic. The future of HF management holds promise as technological advancements enable an expanded user pool to provide individualized and evidence-based patient care.

APPENDICES

Appendix A

PDSA Model (NHS Kent Community Health, n.d.)

Edward Deming's Theory of Quality Improvement

Appendix B

Institutional Review Board Approval

Cedars Sinai

Office of Research Compliance and Quality Improvement, 6500 Wilshire Blvd., Suite 1800, Los Angeles, CA 90048

IRB APPROVAL NOTICE

November 30, 2023

Dear MARGO MINISSIAN:

On 11/30/2023, the IRB reviewed and approved the following submission:

Type of Submission:	Initial Study
Title of Submission:	STUDY00003109: Integration of POCUS
Protocol Title:	Integration of POCUS into NP-led Post-Discharge Clinic
IRB Protocol ID:	STUDY00003109
Investigator:	MARGO MINISSIAN
Funding:	Name: Cedars-Sinai
IRB Review Level:	Expedited
Approval Effective Date:	11/30/2023
Approval Expiration Date, if applicable:	
Documents Reviewed:	• Craigo_POCUS, Category: IRB Protocol; • Craigo_POCUS_Consent, Category: Consent Form; • Craigo_POCUS_Flyer, Category: Recruitment Materials;

If an expiration date is displayed above, a continuing review must be submitted at least 60 days in advance of this date.

If no expiration date is displayed above, this minimal risk study will not require annual continuing review submissions.

In conducting this research, you are required to follow the IRB approved protocol and all applicable IRB Policies and Procedures.

Page 1 of 1

Appendix C

Visual Depiction of POCUS Device

GE Healthcare: Vscan Air™ handheld ultrasound

Appendix D

Participant Information Flyer

CSMC IRB No: STUDY00003109
CSMC Date Effective: 11/30/2023

Cedars Sinai

Does Utilization of Point-of-Care-Ultrasound (POCUS) to Assess Inferior Vena Cava Diameter Correlate with BNP blood level?

Who is eligible to participate?

- Patients with heart failure recently hospitalized who present to the Enhanced Heart Care (EHC) post-discharge clinic.

Participation in this project includes:

- One visit in the EHC post-discharge clinic on the 5th floor south tower.
- One blood draw during clinic visit.
- Examination with a point-of-care ultrasound (POCUS) to assess for fluid overload.

This is a scholarly project.

- This is not a research project.
- Its purpose is to explore the utility of POCUS in the clinical setting as a supplement to the physical examination.

For more information, contact the study coordinator, Christina Craigo at:
Phone: 310-248-7325 Email: christina.craigo@cshs.org

TABLE OF EVIDENCE

CITATION	PURPOSE	SAMPLE and SETTING	METHODS (Design, Interventions, Measures)	RESULTS	DISCUSSION, INTERPRETATION, LIMITATIONS
Laffin, L. J., Patel, A. V., Saha, N., Barbat, J., Hall, J. K., Cain, M., Parikh, K., Shah, J., & Spencer, K. T. (2018). Focused cardiac ultrasound as a predictor of readmission in acute decompensated heart failure. *The International Journal of Cardiovascular Imaging, 34*(7), 1075–1079.	To determine if focused cardiac ultrasound (FCU) of the inferior vena cava (IVC) would predict readmission of acute decompensated heart failure (ADHF) patients after index hospitalization	82 patients enrolled; 70 patients completed the study. Age 69 +/- 14 years 44% Male 1/3 HFpEF Setting: Patients admitted to the general cardiology services at the University of Chicago Medical Center with primary diagnosis of ADHF were screened Subjects excluded if they were admitted to the intensive care unit, required renal replacement therapy or were undergoing evaluation for heart transplant or left-ventricular assist device Duration: 30 days	FCU of the IVC by one of 6 residents not involved in care on admission and daily until discharge. Management decisions not affected by imaging. Subjects asked if sx were improved daily. Baseline demographic data, weight PE findings recorded. Readmission or ED visit within 30 days obtained by medical records/call. Statistical differences were assessed with the use of t tests and Chi square analysis. Binary logistic regression used to assess for predictors of readmission P<0.05 statistically significant.	Primary endpoint hospital readmission and ED visits, in the 30 days post discharge 70% fluid overload on admission LOS 4.9+/2.4 days Significant reduction in weight, HF physical exam findings, reduction IVC 62% had at least one abnormal physical exam finding at time of discharge. ¼ patients had elevated RAP at discharge IVC collapsibility and pt reported dyspnea only significant variables to predict readmissions or ED visit	Inadequate restoration of a euvolemic state contributing factor for readmissions Providers do not require resolution of symptoms prior to discharge. Non-collapsible IVC and improved SOB predictors of readmission Limitations: single study. Use of IVC as a marker for volume status imperfect. Obesity and right HF difficult to assess. Study did not address more targeted therapeutic plan

CITATION	PURPOSE	SAMPLE and SETTING	METHODS (Design, Interventions, Measures)	RESULTS	DISCUSSION, INTERPRETATION, LIMITATIONS
Rattarasarn, I., Yingchoncharoen, T., & Assavapokee, T. (2022). Prediction of rehospitalization in patients with acute heart failure using point-of-care lung ultrasound. *BMC Cardiovascular Disorders, 22*(1).	The purpose of the study was to predict rehospitalization in patients with acute heart failure using point-of-care lung ultrasound.	Prospective cohort of 126 patients mean age 69. Setting: Hospital in Thailand Pts were followed for 6 months	B lines and the size of IVC were assessed with 24 hours of discharge Researchers subsequently examined the rehospitalization rate within 6 months	The mean number of B-lines at discharge was 9+9 and the rate of rehospitalization within 6 months was significantly higher in patients with a significant number of B lines (>12) than in patients with non-significant number of B lines. In univariable analysis, the presence of B lines before discharge was an independent predictor of events at 6 months	This is the first prospective observational study that shows the prediction of rehospitalization for HF events and all-cause mortality at 6 months in patients detected to have significant pre-discharge B-lines using POCUS in the Thai population. Discordance between estimated RAP and B-line quantity was found in 1/3 of patients. The main pathophysiology of pulmonary congestion is the increased LV filling pressure, detectable by the number of B-lines from eight-zone method by point-of-care lung ultrasound and RAP, can be assessed using IVC diameter measurement and its collapsibility. Limitations: missing data including lack of change in body weight. Also, limited number of beds resulting in inadequate diuresis for some patients

CITATION	PURPOSE	SAMPLE and SETTING	METHODS (Design, Interventions, Measures)	RESULTS	DISCUSSION, INTERPRETATION, LIMITATIONS
Zsis, G., Yang, Y., Huynh, Q., Whitmore, K., Lay, M., Wright, L., Carrington, M. J., & Marwick, T. H. (2022). Nurse-Provided Lung and Inferior Vena Cava Assessment in Patients with Heart Failure. *Journal of the American College of Cardiology, 80*(5), 513-523.	To determine the ability of HF nurses to deliver a predischarge lung and IVC assessment to predict 90-day outcomes	240 patients with acute decompensated heart failure (ADHF) Average Age: 77 56% Male 95% NYHA class 3-4 50% HFmrEF or HFpEF Multisite: admitted to the hospital.	HF nurses scanned 240 patients with (ADHF) Images obtained by nurses who were blinded to clinical characteristics and outcomes. Based on a B-line cut-off of 10. Patients were dichotomized as congested or not congested based on IVC diameter and response to sniff test.	Primary endpoint: At 90 days, HF readmissions or mortality occurred in 42 congested patients (37%) compared with 18 non-congested patients (14%) At 30 days, HF readmissions or mortality occurred in 24 (21%) of congested pts compared with 8 (6%) on non-congested patients. Pulmonary congestion increased the 90-day odds of HF readmission and/or death by 3.3 to 4.2-fold independent of demographics, HF characteristics, co-morbidity, and event risk score. Over 90 days, days alive out of hospital were fewer 78.3+/-21.4 day vs. 85.5+/- 12.4 days in congested patients	HF nurses with limited training could use ultrasound imaging to predict post discharge outcomes. Predischarge pulmonary congestion predicted increased 90-day HF readmission or mortality risk. Ineffective decongestion at discharge is common and is a common cause of short-term HF readmission. Study limitations: interstitial fibrosis is an important alternative to pulmonary edema. Larger trials and more extensive training in IVC assessment by nurses is needed to provide strong evidence and explore application

CITATION	PURPOSE	SAMPLE and SETTING	METHODS (Design, Interventions, Measures)	RESULTS	DISCUSSION, INTERPRETATION, LIMITATIONS
Khandwalla RM, Birkeland KT, Zimmer R, Henry TD, Nazarian R, Sudan M, Mirocha J, Cha J, Kedan I. Usefulness of Serial Measurements of Inferior Vena Cava Diameter by VscanTM to Identify Patients with Heart Failure at High Risk of Hospitalization. (2017). *The American Journal of Cardiology, 119*(10):1631-1636.	To evaluate the use of point of care handheld ultrasound (HHU) to noninvasively assess volume status and identify patients at high risk for HF hospitalization in a multidisciplinary HF management program	335 patients treated for HF. 55% Men 45% Women Mean age: 73 Setting: ambulatory care	Researchers retrospectively analyzed patients with HF over 17 months. Measurements of IVC diameter (IVCd) were obtained using POCUS in the supine position from the subcostal window. Log-binomial regression models were used to compare IVCd measurements between patients with and without HF admissions and to estimate the association between IVCd and risk of HF admission.	3,488 measurements 32.4% of patients were hospitalized. Patients with at least 1 hospital admission had a greater mean IVCd than those who were not admitted (2.0 vs 1.8 cm, $p < 0.01$) For every 0.5cm increase in mean IVCd, 38% inc in risk of HF admission. The risk of HF admission increased in patients with IVCd 2.0 to 2.49 cm and ‡2.5 cm compared with patients with an IVCd < 2.0 cm. Increasing IVCd as measured by HHU at the point-of-care is associated with an increased risk of HF admission and may provide clinically useful information at the point-of-care to guide HF management.	Findings suggest that POCUS has the potential to identify high-risk patients and subsequently intervene before inpatient care is needed. Patients without an admission had a smaller minimum IVCd IVCd is directly correlated with RAP. POCUS may improve management of conditions that benefit from serial measurements and to increase the access of echo as a superior diagnostic tool at a reduced cost. Limitation: the degree of variability associated with obtaining IVCd readings despite standardization of the measurement. Data was not collected on whether an active inspiration led to collapsibility, which may dec the specificity of predicting elevated RAP. Clinicians actively managed volume status based on the IVCd, possibly underestimating relationship between IVC and hospitalization.

CITATION	PURPOSE	SAMPLE and SETTING	METHODS (Design, Interventions, Measures)	RESULTS	DISCUSSION, INTERPRETATION, LIMITATIONS
Pellicori P, Shah P, Cuthbert J, Urbinati A, Zhang J, Kallvikbacka-Bennett A, Clark AL, Cleland JGF. Prevalence, pattern and clinical relevance of ultrasound indices of congestion in outpatients with heart failure. (2019). *European Journal of Heart Failure, 21*(7):904-916.	To assess the prevalence and clinical relevance of congestion in outpatients with chronic heart failure.	342 pts with HF Pts were predominantly NYHA class I-II with at least one feature of congestion. Setting: routine follow-up clinic	Clinical exam performed before echocardiography. 2D echocardiogram [lung B-lines IVC diameter; internal jugular vein before and after a Valsalva (JVD ratio)] during a routine check-up Min follow-up 3 months Mean follow-up 234 days	60 patients (18%) died or were hospitalized for HF. In univariable analysis, each clinical and ultrasound measure of congestion was associated with increased risk but, in multivariable models, only higher N-terminal pro-B-type natriuretic peptide and IVC, and lower JVD ratio, were associated with the composite outcome. Congestion by ultrasound was more common, and more severe, with increasing severity of clinical congestion	This analysis confirms previous reports suggesting that increase in IVC diameter or number of B-lines by ultrasound identify patients with HF who have higher plasma concentrations of NT-proBNP and a greater risk of an adverse outcome, regardless of their LVEF. This is the largest prospective study evaluating B-lines in outpatients with HF. NT-proBNP is a consistently strong prognostic marker for patients with stable HF. Limitations: Some patient characteristics, such as a high body mass index, might decrease the number of identifiable lung comets, reflecting less advanced disease32 or a technical obstruction to their visualization. Single center study Researchers did not study the prevalence of congestion by ultrasound in control group.

CITATION	PURPOSE	SAMPLE and SETTING	METHODS (Design, Interventions, Measures)	RESULTS	DISCUSSION, INTERPRETATION, LIMITATIONS
Curbelo J., Aguilera M., Rodriguez-Cortes P., Gil-Martinez P., Suarez Fernandez C. (2018). Usefulness of inferior vena cava ultrasonography in outpatients with chronic heart failure. *Clinical Cardiology*, *41*(4):510-517.	To assess the usefulness of inferior vena cava ultrasonography in outpatients with chronic HF.	95 patients with chronic HF 58.9% F Patients attending an outpatient clinic visit at a university hospital in Spain	Ultrasound study was performed by one of the investigators to measure IVCd with advanced training in the technique. This physician was not involved in the medical management of study subjects. Results were blinded to patients and medical staff attending. Follow-up time for each patient was 1 year after inclusion date. Outcome events checked were worsening HF, defined as an increase in the dose of diuretic required because of symptoms; HF hospital admission; HF mortality; and all-cause mortality.	Worsening HF occurred in 70.9% of patients with IVCCI <30% and 39.1% of patients with IVCCI >50% Hospitalization, 45.3% of patients with IVCCI <30% required admission, compared with 5.9% of patients with IVCCI >50% Mortality was higher in the IVCCI <30% group, with 25.7% all-cause mortality and 18.6% HF mortality, whereas in the IVCCI >50% group these values were 13% and 4.7%, not stat sign ROC analysis: IVCCI was not higher than that for proBNP for any of the outcomes studied	Patients with IVCCI <30% have a risk of clinical worsening 2.8× higher than patients with IVCCI >50%. HF hospitalization, the risk is increased 13.9× Slight decrease in the usefulness of the IVC parameters is observed in this study compared with Pellicori et al. (may be related to operator, older population, and more comorbidities) Limitations: population: older, with many comorbidities, more HFpEF Perhaps a larger sample would show that the relationship between IVCCI and mortality is statistically sign but unlikely to be superior to proBNP

CITATION	PURPOSE	SAMPLE and SETTING	METHODS (Design, Interventions, Measures)	RESULTS	DISCUSSION, INTERPRETATION, LIMITATIONS
Gundersen, G. H., Norekval, T. M., Haug, H. H., Skjetne, K., Kleinau, J. O., Graven, T., & Dalen, H. (2016). Adding point of care ultrasound to assess volume status in heart failure patients in a nurse-led outpatient clinic. A randomised study. *Heart, 102*(1), 29-34.	To study the clinical influence of focused US of the pleural cavities and IVC performed by specialized nurses, to assess volume status in patients with HF in a nurse-led outpatient clinic	62 patients 119 Exams Mean ±SD age was 74±12 years. EF was 34±14% Setting: outpatient clinic at non-university hospital	HF outpatients were prospectively included and underwent laboratory testing, history recording and clinical examination by two nurses with and without an ultrasound examination of the pleural cavities and IVC using a pocket-size imaging device. Each nurse worked in a team with a cardiologist. The influence of the different diagnostic tests on diuretic dosing was assessed descriptively and in linear regression analyses.	Dosing of diuretics differed between the teams in 31 out of 119 consultations. Weight change and volume status assessed clinically with and without HHU predicted dose adjustment of diuretics at follow-up. Change of edema, NT-proBNP, creatinine, and symptoms did not predict dose adjustment of diuretic therapy.	The study shows poor to moderate correlation between the nurses regarding medical history and physical signs. Monitoring the data may perform better than discrete values. However, the routine use of US may improve the assessment of volume status. No other study has shown the clinical influence of routinely including focused US of the pleural cavities and the IVC, performed by specialized nurses, to assess volume status and guide treatment in an outpatient HF clinic. Whether the implementation of POCUS imaging of pleural cavities and the IVC to assess volume status for guidance of therapy will exert an influence on mortality and morbidity remains to be shown. Limitations: single center study. Lack of a gold standard for assessing volume status and the lack of clinical endpoints.

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