# A Guideline Recommendation Implementing Inferior Vena Cava Ultrasound To Guide Hemodynamic Resuscitation of Septic Adults During Air Medical Transport

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## Abstract

**Nature and Scope of the Project:** Sepsis was present in one out of every three hospital deaths (CDC, 2020). Primary and time-sensitive interventions for this common and severe condition include intravenous fluid and vasopressor administration for hemodynamic resuscitation, but inappropriate administration can lead to complications and poorer patient outcomes (Schmidt & Mandel, 2020). In the early stages of sepsis patient care, air medical transport clinicians frequently transport septic patients from small, rural hospitals to hospitals with higher levels of care. These clinicians could utilize inferior vena cava (IVC) ultrasound to guide optimal hemodynamic resuscitation. Therefore, a guideline that utilized IVC ultrasound was created for sepsis management during air medial transport to improve patient outcomes. **Synthesis and Analysis of Supporting Literature:** Through an extensive literature review and synthesis, evidence showed that IVC ultrasound measurements were a reliable and valid tool for assessing hemodynamics (Garg et al., 2016; Jia et al., 2020; Lu et al., 2017; McGregor et al., 2020). **Project Implementation:** An additional literature review was completed. This evidence guided the creation of an IVC ultrasound-guided hemodynamic resuscitation guideline for the management of septic, non-intubated adults. Subsequently, the guideline was given to six emergency department physicians for feedback. This feedback provided insight as to whether the guideline required improvement or could be used in actual clinical practice. **Evaluation Criteria:** Feedback from four emergency department physicians was obtained through an online survey. The qualitative and quantitative data was analyzed through Cronbach's alpha and descriptive analysis. **Outcomes:** Cronbach's alpha coefficient of 1.00 (CI 95%). Most (75%) respondents had agreed or strongly agreed with an average of 4.25 (five-point Likert) regarding

the appropriateness of the targeted population, IVC ultrasound use in sepsis patients, and recommended guideline. Most (75%) of respondents also reported that they would use IVC ultrasound and this guideline for septic patients in their practice due to ultrasound accessibility and usefulness in hemodynamic resuscitation. **Recommendations:** Based on the initial feedback results, this guideline was mostly well received. It would be beneficial to receive additional feedback from more diverse respondents. If the guideline was still received well, it could be offered to an air medical transport organization or other healthcare facilities that have limited access to invasive hemodynamic monitoring equipment.

# A Guideline Recommendation Implementing Inferior Vena Cava Ultrasound To Guide Hemodynamic Resuscitation of Septic Adults During Air Medical Transport

Sepsis occurs in over 1.7 million adults in the United States every year and is present in one out of every three hospital deaths (Centers for Disease Control and Prevention [CDC], 2020). The management of sepsis or septic shock requires aggressive, timely, and optimal hemodynamic resuscitation because inappropriate management can lead to detrimental patient outcomes (Branan et al., 2019). To guide appropriate fluid administration and vasopressor initiation in sepsis patients, ultrasound measurements of the inferior vena cava (IVC) can be of invaluable use (Jaramillo & Ramirez, 2021).

Frequent reassessments of septic patients guide their intravenous (IV) fluid resuscitation and vasopressor initiation and attempt to mitigate complications from inappropriate fluid administration. Physical assessments, vital signs, hemodynamic monitoring values, and laboratory values help assess and reassess fluid volume and the fluid resuscitation effort (Boucher & Wood, 2019). IVC ultrasound measurements can be a beneficial addition to these sepsis assessments in the air medical transport environment to further guide optimal sepsis care. Therefore, in septic adult patients, flight clinicians can utilize an IVC ultrasound-guided sepsis management guideline during air medical transport to guide fluid and vasopressor administration, thereby optimizing hemodynamic resuscitation and mitigating potential complications.

## Problem Identification/Available Knowledge

Of all septic patients in the United States that present to rural emergency departments, 59% require transfer to another hospital (Froehlich, 2019). These patients are in the critical

initial stage of their medical care as explained by the Surviving Sepsis Campaign (Rhodes et al., 2017). This international organization of evidence-based researchers compared the initial hours of sepsis to time sensitive emergencies, such as trauma, acute myocardial infarctions, and cerebral vascular accidents, in which rapid diagnosis and treatment correlated to greater positive outcomes. Flight clinicians are frequently the providers that transport these critical patients. Evidence showed that ultrasound, including IVC ultrasound measurements, can be a reliable and valid tool in assessing hemodynamic monitoring, including IV fluid responsiveness, in intensive care units and emergency departments (Garg et al., 2016; Jia et al., 2020; Lu et al., 2017; McGregor et al., 2019; McGregor et al., 2020).

Sepsis is a progressive condition that begins with an infection that leads to a dysregulated host response, then organ dysfunction and septic shock (Branan et al., 2019; Martin et al., 2019; Rhodes et al., 2017). Sepsis can be life-threatening at any point but is greatest when it has progressed to septic shock (Martin et al., 2019). Shock is caused by circulatory failure that progressively leads to inadequate cell, tissue, and organ perfusion; multiple organ dysfunction syndrome; and death (Martin et al., 2019).

Primary interventions in sepsis management focus on the treatment of circulatory failure through IV crystalloid fluid administration to improve intravascular volume and vasopressor administration to improve vascular tone (Branan et al., 2019; Schmidt & Mandel, 2020). Schmidt and Mandel (2020) cautioned that excessive IV fluid in septic patients has the potential to cause harm, such as cardiogenic or noncardiogenic pulmonary edema, which may progress to acute respiratory distress syndrome (ARDS), and increase the need for additional medical interventions, such as diuretic therapy and thoracentesis. In sepsis and ARDS patients,

Schmidt and Mandel reported that conservative fluid administration was shown to decrease the use of mechanical ventilation and length of stay in the intensive care unit. Thus, having flight clinicians use an IVC ultrasound-guided sepsis management guideline to direct optimal hemodynamic resuscitation during initial sepsis care can mitigate potential complications and promote positive outcomes.

**PICOT Statement**

The guiding PICOT statement for this project was: in septic adult patients, flight clinicians will utilize an IVC ultrasound-guided sepsis management guideline to guide fluid and vasopressor administration, thereby optimizing hemodynamic resuscitation and mitigating potential complications to improve patient outcomes, during air medical transport. See Appendix A for a visual schematic of this statement, corresponding factors, and this project's intervention.

**Literature Review, Matrix, and Synthesis**

The literature review utilized the Medline Complete, Cumulative Index to Nursing and Allied Health Library (CINAHL), and Cochrane Library databases. Search terms used included: adult; sepsis, septic, severe sepsis, and septic shock; fluid balance and fluid management; prehospital, pre-hospital, ambulance, emergency medical services, and EMS; management, treatment, intervention, and therapy; fluid responsiveness; ultrasound, sonography, sonogram, and ultrasonography; Donabedian; and quality improvement. To further narrow the search, inclusion criteria consisted of full text articles in the English language from scholarly, peer-reviewed journals from January 1, 2014 to December 31, 2021.

During the literature review, every appropriate article was read, analyzed, and added to the literature matrix table. This table was vital for organizing, comparing, and contrasting the information from the numerous articles. See Appendix B for the literature matrix table.

The literature that was obtained for review included recent literature from scholarly, peer-reviewed journals that correlated to the quality improvement population, intervention, and environment. Melnyk and Fineout-Overholt's hierarchy, which rates evidence from I (systematic reviews and meta-analyses of randomized controlled trials) to VII (opinion of authorities and reports of expert committees), was used to rate the level of evidence in each article (Melnyk, B. M., & Fineout-Overholt, E., 2015). Most of the articles (16 out of 19) were rated as level IV (case-control or cohort studies). Only three articles had higher levels of evidence, two were rated at level II (randomized controlled trial), and one was rated at level III (non-randomized controlled trial). Therefore, the evidence used for this project was overall moderate to high in strength.

From the extensive literature review, there were two main themes that stood out. First, the research found that using the Surviving Sepsis Campaign, which has offered a frequently used guideline for intravenous fluid administration, fluid formulation may be too aggressive and that providing less fluid and initiating vasopressors sooner has improved patient outcomes (Hjortrup et al., 2016; Ospina-Tascon et al., 2020; Seymourt et al., 2017; Sirvent et al., 2015). Secondly, multiple articles compared a variety of dynamic hemodynamic monitoring methods. They consistently showed that IVC ultrasound measurements were comparable to or even better than other noninvasive methods (Garg et al., 2016; Jia et al., 2020; McGregor et al., 2019; McGregor et al., 2020). Overall, there was a large amount of literature about sepsis

manage and hemodynamic monitoring, but there was minimal information correlating sepsis care and hemodynamic monitoring in the medical transport, especially air medical transport, environment. The environment for most of these studies took place in intensive care units or emergency departments.

**Organizational Project Information**

A private college of 4,000 undergraduate and graduate students in northern Minnesota was the supporting agency for the creation of this ultrasound-guided sepsis management guideline as a guideline recommendation project. Project sponsors included the graduate nursing staff with primary sponsorship from Dr. Mary Larson. After the completion of this guideline recommendation project, it had the potential to be transferred into a quality improvement project at an air medical transport organization.

Stakeholders associated with this project included adult sepsis patients, families of sepsis patients, sending hospitals, receiving hospitals, payers of health care, healthcare providers, and flight clinicians. These stakeholders may benefit from the success of this project physically, financially, or professionally once it can be implemented in clinical practice.

The targeted population for the ultrasound-guided sepsis management guideline included adult patients diagnosed with sepsis. This population was targeted since sepsis is a common medical condition that frequently requires air medical transport from small hospitals to larger hospitals for higher levels of care. It is also a medical condition where an improvement in the initial hours of care can ultimately improve the overall outcome for the patient. More specifically, inclusion criteria for the targeted population to participate in the created guideline included patients 18 years of age or older, diagnosed with sepsis or septic shock by the sending

hospital, and were transported via air medical transports from one medical facility to another. Exclusion criteria included patients that are younger than 18 years of age, were not diagnosed with sepsis or septic shock, were transported from a scene rather than medical facility, were pregnant, had a history of congestive heart failure or an aortic aneurysm, or were morbidly obese.

The targeted participants included this author (Marin Peterson) as the primary creator of the ultrasound-guided sepsis management guideline and the acute care medical professionals that evaluated the guideline. The targeted medical professionals were physicians, residents, physician assistants, and advanced practice registered nurses who worked in emergency departments or intensive care units.

**Gap Analysis**

Specifically at the chosen air medical transport agency, flight clinicians readily assessed septic patients, obtained vital signs, and collected point of care laboratory values to guide sepsis fluid resuscitation. In contrast, chest radiographs and lung auscultation, which can assess for fluid overload (Vardeny & Ng, 2019), cannot be completed within an aircraft. Also, invasive hemodynamic monitoring catheters cannot be inserted by the potential air medical transport organization's clinicians and were rarely placed at small rural hospitals prior to patient transports. Beyond the basic physical and laboratory assessments, advanced hemodynamic assessments are limited in air medical transport.

An implemented evidence-based ultrasound intervention for hemodynamic monitoring and management guidance could deter the downward trajectory of sepsis to septic shock and eventually death on the micro-level. There was no literature that directly corresponded the use

of IVC ultrasound with patient outcomes, hospitalization details, and healthcare costs. But in theory, if this trajectory was deterred and complications were prevented then improved patient outcomes, decreased hospital length of stays, and decreased health care costs could subsequently occur. Therefore, this micro-level change could have dramatic impacts on the meso- and macro-level of care.

**Needs Assessment**

Sepsis and septic shock need to be quickly diagnosed and aggressively treated before they progress into organ failure and death (Martin et al., 2019). Initially, airway and ventilations are ensured, followed by hemodynamic stabilization (Schmidt & Mandel, 2020). Air medical transport clinicians at the selected agency have equipment and guidelines to facilitate quality airway and ventilatory management. Conversely, these clinicians do not have any means of advanced hemodynamic monitoring of septic patients to optimally provide hemodynamic resuscitation.

The ultimate long-term goal was the utilization of the potential air medical transport agency's current Phillips Lumify ultrasound technology to complete IVC measurements to guide IV fluid and vasopressor administration during hemodynamic resuscitation of adults with sepsis. The guideline recommendation project only focused on the initial step toward this long-term goal. The project created a sepsis management guideline that can later be implemented into clinical practice. The immediate goal, or aim, of this project was to create an ultrasound-guided sepsis guideline which used IVC ultrasound measurements to determine patient-specific needs regarding the administration of IV fluids or vasopressors.

**Strengths, Weaknesses, Opportunities, and Threats Analysis**

The potential air medical transport agency's strengths, weaknesses, opportunities, and threats were assessed to allow insight into how this created guideline recommendation could be integrated into the agency for a successful long-term outcome. The agency's strengths included experienced nurses and paramedics who tend to be motivated and driven regarding their knowledge and patient care. These clinicians had a foundation of ultrasound use for assessing trauma, pregnant, or cardiac patients. Additionally, the organization already had the infrastructure to allow for this guideline recommendation project. They had ultrasound equipment at every base of operation and an education center with an ultrasound simulator. The agency also had an established education department that produced mandatory quarterly online and in-person education sessions. This established infrastructure would minimize the cost of implementing the guideline recommendation after this completed initial project.

Weaknesses included the geographic distance from all the air medical transport agency's bases of operation and their distance from the education center, and the potential clinician reaction to learning another new procedure. These bases were located throughout Minnesota and Wisconsin with the educational center located in a metropolitan area in Minnesota. This distance could create a challenge for clinicians to attend an in-person educational course if this guideline recommendation advanced to the clinical implementation stage. Other weaknesses were related to the staff. Not every clinician was as driven or willing to change their practice or learn a new procedure. Clinicians may also have some fatigue or burn out from the recent stressors secondary to the Covid-19 pandemic thereby causing less motivation to learn and complete a new procedure. Lastly, the medical directors and educators may not have extra time or motivation to accept this guideline recommendation.

Coincidentally, this was the current barrier at the beginning of this project. The medical directors were not willing to implement IVC ultrasound into clinical practice due to timing and other obligations. Since this project has now been completed, the IVC ultrasound-guided sepsis management guideline could be represented to this agency for reconsideration.

The next analysis section were the opportunities associated with this agency and project. Ultrasound is a multipurpose technology that offers a variety of health data (Connolly et al., 2017), so it could be a great opportunity for this organization to use its currently available technology to its fullest potential.

The threat to the air medical transport agency and this project was the current healthcare environment. The Covid-19 pandemic caused employees to be out for long periods of time, discouraged group gatherings, and created extra stress to the health care system.

**Theoretical Framework and Change Theory**

The Donabedian framework views quality healthcare as having seven attributes: efficacy, effectiveness, efficiency, optimality, acceptability, legitimacy, and equity (Agarwal et al., 2021). Furthermore, to improve quality, Donabedian emphasizes a structure, process, and outcome approach that is linear and progressive (Panteli et al., 2019). The Donabedian framework concludes that if there was a good structure, then there would likely be a good process, which would then likely create good outcomes (Panteli et al., 2019). Specific to this project, the created evidence-based ultrasound-guided sepsis management guideline (structure) would then be completed by trained flight clinicians with ultrasound technology (process) to improve the quality of patient care (outcome) during and after air medical transport.

The Knowledge-to-Action Cycle (KTA) is a framework that focuses on the creation of knowledge and then the implementation of the knowledge with ongoing reassessments, in a bidirectional cycle, as barriers are presented (Reavy, 2016). Knowledge creation encompasses "knowledge inquiry, synthesis, and product or tools" (Reavy, 2016, p.157). The guideline recommendation project mirrored this framework. Knowledge was obtained through a literature review and analysis. The knowledge was then synthesized into an ultrasound-guided sepsis management guideline. This guideline was assessed by medical professionals which then led into guideline reassessment and consideration for clinical implementation.

Additionally, in the KTA cycle, there are seven phases of the action cycle. This cycle addresses the identification of a problem and application of the knowledge while barriers are assessed as they arise (Reavy, 2016). During these ongoing reassessment cycles, the knowledge use is continuously monitored, outcomes are being evaluated, and the knowledge use is being maintained. These concepts were incorporated into the project during its pre-implementation, implementation, and post-implementation phases so that barriers did not hinder the guideline recommendation project's knowledge, use, and outcomes.

The Donabedian and KTA frameworks offered organized outlines that promoted the success of quality improvements in health care, including this guideline recommendation project. The KTA framework encouraged adaptation and continued use of the guideline recommendation project despite barriers as they arose.

## Goal and Objectives Clarified

The core problems regarding sepsis management were that inappropriate hemodynamic resuscitation in sepsis management led to preventable complications and that

there were limited hemodynamic monitoring options in air medical transport. The goal of this project was to optimize sepsis hemodynamic management through a created evidence-based ultrasound-guided guideline that could subsequently be implemented clinically to decrease preventable complications and improve patient outcomes.

**SMART Objectives**

There were three SMART objectives for this guideline recommendation project. The first objective, due by the end of month one, was the completion of a literature review investigating IVC ultrasound measurements and sepsis management by the guideline creator. This literature was used to obtain high-quality research for the creation an evidence-based guideline. The completion of this objective was nominally (met, not met) measured.

Next, the second objective, due after the first objective was met and by the end of month two, was the creation of the ultrasound-guided sepsis management guideline by the author. The guideline utilized IVC ultrasound measurements to guide the administration of intravenous fluids and vasopressors. The outcome measure for the creation of the ultrasound-guided sepsis management guideline was nominally (met, not met) measured.

Lastly, the third project objective was due after the first and second objectives were met and by the end of month three. It intended to have ten acute care (intensive care or emergency medicine) medical professionals provide feedback about the created guideline via an online survey. This feedback helped to determine if the guideline was ready for implementation within a medical environment or required some revisions prior to implementation. The feedback was obtained through a survey with five-point Likert scales to assess the appropriateness of the targeted population, IVC ultrasound measurements, and created guideline, and was analyzed as

interval data. Additionally, nominal and qualitative feedback was elicited as to whether the medical professionals would utilize this guideline within their current practice.

**Gantt Chart**

This guideline recommendation project was planned to be completed over a three-month period, from January 5th to April 5th, 2022. The first month was scheduled for research, the second month was the creation of the evidence-based guideline, and the third month was for professional evaluation of the guideline with data analysis. The first two milestones were primarily directed by this guideline creator (Marin Peterson) and the last milestone was directed by the guideline creator and feedback by the healthcare professionals. See Appendix C for the Gantt Chart.

**Work Breakdown**

The breakdown of work was divided between two groups. The project coordinator (Marin Peterson) completed a literature review, created a guideline, obtained feedback, analyzed the feedback, and finalized the guideline based on the feedback. The second group was the healthcare professionals that provided their feedback regarding the created guideline. The timeline for these tasks were previously discussed.

**Communication Matrix**

Communication among the groups of participants done electronically, primarily via email. Email communication allowed for multiple individuals from different education and healthcare facilities to efficiently communicate despite varying schedules and distance efficiently and effectively communicate between geographic locations. Communication consisted of this project coordinator and guideline creator (Marin Peterson) with the

sponsoring college's project chair (Dr. Mary Larson). Additional communication was between the guideline creator and the feedback participants regarding the dissemination of the guideline and the guideline evaluation survey. The survey utilized an online survey company, SurveyMonkey, (https://www.surveymonkey.com) for ease of its distribution, completion, and return. This ease was intended to promote high response rates.

### Logic Model

The short-term outcome of the project was to create an ultrasound-guided sepsis management guideline to impact the micro-level of healthcare. The guideline could then progress into a long-term, macro-level change in healthcare with an ultimate improvement in the care of sepsis and decrease in sepsis-related complications. A logic model of this project in correlation within the air medical transport agency is present in Appendix E.

### Budget

Since the project was the creation of a recommended guideline, no budget planning was required because no costs were occurred. If this guideline project was subsequently accepted by the air medical transport agency, a budget would have to be addressed. A positive aspect of this project, within the specified agency, would be a rather small cost since they already have an infrastructure to support this guideline, as was previously discussed. Costs would consist of educator and clinician wages of whom could not participate in the education within their already scheduled hours.

## Methodology and Analysis

This project was initially planned for implementation at a specific air medical transport agency due to its need for optimal sepsis management, its limited availability of advanced

hemodynamic measurement techniques, and its current infrastructure. Despite these factors, the air medical transport organization declined to accept this quality improvement project at this time. Subsequently, this project was supported by a private college in Minnesota for the creation of a guideline recommendation that could be implemented at the initial agency or other air medical transport agencies in the future.

**Intervention Plans**

This guideline recommendation project included three phases: pre-implementation, implementation, and post-implementation. The pre-implementation phase consisted of the guideline creator (Marin Peterson) using the College of St. Scholastica's literature database to obtain recent, high-quality literature regarding IVC ultrasound measurements and sepsis management. This literature was organized and analyzed. It was used to assist in the creation of an IVC ultrasound-guided hemodynamic resuscitation guideline for septic adults.

The implementation phase was the creation of an ultrasound-guided sepsis management guideline by Marin Peterson. The guideline incorporated the literature review to ensure that it was evidence-based. It was presented in a written and diaphragm format for greatest clarity.

After the creation of the guideline, the post-implementation phase began with the distribution of the guideline with an online survey to at least ten acute care medical professionals for feedback. See Appendix D for a copy of the survey tool that was transcribed into an online version on the SurveyMonkey website (https://www.surveymonkey.com) for ease of completion and timely results. The intended medical professionals included physicians,

residents, physician assistants, and advanced practice registered nurses that practice in emergency departments or intensive care units.

The guideline feedback surveys obtained interval and qualitative data. Mean values and standard deviations were determined from three questions that utilized a five-point Likert scale (one was strongly disagree, three was neutral, five was strongly agree). These three questions assessed the respondents' opinions as to the appropriateness of the guideline's targeted population, ultrasound use, and sepsis management recommendations. Additionally, two questions requested nominal (yes, no) and qualitative responses to assess whether the respondents would utilize IVC ultrasound and this guideline in their clinical practice of sepsis patients. Lastly, there were two questions to obtain demographic information (title and location of practice) of the respondents. The goal of this feedback data was to seek professional opinion as to whether this project and guideline were appropriate and deemed usable for clinical practice. The feedback could have also provided suggestions for improvement of the guideline.

## Institutional Review Board/Ethical Considerations

The proposed creation of a guideline recommendation for the use of inferior vena cava (IVC) ultrasound to guide hemodynamic resuscitation of septic adults during air medical transport was submitted to the College of St. Scholastica's institutional review board on November 16, 2021. This project was not considered research and was not utilizing actual patients. Through an expedited review process, it was approved on November 18, 2021. No ethical concerns were present.

## Implementation

An additional literature search of professional journals was completed to guide the creation of the IVC ultrasound guideline for guiding hemodynamic resuscitation of adult septic patients. The Solar search engine through the College of St. Scholastic was utilized to search multiple databases simultaneously. The search terms used included: sepsis, septic, severe sepsis or septic shock; fluid administration; ultrasound, sonography, sonogram, or ultrasonography; and guideline, protocol, practice guideline, or clinical practice guideline. The search was limited by date (January 2012 to December 2022), availability of full text, and from peer-reviewed journals. This literature was incorporated with the previous literature review to provide comprehensive, evidence-based data for the creation of an IVC ultrasound-guided hemodynamic resuscitation in septic adults guideline.

Guideline inclusion and exclusion criteria revolved around the targeted population, adults with sepsis or septic shock, and physiologic conditions that were deemed acceptable for IVC ultrasound and conditions that were deemed unsafe, not feasible, or not reliable for IVC ultrasound. Bortolotti et al. (2018) determined that IVC measurements could be used with accuracy in patients with cardiac arrhythmias, such as atrial fibrillation and those with frequent (more than six per minute) ectopic beats. Multiple studies also showed that the IVC ultrasound measurements were reliable and valid in patients that were mechanically ventilated (Kacar et al., 2019; Lu et al., 2017) or spontaneously breathing (Bortolotti et al., 2018; Caplan et al., 2020; McGregor et al., 2019; McGregor et al., 2020; Preau et al., 2017).

Furtado and Reis (2019) reported instances in which exclusion from the IVC ultrasound guideline should occur. They explained that irregular respiratory patterns cause inconsistent chest pressure variations leading to inaccurate measurements. Secondly, cardiac pathologies,

such as right ventricular dysfunction, significant tricuspid regurgitation, and pericardial tamponade, can hinder venous return which increases right atrial pressure and IVC distention. Lastly, any concerns for increased intra-abdominal (i.e. pregnancy, obesity, ascites) or intrathoracic pressure (i.e. high positive end-expiratory pressure values in mechanical ventilation) could decrease IVC compliance. These physiologic conditions could lead to false negatives.

Marik et al. (2017) analyzed 23,513 patients with severe sepsis or septic shock from multiple hospitals. They determined that an average of 4.4 liters of crystalloid fluid were administered on the first day of care, which was less than what was recommended by the Surviving Sepsis Campaign. It was found that these patients, despite the severity of their illness, who received over five liters of intravenous fluid had a 2.3% higher rate of mortality and $999 in total hospital costs per liter of fluid given over five liters. This study echoed similar studies that found excess fluid is detrimental to patient care and outcomes. This evidence directed the created guideline to focus on patient-specific amounts of fluid to be administered with a maximum intake of three liters. This maximum amount allowed for some additional fluid to be administered in the remainder of the day, subsequently pre-planning for a maximum fluid intake of less than five liters in the first 24 hours of patient care. After the three liters of fluid are administered, vasopressors can be initiated.

The most reliable IVC measurement was found to be four centimeters caudal from the right atrium and vena cava junction (Caplan et al., 2020). An ultrasound longitudinal view in the M-mode allowed for observing the IVC in inspiration and exhalation (Dean, 2017; DeBacker & Fagnoul, 2014; Furtado & Reis, 2019). A captured 2-dimensional image should be measured

with the ultrasound calipers. The longitudinal view allowed for easier identification of the vena cava by less-experienced practitioners and a decreased likelihood of having the image move during the respiratory cycle which can cause inaccurate measurements (Dean, 2017).

The IVC collapsibility index (IVCCI) was utilized rather than IVC diameters alone since IVC diameter sizes and the patient's response to fluids vary individually. Lee et al. (2015) reported that maximal IVC diameters ranged from nine to 27 millimeters in healthy individuals. Additionally, a septic patient's response to IV fluids was not a linear measurement. It depended upon the Frank-Starling curve, which is the ability of the myocardium to contract (Furtado & Reis, 2019). The IVCCI cannot measure the myocardium contractibility but can attempt to capture how the cardiac output has responded to the increase in intravascular volume after IV fluid administration. The formula used to calculate the IVC collapsibility index is IVCCI=(IVCmax–IVCmin)/IVCmax (Dean, 2017). The minimum diameter of the IVC was the IVCmin, which occurs during inspiration, and the maximum diameter of the IVC was the IVCmax, which occurs during exhalation.

The IVCCI cut-off value, which determined the need for additional intravascular fluid, was found to be from 39% to 42% in four studies. Airapentian et al. (2015) reported that a 42% cutoff had a specificity of 97% and a positive predictive value of 90%. Bortolotti et al. (2018) reported a 39% cutoff had a specificity of 88% and sensitivity of 93%. Muller et al. (2012) reported a 40% cutoff had a specificity of 80% and sensitivity of 70%. Lastly, Preau et al. (2017) reported a 41% cutoff value had a specificity of 90% and sensitivity of 56%. For this guideline, the average of 40% was used to guide the use of IV fluid administration.

The literature suggested that calculating the respiratory variation of the IVC in mechanically ventilated patients and non-intubated patients are valid, but it was discussed that a different calculation may be required since they differ between positive- and negative-pressure ventilation physiologies. It was suggested that the IVC distensibility index [(IVCmax-IVCmin)/IVCmin] (Kaptein & Kaptein, 2021; Lee et al., 2015) or the respiratory variation in IVC diameter calculation of (IVCmax-IVCmin)/[(IVCmax+IVCmin)/2] (Lee et al., 2015) may be more accurate calculation methods for mechanically ventilated patients. Therefore, this project decreased the eligible population to only those that are non-intubated and used only the IVCCI for simplicity. If this project were to be implemented and show positive results, the project could later be expanded to include mechanically ventilated patients and different calculation methods.

This evidence led into the creation of the hemodynamic resuscitation guideline which incorporated the ongoing calculation of the total fluid administered, mean arterial pressure (MAP) readings, and IVCCI calculations from ultrasound measurements. Once a total of three liters of IV fluids were administered, a vasopressor should be initiated despite the IVCCI. If a MAP was greater than 65mmHg, there was no need for additional IV fluid boluses or vasopressor use (or titration if it has already been started) but MAPs should be rechecked every 15 minutes. If the MAP was less than 65mmHg and the IVCCI was less than 40%, a 500mL crystalloid IV fluid bolus over 15 minutes should be administered and then the IVCCI and MAP should be reassessed. If the MAP was less than 65mmHg and the IVCCI was greater than 40%, a vasopressor (per the specific medical organization's administration guidelines) should be initiated or titrated and a MAP rechecked every 15 minutes and IVCCI every 30 minutes. When

reassessments of the MAP or IVCCI are completed, the care should be continued based upon those results and the previously mentioned interventions. Clinical judgement should always be utilized along with this guideline, and the guideline can be overridden if needed. See Appendix F for an outline of the guideline and diagram.

The completed Inferior Vena Cava Ultrasound to Guide Hemodynamic Resuscitation in Non-intubated Septic Adults guideline was emailed to six acute care medical providers with permission (and encouragement) for them to forward the guideline and feedback survey to their peers who may be interested in participating. The goal was to receive ten survey responses for feedback. See Appendix G for the cover letter that was attached to the email and guideline which provided some background information on this project for the medical providers.

**Results from Data Collection**

The data from the surveys were analyzed using the Intellectus Statistics website. Questions one through three of the surveys assessed the appropriateness of the targeted population, IVC ultrasound use in septic patients, and the guideline recommendations, respectively. These questions had a Cronbach's alpha coefficient of 1.00 (using a confidence interval of 95%), which indicated excellent reliability.

These three questions collected data using a five-point Likert scale (one was strongly disagree, three was neutral, five was strongly agree). Question one had an average of 4.25 (*SD* = 0.96, $SE_M$ = 0.48, Min = 3.00, Max = 5.00, Skewness = -0.49, Kurtosis = -1.37). Question two had an average of 4.25 (*SD* = 0.96, $SE_M$ = 0.48, Min = 3.00, Max = 5.00, Skewness = -0.49, Kurtosis = -

1.37). Question three had an average of 4.25 (*SD* = 0.96, $SE_M$ = 0.48, Min = 3.00, Max = 5.00, Skewness = -0.49, Kurtosis = -1.37).

**Table 1**

*Summary Statistics Table for Interval and Ratio Variables*

| Variable | *M* | *SD* | *n* | $SE_M$ | Min | Max | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|
| Q1_appropriate_population | 4.25 | 0.96 | 4 | 0.48 | 3.00 | 5.00 | -0.49 | -1.37 |
| Q2_appropriate_intervention | 4.25 | 0.96 | 4 | 0.48 | 3.00 | 5.00 | -0.49 | -1.37 |
| Q3_appropriate_recommendations | 4.25 | 0.96 | 4 | 0.48 | 3.00 | 5.00 | -0.49 | -1.37 |

*Note.* Table created through Intellectus Statistics (2019).

Of the distributed guidelines with surveys, only four surveys were completed. These surveys were completed anonymously by three physicians who worked in emergency departments and one physician that worked in the emergency department and family medicine.

The most frequently reported response in question four, *In your professional care, would you use IVC ultrasound for sepsis management?,* was *Yes* (*n* = 3, 75.00%). These respondents added that they would use this procedure since it "helps guide fluid management" and is "easily accessible in my setting." The most frequently reported response in question five, *In your professional care, would you use these management recommendations for sepsis care?,* was *Yes* (*n* = 3, 75.00%) with explanations that it "guides medical management" and "helps guide fluid resus." There was one survey that did not provide a *Yes* or *No* response to questions four or five and only provided a qualitative response. This respondent reported that they do use IVC ultrasound regularly in their practice but as a qualitative measurement for determining the type of shock present in critically hypotensive patients.

Frequencies and percentages are presented in Table 2.

**Table 2**

*Frequency Table for Nominal Variables*

| Variable | *n* | *%* |
|---|---|---|
| Q4_would_you_use_IVC_US | | |
| YES | 3 | 75.00 |
| No | 0 | 0.00 |
| Missing Data | 1 | 25.00 |
| Q5_would_you_use_this_guideline | | |
| YES | 3 | 75.00 |
| No | 0 | 0.00 |
| Missing Data | 1 | 25.00 |

*Note.* Table created through Intellectus Statistics (2019).

**Discussion of Data**

The survey results were overall positive regarding the guideline and its potential use in practice. Three emergency medicine physicians agreed or strongly agreed with the use of IVC ultrasound in septic patients and that they would use it within their own practice due to availability and usefulness in guiding medical care. One emergency medicine physician was neutral about the use of IVC ultrasound in septic patients and this guideline. They further clarified that they believed that IVC ultrasound can be useful and was used frequently within their practice but more so for qualitative feedback and diagnostic purposes.

To strengthen the feedback of this guideline recommendation project, more survey responses could have been obtained and from more diverse respondents. Only four responses were obtained out of six known surveys distributed. Additional surveys may have been distributed by the initial six provider who were contacted, but the total number of distributed

surveys were unknown. A larger response would have provided greater insight or a stronger stance for or against the use of IVC ultrasound and the proposed guideline. Also, the respondents were only physicians who worked in emergency departments. If other providers, such as physician assistants or advance practice registered nurses, or providers from intensive care units could have also completed the survey, a different view may have been obtained. This differing view could have provided additional insight into the guideline.

Additionally, there was minimal constructive feedback provided. Most of the qualitative feedback was brief and positively reflected the use of IVC ultrasound and this guideline. One respondent addressed their concern that IVC ultrasound was useful in practice but was more useful in qualitative measurements and overall diagnosis. This physician's feedback may suggest that they believed that IVC ultrasound and this guideline may not be useful in dynamic guiding of hemodynamic resuscitation, or it may suggest that this physician has not used IVC ultrasound in this way. Having additional qualitative feedback from more survey responses with additional suggestions for improvement and opinions could strength the project or provide insight into the project's shortcomings. Additionally, if a future survey was created for additional feedback, the questions could prompt for more specific feedback, such as if the respondent has any specific suggestions for guideline changes or improvement.

**Dissemination**

Prior to dissemination of this guideline recommendation, additional feedback should be obtained to ensure its quality and that it does not require any alteration prior to clinical use. After additional feedback, this guideline can be offered to the initially identified air medical transport organization that currently utilizes ultrasound for other patient care interventions.

Other organizations that use ultrasound can also be sought and provided with this information for the advancement of their patient care. It is possible, that this guideline could be offered to other medical environments. Rural hospitals or any emergency departments with limited hemodynamic monitoring capabilities or with time-sensitive patient care situations in which invasive hemodynamic monitoring equipment cannot be place promptly could benefit from IVC ultrasound and this hemodynamic resuscitation guideline.

If an organization accepts the guideline recommendation for hemodynamic management of their septic adults, they could collect data pre- and post-implementation. This data would help determine if this project's primary goal of improving septic patient outcomes was achieved.

**Conclusion**

IVC ultrasound can be used as an advanced hemodynamic assessment tool in septic patients to administer IV fluids and vasopressors in a patient-specific manner, thereby optimizing sepsis care and decreasing the complications of fluid overload. This subsequently can improve a patient's overall health outcomes and provide a decrease in health care costs. IVC ultrasound is also a feasible and reliable diagnostic tool for the unique and resource-limited air medical transport environment to improve the quality of care in sepsis management.

A guideline was created for using IVC ultrasound to guide hemodynamic resuscitation in septic adults. This guideline was received by most emergency department physicians who reported that they would use it in their own practice. Other than just in the air medical transport environment, this guideline has the potential to improve health outcomes of septic

patients in any medical environment with limited access to invasive hemodynamic monitoring environments or in which the patient requires prompt hemodynamic assessment.

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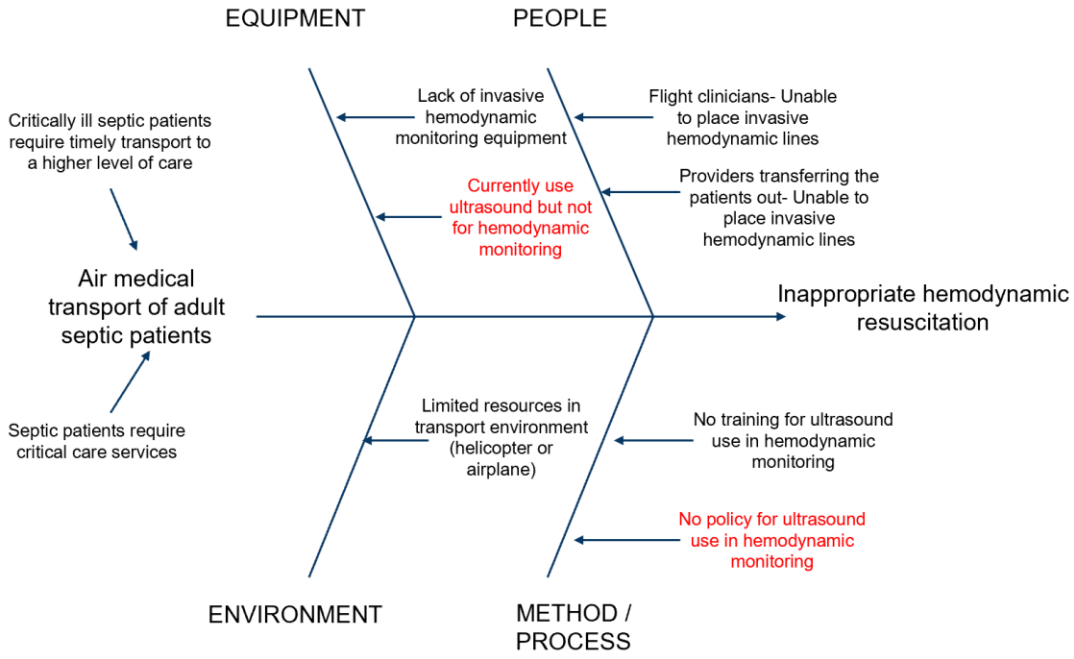
## Appendix A: PICOT Schematic

**Inappropriate hemodynamic resuscitation may cause medical complications (pulmonary edema, ARDS), increased use of mechanical ventilation, and increased length of stays in the intensive care unit (Schmidt & Mandel, 2020).**




Intervention: Create a policy for the use of ultrasound to guide hemodynamic resuscitation in septic adults to ultimately provide optimal hemodynamic, thus decreasing complications.

## Appendix B: Literature Matrix Table

| Reference | Purpose/ Question | Design | Sample | Intervention | Results | Notes |
|---|---|---|---|---|---|---|
| Agarwal, N., Youngerman, B., Kaakaji, W., Smith, G., McGregor, J. M., Powers, C. J., Guthikonda, B., Menger, R., Schirmer, C. M., Rosenow, J. M., Cozzens, J., & Kimmell, K. T. (2021). Optimizing medical care via practice guidelines and quality improvement initiatives. *World Neurosurgery.* https://doi.org/10.1016/j.wneu.2021.02.013<br><br>United States<br><br>Level of Evidence (Melynk & Fineout-Overholt, 2015): N/A | Promote the use of clinical practice guidelines and quality improvement initiatives to improve patient care, quality of care, and healthcare costs. | N/A | N/A | N/A | Promotion of clinical practice guidelines and quality improvement initiatives based off safe and evidence-based practice. | |
| Betancourt, M. G., Moreno-Montoya, J., Gonzalez, A. B., Ovalle, J. C., & Martinez, Y. F. B. (2016). Learning process and improvement of point-of-care ultrasound technique for subxiphoid visualization of | Determine the number of ultrasound procedures needed to be done to achieve competency in optimal image quality. | Cohort study | 8 medical residents of any residency year and who have had no previous ultrasound experience | Medical residents attended a 40-minute educational conference regarding the ultrasound procedure. Then utilized 3 human models to evaluate IVC measurements | Average time for each image procedure was 17.3 seconds.<br><br>11 repetitions showed a rate of 80% acceptable image quality. 21 repetitions showed a rate of 90% acceptable image quality. | |

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| the inferior vena cava. *Critical Ultrasound Journal, 8*(4). https://doi.org/10.1186/s13089-016-0040-1<br><br>Colombia<br><br>Level of Evidence (Melynk & Fineout-Overholt, 2015): IV | | | | for a total of 25 times per resident. Images were evaluated by an emergency medicine physician (expert) in this technique. | Results positively correlate with other studies and the American College of Emergency Physicians' recommendations | |
| Bortolotti, P., Colling, D., Colas, V., Voisin, B., Dewavrin, F., & Poissy, J. (2018). Respiratory changes of the inferior vena cava diameter predict fluid responsiveness in spontaneously breathing patients with cardiac arrhythmias. *Annals of Intensive Care, 8*(1). http://dx.doi.org/10.1186/s13613-018-0427-1<br><br>France<br><br>Level of Evidence (Melynk & Fineout-Overholt, 2015): IV | Evaluate the reliability of IVC collapsibility to predict preload dependence in patients with arrhythmias. | Prospective cohort study | 55 adult patients in an ICU of 2 different hospitals who had irregular cardiac rhythms (atrial fibrillation n=29 or recurrent atrial extrasystoles >6/min n=26) and signs of acute circulatory failure.<br><br>Data taken from May 2012 - May 2015.<br><br>Exclusion criteria: high-grade aortic insufficiency, impaired transthoracic or abdominal echogenicity | The patients were all spontaneously breathing and in semi-recumbent position. They had measurements taken prior to and after a 500ml infusion of 4% gelatin (volume expander).<br><br>Measurements included vital signs, oral cavity pressures (measured standard and deep inspirations), IVC diameters during 3 spontaneous and 3 standardized respiratory cycles, and velocity time integral measures of aortic blood flow during 1 | Determined that IVC collapsibility is an accurate predictor of fluid responsiveness in spontaneously breathing patients with arrhythmias. The standard breathing IVC collapsibility was found to have a specificity of 88% and sensitivity of 93%. | Spontaneous breathing |

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| | | | , active exhalation, pulmonary edema due to heart failure, pregnancy, abdominal compartment syndrome. | or more spontaneous respiratory cycles.<br><br>US measurements taken by 3 blinded US experts. | | |
| Caplan, M., Durand, A., Bortolotti, P., Colling, D., Goutay, J., Duburcq, T., Drumez, E., Rouze, A., Nseir, S., Howsam, M., Onimus, T., Favory, R., & Preau, S. (2020). Measurement site of inferior vena cava diameter affects the accuracy with which fluid responsiveness can be predicted in spontaneously breathing patients: A post hoc analysis of two prospective cohorts. *Annals of Intensive Care, 10*(168). https://doi.org/10.1186/s13613-020-00786-1<br><br>France<br><br>Level of Evidence (Melynk & Fineout-Overholt, 2015): IV | Test the accuracy of different IVC measurement sites in spontaneously breathing patients with sepsis-related circulatory failure. | Cohort study, completed post hoc from 2 previous prospective cohorts | 81 adult patients who are spontaneously breathing and receiving care for sepsis in an ICU with symptoms of circulatory failure.<br><br>Exclusion criteria: high-grade aortic insufficiency, inability to obtain an ultrasound view, active exhalation, pulmonary edema, heart failure, abdominal compartment syndrome. | Data was collected from velocity-time integral of aortic blood flow measurements by doppler and IVC measurements which were compared with standardized and non-standardized breathing maneuvers. | A linear correlation was found between IVC measurements and standard breathing with volume expansion changes in stroke volume. The most reliable IVC measurement site was found to be 4cm caudal from the cavo-atrial junction. | Spontaneously breathing |
| DeLorenzo, R. A., & Holbrook- | Evaluate the effectiveness | Cohort study | 14 registered | Nurses attended a | Results showed that the nurses had | |

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| Emmons, V. L. (2014). Ultrasound measurement of inferior vena cava diameters by emergency department nurses. *Advanced Emergency Nursing Journal, 36*(3), 271-278. https://doi.org/10.1097/TME.0000000000000025<br><br>United States<br><br>Level of Evidence (Melynk & Fineout-Overholt, 2015): IV | of training nurses to complete US measurements. | | nurses from the emergency department and critical care unit, who had no ultrasound experience, were selected through a convenience sample. | structured, 3.5-hour US training program: included basic principles to hands on practice with peers. Then nurses completed US exams on patients. Expert sonographer from research team also completed an exam on the same patient. The nurse and sonographer were blinded to each other's results. | slight overestimation of transverse measurements, but was not clinically significant. The nurse-expert correlation coefficients were 0.68 for the longitudinal view and 0.59 for the transverse view. Overall, nurses can be trained through a short didactic and hands-on educational program to measure the IVC with reasonable accuracy. | |
| Froehlich, A., Tegtmeier, R. J., Faine, B. A., Reece, J., Ahmed, A., & Mohr, N. M. (2019). Opportunities for achieving resuscitation goals during the inter-emergency department transfer of severe sepsis patients by emergency medical services: A case series. *Journal of Critical Care, 52*, 163-165. https://doi.org/10.1016/j.jcrc.2019.04.017<br><br>United States | Analyze emergency medical services (EMS) that provide interfacility transfer and care to adult sepsis patients and determine how it contributes to sepsis treatment goals. | Retrospective cohort study | 39 adult patients that were transferred by 13 ambulance services between 9 hospitals | No intervention was completed.<br><br>Data was retrieved from EMS patient records and the sending/receiving facilities. The data measured IV fluid administration, antibiotic administration, and lactate levels drawn. This data was compared to the sepsis treatment goals from the Surviving Sepsis | 74% of the patients were transported after the three-hour initial guideline goals. 28% (n=11) were within the three-hour window which allowed EMS an opportunity to help achieve the sepsis treatment goals. Of the 28%, only 27% (n=3) met the fluid administration goals. Out of all the patients, 77% received antibiotics prior to transfer and only 5% received antibiotics in transport. No lactate levels were drawn during transport. | |

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| Level of Evidence (Melynk & Fineout-Overholt, 2015): IV | | | | Campaign guidelines. | Results show gaps in care and the achievement of sepsis treatment goals that could potentially be accomplished by EMS. | |
| Garg, M., Sen, J., Goyal, S., & Chaudhry, D. (2016). Comparative evaluation of central venous pressure and sonographic inferior vena cava variability in assessing fluid responsiveness in septic shock. *Indian Journal of Critical Care Medicine, 20*(12), 708-713. https://doi.org/10.4103/0972-5229.195706<br><br>India<br><br>Level of Evidence (Melynk & Fineout-Overholt, 2015): II | Compare the efficacy of IVC collapsibility index vs central venous pressure (CVP) in predicting fluid responsiveness in septic shock. | Prospective randomized study | 31 septic shock patients that required either invasive or non-invasive ventilatory support.<br><br>Exclusion criteria: congestive heart failure, elevated intra-abdominal pressure, poor echo window | The patients were randomly divided into one of two groups: CVP (n=15) and IVC CI (n=16).<br><br>Both groups were given 500ml fluid boluses with measurements obtained until one of the designated endpoints (MAP ≥65, CVP >12, or IVC CI <20%) were reached. | Comparing the results of the two groups, the IVC CI is noninferior to CVP. Both groups had no difference in fluid administration and outcome variables (pulse rate, mean blood pressure, pH) | Mechanically ventilated |
| Hjortrup, P. B., Haase, N., Bundgaard, H., Thomsen, S. L., Winding, R., Pettila, V., Aaen, A., Lodahl, D., Berthelsen, R. E., Christensen, H., Madsen, M. B., Winkel, P., Wetterslev, J., Perner, A., The CLASSIC Trial Group, & The | Comparing the effects of restricting IV fluid administration versus standard protocol of IV fluid administration for septic adult patients within the ICU. | Randomized control trial<br><br>Computer randomized with blinded statistician | 151 adult patients with septic shock in 9 Scandinavian ICUs | Standard Protocol: Administration of crystalloid fluids based on the Surviving Sepsis Campaign guidelines-state and dynamic hemodynamic measurements | Between the cohorts, there were no differences in the rates of fluid or norepinephrine adverse reactions. There were no statistically significant differences in the rate of death at day 90, duration of mechanical ventilation, need for renal therapy, and | |

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| Scandinavian Critical Care Trials Group. (2016). Restricting volumes of resuscitation fluid in adults with septic shock after initial management: The CLASSIC randomized, parallel-group, multicentre feasibility trial. *Intensive Care Medicine, 42,* 1695-1705. https://doi.org/10.1007/s00134-016-4500-7<br><br>Countries of Scandinavia<br><br>Level of Evidence (Melynk & Fineout-Overholt, 2015): II | | | | Fluid Restriction: Administration of crystalloid in 250-500ml boluses based on signs of severe hypoperfusion (1. lactate ≥ 4 mmol/L, 2. MAP < 50 despite norepinephrine infusion, 3. mottling beyond kneecap edge, 4. oliguria) | number of ischemic events.<br><br>The fluid restriction group had lower rates of worsening acute kidney injury (standard 39 of 72, restriction 27 of 73). | |
| Jaramillo, G. D., & Ramirez, S. M. (2021). USER protocol as a guide to resuscitation of the patient with septic shock in the emergency department. *Open Access Emergency Medicine, 13,* 33-43.<br><br>Colombia<br><br>Level of Evidence (Melynk & Fineout- | Compare standard IV fluid administration based on the Surviving Sepsis Campaign vs basing IV fluid/ vasopressor administration on the patient's fluid volume assessed through ultrasound in sepsis patients. | Prospective, controlled cohort study | 83 adult (> 18 years old) sepsis patients that started care in the emergency department.<br><br>Data taken from August 2019 - January 2020. | 1. Control group (n=44): Start IV fluid administration of an initial bolus 30ml/kg.<br><br>2. Intervention group (n=39): Use of US (passive leg rising test by doppler-guided carotid flow test and/or doppler snuffbox resistance index) to guide fluid and | Fluid balances were statistically significantly less in the intervention group at 4 and 6 hours of care and the initiation time of norepinephrine was significantly shorter (at 3hrs, 53% of the intervention group had norepinephrine vs 18.8% of the control group). There was a significant decrease in the time to BP MAP >65 mmHg in the intervention group. No | Uses different US volume measurement methods than measuring the IVC. |

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| Overholt, 2015): III | | | | vasopressor administration.<br><br>Outcomes measured were mortality rates, fluid balances, time of vasopressor administration, time of recovered blood pressure. | difference in ICU length of stay, hospital length of stay, and mortality rate. | |
| Jia, M., Yang, J., Peng, F., Wang, Y., Liao, G., & Gao, Y. (2020). Analysis of volume management by comparing between critical care ultrasound examination and pulse indicator cardiac output in patients with septic shock. *Journal of the Pakistan Medical Association, 70*(10), 51-56.<br><br>China<br><br>Level of Evidence (Melynk & Fineout-Overholt, 2015): IV | Compare the use of US examinations and pulse indicator cardiac output (PICCO) to assess intravascular volume in septic shock patients. | Comparative study | 30 adults (≥ 18 years) diagnosed with septic shock and cared for in the ICU from July 2017 to June 2018.<br><br>Exclusion criteria: Contraindications for PICCO catheterization, inability to obtain IVC US measurements, and ICU treatment time was less than 3 days. | IVC, PICCO, and CVP measurements, in addition to lactic acid and oxygenation index measurements, were taken at 0700 on the first, second, and third day of ICU admission and were taken at 1600 on the first day. The data was then analyzed. | Accuracy was: CVP 53.3%, IVCmax 83.3%, IVCmin 90.0%, total end-diastolic volume index (GEDI) 76.7%.<br><br>Shows IVC and PICCO are accurate, and more accurate than PVC. PICCO requires an invasive catheter which has potential complications.<br><br>Using the lactate and oxygenation levels, there was an ideal IVC measurement of 1.5≤IVC<2cm for IVCmin and 2≤IVC<2.5cm for IVCmax. No ideal PICCO could be determined. | Unknown if patients were spontaneously breathing or mechanically ventilated. |
| Kacar, C. K., Uzundere, O., & Yektas, Abdulkadir. (2019). A two parameters for the evaluation of hypovolemia in patients with septic shock: | Determine the correlation between the IVC collapsibility index and cardiac output changes that | Prospective observational cohort study | 56 adults (ages 18-90 years) diagnosed with septic shock.<br>Data taken from June 2017 to | All patients received parasternal long axis subcostal cardiac imaging, subxiphoid IVC imaging, and left ventricular | There was a moderate positive correlation with was statistically significant (P=0.008) between the IVC collapsibility index and cardiac output. Researchers determined either | Mechanically ventilated but were spontaneously breathing. |

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| Inferior vena cava collapsibility index (IVCCI), delta cardiac output. *Medical Science Monitor, 25,* 8105-8111. https://doi.org/10.12659/MSM.919434<br><br>Turkey<br><br>Level of Evidence (Melynk & Fineout-Overholt, 2015): IV | occur during passive leg raising test of spontaneously breathing intubated septic patients. | | December 2017 | out flow tract imaging completed by a cardiologist and intensive care specialist. | measurement could be utilized to determine hypovolemia in septic shock. | |
| Kashyap, R., Anderson, P. W., Vakil, A., Russi, C. S., & Cartin-Ceba, R. (2016). A retrospective comparison of helicopter transport versus ground transport in patients with severe sepsis and septic shock. *International Journal of Emergency Medicine, 9*(15). https://doi.org/10.1186/s12245-016-0115-6<br><br>United States<br><br>Level of Evidence (Melynk & Fineout-Overholt, 2015): IV | Investigate the role of helicopter EMS in transporting severe sepsis and septic shock adult patients. | Retrospective cohort study | 181 adult (>18 years old) patients diagnosed with severe sepsis or septic shock and were transported from an acute care facility by ground or air medical services | No intervention was completed.<br><br>The patients were divided into two cohorts:<br>1. ground transport (n=121)<br>2. air transport (n=60). | Patients transported by air met the severe sepsis/septic shock criteria sooner than the ground transport (1.2 vs 2.9 hours) and had higher SOFA scores (9 vs 7). Patients transported by air were more likely to develop ARDS, require mechanical ventilation, and have higher mortality rates. Air had faster transport times (1.3 vs 1.7 hours). Faster transport times trended towards decreased mortality but it was not statistically significant. | |
| Lu, N., Xi, X., Jiang, L., Yang, D., & Yin, K. (2017). Exploring the best | Evaluate the effectiveness in determining fluid | Prospective observational study | 49 adults (≥18 years) diagnosed with septic shock and | Before and after a 200ml fluid bolus, the two cohorts had | If the patients had an increase in their cardiac index of ≥10% then they were deemed to be | Mechanically ventilated |

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| predictors of fluid responsiveness in patients with septic shock. *American Journal of Emergency Medicine, 35,* 1258-1261. http://dx.doi.org/10.1016/j.ajem.2017.03.052<br><br>China<br><br>Level of Evidence (Melynk & Fineout-Overholt, 2015): IV | responsiveness in multiple invasive and noninvasive hemodynamic measurement methods. | | required mechanical ventilation.<br><br>Exclusion criteria: contraindication to fluid resuscitation, pregnancy, neurogenic shock, arrhythmia, peripheral vascular disease or stenosis, contraindications to abdominal US.<br><br>Data taken from January 2012 to December 2015. | measurements taken: CVP, intrathoracic blood volume index, stroke volume variation (SVV), pleth variability index (PVI), IVC diameter US, brachial artery US, and carotid artery US to determine fluid responsiveness.<br><br>US measurements were completed by an ultrasound technician. | fluid responders (n=27), those that did not were non-responders (n=22).<br><br>Before the fluid bolus, the responder cohort had higher SVV, PVI, IVC, brachial, and carotid readings compared to the non-responder cohort. A positive correlation was made with all of this measurements and the cardiac index after the fluid challenge, but carotid artery ultrasound was found to be the best predictor for fluid responsiveness. | |
| McGregor, D., Sharma, S., Gupta, S., Ahmed, S., Godec, T., & Harris, T. (2019). Emergency department non-invasive cardiac output study (EDNICO): A feasibility and repeatability study. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine, 27*(30). https://doi.org/1 | Evaluate the feasibility and repeatability of 6 non-invasive fluid responsiveness assessment methods associated with cardiac output in the emergency department. | Prospective observational study | 76 adult (>18 yrs) patients that required IV fluid administration<br><br>Exclusion criteria: pregnancy, abdominal surgery, mechanical ventilation, immediate intervention required | The tested methods were done before and after a 250-500ml IV fluid bolus. They were completed by trained junior residents or emergency department nurses.<br><br>Tested methods:<br>1. left ventricular outflow tract echocardiography derived velocity time integral | The feasibility rates included 97.6% for bioreactance (highest), 84.1% for IVC collapsibility index (middle), and 76.8% for suprasternal aortic doppler (lowest). No difference in repeatability among all of the methods. Mean time regarding ultrasound methods was 2 min 30 seconds compared to bioreactance and the plethysmography method which took a median time of over 7 minutes. | Spontaneously breathing |

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| 0.1186/s13049-019-0586-6<br><br>United Kingdom<br><br>Level of Evidence (Melynk & Fineout-Overholt, 2015): IV | | | | 2. common carotid artery blood flow US<br>3. suprasternal aortic doppler<br>4. bioreactance<br>5. plethysmography with digital vascular unloading method<br>6. IVC collapsibility index | | |
| McGregor, D., Sharma, S., Gupta, S., Ahmed, S., & Harris, T. (2020). Emergency department non-invasive cardiac output study (EDNICO): An accuracy study. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine, 28*(8). https://doi.org/10.1186/s13049-020-0704-5<br><br>United Kingdom<br><br>Level of Evidence (Melynk & Fineout-Overholt, 2015): IV | Determine the accuracy of 5 non-invasive measurement methods in assessing fluid responsiveness in adult patients within the emergency department. | Prospective observational study | 76 adult patients were recruited in the initial study, this study utilized the data from 33 of those patients who received 250-500ml of IV fluids<br><br>Exclusion criteria: Mechanical ventilation, shock, voluntary withdrawal, IV fluid administration outside of inclusion criteria | 5 methods were tested against a reference standard (left ventricular outflow tract echocardiography derived velocity time integral)<br><br>Tested methods:<br>1. common carotid artery blood flow US<br>2. suprasternal aortic doppler<br>3. bioreactance<br>4. plethysmography with digital vascular unloading method<br>5. IVC collapsibility index | Specificity and sensitivity for each test:<br>1. common carotid artery blood flow US<br>46.2% & 45%<br><br>2. suprasternal aortic doppler<br>61.5% & 63.2%<br><br>3. bioreactance<br>46.2% & 50%<br><br>4. plethysmography with digital vascular unloading<br>50% & 41.2%<br><br>5. IVC collapsibility index<br>63.6% & 47.4% | Spontaneously breathing |
| Mohr, N. M., Harland, K. K., Shane, D. M., Ahmed, A., Fuller, B. M., & Torner, J. C. | Evaluate the impact of regionalization of sepsis care, and the cost and role | Observational case-control study | 18,246 adults (≥18 years old) diagnosed with severe sepsis or | The patients were divided into 2 cohorts:<br>1. Patients that were transferred to | Of all the patients, 63% were from rural areas. Of the transferred patients, there were higher rates of | Encourages the benefits of regionalization |

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| (2016). Inter-hospital transfer is associated with increased mortality and costs in severe sepsis and septic shock: An instrumental variables approach. *Journal of Critical Care, 36,* 187-194. http://dx.doi.org/10.1016/j.jcrc.2016.07.016<br><br>United States<br><br>Level of Evidence (Melynk & Fineout-Overholt, 2015): IV | of interfacility transfers of sepsis patients. | | septic shock and treated in Iowa emergency departments from 1/1/2005 to 12/31/2014. | another hospital.<br>2. Patients that remained within their local hospital and were not transferred. | mortality (20% vs 12%) and had longer hospital stays (9 vs 4 days). The patients that transferred out of an inpatient setting had higher mortality rates than those transferred directly out of the ER (23% vs 19%). Costs were higher for the transferred group and was attributed to differences in inpatient medical costs. | and the better sepsis care and adherence to sepsis guidelines at larger, more specialized hospitals. |
| Ospina-Tascon, G. A., Hernandez, G., Alvarez, I., Calderon-Tapia, L. E., Manzano-Nunez, R., Sanchez-Ortiz, A. I., Quinones, E., Ruiz-Yucuma, J. E., Aldana, J. L., Teboul, J., Cavalcanti, A. B., DeBacker, D., & Bakker, J. (2020). Effects of very early start of norepinephrine in patients with septic shock: A propensity score-based analysis. *Critical Care 24*(52). https://doi.org/10.1186/s13054-020-2756-3 | Evaluate if the administration of vasopressors early on in septic shock treatment, even prior to the completion of the initial IV fluid bolus, would improve patient outcomes. | Cohort study using prospective data<br><br>Study utilized 1:1 propensity matching of two cohorts based on similar variables for additional data analysis | 337 adults with septic shock being treated in an ICU over a 24-month time period (1/2015-2/2017)<br><br>During patient matching analysis, 93 patients had very early administration of vasopressors and 93 patients had delayed administration of vasopressors | Patients were divided into cohorts based on when their vasopressor was initiated:<br>1. very early administration was during or <1hr after initial IV fluid bolus,<br>2. delayed administration was >1hr after initial IV fluid bolus.<br><br>The initiation of the vasopressor was determined by hemodynamic, pulse pressure, and stroke volume | The very early vasopressor administration group had received significantly less fluids throughout their entire hospitalization, a lower fluid balance, and a significantly decreased rate of mortality. | Study used dynamic hemodynamic monitoring (including US) to determine when to initiate vasopressor. |

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| Colombia<br><br>Level of Evidence (Melynk & Fineout-Overholt, 2015): IV | | | | measurements. | | |
| Panteli, D., Quentin, W., & Busse, R. (2019). Understanding healthcare quality strategies: A five-lens framework. *Improving Healthcare Quality in Europe: Characteristics, Effectiveness and Implementation of Different Strategies.* https://www.ncbi.nlm.nih.gov/books/NBK549261/<br><br>Denmark<br><br>Level of Evidence (Melynk & Fineout-Overholt, 2015): N/A | Create a comprehensive healthcare quality improvement framework. | N/A | N/A | N/A | Reviewed previous healthcare quality improvement models to create a comprehensive model. | |
| Preau, S., Bortolotti, P., Colling, D., Dewavrin, F., Colas, V., Voisin, B., Onimus, T., Drumez, E., Durocher, A., Redheuil, & Saulnier, F. (2017). Diagnostic accuracy of the inferior vena | Determine if the IVC collapsibility index during deep standardized inspiration of non-intubated patients can predict fluid responsiveness | Prospective study | 90 non-intubated adult patients with spontaneous breathing, normal sinus rhythm, and sepsis.<br><br>Exclusion criteria: high-grade | The patients were in a semi-recumbent position with the head of bed at 30-40 degrees. Vital signs, oral cavity pressures (measures standard and deep | Using the IVC collapsibility index with deep standardized inspiration is a feasible predictor of fluid responsiveness in non-intubated septic patients-sensitivity of 84% and specificity of 90%. | Spontaneously breathing |

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| cava collapsibility to predict fluid responsiveness in spontaneously breathing patients with sepsis and acute circulatory failure. *Critical Care Medicine, 45*(3). https://doi.org/10.1097/CCM.0000000000002090<br><br>France<br><br>Level of Evidence (Melynk & Fineout-Overholt, 2015): IV | | | aortic insufficiency, inability to US, active exhalation, pulmonary edema, pregnancy, or abdominal compartment syndrome.<br><br>Data taken from November 2011 to January 2014. | inspirations), and US images were taken before and after an infusion of 4% gelatin 500ml over 30 minutes.<br><br>US measurements were taken by trained operators blinded to the clinical data and results. | | |
| Rhodes, A., Evans, L. E., Alhazzani, W., Levy, M. M., Antonelli, M., Ferrer, R., Kumar, A., Sevransky, J. E., Sprung, C. L., Nunnally, M. E., Rochwerg, B., Rubenfeld, G. D., Angus, D. C., Annane, D., Beale, R. J., Bellinghan, G. J., Bernard, G. R. Chiche, J., Coopersmith, C., … Dellinger, R. P. (2017). Surviving Sepsis Campaign: International Guidelines for Management of Sepsis and Septic Shock: 2016. *Critical Care* | Provide evidence-based sepsis treatment guidelines. | N/A | Committee of 55 international experts from 25 international organizations met to complete the evidence-based guidelines. | N/A | An up-dated version of the Surviving Sepsis Campaign Guidelines for the Management of Sepsis and Septic Shock. | |

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| *Medicine*, *45*(3), 486-552. https://doi.org/10.1097/CCM.0000000000002255<br><br>United States<br><br>Level of Evidence (Melynk & Fineout-Overholt, 2015): N/A | | | | | | |
| Seymour, C. W., Gesten, F., Prescott, H. C., Friedrich, M. E., Iwashyna, T. J., Phillips, G. S., Lemeshow, S., Osborn, T., Terry, K. M., & Levy, M. M. (2017). Time to treatment and mortality during mandated emergency care for sepsis. *The New England Journal of Medicine, 376*(23), 2235-2244. https://doi.org/10.1056/NEJMoa1703058<br><br>Unites States<br><br>Level of Evidence (Melynk & Fineout-Overholt, 2015): IV | Determine if more rapid treatment of sepsis improves patient outcomes. | Retrospective study | 49,331 patients from 149 New York hospitals.<br><br>Data was taken the New York Department of Health from 4/1/2014 to 6/30/2016. | Compared the cohort of patients that had the 3-hour bundle from the Surviving Sepsis Guidelines completed within 3 hours to those that had it completed over 3 hours. | 82.5% of the patients had the 3-hr bundle completed within 3 hours. The patients that had it completed over 3 hours had higher in-hospital mortality. If the IV fluid bolus was completed before 3 hours or after, there was no change in mortality rates. | Everything in the 3-hour bundle improved mortality except for rate of IV fluid administration. |
| Sirvent, J., Ferri, C., Baro, A., Murcia, C., & Lorencio, C. (2015). Fluid balance in sepsis and septic shock | To determine if fluid balance contributes to mortality in patients with severe | Prospective and observational cohort study | 42 ICU patients with sepsis/septic shock | No intervention was completed.<br><br>The study compared the | Of the 42 patients, 15 patients (35.7%) did not survive within a 28-day period. This group were all in septic shock versus only | |

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| as a determining factor of mortality. *American Journal of Emergency Medicine, 33*, 186-189. http://dx.doi.org/10.1016/j.ajem.2014.11.016<br><br>Spain<br><br>Level of Evidence (Melynk & Fineout-Overholt, 2015): IV | sepsis or septic shock. | | | fluid balance of sepsis survivors and non-survivors at 48, 72, and 96 hours into treatment. | having sepsis and had higher Simplified Acute Physiology Score II results, concluding these patients were sicker. They also had statistically significant higher positive fluid balances at all three-time intervals during care. | |

*Note.* Level of evidence reference: Melnyk, B. M., & Fineout-Overholt, E. (2015). *Evidence-based practice in nursing and healthcare: A guide to best practice* (3rd ed.). Wolters Kluwer.

## Appendix C: Gantt Chart

| Phases | Month 1: Jan 5- Feb 5 | Month 2: Feb 5- Mar 5 | Month 3: Mar 5- April 5 |
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| **Pre-implementation:** Complete research | | | |
| **Implementation:** Create guideline | | | |
| **Post-implementation:** Seek and evaluate professional feedback regarding guideline | | | |

## Appendix D: Measurement Tool

### Professional Review of the Recommended Inferior Vena Cava Ultrasound (IVC) and Sepsis Management Guideline

1. Is the targeted population (see inclusion/exclusion criteria) appropriate for the IVC ultrasound intervention and sepsis management guideline?

1 2 3 4 5 (1 – strongly disagree, 3 – neutral, 5 – strongly agree)

2. Is this intervention (IVC ultrasound) appropriate for sepsis patients?

1 2 3 4 5 (1 – strongly disagree, 3 – neutral, 5 – strongly agree)

3. Are the sepsis management recommendations in relation to the IVC ultrasound measurements appropriate?

1 2 3 4 5 (1 - strongly disagree, 3 – neutral, 5 – strongly agree)

4. In your professional care, would you use IVC ultrasound for sepsis management?

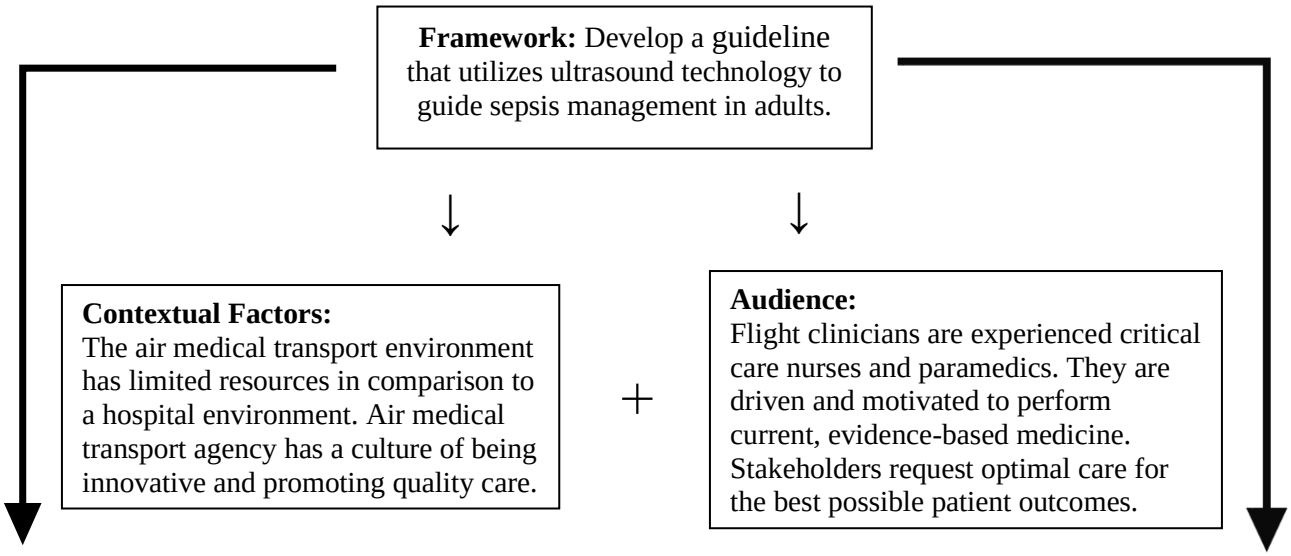
Yes / No
Why or why not?

5. In your professional care, would you use these management recommendations for sepsis care?

Yes / No
Why or why not?

Professional Title (resident, MD, PA, NP): _____
Area of Expertise (clinic, internal medicine, emergency medicine, etc.): _____

## Appendix E: Logic Model




| **Resources:** | **Activities:** | **Outputs:** | **Short-term Outcomes:** | **Intermediate or Long-term Outcomes:** | **Outcome/ Desired Effect:** |
|---|---|---|---|---|---|
| -Literature to guide an evidence-based guideline.<br>-Ten acute care providers to evaluate the guideline.<br>**Barriers:**<br>Covid-19 may create barriers to in-person meetings. | -Create an evidence-based ultrasound-guided sepsis management guideline.<br>-Request acute care providers to complete a survey regarding the guideline. Goal is to have feedback from 10 providers. | Creation of an ultrasound-guided sepsis management guideline with medical provider feedback. | An ultrasound-guided sepsis management guideline created with revisions as needed based upon medical provider feedback. | The refined ultrasound-guided sepsis management guideline will be implemented at an air medical transport organization. | Guideline use will improve septic patient outcomes (decreasing rates of complications, length of hospital stays, and mortality rates), which can then decrease health care costs. |

*Note.* Table adapted from Reavy (2016, p.175).

## Appendix F: Guideline Outline and Diagram

Inferior Vena Cava Ultrasound to Guide Hemodynamic Resuscitation in Non-intubated Septic Adults

Purpose:
To obtain and maintain a mean arterial pressure (MAP) of 65 mmHg or greater in a sepsis/septic shock patient as quickly into care as possible with initial intravenous (IV) fluid administration then subsequent vasopressor administration. Using Inferior vena cava collapsibility index (IVCCI) from ultrasound measurements to guide optimal administration of IV fluid and vasopressor, which will then mitigate risks and improve patient outcomes.

Inclusion Criteria:
Adult patients (≥ 18 years of age), interfacility transport, diagnosed with sepsis or septic shock, non-intubated patients with a regular breathing pattern, and have a sinus rhythm or an atrial arrhythmia.

Exclusion Criteria:
Neonate or pediatric patients (< 18 years of age), does not have a sepsis or septic shock diagnosis, transport from a scene location, have irregular respiratory patterns (i.e. Kussmaul or Cheyne-Stokes respirations), have a ventricular arrhythmia, are mechanically ventilated, are pregnant, have a history of congestive heart failure or an aortic aneurysm, have cardiac tamponade, concerns for increased intra-abdominal pressure or chest pressure, are morbidly obese, or if the clinician is unable to obtain adequate view of the inferior vena cava.

IVC Collapsibility Index Calculation:
**IVCCI % = (IVCmax–IVCmin) / IVCmax x 100**

Guideline:
1. Obtain total IV fluid amount administered thus far in patient care for ongoing monitoring of fluid intake. **Once a total of three liters of IV fluids have been administered, a vasopressor should automatically be initiated despite the IVCCI.**
2. Care based upon MAP and IVCCI ultrasound measurement.
    - **If MAP is <65 mmHg and IVCCI < 40%:**
        - -administer 500ml crystalloid IV fluid bolus over 15 minutes, then reassess IVCCI and MAP and continue care based upon results
    - **If MAP is <65 mmHg and IVCCI > 40%:**
        - -initiate or titrate vasopressor per administration guidelines of organization
        - -recheck MAP every 15 minutes, continue care based upon results
        - -recheck IVCCI every 30 minutes, continue care based upon results
    - **If MAP is > 65mmHg:**
        - -continue to monitor the patient's MAP every 15 minutes, continue care based upon results

*Clinical judgement should also be utilized along with this guideline and can override the guideline.


Step 1.
Check total of IV fluid intake.
Obtain MAP and IVCCI.
Step 2.
MAP < 65mmHg and IVCCI < 40%
- 500mL IV crystalloid bolus over 15 minutes
- Recheck MAP and IVCCI after bolus completion
MAP < 65mmHg and IVCCI > 40%
- Initiate or titrate vasopressor
- Recheck MAP every 15 minutes
- Recheck IVCCI every 30 minutes
MAP > 65mmHg
- Recheck MAP every 15 minutes
Step 3.
- Based on MAP and IVCCI reassessments, go back to the appropriate Step 2 intervention set.
- Keep totaling IV fluid intake.
*After a total of 3 liters of IV fluids are administered, initiate a vasopressor.
*Note: Always use clinical judgement along with the guideline. Clinical judgement can override the guideline.

## Appendix G: Feedback Request Cover Letter

Dear Medical Professional,

I am a Doctor of Nursing Practice student at the College of St. Scholastica, and I am currently completing my doctoral quality improvement project. My project proposes the use of inferior vena cava ultrasound to guide hemodynamic resuscitation in non-intubated septic adults during air medical transportation.

Critically ill septic adults are frequently transported from small, rural hospitals to larger hospitals for higher levels of care via air medical transport. This transport provides an opportunity for air medical clinicians to initiate or continue optimal care in the vital initial hours of sepsis management. The Surviving Sepsis Campaign encourages the use of 30mL/kg of intravenous fluid administration along with dynamic hemodynamic monitoring for sepsis management and eventually vasopressor administration. Although, inappropriate administration of intravenous fluids and vasopressors can lead to complications, additional medical treatments, and poorer patient outcomes. To manage appropriate fluid and vasopressor administration, air medical clinicians do not have access to invasive hemodynamic monitoring equipment, the physical space to complete passive leg raising tests, or the ability to lung auscultation during flight.

Ultrasound is a technology that many air medical transport organizations are starting to utilize for lung, cardiac, abdominal, and fetal assessments. Ultrasound has the potential to provide dynamic hemodynamic monitoring through assessing a patient's fluid status through inspiratory and expiratory measurements of the inferior vena cava. These measurements can guide additional intravenous fluid administration or the initiation of a vasopressor, thereby mitigating potential complications.

A literature review was completed regarding the use of ultrasound and inferior vena cava measurements in assessing fluid status of mechanically ventilated and spontaneous breathing patients and in atrial fibrillation. This research guided me in the creation of a guideline for the use of inferior vena cava ultrasound to guide intravenous fluid and vasopressor administration in non-intubated septic adults during air medical transport.

**I am seeking your professional feedback regarding this guideline for further improvement of it. Below is the proposed guideline and references. A feedback questionnaire can be completed via Survey Monkey at https://www.surveymonkey.com/r/KC9K2D2**

Thank you for your time and feedback!

Sincerely,
Marin Peterson
Mpetereson9@css.edu