Point-of-care ultrasound assessment of left ventricular function in rapid atrial fibrillation or flutter patients in the emergency department

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A thesis submitted to the University of Ottawa in partial fulfillment of the requirements for the Master's of Science degree in Epidemiology

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Preface

We would like to disclose that both articles in this article-based thesis were approved by the Ottawa Hospital Research Institute (OHRI) -Ottawa Health Science Network Research Ethics Board (OHSN-REB).

The first article entitled "*Utilization of Cardiac Point-Of-Care Ultrasound for Atrial Fibrillation Management by Canadian Emergency Physicians: A Cross-Sectional Survey*" received approval on the 27th of October 2023. Master's of Science in Epidemiology applicant Dr. Sophia-Maria Giannakakis is the primary author of this article and contributed in the methodological design, data collection and writing of the majority of the article. Drs. Ian Stiell, Jeffrey J. Perry, and Michael Y. Woo are co-authors. They contributed their help in methodological design as well as review and editing of the manuscript for publication. This article was submitted and accepted for publishing in the Canadian Journal of Emergency Medicine.

The second article entitled "*Point-Of-Care Ultrasound for Left Ventricular Function in Patients With Rapid Atrial Fibrillation In The Emergency Department*" received approval on the 20th November 2023. Master's of Science in Epidemiology applicant Dr. Sophia-Maria Giannakakis is the primary author of this article and contributed in the methodological design, data collection, analysis, and writing of the majority of the article. Drs. Ian Stiell, Jeffrey J. Perry, and Michael Y. Woo are co-authors. Additional co-authors and collaborators include Drs Angeline Law and Habibat Garuba, two Ottawa Hospital cardiologists who provided input and interpretation of point-of-care ultrasound images. Dr. Monica Taljaard, senior scientist at the Ottawa Hospital Research Institute, helped with statistics and editing of the final manuscript for publication.

Thesis abstract

Objective: The aim of this thesis is to evaluate the utilization of point-of-care ultrasound (POCUS) for left ventricular function (LVF) assessment by emergency physicians for the diagnosis and management of heart failure in rapid atrial fibrillation or flutter.
Methods: A national survey of emergency physicians explored the integration and perceived barriers related to POCUS use in rapid atrial fibrillation or flutter. Subsequently, a health records review at The Ottawa Hospital ED studied diagnostic agreement of POCUS LVF assessment between ED physicians, cardiologists, and ED POCUS expert. Secondary outcomes were also analyzed regarding rapid atrial fibrillation or flutter management.
Results: A fair level of agreement between cardiologists and ED physicians (k= 0.34 CI 95% 0.10-0.58) and moderate agreement was found between cardiologists and ED POCUS expert physician (kappa = 0.63 (CI 95% 0.43-0.82). A higher proportion of rapid atrial fibrillation/flutter patients with ED-performed POCUS were admitted to hospital (40% vs 19%, $p<0.0001$) and rate controlled with beta blocker (38% vs 24%, $p=0.009$) or digoxin (14% vs 5%, $p=0.007$).
Conclusion: The utilization of POCUS in the rapid atrial fibrillation/flutter patients can help guide diagnosis and management of heart failure in the ED.

Acknowledgments

I would like to thank my TAC supervisors Drs. Jeffrey Perry , Ian Stiell, and Michael Woo. Their expertise in methodology and point-of-care ultrasound were essential to my academic learning, but also how to navigate the world of research. Their patience and support throughout this process has been greatly appreciated. Most importantly, their words of wisdom from years of experience will certainly help me develop my own career as a clinical researcher.

A special thank you to Angela Marcantonio and Carolyne Kennedy for their constant support in organizing meetings between busy physicians and helping navigate the publication journals.

I would like to acknowledge and thank my POCUS fellowship mentors, Dr. Brandon Ritcey, Dr. Rajiv Thavanathan, Dr. Rory Connoly, Dr. Nathan Hecht, Dr. Paul Pageau, and Dr. Michael Woo. They were not only generous in sharing their vast knowledge, but also inspired the possibilities in POCUS-related research.

A very special thank you to my very patient spouse Catherine Germain Morasse who keeps me grounded and held up our life in Montreal while I completed a double fellowship in Ottawa.

Bonne lecture!

Financial support statement

A grant was awarded in 2023 from The Ottawa Hospital's Department of Emergency Medicine to support the two research projects.

Abbreviations

AF-Atrial fibrillation

AFL- Atrial flutter

CAEP : Canadian Association of Emergency Physicians

ED- Emergency department

HF- Heart Failure

LVF- Left ventricular function

LVSF- Left ventricular systolic function

POCUS -Point-of-care ultrasound

TOH- The Ottawa Hospital

TTE- Transthoracic echocardiogram

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Chapter 1: Introduction

Rationale/ statement of problems

Patients presenting to Canadian emergency departments (ED) are often medically complex due to an aging population and multiple co-morbidities. This is the case for patients presenting with acute atrial fibrillation or flutter, common rapid cardiac arrhythmias in the ED, whose treatment is guided by the presence of certain comorbidities, notably concomitant heart failure [1-2]. The presence of heart failure with atrial fibrillation increases the risks of hospital admission and economic burden on the health system and mortality [1-6]. Early treatment choices by emergency physicians in the ED can help avoid decompensating heart failure in patients with acute rapid atrial fibrillation i.e. irregular heart rate above 110 beats per minute [7-9]. These patients may be difficult to identify because lack of prior echocardiographic evidence of pre-existing heart failure or access to prior echocardiographic imaging may not be available in the acute setting. Heart failure is a clinical diagnosis based on patient symptoms and is classified primarily by evaluating left ventricular function with echocardiography [10]. The utilization of point-of-care ultrasound (POCUS) by emergency physicians can help identify the presence of heart failure with reduced left ventricular function but has not been studied specifically in the acute rapid atrial fibrillation/flutter patients presenting to the emergency department. Beyond guiding the diagnosis of heart failure in the rapid atrial fibrillation/flutter population, POCUS can potentially impact patient care notably through appropriate rate and rhythm control treatment and decision-making regarding disposition.

Objectives:

The overall aim of this thesis is to evaluate the feasibility of utilizing POCUS left ventricular function assessment by ED physicians on the acute rapid atrial fibrillation or flutter patients.

Specific objectives:

1) To explore the current use by ED physicians of POCUS left ventricular function assessment in the rapid atrial fibrillation or flutter patients.
2) To assess the diagnostic accuracy of identifying left ventricular dysfunction by emergency physicians in the rapid atrial fibrillation or flutter population.
3) To determine the effect of POCUS utilization on ED physician's decision-making regarding treatment and disposition of patients in rapid atrial fibrillation or flutter.

Overview of chapters

Chapter 1 of this article-based thesis has set the objectives for the remainder of the manuscript.

Chapter 2 is divided into several sections. It will begin by contextualizing atrial fibrillation or flutter in the ED through epidemiological data with a focus on Canadian derived statistics. The next section will help classify atrial fibrillation or flutter and present standard patient management including treatment in the ED. This will be followed by a review of the current guidelines from leading scientific societies with a focus on POCUS integration within atrial fibrillation or flutter management: Canadian Cardiovascular Society, American Heart

Association and the European Society of Cardiology. To properly understand how POCUS can be utilized in atrial fibrillation or flutter, a section is dedicated to the relationship between heart failure and atrial fibrillation as well as its treatment approach. As the assessment of left ventricular function in this particular patient population has not been specifically studied, the last section of this chapter presents the current use of POCUS left ventricular function assessment in the general ED population with suspected heart failure. This chapter makes an important distinction between cardiac POCUS and comprehensive echocardiography for the assessment of left ventricular function by emphasizing POCUS being utilized within a clinical context to answer specific clinical questions at the bedside.

Chapter 3 will describe the methodological approach to studying a novel utilization of POCUS. As research in POCUS is a growing field, it presents methodological challenges. For cardiac POCUS, specific challenges included the choice of a gold standard, variable POCUS archiving compliance and limitations related to medical chart review. Despite such challenges, this chapter will inform on the impact of this article-based thesis and the studies published, notably within emergency medicine practice.

Chapter 4 presents the first article entitled "*Utilization of Cardiac Point-Of-Care Ultrasound for Atrial Fibrillation Management by Canadian Emergency Physicians: A Cross-Sectional Survey*". It is the first study presented in this manuscript because it is an exploratory survey on how emergency physicians utilize and integrate POCUS LVF assessment in the acute AF/AFL population. It also explored clinical decision making for treatment, patient disposition, and perceived barriers for use.

Chapter 5 presents the second article entitled "*Point-Of-Care Ultrasound for Left Ventricular Function In Patients With Atrial Fibrillation In The Emergency Department*". This study aimed to evaluate the accuracy of POCUS LVF assessment on acute rapid AF/AFL in the ED by performing agreement analysis between cardiologists and emergency physicians in real-world archived POCUS images. Through medical chart review, it also evaluated the impact on treatment choices and patient disposition by comparing acute rapid AF/AFL patients who had POCUS performed by an emergency physician compared to those who did not have a POCUS LVF assessment.

Chapter 6 is the concluding chapter. It will present an overview of the results of the aforementioned studies and how they relate to the existing literature. Limitations will also be detailed in this chapter in order to better understand the impact on future research and clinical practice.

Chapter 2: Review of the literature

Epidemiology of atrial fibrillation and atrial flutter

Recent Canadian epidemiological data on atrial fibrillation or flutter is difficult to determine in the emergency department. Cited by the latest 2020 Canadian Cardiovascular Society Guidelines and considered to be an underestimation, the population prevalence of atrial fibrillation or flutter is estimated at 1-2% [1,11-12]. As the most common acute dysrhythmia treated by emergency physicians, there is an upwards trend in emergency department visits likely explained by rising populational risk factors predisposing to atrial fibrillation or flutter, notably an aging population, hypertension, diabetes, chronic kidney disease and heart failure [11-13]. A study by Sandhu et al. (2021) using Canadian Institute of Health Information derived data between 2006-2015 estimated the incident rate of hospitalisations at 318 per 100 000 population for non-valvular atrial fibrillation [3].

Complications of atrial fibrillation or flutter include stroke, arrhythmia-induced cardiomyopathy, risk of bleeding, and death [1,13-14]. An international cohort study by Healy et al. (2016) found a higher proportion of patients died of heart failure compared to stroke over 1-year from an initial emergency department visit for acute atrial fibrillation [13]. Atrial fibrillation complicated by heart failure has been identified as an area for greater prevention [13,14].

Classification atrial fibrillation and flutter

Atrial fibrillation can be classified based on its chronicity and treatment response with initial diagnosis based on electrocardiographic evidence of atrial fibrillation [11,15-17]. As defined by various scientific societies such as the Canadian Cardiovascular Society, American Heart Association and European Society of Cardiology, they divide atrial fibrillation into four clinical patterns [11,15-17]:

1) first diagnosis atrial fibrillation;
2) paroxysmal atrial fibrillation (lasting less than 7 days);
3) persistent atrial fibrillation (lasting more than 7 days - 1 year);
4) permanent atrial fibrillation (therapeutic choice to not return to sinus rhythm).

It should be noted that atrial flutter does not have a distinct categorization as it often coexists with atrial fibrillation and has a similar acute treatment approach [11,15-17].

In the ED, atrial fibrillation can be further classified as symptomatic and asymptomatic [16,18]. Symptomatic AF can range from palpitations, pre-syncope, syncope, dizziness, chest pain and dyspnea. A distinction is also made for primary AF and secondary AF. Secondary AF is defined as AF due to underlying acute medical condition, for example sepsis, myocardial infarction or heart failure [15-17].

Treatment Approaches to acute rapid AF/AFL

The treatment approaches to atrial fibrillation or flutter have different goals depending on whether patients present acutely compared to long term management. The management approach presented in this section is for patients in acute rapid atrial fibrillation or flutter set in the emergency department or acute care setting.

There are two major treatment concepts: rate control and rhythm control. Rate control aims to decrease heart rate below 110bpm [7]. This is achieved through medications such as beta blockers, calcium channel blockers, or digoxin. Rhythm control aims to return the patient back to a normal sinus rhythm whether this is accomplished pharmacologically or through electrical cardioversion [15-17]. The return to a normal rhythm is influenced by the patient' anticoagulation status, time of presentation and CHADS-65 score, as these factors are related to thrombus formation within the cardiac chambers and risk of subsequent stroke. Early electrical rhythm control can be considered in the ED for rapid atrial fibrillation patients who are properly anticoagulated or with "low risk" of stroke, regardless of left ventricular dysfunction [15-17,19-21]. Table 1 summarizes a general approach to acute rapid atrial fibrillation or flutter approach.

Table 1 Treatment Approach to Acute Rapid Atrial Fibrillation or Flutter

<table>
<tr><td colspan="2">Hemodynamic instability = electrical cardioversion</td></tr>
<tr><td colspan="2">Atrial fibrillation due to a secondary cause = treat underlying cause</td></tr>
<tr><td>If anyone these criteria:
1. Anticoagulation ≥3weeks
2. sudden onset <12h
3. Sudden onset between 12-48h with low CHADS-65 score
4. No thrombus on transesophageal echocardiogram</td><td>Rhythm Control
1. Electrical cardioversion
2. Pharmacological cardioversion
▪ Preferred agent procainamide IV</td></tr>
<tr><td colspan="2">If unable to rhythm control, proceed to Rate Control*</td></tr>
<tr><td><u>If LVEF <40%,</u>
Beta blockers (commonly IV metoprolol)
Digoxin IV/PO</td><td>If LVEF >40%.
Beta blockers (commonly IV metoprolol)
Calcium channel blockers (commonly IV diltiazem)
Digoxin if persistent</td></tr>
<tr><td colspan="2">Indications for hospital admission
1. Persistent symptoms
2. Acute Coronary Syndrome
3. Decompensated heart failure</td></tr>
</table>

*Initial rate control medication is often administered intravenously, then combined with an oral formulation for rate control maintenance. (eg.: metoprolol PO, bisoprolol PO, diltiazem PO, verapamil PO)

**Amiodarone can also convert to normal sinus rhythm.

This table is adapted from *Stiell IG, de Wit K, Scheuermeyer FX, Vadeboncoeur A, Angaran P, Eagles D, et al. 2021 CAEP Acute Atrial Fibrillation/Flutter Best Practices Checklist. Canadian journal of emergency medicine. 2021;23(5):604–10* [20]

Relationship between heart failure and atrial fibrillation

Heart failure is often comorbid with atrial fibrillation and their causality is bi-directional making it difficult to determine which condition is exacerbating the other in acute settings [22-25]. Based on the Framingham Heart Study cohort, whether atrial fibrillation or heart failure were the initial entity to be diagnosed, the development of the other condition was associated with higher lifetime all- cause mortality, more notably for women [22]. A multicenter prospective prognostic study EMERG-AF determined that patients with atrial fibrillation presenting to the ED in acute heart failure had a higher risk 1-year major cardiovascular events (OR=1.797; 95% CI, 1.285–2.512; P=0.001) compared to those who did not have acute heart failure [26]. Major cardiovascular events included "arrhythmias, acute coronary syndrome, and acute heart failure" [26].

Heart failure is defined as a clinical and symptomatic syndrome based on the Framingham Heart Study [9,10,22-23]. Left ventricular dysfunction can be divided into systolic and/or diastolic dysfunction [9-10]. Left ventricular systolic function is the heart's ability to eject blood to produce cardiac output. The severity of left ventricular systolic dysfunction is mainly used to classify heart failure as it relates to severity of symptoms and prognostication [9-10,16]. Whereas, left ventricular diastolic dysfunction relates to the ventricles filling impairment and can lead to symptomatic heart failure with preserved systolic function [9-10,16]. It is important to distinguish between heart failure with preserved ejection fraction ≥50% (HFpEF) and reduced ejection fraction< 40%(HFrEF) as the latter should be treated more aggressively in arrhythmia-induced cardiomyopathy [22-25]. In acute rapid atrial fibrillation, arrythmia-induced cardiomyopathy is defined by persistent rapid atrial fibrillation between 120-160bpm leading to symptomatic or asymptomatic HFrEF [23-24]. Treatment should prioritize rate control of rapid atrial fibrillation with either digoxin or amiodarone intravenously aiming for a heart rate below 110bpm. However, in the context of acutely decompensating HFrEF and concomitant rapid atrial fibrillation, diuresis may be the more appropriate treatment [22-25]. In both clinical scenarios, treatment of a precipitating cause of rapid atrial fibrillation or decompensated heart failure should take priority above rate or rhythm control.

There is some controversy regarding rate control in patients with rapid atrial fibrillation and heart failure due to the lack of strong data and high bias [27]. Studies conducted in the ED comparing IV metoprolol to IV diltiazem have demonstrated worsening heart failure and hypotension with IV diltiazem in rapid atrial fibrillation [28-30]. This is pharmacologically explained by the negative inotropic effects of non-dihydropyridine calcium channel blockers such as diltiazem compared to beta blockers, hence affecting heart's contractility [27-30]. A study by Schmitt et al.(2023) showed worsening heart failure within 24h for ED patients with rapid atrial fibrillation who were rate controlled with IV diltiazem and had reduced left ventricular ejection fraction <50% compared to those with preserved ejection fraction >50% (17.1% vs 4.8%, p=0.005) [30].

Existing management guidelines for atrial fibrillation in the emergency department

There exist recent and revised guidelines for the management of atrial fibrillation [11,15-17]. The guidelines do not mention the use of POCUS to help determine left ventricular function, but have specific recommendations for rate, rhythm and volume control pertaining to severely decreased left ventricular ejection fraction under 40%. Notably, preference for digoxin or beta blockers for rate control and the avoidance of the use of non-dihydropyridine calcium channel blockers in severely reduced left ventricular function [11,15-17]. The 2024 ESC guidelines support performing transthoracic echocardiography (TTE) within the patient's care pathway to help determine either left ventricular function or valvular pathologies to guide rate or rhythm control, especially when there is a change in their clinical status [16]. Specific guidelines for Canadian emergency physicians, 2021 CAEP Acute Atrial Fibrillation/Flutter Best Practices Checklist, indicate that POCUS can help determine left ventricular function status, but do not provide evidence in support of the statement [20].

Echocardiographic and POCUS assessment of left ventricular function

The American Society of Echocardiography has set the definitions and recommendations on the assessment of left ventricular function [31]. In the context of comprehensive 2D echocardiography, end-diastolic and end-systolic volume calculations using modified Simpson's rule are used to calculate left ventricular ejection fraction. See table 2 for quantitative left ventricular ejection fraction categorisation. If available, 3D echocardiography can be performed for greater accuracy of left ventricle ejection fraction [31]. It is important to distinguish between a global assessment and segmental left ventricular function which looks for regional wall motion abnormalities [31]. Conjointly with the American College of Emergency Physicians, the American Society of Echocardiography has recognised that these methods are not feasible at the bedside, focused cardiac ultrasound is recognized as the bedside assessment of global LV systolic dysfunction to aid in clinical decision making [32-33].

Table 2 Quantitative LVEF Categorisation

	Normal	Mildly Reduced	Moderately Reduced	Severely Reduced
LVEF %	53-73%	41-53%	30-40%	<30%

*Noted that these values vary slightly with biological sex

1. Adapted from Lang, Roberto M., et al. "Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging." Journal of the American Society of Echocardiography, vol. 28, no. 1, 2015, pp. 1-39.e14, https://doi.org/10.1016/j.echo.2014.10.003.

In the ED, POCUS has been clinically integrated to qualitatively assess left ventricular function in patients presenting with suspected heart failure or cardiogenic shock [34-39]. The most recent systematic review and meta-analysis by Albaroudi et al. (2021) found sensitivity 89% (95%CI 80-94%) and specificity 85% (95% CI 80-89%) as well as a Cohen's kappa k=0.68 (95% CI,

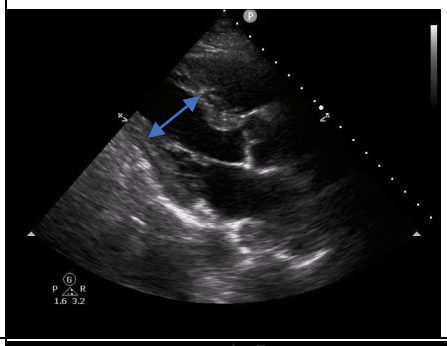
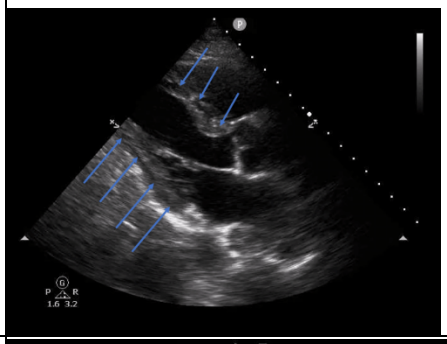
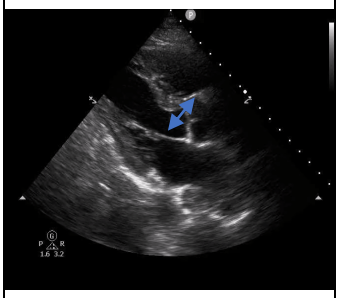
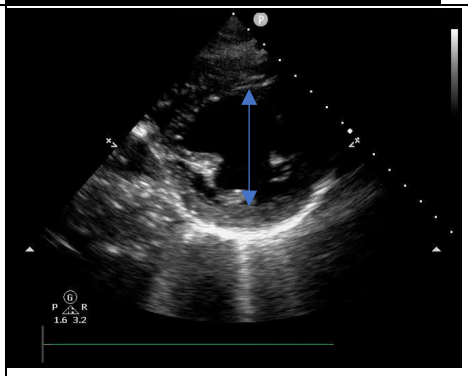
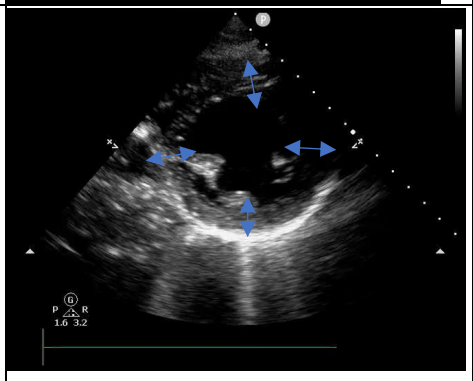
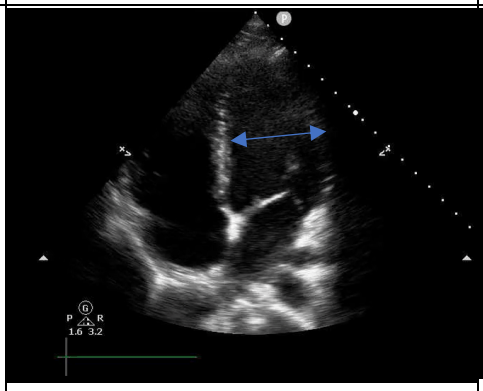
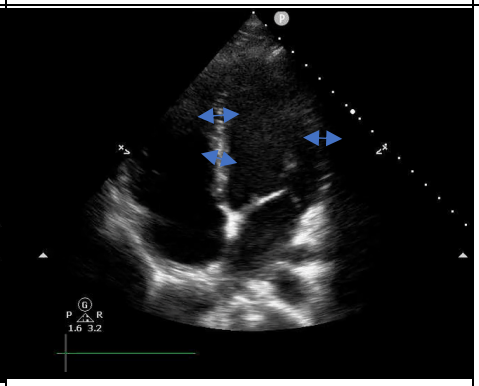
0.57– 0.79) (i.e. moderate interobserver agreement) when comparing visual estimation of LVSF in the ED with expert sonographers [34]. When categorizing left ventricular function as normal, reduced or severely reduced, Randazzo et al. (2003) determined the highest raw agreements between ED sonographers and cardiologists to be in the extremes of categorization: 70.4% in the normal category (LVEF >55%) and 90 % in the severely reduced category (LVEF <30%) [36].

Qualitative assessment of left ventricular function can be done by one or a combination of several methods which "eyeball" to estimate left ventricular ejection fraction: visual estimation of endocardial excursion, fractional shortening, myocardial thickening and E-point septal separation [37]. All these methods can be obtained with 2D echocardiography parasternal long axis, parasternal short axis or apical 4 chamber views using a low frequency cardiac probe [37]. See table 3 for illustrative POCUS image acquisition.

1) Visual estimation of endocardial excursion determined by eyeballing the global endocardial movement has been shown to correlate well with quantitative measures including Simpson's method [38-42].
2) Fractional shortening is determined by left mid-ventricle diameter differences between end-diastole and end-systole. It is considered normal if there is more than 25-30% shortening. Although this can be done linear measurement using M-mode, it can also be visually "eyeballed" [31,37].
3) Myocardial thickening is the relative difference between end-diastolic and end-systolic thickness of 40% during systole [37,43].
4) E-point septal separation (EPSS) measured as the distance between the anterior mitral valve leaflet and the septum wall during early diastole. Greater than 7mm considered to correlate with severe reduced left ventricular function. This method can be done by eyeballing or linear measurements during M-mode [44-45].

There are general limitations to left ventricular function visual assessment that can either underestimate or overestimate its severity. Valvular pathologies such as mitral valve stenosis or aortic insufficiency affect EPSS assessment by falsely overestimating severity [37]. Regional wall motion abnormalities affect the ability to visually assess left ventricular function when assessing myocardial thickening and endocardial excursion [37,43]. When considering the effects of heart rate, tachycardia decreases left ventricular filling time, consequently decreasing left ventricular ejection fraction. More specifically in patients with atrial fibrillation, tachycardia paired with irregular RR intervals negatively affect stroke volume, consequently decreasing left ventricular ejection fraction [46]. A systematic review found limited validity and reproducibility of left ventricular function in atrial fibrillation patients who underwent comprehensive echocardiography at average heart rates of 79bpm due to lack of data and found that diastolic measures where more valid and correlated better with mortality [46]. To my knowledge and the premise of this article-based thesis, such studies have not been done in the ED for using visual estimation to differentiate normal from severely reduced left ventricular function in atrial fibrillation patients.

Table 3 Visual Estimation of Left Ventricular Function

	Fractional shortening	Myocardial shortening	EPSS
PSLA			
PSSA			
A4C			

*End point septal separation (EPSS), Parasternal long axis (PSLA), Parasternal Short Axis (PSSA)

Chapter 3: Thesis Conceptual framework

Methodological Challenges

This article-based thesis' main objective is to evaluate the feasibility of utilizing POCUS left ventricular function assessment by ED physicians in patients presenting with acute rapid atrial fibrillation or flutter. The conceptual framework guiding this thesis can be found within feasibility research and is framed as hypothesis generating to study an observed clinical practice in the "real world" acute care setting. Due to ambiguity in the literature regarding the term feasibility, Eldridge et al. (2016) provide a definition based on an expert driven Delphi survey: a feasibility study "asks whether something can be done, should we proceed with it, and if so, how" [47]. Considering that feasibility studies have been more commonly used in preparation for randomised control trials, Lancaster & Thabane (2019) propose a guideline for non-randomised feasibility studies [47-50]. Guided by this definition, the thesis' objectives of studying the use, barriers to use, diagnostic accuracy and potential effect left ventricular POCUS assessment in rapid atrial fibrillation align with its overall aim to evaluate feasibility within a hypothesis generating framework with the future goal for larger prospective cohort studies (see figure 1 for an illustration of the conceptual framework).

Canadian emergency physicians have national recommendations for POCUS use which include scope of practice and training requirements. It is also recognized that POCUS research is a growing field with need for more rigorous supportive evidence [51]. As cardiac POCUS left ventricular function assessment is recognized as a core skill within emergency medicine practice, clinical observation has revealed emergency physicians integrating POCUS left ventricular function assessment in acute atrial fibrillation or flutter patients and making clinical decisions regarding treatments and patient disposition. The extent of this practice and its reliability to diagnose left ventricular dysfunction in this specific population is novel, consequently there are methodological challenges that where anticipated when choosing the study designs for this thesis.

In order to study a novel application of cardiac POCUS, a survey design for the first article of this thesis aimed to explore the current utilization of cardiac POCUS by emergency physicians in the ED atrial fibrillation or flutter patients. The second article of this thesis is a reliability study which aimed to assess the accuracy of POCUS left ventricular function assessment by emergency physicians. One methodological challenge was choosing the gold standard for left ventricular assessment. The highest level of accuracy and considered to be a gold standard is cardiac MRI, but it is not clinically common to order this test for left ventricular function due to accessibility [10,52-54]. Comprehensive echocardiograms would be the second most appropriate choice as the most used in the clinical setting for left ventricular assessments, but this modality does not answer focused cardiac clinical questions at the bedside. For the interpretation of "real world" emergency physician derived POCUS images which have varying image quality, cardiologists and ED physician with POCUS expertise were chosen to evaluate agreement of POCUS left ventricular function of ED physicians with general POCUS skills. Another methodological challenge was having enough archived POCUS images. Although quality

assurance standards have minimum requirements for archiving POCUS images, it is difficult to predict the percentage of imaging that would be archived by practicing emergency physicians [55-56].

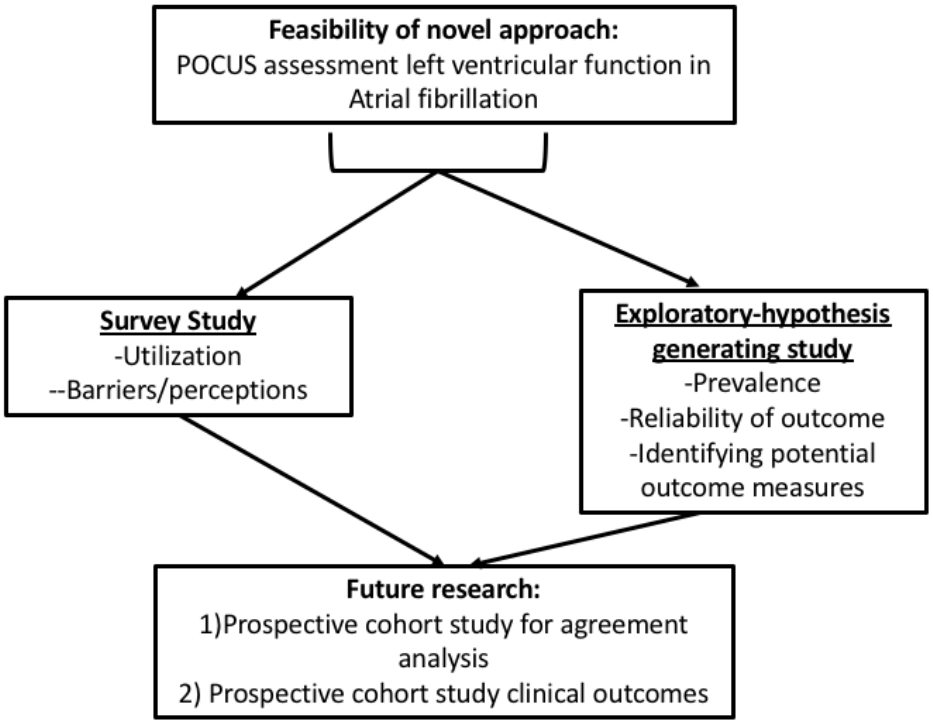


Figure 1Conceptual framework

Thesis Impact on Clinical and Research Implications

The clinical impact of this thesis is to provide supporting hypothesis generating data to a clinical practice. The ability to integrate POCUS left ventricular function assessment to determine the presence of decompensated heart failure would potentially help guide treatment choices and clinical decision making for safe patient disposition. The acute management of rapid atrial fibrillation or flutter requires the knowledge of a patient's left ventricular function, this information is not always readily available by prior echocardiograms or may have never been assessed. POCUS's rapid and accurate assessment would help avoid the use of harmful rate control agents in decompensated heart failure, thus improving patient safety and physicians' confidence in treatment choices. It could potentially help stratify patients needing hospital admission as atrial fibrillation patients with severely decreased left ventricular function would require further work up and more timely specialist referrals. As for the research implications, the articles in this thesis provide support for the feasibility and reliability POCUS left ventricular function use in the ED within a specific population. As POCUS research grows, the study designs chosen within this thesis reveal some of the methodological challenges to POCUS research in general and can help guide future POCUS research.

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Chapter 4

Abstract #1

Introduction: As point-of-care ultrasound (POCUS) applications expand in the emergency department (ED), its utilization within the management of patients presenting with rapid atrial fibrillation (AF) or flutter (AFL) is unclear. The co-morbidity of heart failure and AF/AFL complicates the rate/rhythm control and disposition of this population. ED physicians diagnose heart failure by integrating POCUS left ventricular function assessment, but studies have not focused on the rapid AF/AFL population.

Methods: Our survey aimed to explore the use, integration, and perceived barriers of POCUS left ventricular function assessment in AF/AFL patients. Canadian ED physicians and residents who are members of the Canadian Association of Emergency Physicians (CAEP) completed an online survey through email between February-March 2024.

Results: We received 91 responses. For patients presenting with rapid AF/AFL with no prior imaging in the last 12 months, 51% of respondents indicated using cardiac POCUS for left ventricular function assessment. Half of respondents indicated that distinguishing between normal and severely reduced left ventricular function with POCUS would help guide management in rapid AF/AFL patients, and 77% responded that it would help guide disposition. A majority, 63% of respondents, agreed the assessment of left ventricular function would assist to determine if they will use calcium channel blockers. Perceived barriers included confidence in interpretation, skill level, machine accessibility and accuracy of left ventricular function assessment in rapid AF/AFL patients.

Conclusion: Our survey demonstrated that half of ED physicians and residents are currently integrating POCUS left ventricular function assessment in rapid AF/AFL patients and most adapt their clinical decision making based on their findings, notably in whether or not to use calcium channel blockers. Amongst the perceived barriers, ED physicians most commonly reported low POCUS expertise level and the accuracy of left ventricular assessment in rapid AF/AFL.

KEYWORDS: POCUS, atrial fibrillation, survey

Title: Utilization of Cardiac Point-Of-Care Ultrasound for Atrial Fibrillation Management by Canadian Emergency Physicians: A Cross-Sectional Survey

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Disclaimer: The findings represent the work of the authors and not their institutions.

Conflicts of Interest: The authors of this study have no conflicts of interest.

Sources of support: We received funding from The University of Ottawa Department of Emergency Medicine Grant

Acknowledgment: We would like to thank Angela Marcantonio for her assistance in the project as part of the Ottawa Hospital Research Institute-Emergency Research.

Introduction:

Patients presenting to the emergency department (ED) with acute atrial fibrillation (AF) often have comorbidities [1,2]. One common issue is that these patients may have heart failure which may be a predictor of hospital admission. [1,3]. An international multicenter cohort study by Healy et al. (2016) demonstrated heart failure was the leading cause of death within one year of presenting to the ED with atrial fibrillation [4].

The *2021 Canadian Association of Emergency Physicians (CAEP) Acute Atrial Fibrillation/Flutter Best Practices Checklist* suggest performing POCUS to determine left ventricular function in rapid AF and flutter(AFL) patients, but no evidence is provided to support this statement [5]. A systematic review and meta-analysis by Albaroudi et al. (2022) on POCUS left ventricular function assessment by expert sonographers found 89% sensitivity in the visual estimation of left ventricular function in the ED [6]. Given ED physicians primarily manage rapid AF/AFL patients, identifying co-existent heart failure may help in selecting rate control options by avoiding calcium channel blockers, opting for digoxin, and prioritizing volume control [7].

The goal of our study was to investigate the current use of POCUS left ventricular function in AF/AFL patients by Canadian ED physicians and residents. Our specific objectives were to assess: 1) confidence and agreement levels for POCUS left ventricular function assessment in rapid AF/AFL patients; 2) integration of POCUS findings into management and disposition; and 3) perceived barriers for POCUS utilization.

Methods:

Study design:

We conducted a cross-sectional online survey to assess the use of cardiac POCUS by Canadian emergency physicians and residents to assess left ventricular function for AF/AFL patients. The survey follows the Consensus-Based Checklist for Reporting of Survey Studies (CROSS) [8]. .

Data collection:

Our questionnaire contained 17 questions divided into four categories: 1) demographics, 2) cardiac POCUS utilization in patients with AF/AFL, 3) cardiac POCUS integration for the management, 4) perceived barriers to cardiac POCUS use in AF/AFL patients. The questionnaire consisted of 16 multiple-choice questions and one open ended question for the perceived barriers. Likert scales and confidence interval scales were used within the various categories (Supplement I). The questionnaire was available in both French and English.

The initial questionnaire was created using current literature and expert opinion. Cognitive interviews, consisting of voluntary one-on-one interviews with five local emergency physicians and residents, who were not part of the sample population, with some POCUS or research expertise. Respondents were asked to read the questions out loud and to articulate any thoughts around questions being unclear, unnecessary or offensive. This was done in both English and French. We also asked the interview participants to pre-test the survey on their personal devices (tablets, computers, cellular phones).

Sample characteristics and survey administration:
We surveyed the 1500 CAEP members who agreed to receive the online survey through email, who were sent three email contacts on February 26th, March 11th and March 25th 2024. A period of one month after the last email contact was allocated prior to closing the survey.

The online survey was developed with The Ottawa Hospital's Institutional QualtricsXM [9]. QualtricsXM is an online survey platform which allowed for anonymized data collection and single response retrieval from a given email which prevented duplicate responses [9].

Statistical analysis:
Descriptive statistics were used to analyze the data. The open-ended questions were thematically reviewed (SMG). Surveys over 50% incomplete were excluded from the analysis.

Ethical considerations:
Ethics approval was obtained from the Ottawa Health Science Network Research Ethics Board. Online informed consent was required immediately prior to participants completing the online survey.

Results:
Our survey yielded 94 responses and we retained 91 responses for analysis. Of the 91 responses, four were completed in French. The average time to completion was 11 minutes. Most respondents were male (68%) and most participants were credentialed as either CCFP-EM (40%) or FRCPC-EM (42%,). The vast majority practiced in an academic setting representing 71% of respondents. Overall, 51% of ED physicians assessed left ventricular function in suspected heart failure, most often for chest pain, shortness of breath, and cardiac arrest. Most ED physicians were confident in generating (80%) and interpreting (67%) left ventricular function.

Regarding left ventricular function assessment in rapid AF/AFL patients with no recent (1 year) echocardiography, 51% utilized POCUS at least sometimes in their practice whereas 49% answered "never". A little over half of respondents, 59% had at least some confidence in their left ventricular interpretations in AF/AFL patients. One question asked respondents to visually estimate left ventricular function on cardiac POCUS views of parasternal long axis and apical four chambers of a heart in rapid atrial fibrillation, the majority 82% classified left ventricular function as being severely reduced with only 2% misclassifying the images as normal left ventricular function.

When asked "would knowing the left ventricular function status of your patient with AF/AFL through POCUS help avoid the use of calcium channel blockers?", 63% of respondents agreed. More specifically, when asked if distinguishing between normal and severely reduced left ventricular function in ED acute AF/AFL patients would help guide management, 51% responded "yes" compared to 16% responded "no". Most 77% respondents agreed that identifying new severely reduced left ventricular function on POCUS in AF/AFL patients would help guide patient disposition.

Survey participants were questioned on barriers in using cardiac POCUS for the assessment of left ventricular function in AF/AFL patients. Of the 87 respondents, 53% reported perceived barriers. Many participants commented on their skill level in cardiac POCUS. Others identified time constraints, machine maneuverability and machine accessibility. Some comments reflected on the accuracy of left ventricular function interpretation in AF/AFL patients.

Discussion:

Interpretation:
Our survey revealed that Canadian emergency physicians are utilizing POCUS for left ventricular function assessment for acute AF/AFL patients and most respondents are confident with their interpretations. Importantly, respondents agree that distinguishing between normal and severely reduced left ventricular function with POCUS can help manage acute rapid AF/AFL and guide rate control medication choice by avoiding calcium channel blockers.

Previous studies:

To our knowledge, we are the first ED based study to explore POCUS utilization specifically on AF/AFL patients. Literature assessing the accuracy of left ventricular function in atrial fibrillation patients is mainly by cardiologists in outpatient settings and is not representative of ED reality[10]. Whereas as emergency physicians qualitatively interpret left ventricular function for rapid clinical decision making, cardiologists quantify left ventricular ejection function while taking into account beat-to-beat RR interval variability as well as tachycardia and can more accurately assess diastolic function rather than left ventricular ejection fraction in atrial fibrillation patients [10].

Specific to the ED setting, our survey respondents identified perceived barriers of ED POCUS assessment of left ventricular function in AF/AFL patients. Similar barriers were found in comparison to a 2019 Canadian study on general POCUS use in the ED which included lack of expertise or training, lack of access to equipment and time to perform the POCUS [11]. Accuracy of left ventricular function assessment in AF/AFL population was a concern for some respondents which specified that their management decision would not be based solely on POCUS examination but taking into consideration the rest of the clinical picture. Despite these barriers, our respondents agreed that assessing and interpreting left ventricular function in AF/AFL patients can have an impact on treatment management i.e. avoidance of calcium channel blockers, as well as some respondents agreed on guiding disposition. Recently published RAFF-5 study which implemented the CAEP Checklist for the management of AF/AFL patients in the ED, found suboptimal care in areas that included inadequate use of rate control agents and inappropriate prescription of rate or rhythm control agents [12].

Strengths and limitations:

Our exploratory study surveyed members within the largest Canadian emergency medicine association which often sets the standards for emergency medicine practice in Canada. A strength of our survey was its focus on a specific patient population in order to better understand POCUS implications. We recognize some limitations in our study affecting its generalizability.

There is a likely nonresponse bias as we assume physicians with more familiarity with POCUS were more incline to answer the survey. A spectrum bias may affect the results of the survey as the sample of CAEP member surveyed where mainly from academic centers. Rural and isolated settings were likely underrepresented and would have differing ED realities regarding accessibility to POCUS machines and rapid specialized cardiology care would be more limited.

Clinical implications:

The importance of identifying left ventricular dysfunction in patients presenting with acute AF/AFL is to prevent decompensation or death due to suboptimal or incorrect treatment choices for rate control and volume control. Assessment of left ventricular function in ED can serve as an extra data point in optimizing the management and safety of this patient population. The co-existence of heart failure with acute AF/AFL can help disposition decisions for admission or emergent cardiology consultation. Identifying ED physicians' barriers to POCUS use is valuable and can be used in quality improvement projects in local ED to improve overall POCUS use and efficiency as well as understand its limitations when applied to the AF/AFL population.

Research implications:

Future research should evaluate the feasibility of using POCUS left ventricular function in the ED AF/AFL population. Observational studies regarding management pathways and disposition need further investigation.

Conclusion:

Our survey demonstrated that Canadian ED physicians and residents are assessing POCUS left ventricular function in acute AF/AFL patients. Specific perceived barriers to POCUS use and integration included POCUS expertise and accuracy of left ventricular assessment in rapid AF/AFL.A third of ED physicians agree that identifying left ventricular dysfunction on POCUS would avoid rate controlling with calcium channel blockers and 77% agree that diagnosing new severely reduced left ventricular function would guide patient disposition.

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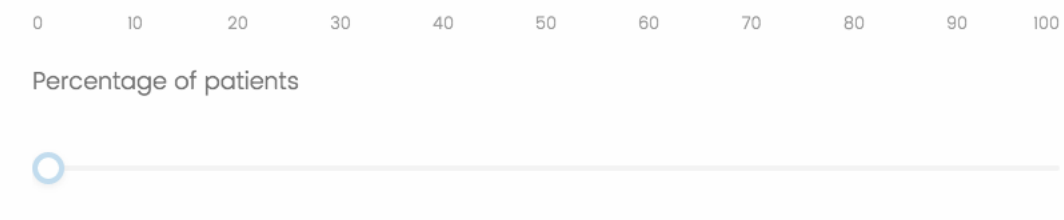
Supplement I: Survey Questionnaire-English Version

1. Which licensing credential best applies to you?
    - CCFP
    - CCFP-EM
    - FRCPC-EM
    - I am a resident in the CCFP or CCFP-EM program
    - I am a resident in the FRCPCP-EM program
    - I am a fellow in the acute point of care ultrasound program
    - Other: please specify
2. In which emergency medicine setting do you spend most of your time practicing?
    - Academic university emergency department
    - Urban/suburban community emergency department
    - Rural community emergency department
    - Isolated/remote hospital
    - Prefer not to disclose
3. Which of the following best describes your gender identity?
    - Woman
    - Man
    - Transgender Woman
    - Transgender Man
    - Non-binary
    - Not listed
    - Prefer not to disclose
4. How many years have you been practicing medicine since completing residency?
    - 0-5 years
    - 6-10 years
    - 11-15 years
    - 16-20 years
    - 21-25 years
    - Over 25 years
    - I am a fellow/resident
5. Do you use point-of-care ultrasound (POCUS) during your clinical shifts?
    - Yes
    - No
6. How often do you assess for left ventricular function using POCUS for patients in which you suspect heart failure?



7. Are you trained to perform cardiac POCUS (other than the subxiphoid view for pericardial effusion)?

- Credentialed during residency training
- POCUS Felloship credentialed
- Formal courses (ex: EGLS, cPOCUS…)
- Self-taught
- No experience
- I prefer not to disclose

8. How confident are you in generating cardiac POCUS views (i.e. parasternal long axis, parasternal short axis and apical 4 chamber view)?
    - No confidence
    - Little Confidence
    - Some confidence
    - Confident
    - High Confidence
9. How confident are you in interpreting left ventricular function using POCUS views (i.e.parasternal long axis, parasternal short axis and apical 4 chamber view)?
    - No confidence
    - Little Confidence
    - Some confidence
    - Confident
    - High Confidence
10. In your emergency practice, for which clinical presentations do you use POCUS to assess left ventricular function? You may choose more than one option
    - I do not currently assess left ventricular function
    - Chest pain
    - Shortness of breath
    - Hypotension/shock
    - Palpitations
    - Syncope
    - Return to spontaneous circulation
    - Other: please specify
11. If a patient presents with rapid atrial fibrillation or flutter, how often do you use POCUS to assess left ventricular function? Please consider that the patient has no recent available comprehensive transthoracic echocardiogram in the last 12 months.
    - Always
    - Most of the time
    - About half the time
    - Sometimes
    - Never
12. If a patient presented with rapid atrial fibrillation or flutter (heart rate between 110-160), how confident would you be in qualitatively assessing severe left ventricular function on cardiac POCUS?
    - No confidence
    - Little Confidence
    - Some confidence
    - Confident
    - High Confidence
    - I do not currently assess left ventricular function

13. Please play these clips of a parasternal long axis view and apical 4-chamber view of the heart in rapid atrial fibrillation. To the best of your ability, how would you visually estimate the left ventricular function?
    - Hyperydnamic
    - Normal
    - Reduced
    - Severely reduced
    - Indeterminate
    - Prefer not to answer
14. Do you believe that using POCUS at the bedside to make a distinction between normal and severely reduced left ventricular function could help guide your management of acute atrial fibrillation?
    - Yes
    - Maybe, please comment
    - No
    - Prefer to not disclose
15. Would knowing left ventricular function status of your patient with rapid atrial fibrillation through POCUS help avoid the use of calcium channel blockers.
    - Strongly disagree
    - Somewhat disagree
    - Neither agree nor disagree
    - Somewhat agree
    - Strongly agree
16. Would identifying new severely reduced left ventricular function in atrial fibrillation patients help guide patient disposition
    - Strongly disagree
    - Somewhat disagree
    - Neither agree nor disagree
    - Somewhat agree
    - Strongly agree

17. Do you perceive barriers in the use of cardiac POCUS to assess left ventricular function in patients presenting with atrial fibrillation? If yes, please explain your answer.
    - Yes, please comment
    - Maybe , please comment
    - No

Supplement II:

Table of full "Survey results of Canadian ED physicians/residents' POCUS use and integration in patients with acute atrial fibrillation/flutter patients"

Demographics	
Male Gender (%) N=88	68
Licensing credentials (%)	**N=89**
Certified with the College of Family Physicians	6.7
Certified with the College of Family Physicians-Emergency medicine competency	39
Royal College of Physicians and Surgeons Certification in Emergency Medicine	41.6
Resident	9
Fellow	1.1
Other	1.1
ED settings (%)	**N=88**
Academic	70.5 (62)
Urban	19.3 (17)
Rural	10.2 (9)
Isolated	0 (0)
Years of practice %(n)	**N=88**
0-10 years	41 (36)
11-20years	19(17)
Over 20 years	31 (27)
I am a resident or fellow	9.0 (8)
POCUS training % (n)	**N=91**
Residency training	17.6 (16)
Fellowship training	5.5 (5)
Formal courses	34.1 (31)
Self-taught	17.6 (16)
Combination*	15.4 (14)
No experience	9.9 (9)
Cardiac POCUS Utilization	
Assessment of left ventricular function in suspected heart failure (mean percentage of patients)	50.5
Clinical presentation- left ventricular function assessment % (n)	**N=91**
Chest pain	32(29)
Shortness of breath	63(57)
Hypotension	76(69)
Return of spontaneous circulation	70(64)
Syncope	27(25)
Palpitations	15(14)
Other	13(12)
I do not assess LV function	20(18)
Confidence generating cardiac POCUS views %(n)	**N=91**
No/Little confidence	20 (18)
Some/confident/high confidence	80 (73)
Confidence interpreting left ventricular function% (n)	**N=91**
No / Little confidence	26 (24)
Some/confident/high confidence	74 (67)

POCUS left ventricular function utilization in AF/AFL patients	
Confidence interpreting left ventricular function AF/AFL %(n)	**N=91**
No/Little confidence	27(25)
Some/confident/high confidence	59 (54)
I do not assess	13.2 (12)
Left ventricular function assessment in AF/AFL % (n)	**N=91**
Always	6.6 (6)
Most of the time	17.6 (16)
About half the time	7.7 (7)
Sometimes	18.7 (17)
Never	49.5 (45)
Integration POCUS left ventricular function assessment in acute AF/AFL	
Distinction between normal and severely reduced left ventricular function to change management %(n)	**N=88**
Yes	51(45)
No	16(14)
Maybe	33(29)
Avoid the use of calcium channel blockers %(n)	**N=88**
Strongly/somewhat/neither disagree	38 (33)
Somewhat/strongly agree	63 (55)
Guide disposition % (n)	**N=88**
Strongly/somewhat/neither disagree	23 (20)
Somewhat/strongly agree	77 (68)

*Represents any combination amongst the categories, example formal courses and self-taught.

Appendix I:

Utilization of Cardiac Point-Of-Care Ultrasound for Atrial Fibrillation Management By Canadian Emergency Physicians: A Cross-Sectional Survey

Dear CAEP members,

We invite you to please fill out a 5-10-minute survey on the use of cardiac point-of-care ultrasound (POCUS) in patients presenting with atrial fibrillation in Canadian emergency departments.

Point-of-care ultrasound is increasingly being applied by emergency physicians to answer specific clinical questions at the bedside. Common applications in cardiac POCUS include assessment of pericardial effusion and left ventricular systolic function. Left ventricular systolic function assessment in patients presenting with atrial fibrillation to the emergency department has not been readily studied. The 2021 Canadian Association of Emergency Physicians (CAEP) Acute Atrial Fibrillation/Flutter Best Practices Checklist suggest using POCUS assessment of left ventricular function to guide treatment options for rate control. Our study aims to explore how emergency physicians are currently using cardiac POCUS within this population and ascertain barriers to practicability.

This study has been reviewed by the Ottawa Health Science Network Research Ethics Board (OHSN-REB). If you have any questions about your rights as a study participant, you may contact the Chairperson of the OHSN-REB at +1 613-798-5555, extension 1671.

By clicking the hyperlink or QR code below, you will be directed to the consent form for the study. Participation is voluntary.

If you have any questions, please contact the research fellow Dr. Sophia-Maria Giannakakis.

Thank you,

Sophia-Maria Giannakakis, MD, CCFP-EM
Acute POCUS Fellow (2022-2023)
Emergency Medicine Research Fellow
Master's in Epidemiology (2nd year), University of Ottawa

Appendix II

The Ottawa Hospital Research Institute | L'Hôpital d'Ottawa Institut de recherche

October 27, 2023

Dr. Jeffrey Perry

Ottawa Hospital - Civic Campus
Department of Emergency Medicine
F6, Room 647
1053 Carling Avenue
Ottawa, ON K1Y 4E9

Re: OHRI Institutional Approval for Ottawa Health Science Network Research Ethics Board (OHSN-REB) Submission

Protocol ID#: 20230478-01H;

Utilization of Cardiac Point-Of-Care Ultrasound for Atrial Fibrillation Management By Canadian Emergency Physicians: A Cross-Sectional Survey

Dear Dr. Jeffrey Perry,

This letter serves as **Ottawa Hospital Research Institute (OHRI)** Institutional Approval for the above-referenced study. Please maintain this documentation in your investigator study file.

Based on the information you provided about this study through the Clinical Research Registration Form, you have satisfied the requirements for institutional (OHRI) approval. This includes initial research ethics approval by OHSN-REB, appropriate departmental/service area notifications and execution (fully signed versions) of all agreement(s) required to begin the study locally. Please note there may be additional agreement(s) pending execution that are required to send funds, samples, or data to external sites, but are not required for you to begin your study locally.

Changes and/or additions to your study that may require additional agreement(s) or revisions to existing agreement(s) must be communicated to the OHRI Contracts Office. This should be undertaken simultaneously with any related OHSN-REB amendment submission.

Changes and/or additions to your study that affect various hospital/institution departments (e.g., pharmacy, Department of Medical Imaging, EORLA, EEG, etc.) must be communicated to the relevant departments.

As mentioned in the 'Response' tab of the Ethics application, you have 3 months from the date of initial OHSN-REB approval to submit French documents including the translation certificate to OHSN-REB through the Translated Documents section of the ethics application (if applicable).

Should you have any questions, please contact REBadministration@ohri.ca or 613-798-5555 extension 16719.

[redacted]

Penny Phillips
Director, Clinical Research Administration
Ottawa Hospital Research Institute | Institut de recherche de l'Hôpital d'Ottawa

Civic Campus, Box 675, 725 Parkdale Avenue, Ottawa, Ontario, K1Y 4E9
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Chapter 5

Abstract #2

Introduction: There is a literature gap regarding point-of-care ultrasound (POCUS) assessments of left ventricular function for patients in acute rapid atrial fibrillation (AF) or flutter (AFL) in the ED. We sought to evaluate reliability of POCUS left ventricular function assessments in this population.
Methods: We conducted a health records review of adult patients who presented with rapid AF/AFL, heart rate above 110, to a tertiary care hospital ED. POCUS scans archived by ED physicians were interpreted by two cardiologists and one ED physician with POCUS expertise to categorize left ventricular function as non-severe or severely reduced function. Agreement analysis were performed using Cohen's kappa with 95% confidence interval (CI). We also compared rate or rhythm control medication, electrical cardioversion, sinus rhythm at discharge, and patient disposition between rapid AF/AFL patients who had POCUS performed and those without POCUS.
Results: We identified 332 acute AF/AFL ED patients during our study period, of which 128(38%) had POCUS assessing left ventricular function. All archived POCUS scans (100/128) were used for agreement analysis. We found a moderate level of agreement between cardiologists and ED POCUS expert (k= 0.63 CI 95% 0.43-0.82) and fair level of agreement between cardiologists and ED physicians (k= 0.34 CI 95% 0.10-0.58). A higher proportion of patients with POCUS received beta blockers (38% vs 24%, p=0.009) or digoxin (14% vs 5%, p=0.007) compared to those without POCUS. Admission rates were higher in the POCUS group (40% vs 19%, p<0.0001).
Conclusion: Among patients with rapid AF/AFL evaluated in the ED, one-third had POCUS left ventricular function assessments. ED physicians and ED POCUS expert reliability ranged from fair to moderate when distinguishing non-severe from severely reduced left ventricular function in rapid AF/AFL. Interpretation and integration of left ventricular function in acute AF/AFL population is feasible and can help guide treatment and disposition.

Keywords: POCUS, atrial fibrillation, left ventricular function

Title: Point-Of-Care Ultrasound for Left Ventricular Function In Patients With Atrial Fibrillation In The Emergency Department

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Disclaimer: The findings represent the work of the authors and not their institutions.

Conflicts of Interest: The authors of this study have no conflicts of interest.

Sources of support: We received funding from The University of Ottawa Department of Emergency Medicine Grant

Acknowledgment: We would like to thank Angela Marcantonio for her assistance in the project as part of the Ottawa Hospital Research Institute-Emergency Research.

Title: Point-Of-Care Ultrasound for Left Ventricular Function In Patients With Atrial Fibrillation In The Emergency Department

Introduction:

A growing number of co-morbidities and an aging population are contributing to the rise in atrial fibrillation presentations in the emergency department (ED) [1,2]. The co-existence of atrial fibrillation and heart failure is associated with more complex medical management and higher all-cause mortality [3,4]. In Canada, the *2021 CAEP Acute Atrial Fibrillation/Flutter Best Practices Checklist* is the latest guideline for emergency physicians in the management of atrial fibrillation [5].These guidelines suggest rate or rhythm control pathways to treat symptomatic rapid acute atrial fibrillation (AF) and flutter (AFL) for patients presenting to the ED depending on the patient's hemodynamic stability, anticoagulation status, time since symptom onset, and co-morbidity including left ventricular function [5].

Patients presenting to the ED in rapid AF/AFL with a heart rate above 110 bpm may benefit from a point-of-care ultrasound (POCUS) left ventricular function assessment to help guide their acute treatment [5]. In particular, POCUS may be beneficial if left ventricular function has never been assessed by echocardiography or echocardiographic reports are not available to the treating emergency physicians. Cardiac POCUS performed by emergency physicians has been well studied and is often used clinically to qualitatively determine left ventricular function systolic for patients presenting to the ED in suspected cardiogenic shock or decompensated heart failure [6-10]. However, previous ED derived studies assessing left ventricular function have not specifically included patients with rapid AF/AFL [6-10]. Sonographer performed echocardiograms aim to provide precise quantitative left ventricular ejection fractions whereas emergency physicians aim to visually estimate left ventricular systolic function to make rapid bed-side clinical decisions [11]. Visual estimation in emergency settings has been used to categorize left ventricular systolic function into normal, reduced or severely reduced function, respectively approximating ejection fraction as equal or above 50%, 30-49%, and under 30% dysfunction [6,8].

The evaluation by emergency physicians of left ventricular function in rapid AF/AFL patients has the potential to guide rate and rhythm control treatments, disposition decision-making and prevent the development of decompensated heart failure [3,11-12]. There is a significant lack of evidence for emergency physician performed POCUS for the evaluation of left ventricular function in patients presenting to the ED in rapid AF/AFL. The aim of our study was to demonstrate the utilization and accuracy of POCUS left ventricular function assessment for rapid AF/AFL patients in the ED. Our objectives included: 1) assessing the current use of POCUS by ED physicians in the management of acute rapid AF/AFL patients at The Ottawa Hospital, 2) determining level of agreement between cardiologists and an ED POCUS expert for left ventricular function interpretation, 3) determining agreement between frontline ED physicians and cardiologists for left ventricular function interpretation and 4) comparing the clinical management, including medications used and rates of hospitalization, between patients who had a POCUS assessment of left ventricular function and those who did not have POCUS performed in the ED.

Methods:

Study Design and Setting:
We conducted a health records review of patients presenting to the ED in rapid AF/AFL over a 6-month study period from August 1st 2023 to January 30th 2024. This study was conducted in two university tertiary-care EDs on separate campuses of The Ottawa Hospital: Civic and General campuses. Ethics approval from the Ottawa Health Science Network Research Ethics Board was obtained.

Study Participants:
We included adult patients over 18 years of age, presenting to ED with rapid AF or AFL. Rapid AF or AFL was confirmed by an electrocardiogram or rhythm strip with a heart rate above 110 beats per minute. This definition is based on the past RAFF 5 Trial, which included a similar patient population and was conducted in the same hospital [12]. We had estimated approximately 20 patients with rapid AF/AFL per month and planned a convenience sample to include 120 consecutive patients in 6 months.

Study Intervention:
A month prior to the study period, POCUS-credentialed emergency physicians and residents were provided a brief educational module by email with a standardized approach to qualitatively assess left ventricular systolic function. The module included how to assess left ventricular function through cardiac parasternal long axis, short axis and apical 4-chamber views and suggested nomenclature for left ventricular function classification: hyperdynamic, normal, reduced or severely reduced left ventricular function. Qualitative or visual estimation of left ventricular systolic function included a combination assessment of myocardial thickening, fractional shortening, and E-point septal separation. The educational module also reminded physicians how to save their images on Qpath POCUS Archiving Platform (Telexy Healthcare, Canada) [13].

Data Collection:
Data were collected through electronic medical health records review with Epic Systems [14]. We reviewed consecutive charts of patients who visited The Ottawa Hospital EDs between August 1st 2023 and January 31st 2024. Medical charts were identified in Epic based on the physician's final ED diagnosis corresponding to an ICD-10 code [15] "atrial fibrillation and flutter"(I48), "paroxysmal atrial fibrillation" (I48.0), "persistent atrial fibrillation" (I48.1), "chronic atrial fibrillation" (I48.2), "typical atrial flutter" (I48.3), "atypical atrial flutter"(I48.4), "atrial fibrillation and flutter unspecified" (I48.9) [15]. We reviewed the ED triage notes, nursing notes, physician's notes and consultant notes as well as pertinent hospital discharge summaries. We also extracted the corresponding POCUS images saved onto the Qpath system.

Outcomes:
Qualitative left ventricular function was independently ascertained by two blinded cardiologists. We also had POCUS images independently reviewed by a blinded ED physician with POCUS fellowship level expertise. The images used for interpretation were obtained from archived Qpath POCUS scans performed by TOH ED physicians during the study period. For efficiency, each cardiologist was randomly assigned half the POCUS images and the ED POCUS expert

interpreted all the images provided to them. Study expert assessors were not provided the treating ED physician's interpretation of their POCUS images. The cardiologists and expert ED POCUS physician categorized left ventricular function as either normal, non-severely reduced, severely reduced or indeterminate left ventricular function. Frontline ED physicians left ventricular function assessments were based on their medical chart interpretations and were categorized into the aforementioned categories of normal, non-severely reduced, severely reduced or indeterminate. This mapping was done by one of the authors (SMG). If an emergency physician or resident did not record their images in Qpath, but only documented their POCUS findings in the medical charts, we collected these data and used it to assess POCUS utilization in the ED.

Our secondary clinical outcomes were rate or rhythm control medications, attempted pharmacological or electrical cardioversion, sinus rhythm at discharge, and hospital admissions.

Statistical analysis:
Descriptive statistics described demographic data through means with standard deviations, frequencies and medians. Cohen's kappa with 95% confidence interval was used to calculate agreement between cardiologists and the ED physician with POCUS fellowship level expertise, and then between the cardiologists and frontline ED physicians. The interpretations were classified into the following two categories for analysis: 1) non-severely reduced left ventricular function (included classification as normal, non-severe, or indeterminate) and 2) severely reduced left ventricular function. We also calculated raw percentage agreement between the ratings on the original scale and the dichotomized scale.

We performed Chi-squared tests and Fischer's Exact Test, as appropriate, to analyze differences in the secondary clinical outcomes for rapid AF/AFL patients who had a POCUS performed by an ED physician or resident compared to those who did not have a POCUS. The data analysis was conducted using SAS Software SAS Institute Inc., Cary, NC, USA [16].

Results:
Among the included 332 rapid AF/AFL patients, 128 (38.5%) had a POCUS performed by an ED physician or resident (Table 1). Of the 128 POCUS scans performed, 100 (78.1%) had POCUS images saved on Qpath. There were 51 different frontline ED physicians and residents who saved their images. Amongst the saved POCUS images by frontline ED physicians, 44% were performed by ED residents and 48% by ED attendings. Of the 100 POCUS scans, eight were missing information on Qpath regarding who in the ED acquired and saved the image. Rapid AF/AFL patients had an average age of 70.9 (SD± 13.1) years and were predominantly female 50.9% (169/332). Average heart rate was 140 bpm (SD ±20) and mean CHADS2-VaSc score was three.

The binary classifications of left ventricular function by the ED POCUS expert physician and cardiologists are presented in Table 2. We found a Cohen's kappa of 0.63(CI 95% 0.43-0.82) with an 88% raw agreement (74% non-severe,14% severely reduced). For the five images classified as severely reduced by the cardiologists, but non-severe by the ED POCUS expert, none had been subcategorized as normal in the original categorization (see supplement I). When

comparing frontline ED physicians and cardiologists, we found a Cohen's kappa of 0.34 (CI 95% 0.10-0.58) with an 85% raw agreement (80% non-severe, 5% severely reduced) (Table 3).

Table 4 summarizes our secondary outcomes. A higher proportion of patients in the POCUS group received digoxin compared to those without a POCUS (14% vs 5%, p=0.007). Also, a higher proportion of rapid AF/AFL patients in the group with POCUS were rate controlled with beta blockers (37.5% vs 24.0%, p=0.009). Only four patients in the entire sample received calcium channel blockers. Patients with POCUS had a higher hospital admission rate (39.8% vs 19.1%, p<0.0001). A higher proportion of patients who did not have a POCUS performed had a sinus rhythm at ED discharge (68.1% vs 53.1%, p=006).

Discussion:

Interpretation

Our study demonstrated that ED physicians currently use POCUS to assess left ventricular function in about a third of patients presenting with acute rapid AF/AFL. We found a moderate level of agreement in the interpretation of real-world POCUS derived images when distinguishing non-severe from severely reduced left ventricular function assessed by an ED POCUS expert versus blinded cardiologists. Only fair agreement was found between cardiologists and frontline ED physicians suggesting that level of expertise may have factored into accurate assessment of left ventricular assessment. From a clinical management perspective, emergency physicians who performed POCUS on rapid AF/AFL patients had a higher usage of rate control medications and a higher proportion of patients admitted to hospital from the ED compared to patients without POCUS.

Previous studies

We found no prior studies evaluating POCUS assessment of left ventricular function in this specific ED population with rapid AF/AFL. A meta-analysis by Albaroudi et al. showed substantial agreement between ED physicians and expert sonographers with a kappa of 0.68 [95% confidence interval (CI), 0.57–0.79] of visual estimation of left ventricular function assessment for various other clinical presentations in the ED but not for rapid AF/AFL [6]. POCUS left ventricular function assessment has been mainly studied in diagnostic studies pertaining to differentiating cardiogenic shock from other undifferentiated hypotension to help with clinical decision making [17,18]. Our study aimed to demonstrate agreement when distinguishing in the extremes of left ventricular function between non-severe and severely reduced in rapid AF/AFL. This agreement within the extremes was demonstrated in the general ED population by Randazzo who showed good agreement between expert ED sonographers and comprehensive echocardiograms when visually assessing left ventricular function [8]. Left ventricular function is not a stand-alone assessment but should be used concomitantly integrating the entire clinical presentation. POCUS lung assessment of bilateral B-line pattern indicative of pulmonary edema can also help in diagnosing decompensated heart failure in critically ill patient along with clinical presentation and biomarkers [19,20].

Our team recently performed a survey through the Canadian Association of Emergency Physicians (CAEP) which demonstrated that ED physicians do use POCUS to qualitatively assess left ventricular function in rapid AF/AFL patients to help guide treatment and disposition [21]. The Ottawa Hospital ED was a site for the 2024 RAFF-5 study which implemented the

Canadian Association of Emergency Physicians AF/AFL Best Practices Checklist [12]. The RAFF-5 study identified that one of the areas of suboptimal care was the "inappropriate prescription of rate or rhythm control agents" [12]. Our study revealed that patients in rapid AF/AFL who had an ED POCUS were more likely to be rate controlled with beta blocker or digoxin which aligns with clinical practice guidelines as well as ED studies recommending avoiding calcium channel blockers and prioritizing digoxin for rhythm control in clinically decompensated heart failure with reduced ejection fraction [22-26]. Hence, the importance of distinguishing between non-severely and severely reduced left ventricular function due the differences in treatment management.

Strength and Limitations:
The strength of our study is its real-world evaluation of left ventricular function assessment by frontline ED physicians who made treatment and disposition decisions based on their POCUS evaluations. We acknowledge that a health records review in two academic emergency departments center are less generalizable, but we have shown the feasibility of studying POCUS in the ED rapid AF/AFL population.

The degree of accuracy of left ventricular function classification between cardiologists and ED physicians should be interpreted within the scope of POCUS utilization by ED physicians making clinical decisions in the field. We chose to have cardiologists interpret ED physicians acquired POCUS images rather than sonographer performed echocardiograms to adequately capture the ED context of rapid AF/AFL who require immediate medical interventions. Our main explanation for the fair agreement level is likely due to the heterogeneity in terminology used by the ED physicians which made classification difficult. Also, in the ED setting, optimal image acquisition is more challenging compared to standardised models. Considering that ED physicians made decisions based on their interpretations, we chose to include indeterminate POCUS image interpretations within our study rather than exclude them.

Clinical Implications:
This study highlights the utility of POCUS-derived left ventricular function assessments in the ED to assist in decision-making on treatment and disposition for patients who present in rapid AF/AFL and who may have severely reduced function. A higher proportion of rapid AF/AFL patients with POCUS were admitted to hospital compared to the non-POCUS group. Demographically, these patients were slightly older with a mean age of 72, had a slightly higher mean heart rate, and had higher proportion of new onset-first episode atrial fibrillation. The appropriate integration of cardiac POCUS can optimize treatment options and increase patient safety by avoiding calcium channel blockers or identifying a patient who may need admission. Patient continuity of care can also be improved through proper recording and archiving of cardiac POCUS images which can be shared with cardiologists and communicate findings more efficiently [27,28]. From a clinical education perspective, our study indirectly revealed a need for a more standardized approach or national guidelines for cardiac POCUS training pertaining to bedside decision making and the need for more cardiac POCUS training for ED physicians. Although fair agreement was found between frontline ED physicians and cardiologists, there was moderate level of agreement between cardiologists and the ED POCUS expert when interpreting archived images. This suggests that level of training and expertise may influence accuracy of left ventricular function interpretation.

Research Implications:
Future research directions may include multi-centered and prospective cohort studies with standardised nomenclature for POCUS left ventricular function assessment to better capture the effect of integrating POCUS in ED rapid AF/AFL management pathways. A prospective cohort study would allow the assessment of clinical outcomes such as treatment response, mortality as well as more policy-forward outcomes such as ED length of stay and repeat ED visits.

Conclusion:
This is the first study to assess the accuracy of using POCUS left ventricular function assessment on the ED rapid AF/AFL population. The interpretation of left ventricular function by ED physicians showed fair agreement with cardiologists when distinguishing non-severe from severely reduced left ventricular function in the setting of real-world POCUS images derived by ED physicians. The level of agreement was higher when comparing cardiologists and an ED POCUS expert interpretation. The POCUS assessment of left ventricular function in rapid AF/AFL patient in the ED can help guide rate control strategies as well as clinical decision-making regarding patient admissions.

Table 1 Characteristics and Management of the Study Subjects

	Total (n=332)	**POCUS** (n=128)	**Non-POCUS** (n=204)
Age (years) (SD)	70.9 ± 13.1	72.9±12.9	69.6±13.1
Sex (female) %	50.9	53.1	49.5
Vital Signs			
Initial HR (bpm) (SD)	140 ±20	142±23	139±18
Systolic blood pressure (mmHg) (SD)	130±25	126±25	132±25
Respiratory rate (per min) (SD)	19±5	20±8	18±3
SaO2	97 ±5	96±8	97±2
Temperature (Celcius)	36.2±1.0	36.3±1.1	36.2±0.9
First episode Afib (%)	31.9	39.8	27.0
CHADS2-VaSc score	3±1.8	3±2.0	3±1.8
ED POCUS performed (%)	38.6	100	0
Recorded in Qpath	30.1	78.1	-
ED electrical cardioversion (%)	44.0	39.8	46.6
ED chemical cardioversion (%)	16.9	19.53	15.2
Rate control agents (%)			
-Beta-blockers	29.2	37.5	24.0
-Calcium channel blockers	1.21	0.78	1.48
-Digoxin po/IV	8.7	14.1	5.39
Sinus rhythm at discharge (%)	62.4	53.1	68.1
Hospital admission (%)	27.1	39.8	19.1
Echocardiogram in 30 days (TEE or TTE) (%)	38.8	53.1	29.9

[*] *numerical variables: mean ± standard deviation*

****ED chemical cardioversion medications include procainamide, amiodarone, vernakalant*

*****Rate control medications include metoprolol, bisoprolol, diltiazem, digoxin*

Table 2 Levels of Agreement between cardiologists and ED POCUS expert physician using binary POCUS left ventricular function interpretations

	Expert ED POCUS physician		
Cardiologist	**Non-severe**	**Severe**	**Total**
Non-severe	74	7	81
Severe	5	14	19
Total	79	21	100

*ED POCUS which were saved onto QPath
*Non severe included categories of normal, reduced and indeterminate
*Severe included only severely reduced category
Raw agreement= 74% (non severe) + 14% (severe) = 88%
Cohen's kappa 0.63 CI 95% 0.43-0.82

Table 3 Levels of Agreement between cardiologists and ED physicians using binary POCUS left ventricular function interpretations

	ED physicians		
Cardiologist	**Non-severe**	**Severe**	**Total**
Non-severe	80	1	81
Severe	14	5	19
Total	94	6	100

*ED POCUS which were saved onto QPath
*Non severe included categories of normal, reduced and indeterminate
*Severe included only severely reduced category
Raw agreement= 80% (non severe) + 5% (severe) = 85%
Cohen's kappa 0.34 (95%CI 0.10-0.58)

Table 4 Secondary outcomes comparing association of rapid AF/AFL patients who had a POCUS performed by ED physicians versus non-POCUS patients

	POCUS %(n=128)	**Non POCUS %(n=204)**	**p-value**
Rate control			
-Beta-blockers	48 (37.5)	49(24.0)	0.0086
-Calcium channel blockers	1(0.8)	3 (1.5)	1.0000**
-Digoxin	18 (14.0)	11(5.4)	0.0065
ED electrical cardioversion	51(39.8)	95(46.5)	0.23
ED chemical cardioversion	25 (19.5)	31(15.2)	0.30
Sinus rhythm at discharge	68 (53.1)	139(68.1)	0.006
Hospital admission	51 (39.8)	39(19.1)	<0.0001
Echocardiography 30 days (TEE or TTE)	68(53.1)	61(29.9)	<0.0001

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Supplement I

Tables for the levels of agreement with original categories of POCUS left ventricular function interpretations

Levels of agreement between cardiologists and ED physicians: POCUS left ventricular function interpretations

	ED physicians				
Cardiologists	**Normal**	**Reduced**	**Severely reduced**	**Indeterminate**	**Total**
Normal	26	3	1	2	32
Reduced	12	9	0	4	25
Severely reduced	4	10	5	0	19
Indeterminate	17	3	0	4	24
Total	59	25	6	10	100

*ED POCUS which were saved onto QPath

Raw agreement 26% (normal) + 9% (reduced) + 5% (severely reduced) + 4% (indeterminate)= 44%

Cohen's kappa 0.16 CI 95% 0.02-0.31

Levels of agreement between cardiologists and expert ED POCUS physician: POCUS left ventricular function interpretations

	Expert ED POCUS physician				
Cardiologists	**Normal**	**Reduced**	**Severely reduced**	**Indeterminate**	**Total**
Normal	22	6	1	3	32
Reduced	9	11	4	1	25
Severely reduced	0	4	14	1	19
Indeterminate	8	5	2	9	24
Total	39	26	21	14	100

*ED POCUS which were saved onto QPath

Raw agreement 22% (normal) + 11% (reduced) + 14% (severely reduced) + 9% (indeterminate)= 56%

Cohen's kappa 0.40 CI 95% 0.27-0.53

Supplement II : OHRI-REB Letter of Approval

The Ottawa Hospital Research Institute | L'Hôpital d'Ottawa Institut de recherche

November 20, 2023

Dr. Jeffrey Perry

Ottawa Hospital - Civic Campus
Department of Emergency Medicine
F6, Room 647
1053 Carling Avenue
Ottawa, ON K1Y 4E9

Re: OHRI Institutional Approval for Ottawa Health Science Network Research Ethics Board (OHSN-REB) Submission

Protocol ID#: 20230483-01H;

Acute Point-Of-Care Ultrasound for Left Ventricular Function Interpretation In Patients With Atrial Fibrillation In The Emergency Department: A Feasibility Study.

Dear Dr. Jeffrey Perry,

This letter serves as **Ottawa Hospital Research Institute (OHRI)** Institutional Approval for the above-referenced study. Please maintain this documentation in your investigator study file.

Based on the information you provided about this study through the Clinical Research Registration Form, you have satisfied the requirements for institutional (OHRI) approval. This includes initial research ethics approval by OHSN-REB, appropriate departmental/service area notifications and execution (fully signed versions) of all agreement(s) required to begin the study locally. Please note there may be additional agreement(s) pending execution that are required to send funds, samples, or data to external sites, but are not required for you to begin your study locally.

Changes and/or additions to your study that may require additional agreement(s) or revisions to existing agreement(s) must be communicated to the OHRI Contracts Office. This should be undertaken simultaneously with any related OHSN-REB amendment submission.

Changes and/or additions to your study that affect various hospital/institution departments (e.g., pharmacy, Department of Medical Imaging, EORLA, EEG, etc.) must be communicated to the relevant departments.

As mentioned in the 'Response' tab of the Ethics application, you have 3 months from the date of initial OHSN-REB approval to submit French documents including the translation certificate to OHSN-REB through the Translated Documents section of the ethics application (if applicable).

Should you have any questions, please contact REBadministration@ohri.ca or 613-798-5555 extension 16719.

[redacted]

Penny Phillips
Director, Clinical Research Administration
Ottawa Hospital Research Institute | Institut de recherche de l'Hôpital d'Ottawa

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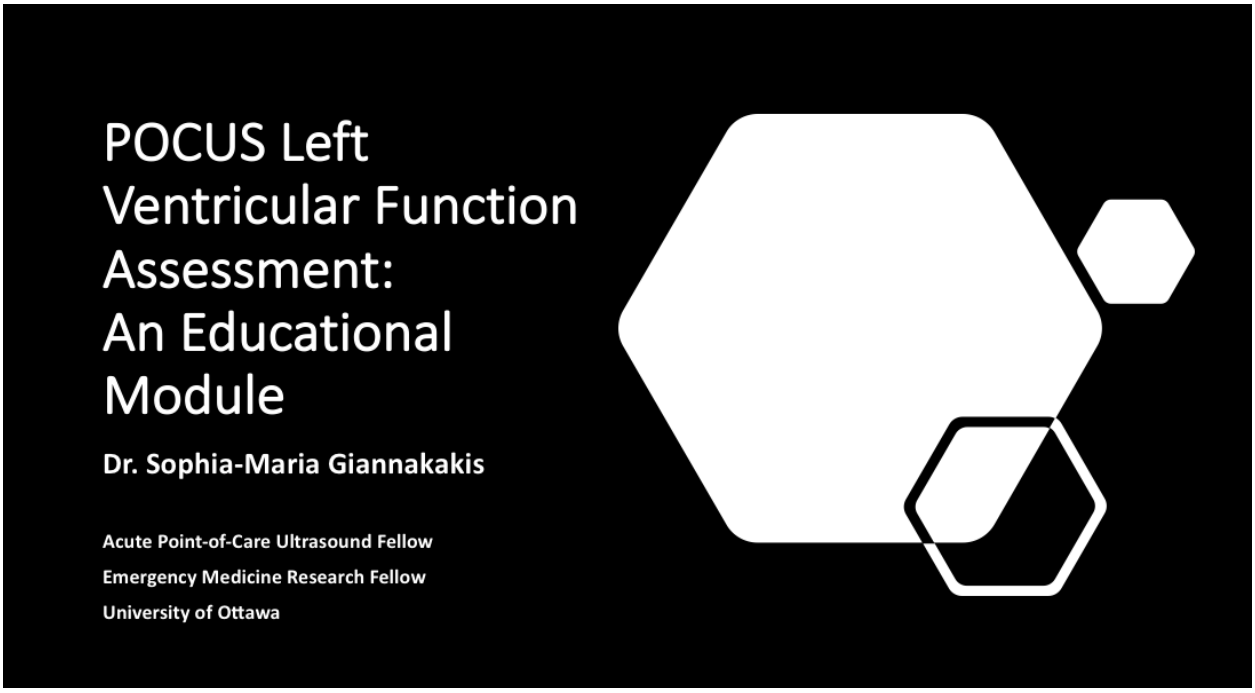
Appendix I
Educational Module Powerpoint



Chapter 6: Discussion

Overview of research findings

This article-based thesis presents two articles supporting the feasibility of evaluating POCUS left ventricular function utilization by emergency physicians for patients in acute rapid atrial fibrillation or flutter. The standard of care for the treatment of rapid atrial fibrillation or flutter depends on knowing left ventricular function to guide rate and rhythm control, but this clinical information may not be readily available in the medical chart or may have never been assessed prior to the acute presentation in the ED. An exploratory survey of Canadian emergency physicians tended towards the hypothesis that ED physicians are currently utilizing POCUS left ventricular function assessments in suspected heart failure in rapid atrial fibrillation or flutter patients. Notably, over half of ED physicians responded that distinguishing between severely reduced from normal left ventricular function in rapid AF/AFL helps guide their management specifically in avoiding calcium channel blockers [1]. Knowing ED physicians were using POCUS left ventricular function in this specific population, an interobserver agreement study was undertaken between ED physicians and different experts in cardiac left ventricular function assessment i.e. cardiologists and ED physician with POCUS fellowship expertise. Distinguishing non-severely from severely reduced left ventricular function through visual estimation of archived ED POCUS images, the study revealed fair agreement (k=0.34 95%CI 0.10-0.58) between ED physicians and cardiologists compared to moderate agreement (k=0.63 CI 95% 0.43-0.82) between cardiologists and ED POCUS expert. These findings suggest level of expertise and training may influence interpretation of POCUS left ventricular function. Despite this variation in interobserver agreement, ED physicians who performed POCUS on acute rapid atrial fibrillation or flutter patients had rate controlled a higher proportion of patients with beta blockers and digoxin compared to no POCUS performed (respectively, 37.5% vs 24.0%, p=0.009 and 14% vs 5%, p=0.007). Similarly, a higher proportion of patients who had a POCUS performed for rapid atrial fibrillation or flutter were admitted to hospital (39.8% vs 19.1%, p<0.0001). In brief, ED physicians POCUS left ventricular function assessment the potential to impact clinical decision-making regarding treatment and disposition.

Discussion and Limitations: Article I

The exploratory cross-sectional survey utilized the Canadian Association of Emergency Physicians (CAEP) to reach emergency physicians and residents nationally, thus providing a platform via online email to reach a variety of physicians practicing in different contexts around the country. A survey through CAEP provided a cost and time effective platform for survey distribution in the context of a thesis. The survey's demographics showed that most respondents (89.8%) practiced most of the time in academic or urban ED settings compared to 10.2% in rural or isolated settings [1]. This phenomenon introduces an underrepresentation bias likely due to the sampling of individuals who participate in more academic activities produced by CAEP. This bias would affect generalizability of the survey. Do ED physicians practicing in rural settings use POCUS differently or do they experience different barriers? A recent Canadian survey on ED POCUS use in rural settings showed that 94% of their respondents utilized cardiac POCUS citing it as one of the most commonly indicated POCUS uses [2]. This high use of POCUS is likely due to limited access to comprehensive imaging [2]. A survey by Leschyna et al. (2019) interestingly showed that POCUS use was not related to ED setting, but rather ED use was correlated with

POCUS training [3]. Our survey study aligns with other studies who cited one of the major perceived barriers being skill level and access to training especially in rural settings [3-7]. Despite lack of training or skill level being named as a barrier by respondents in our survey, 59% ED physicians felt some level of confidence when interpreting POCUS left ventricular function in rapid atrial fibrillation or flutter patients [1].

A limitation of our cross-sectional email survey is the poor response rate at 6% (91 respondents out of 1500 emails to members). A downside to the convenience of a CAEP survey is that the sample likely did not include enough of a variety of the Canadian emergency physician population as shown by the lack of rural practicing ED physicians and French language speaking physicians. Comparatively, Andafi et al.2025 survey of Canadian Emergency Physicians yielded a 10% response rate [2]. Low response rates are not unusual in physician surveys across specialties [8]. Due to time and budget limitations, the decision was made to use a single method for survey administration rather than a mixed-methods, for example, adding a postal survey to specific groups [8-11]. The survey's response rate could have been improved by increasing our sampling frame by sending email blasts to specific registered provincial college registrants with a CCFP-EM or FRSCP-EM title or other specific emergency medicine societies such as *the Society of Rural Physicians* of Canada or the *Association des médecins d'urgence du Québec* [11]. There may be a non-response bias in our survey because responders who participate generally have a more "open-minded attitude"[10], we could assume they would be more willing to answer a survey which explores a novel POCUS utilization [10]. It would be difficult to know if our survey's non-respondents differ significantly from responders without sending follow-up questionnaire to the non-respondents.

Discussion and Limitations: Article II

The second article in this thesis is a reliability study using interobserver agreement analysis between various levels of expertise between ED physicians, cardiologists and ED POCUS expert in the assessment of left ventricular function in rapid atrial fibrillation or flutter using real-world archived POCUS images. Image acquisition by frontline ED physicians impacted image quality and was a likely determining factor influencing the levels of agreement in the study. Standards of POCUS use in the ED require quality assurance of acquired images [12]. Qpath, the software on which the images were archived, includes an image quality assessment (QA) scale (see appendix II). This scale is mainly used during POCUS fellowship and residency training programs of The Ottawa Hospital for educational purposes of competency assessment, but rarely used by ED physicians for their own image quality assessment. There exist other general scales such as American College of Emergency Physicians Emergency Ultrasound Standard Reporting Guidelines as well as cardiac specific QA scales [13-15]. A suboptimal image quality lending to an uninterpretable image, as judged by the POCUS operator, would be classified as an indeterminate scan. In our study, we chose to group the indeterminate scans into the non-severe left ventricular function rather than excluding these POCUS images. Despite indeterminate classification, ED physicians would make clinical decision based on this indeterminate finding, thus representing a real-world scenario. There was variation in the number of POCUS scans classified as indeterminate based on level of expertise in our study. Cardiologists classified 24 POCUS images as indeterminate, ED POCUS expert 14 images, frontline ED physicians classified 10 of their images as indeterminate. If the indeterminate images were to be excluded,

the Cohen's kappa would likely have improved, but would not have been representative of image acquisition by frontline ED physicians. A retrospective study on cardiac POCUS image quality showed under 2% of ED physicians recorded the diagnostic impact of poor image quality on their diagnostic accuracy [15]. Noting that image quality is not only influenced by individual technical skill, but also patient body habitus and the ED environment such as our patients in rapid atrial fibrillation or flutter [15]. A reproducibility study of clinicians visually estimating left ventricular function in 20 apical four chamber views of varying image quality demonstrated poor intra-observer left ventricular function estimations when image quality was poor [16]. Quality assurance programs reviewing image quality by ED physicians could potentially help mitigate the impact of heterogeneity in image quality [15-16]. There were 51 frontline ED physicians and residents who acquired images in our study, this could be the source of variability in the image acquisition skills and quality of the generated images.

Another factor influencing the agreement analysis results may have been the heterogeneity in the nomenclature used by ED physicians to classify left ventricular function, potentially leading to misclassification bias. For example, it is difficult to truly know if an ED physician who qualified left ventricular function as reduced in their medical chart meant this as moderately reduced or severely reduced. Some ED physicians qualified the left ventricular function as "poor" or "significantly reduced", one may assume this to mean severely reduced. Also, the mapping was done by only one author and based on their subjective categorization, and so may have contributed to misclassification bias. Based on the most recent systematic review and meta-analysis of studies comparing ED physicians to expert sonographers left ventricular function assessment, most studies used normal, reduced and severely reduced categorisation [18]. Clinically, it is more important for ED physicians to distinguish between severely reduced from non-severe left ventricular function, raw agreement becomes important in the interpretation of our results because Cohens kappa is biased by the prevalence of each category [18]. A weighted kappa could have placed levels of importance to difference left ventricular function categories when three or more categories are analyzed, but binary categorization was more clinically relevant [18]. It is also possible that the frontline ED physicians may have had access to prior echocardiographic reports of their patients and this may have influenced their categorization of POCUS left ventricular function. If a future reproducibility study were to be done, it should take prior echocardiography interpretation into account.

As for the secondary outcomes of the study, ED physicians who performed a POCUS on rapid atrial fibrillation or flutter patients had a higher proportion of patients who were rate controlled with beta blockers or digoxin, who were admitted to hospital and who underwent an echocardiogram within 30 days. Whereas, ED physicians who performed did not perform a POCUS on rapid atrial fibrillation or flutter patients had a higher proportion of patients who were discharged with sinus rhythm. The clinical significance of the secondary outcomes should be interpreted cautiously. The bidirectionality of atrial fibrillation and heart failure is complicated by numerous confounders that were not controlled for in this study. For instance, a study evaluating 30-day mortality of patients presenting to the ED with atrial fibrillation and decompensated heart failure had to control for 54 confounders [19]. In terms of hypothesis-generating, patients in rapid atrial fibrillation or flutter who had a POCUS performed may have been clinically more ill or in decompensated heart failure than those who did not have a POCUS in the ED. Additional data pertaining to severity of symptomology and biomarkers such as

troponins and natriuretic peptide could have aided to stratify patients in decompensated heart failure [20]. The combination of lung POCUS, inferior vena cava, and POCUS left ventricular function assessment in acute undifferentiated dyspneic patients in the ED has shown sensitivities above 90% and the ability to influence volume control [21-24]. The main study design was to assess interobserver agreement, and so the secondary outcomes are more likely to be influenced by confounders which were not accounted for in this study. Further multivariate analysis was not performed as it would not be appropriate with the current study design. Future study designs should consider randomisation or standardised POCUS protocols to help control for as confounders [25]. POCUS research in the ED may make randomisation at the patient level difficult due to the inherent nature of the environment. Hence, our data should rather be interpreted as identifying potential outcome measures for future studies.

A special mention should be made for a subset of the rapid atrial fibrillation or flutter population who may present in cardiogenic shock whether from myocardial infarction or a secondary cause such as septic cardiomyopathy. Although not specific to the atrial fibrillation or flutter population, an international randomized controlled trial part of the Shoc-ED investigators (2022), demonstrated that in ED patients presenting with undifferentiated hypotension, POCUS had similar diagnostic accuracy to non-POCUS for diagnosing cardiogenic shock (specificity 95.5% [CI 89.9–98.5); sensitivity 80% [CI 51.9–95.6)] amongst the undifferentiated hypotensive ED patients [26]. This subset of extremely ill patients are the ones for which ED physicians would want a timely diagnosis and treatment. Contrary to the extremes, there also seems to be a growing literature regarding atrial fibrillation and prognostication with preserved left ventricular function [27-30]. A study in the ED showed the feasibility in POCUS evaluation of diastolic function assessment in diagnosing subclinical heart failure [30]. Diastolic function requires more quantitative measurements which may be more difficult for ED physicians without advanced training [31-32].

Clinical Implications:

This thesis provides preliminary support to an observed clinical practice by assessing its feasibility to use POCUS in the rapid atrial fibrillation patient. For emergency physicians, the ability to distinguish between non-severely reduced and severely reduced left ventricular function in patients with suspected decompensated heart failure in the context of rapid atrial fibrillation or flutter has the potential to guide decision making: 1) choice of rate control medications 2) optimize treatment options notably volume control in decompensated heart failure 3) help stratify which patients may need hospital admissions. Although not directly evaluated in this thesis, cardiac POCUS may decrease time to diagnosis of decompensated heart failure as the diagnosis is made at the bedside, consequently aiding in cognitive offloading for ED physicians and time to treatment. Image archiving and sharing of these images can help show the dynamic changes to treatment as well as communicating clinical findings with consultants, notably cardiologists, hence providing another data point in the patient's continuity of care [12,33]. Improvement in chart documentation and archiving can be achieved when strategies for better integration of POCUS within the ED workflow are implemented [34-35].

For clinicians to fully optimize cardiac POCUS in their clinical practice, more training opportunities through residency or physicians continuing professional education programs. The

lack of cardiac POCUS training emerged as a theme in both the articles of this thesis. This barrier and need aligns with previous Canadian POCUS training needs assessments [36-37].

Future Research Implications:

The articles in this thesis demonstrated the feasibility of utilizing POCUS for left ventricular function assessment for rapid atrial fibrillation or flutter population in the ED. One future research direction would be a replication study with a standardized operating protocol for image acquisition and image quality assessment by the ED physicians in real time. These changes would hopefully improve agreement with cardiologists and expert POCUS users. Other future research directions should include prospective cohort studies and longer time periods to improve the sample size. A prospective cohort study with patient-oriented outcomes would be clinically helpful for ED physicians such as evaluating worsening heart failure symptoms, need for oxygenation, ED return visits, and ICU admissions. A stratification by patient co-morbidities or severity of illness can also be helpful considering that rapid atrial fibrillation or flutter can be a decompensation of the arrhythmia, decompensation of heart failure, triggered by a secondary cause or a combination of these scenarios. The challenge remains in controlling the confounding variables in this ED population.

POCUS research in-and-of-itself has methodological challenges pertaining to blinding the operator to the clinical scenario [38-39]. A recent 2025 framework for standards for POCUS research reporting (SPUR) was developed to aid researchers in the design process. If resources and funding are available, ideal scenarios would include having separate operators with standardised training perform the POCUS scan in the ED, likely improving the validity of the left ventricular function assessment [39].

Conclusion

The articles in this thesis have demonstrated feasibility of the utilization of POCUS left ventricular function assessment in a novel patient population of rapid atrial fibrillation or flutter in the ED. In clinical practice, ED physicians have been using this application of POCUS left ventricular function for this specific population. Depending on level of expertise, the accuracy of POCUS left ventricular function assessment in these patients varied from fair to moderate when distinguishing non-severe from severe left ventricular function. The clinical significance of the ability to distinguish the extremes of left ventricular function in the rapid atrial fibrillation or flutter patients could potentially impact decision making by guiding rate control choice of medications and patient's disposition. Challenges such as image quality, image archiving, and cardiac POCUS training emerged as potential domains for future improvement. This thesis' contribution lays the ground work for future academic and clinical research in the cardiac POCUS domain by helping ED physicians safely optimize their care of rapid acute atrial fibrillation or flutter.

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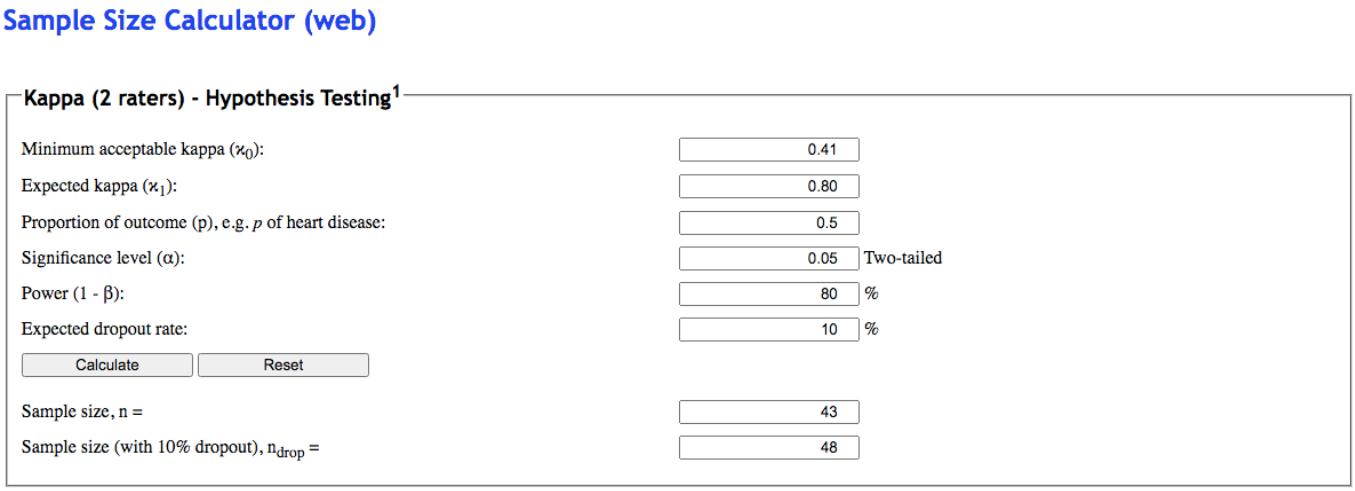
Appendix I:

Sample size estimator for two raters, dichotomous outcome



Direct URL: https://wnarifin.github.io/ssc/sskappa.html

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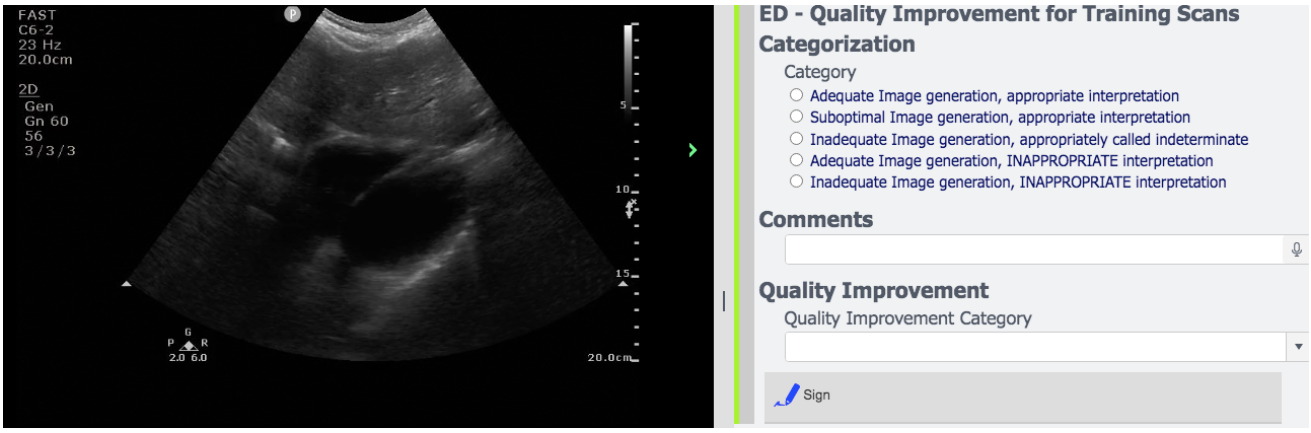
Appendix II:
The Ottawa Hospital ED Quality Improvement Scale for Training Scans



Anonymized Screenshot from Qpath