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Original Research

Creation of a Flight Nurse Critical Care Ultrasound Program

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A B S T R A C T

Objective: Our objectives were 2-fold: to describe the creation of a flight nurse (FN) ultrasound (US) program and to evaluate whether critical care US performed by nonphysician providers in the prehospital setting can clarify patient assessment.

Methods: Twenty FNs completed a didactic and hands-on US curriculum focusing on critical care modalities. FNs displayed competency by successful completion of an objective-structured clinical examination. Portable US devices were used during patient transports when deemed clinically indicated by the FN. If US was subsequently performed, the FN was asked if US use prompted a change in assessment. Associations were evaluated with chi-square and bivariate logistic regression analyses.

Results: FNs reported US use during 102 (12.3%) patient transports, of which intensive care unit (ICU) to ICU (58.8%) constituted the majority of cases followed by emergency department (ED) to ED (28.4%), ED to ICU (4.9%), and scene to ED (2.9%). FNs agreed or strongly agreed that US use clarified the cause of patient symptoms in 67.4% of transports.

Conclusion: FNs were more likely to perform US when they expressed lower confidence in their initial patient assessment. FNs reported that US helped to clarify patient assessments.

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Point-of-care ultrasound (US) performed in the prehospital setting has shown promise, but the effect of prehospital US on clinical outcomes is unclear. Randomized controlled trials that examine the use of prehospital US are needed^{1,2}; however, multiple studies suggest that its use may improve diagnosis, management, and hospital referral in both trauma and nontrauma patients.^{1–5} As of 2014, less than 5% of emergency medical systems in North America use US in the prehospital setting, and, of those that do, most include physicians as members of their prehospital team.⁶

To date, several resuscitative and/or critical care US protocols have been designed to aid medical providers in the rapid assessment and diagnosis of critically ill patients with undifferentiated hypotension

or dyspnea in the emergency department (ED) or intensive care unit (ICU).^{7–10} These protocols share many common concepts including the use of multiple core US modalities such as cardiac, lung, aorta, inferior vena cava (IVC), focused assessment with sonography for trauma (FAST), and others. Physicians have performed many of these protocols and US modalities in the prehospital setting,^{11–13} whereas prehospital US performed by nonphysician providers (nurses and paramedics) thus far has largely focused on a single, limited application such as FAST, identification of a pneumothorax, or assessment for pericardial effusion and cardiac standstill.⁶ To our knowledge, the only example of nonphysician providers using a multiapplication US assessment to guide management in the prehospital setting was shown by the Shock Trauma Air Rescue Society, a Canadian critical care helicopter emergency medical service staffed by physicians and nonphysicians. In this case, prehospital US was initially performed by physicians only. Later, 6 nurses with critical care experience were trained in FAST, identification of a pneumothorax, and assessment of volume status (IVC and internal jugular vein changes with respiration), and they performed a variety of other additional applications.¹¹

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Table 1
Ultrasound applications and learning objectives for critical care flight nurses

Cardiac	Identify relevant anatomy in parasternal long axis, parasternal short axis, apical 4-chamber view, and subcostal view Estimate gross left ventricular systolic function
Pulmonary	Identify pericardial effusion and signs of tamponade including plethoric IVC and right ventricular free wall collapse Identify and understand significance of A-lines and B-lines Identify lung sliding
IVC	Identify pleural effusion or hemothorax Estimate size and respiratory variation
FAST	Understand significance as it relates to volume status and fluid tolerance Identify free fluid in the right upper quadrant, left upper quadrant, and pelvis
Procedural Guidance	Identify pericardial effusion Identify relevant anatomy and vessel compressibility Visualize needle in short axis

There are no published reports that describe the creation of a nonphysician air medical crew, or flight nurse (FN), critical care US program.

Our objectives were 2-fold: to describe the creation of an FN US program and to evaluate whether critical care US performed by FNs in the prehospital and interhospital setting can clarify patient assessment.

Methods

Study Setting

The study was conducted at a tertiary care academic hospital in the United States. During a 3-year period from 2015 to 2017, the program transported, on average, 900 patients by air and 350 patients by ground per year. The flight crew consists of FNs who are dually certified as paramedics with additional critical care training and expertise. Before this study, the FNs had no previous US experience.

US Education

Twenty FNs participated in a focused didactic and hands-on curriculum that emphasized the critical care US applications believed to be most relevant and important for prehospital providers (Table 1). Content focused on achieving US skills that may impact and change prehospital care. This included imaging techniques that may assist with diagnosis and management (eg, cardiac and pulmonary US for the identification of heart failure and pulmonary edema) or in preparation for the inbound patient at the receiving hospital (eg, positive FAST scan allowing earlier mobilization of trauma team resources). The initial US training was conducted over 4 months and focused on US assessments of the heart, lungs, IVC, abdominal aorta, and FAST examination. Educational content included 5 different 2-hour didactic and hands-on sessions led by US faculty as well as asynchronous instructional US videos. Practical skills education included independent and guided practice scanning healthy volunteers, and each FN was required to log at least 10 practice scans on ED patients for each US application. An objective structured clinical examination (OSCE) was developed to assess the skills and associated knowledge obtained during training (Appendix 1). Each FN was required to display competency as measured by successful completion of the OSCE administered by US faculty before integrating US into clinical practice.

Multiple approaches were used to encourage skill maintenance. All FNs demonstrated ability to complete the initial OSCE on a quarterly basis. FNs were encouraged to join US faculty and ED residents during ED-based educational US scanning shifts for additional guided learning as available. After several months, 5 FNs identified themselves as particularly interested in US and sought additional

scheduled instruction, and this group of “superusers” continues to scan with US faculty on a regular basis. US cases were presented monthly at an FN conference by faculty and FN superusers.

Images and video clips were saved on handheld portable US devices (SonoSite iVIZ; SonoSite, Bothell, WA) and wirelessly uploaded to a cloud-based workflow solution software (Telexy Qpath E; Telexy, Lake Buena Vista, FL) at the conclusion of each transport. Feedback about correctness of interpretation and tips for optimizing image acquisition, when applicable, was given to the performing FN by US faculty.

Design

A prospective cohort study was conducted using a survey data collection approach. The study was exempt after review by the institutional review board. Handheld portable US devices were used during patient transports from both scene activations and referring hospitals. FNs were encouraged to perform US in the case of hypotension, respiratory distress or hypoxia, unclear cardiac function or intravascular volume status, and when deemed otherwise clinically indicated by the FN. Surveys were completed by the FN after the transport. FNs were asked about their confidence in their initial assessment of the patient's cardiac function, intravascular volume status, underlying cause of hypotension, and source of respiratory distress (when applicable) before any use of US. Attitudinal responses were reported using a 5-point Likert-type scale (ranging from 0 = strongly disagree to 4 = strongly agree, with higher scores indicating greater confidence). If US was subsequently performed, the FN was asked if US use prompted a change in assessment or management. Patients were classified as critically ill or not critically ill by overall clinical impression of the transporting FN. The primary outcome was the relationship between the likelihood of performing an US and the degree of FN confidence in initial patient assessment characteristics without the aid of US.

Data Analysis

Hypotheses were tested with chi-square and bivariate logistic regression analyses. An alpha level of .05 was used to assess statistical significance. All analyses were conducted with SPSS statistical software (Version 24.0; IBM Corp, Armonk, NY).

Results

Transport Characteristics

Over a 14-month period, the FNs completed 829 surveys and reported US use during 102 (12.3%) patient transports, and there was a positive trend in the percentage of transports with US use over time

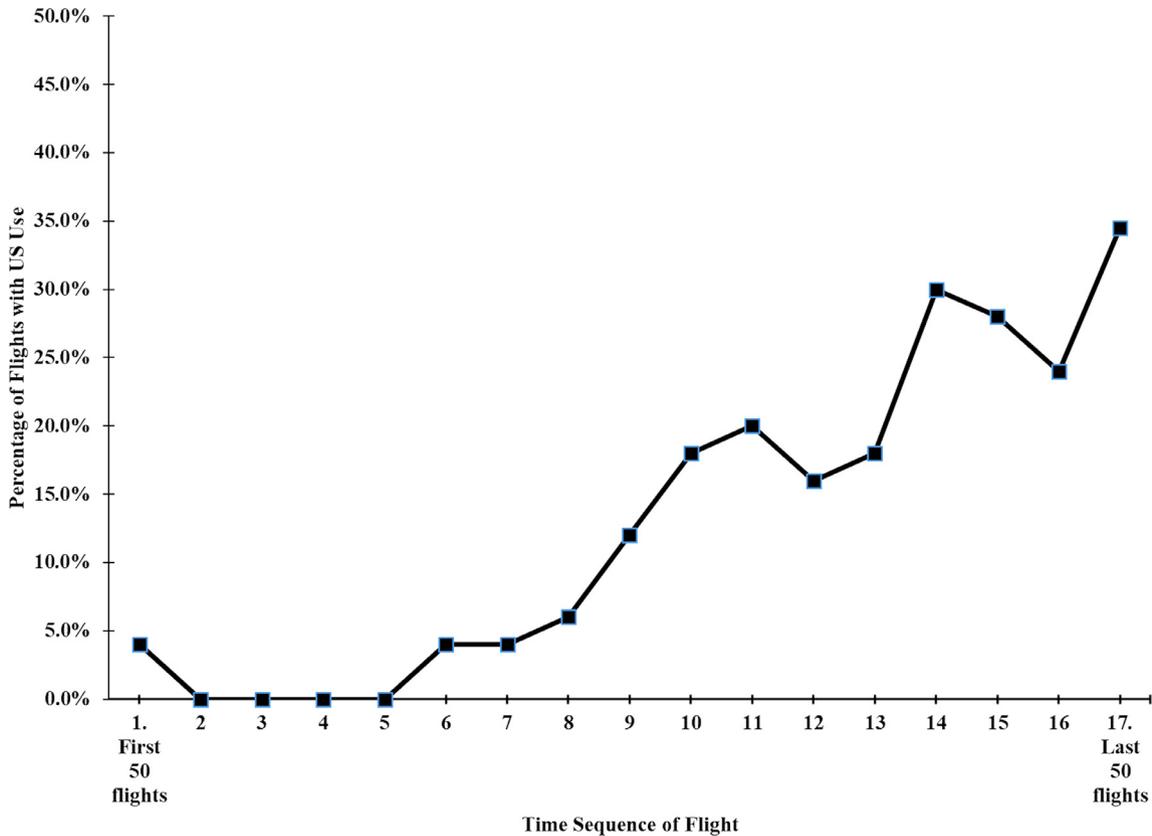


Figure 1. Ultrasound use by flight nurses during transport increased over time.

(Fig. 1). Of the transports in which US was used, ICU to ICU (58.8%) constituted the majority of cases followed by ED to ED (28.4%), ED to ICU (4.9%), and scene to ED (2.9%) (Fig. 2). US was more likely to be used with patients thought by the FN to be critically ill (92%) compared with patients thought to be non-critically ill (73%) ($\chi^2_1 = 17.6$, $P < .001$). The FNs agreed or strongly agreed that US use clarified patient assessment in 67.4% of transports.

Primary Outcome

FNs were significantly more likely to use US when less confident in the initial assessment of patient cardiac function, intravascular volume status, and cause of respiratory distress without US (Fig. 3). Specifically, we conducted logistic regression analysis of confidence ratings in the initial patient assessment as predictors of the odds of US use. The results showed that lower confidence ratings in the initial assessment were associated with statistically significantly higher odds of US use for 1) knowledge of the patient's cardiac function (odds ratio [OR] = 1.4; 95% confidence interval [CI] = 1.2–1.7), 2) knowledge of the patient's volume status (OR = 1.4; 95% CI, 1.1–1.6), and 3) knowledge of the cause of the patient's respiratory distress (OR = 1.3; 95% CI, 1.0–1.6). Lower confidence for knowledge of the cause of the patient's hypotension was also associated with higher odds of US use, but this association was not statistically significant (OR = 1.2; 95% CI, 0.9–1.5).

Discussion

Our study describes the creation of an FN critical care US program. We identified critical care US applications that may be useful to FNs and developed strategies for initial US education, skill maintenance, and learner assessment. FNs reported US use in approximately one tenth of patient transfers, and US use was more likely when caring

for a patient who was subjectively judged to be critically ill. FNs were significantly more likely to use US when less confident in their initial assessment of patient cardiac function, intravascular volume status, and cause of respiratory distress. When US was used, FNs reported that its use clarified patient assessment in approximately two thirds of transfers.

In some cases, US use was notably helpful in patient assessment. Several examples include 1) the identification of a pericardial effusion and tamponade (Fig. 4) in a patient being transferred for thoracic aortic dissection that allowed early mobilization of receiving hospital resources and management by an attending cardiothoracic surgeon immediately on arrival, 2) correct interpretation of a positive FAST (Fig. 5) that upgraded the prehospital alert to full trauma team activation in a patient transferred from the scene of a motor vehicle accident, 3) identification of pericardial effusion and tamponade (Fig. 6) in a patient being transferred with working diagnoses of septic shock and hypoxic respiratory failure, and 4) identification of mitral valve vegetation (Fig. 7) in a patient being transferred with a working diagnosis of sepsis and possible endocarditis.

Shock Trauma Air Rescue Society, a Canadian critical care helicopter emergency medical service staffed by both physicians and non-physicians, reported that 6 nurses with critical care training and experience were trained and qualified as Canadian Emergency Ultrasound Society-independent practitioners for FAST in 2009. Several years later, their scope of practice was expanded to assessments for a pneumothorax and volume status using IVC and internal jugular respiratory variation. In addition to these US modalities, results from a 5-year retrospective review of US use suggest these Canadian FNs also performed assessments for cardiac activity, pericardial effusion, and, rarely, abdominal aortic aneurysm.¹¹

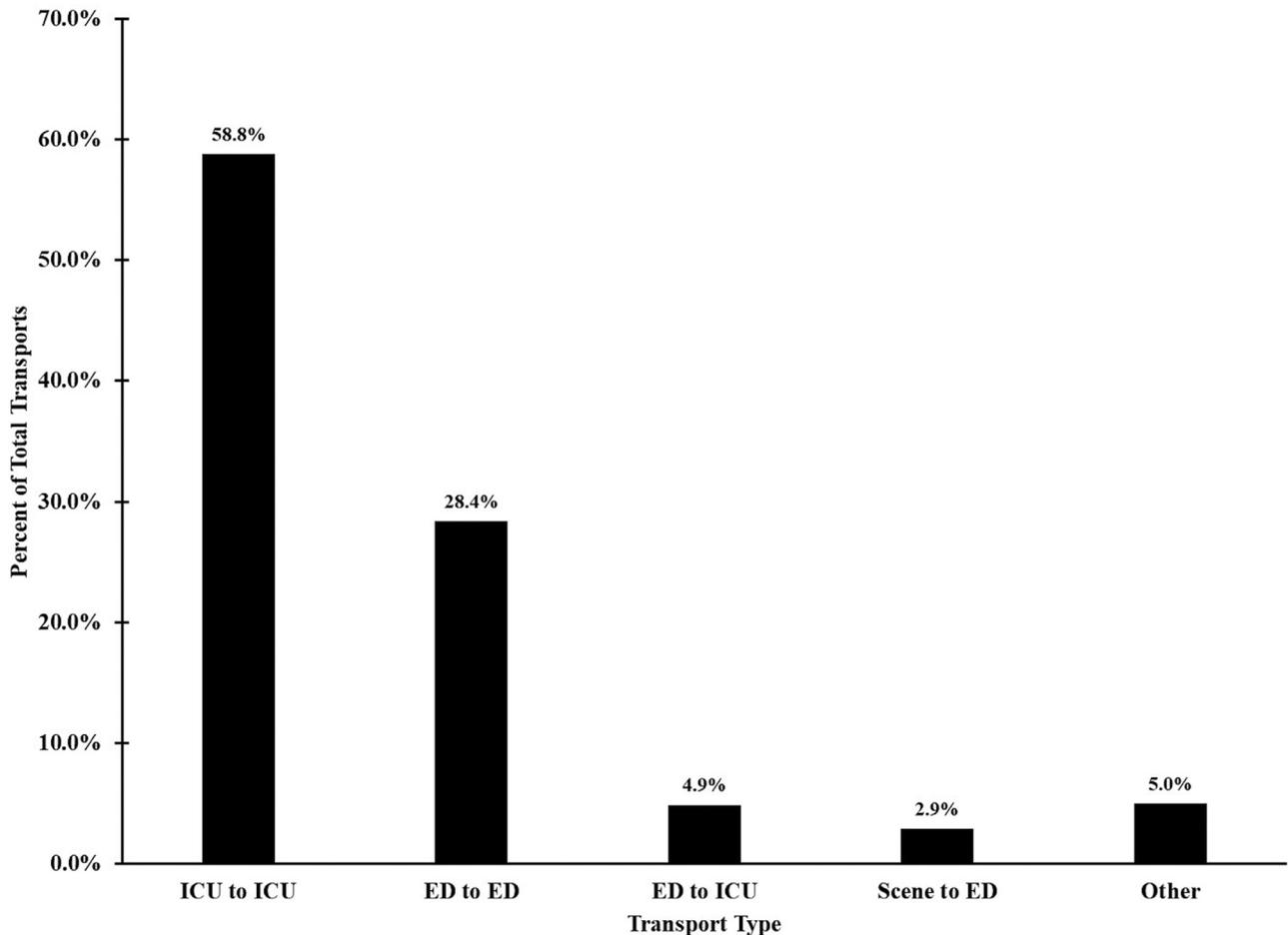


Figure 2. Distribution of transport types. ED = emergency department; ICU = intensive care unit.

In contrast, in the United States, there currently is no analogous independent US practitioner certification available to nonphysician prehospital providers, and education programs vary considerably (from 2 minutes to 2 days) and do not appear to align with qualification level or clinical experience.¹⁴ Given the lack of established educational standards and certification pathway, we chose to develop an educational model and assessment tool specifically designed to address the needs of our FNs. A similar institution- and crew-specific education approach was described by the Nightingale Regional Air Ambulance flight crew in which FNs, paramedics, and pilots were trained to perform FAST examinations.¹⁵ A combination of cardiac, pulmonary, volume status, and FAST examinations in the evaluation of a patient with dyspnea or hypotension is commonplace in emergency medicine and critical care literature,^{16,17} but its use by FNs is not yet well described. Our FNs combine information from multiple US applications, deciding which applications are necessary based on their clinical judgment, as opposed to following a rigid protocol. This allows for increased flexibility and time-efficient US usage.

Critical care US performed by FNs remains uncommon in the United States. To address this need, we have established and assessed the feasibility and potential benefits of an educational intervention designed to introduce critical care US to FNs. Directions for future study will examine skill retention by FNs, expansion of the FN US curriculum to include new approaches, and the

relationship between critical care US use by FNs and patient care –centered outcomes.

Limitations

This study has several limitations. There were many cases in which US was used by the FNs, but the corresponding video and images were not saved and available for expert review. Especially in the initial phase of clinical US integration, both user error and technical difficulties contributed to inconsistent image archiving. With regard to US use and the effect on patient management, we did not ask the FNs to record their US interpretation and its specific effect on subsequent management for every patient (eg, a US finding prompting an intravenous fluid bolus, the addition of a vasopressor, or performance of a thoracostomy). As previously described, in some cases, the effect of US on diagnosis was particularly notable. Unusual cases such as these were easily identified and reviewed; however, the details of most cases (eg, US effect on the decision to administer intravenous fluids) were not available. Without these data, we are unable to draw conclusions about the percentage of technically adequate or correctly interpreted US studies.

There was a positive trend in the percentage of transports with US use during the course of the study. Similar to the adoption of any technology by a group of new users, the degree of enthusiasm for and the frequency of integration into clinical

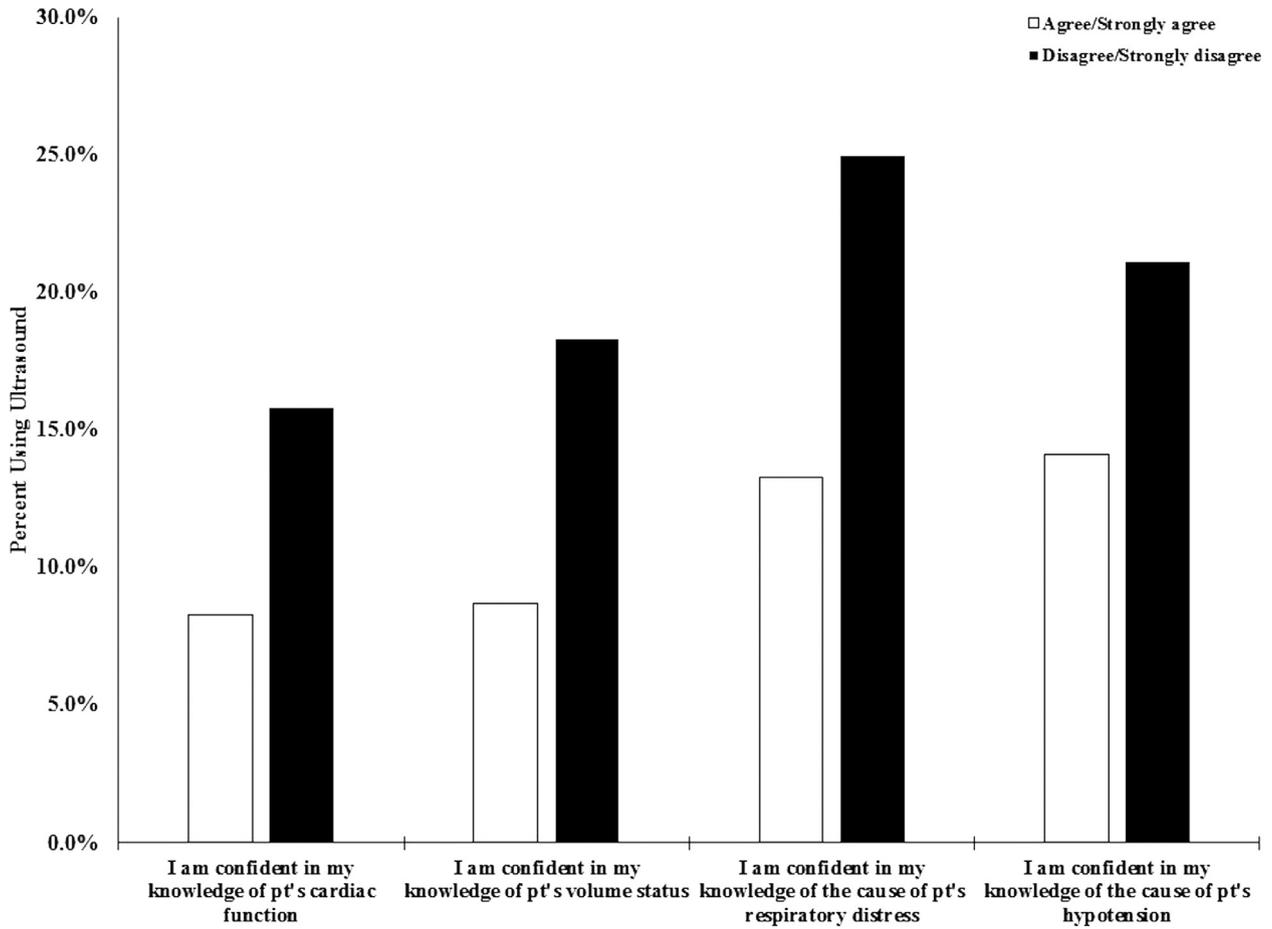


Figure 3. Flight nurses used ultrasound more often when not confident about the cause of their patient's cardiac function, volume status, respiratory distress, or hypotension.

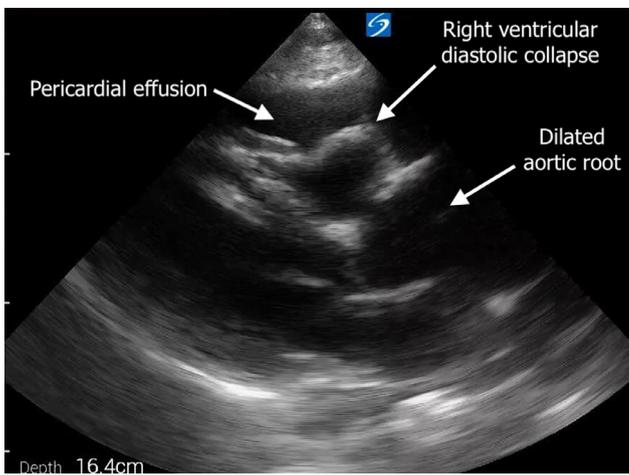


Figure 4. Parasternal long axis view obtained by flight nurses while transporting a patient with a thoracic aortic dissection. Ultrasound was concerning for pericardial tamponade given presence of a pericardial effusion and diastolic right ventricular collapse.

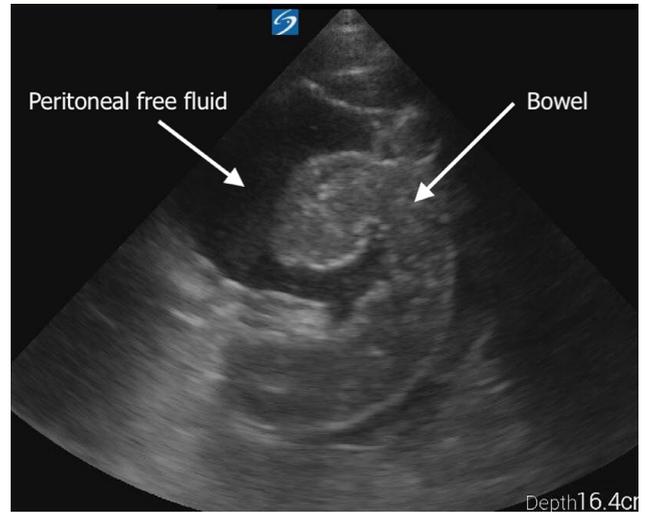


Figure 5. Abdominal paracolic gutter view obtained by flight nurses performing a FAST exam while transporting a patient from the scene of a motor vehicle accident. FAST was positive for free fluid.

practice likely varied among the group of FNs; however, we did not track the frequency with which individual FNs performed US during patient transports or in the ED as a part of ongoing skills maintenance.

This is a single-site investigation, which may limit its generalizability. For example, our FNs most often transport patients from a transferring hospital ED or ICU, and flight times are commonly 30 minutes or more. The prevalence of this type of transport and the

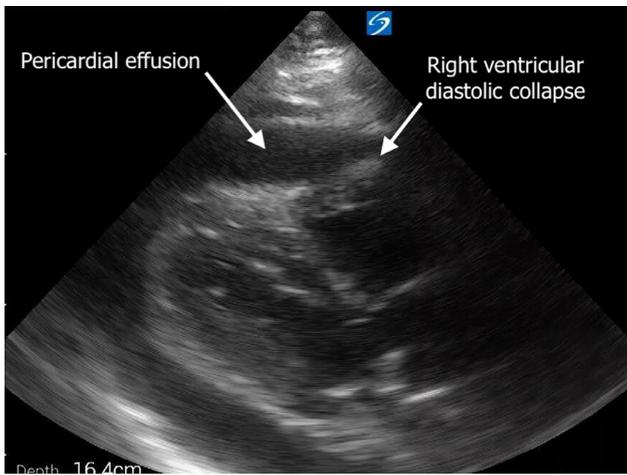


Figure 6. Parasternal long axis view of obtained by flight nurses while transporting a patient from an outside hospital with working diagnosis of hypoxic respiratory failure and septic shock. Ultrasound was concerning for pericardial tamponade given presence of pericardial effusion and diastolic right ventricular collapse.

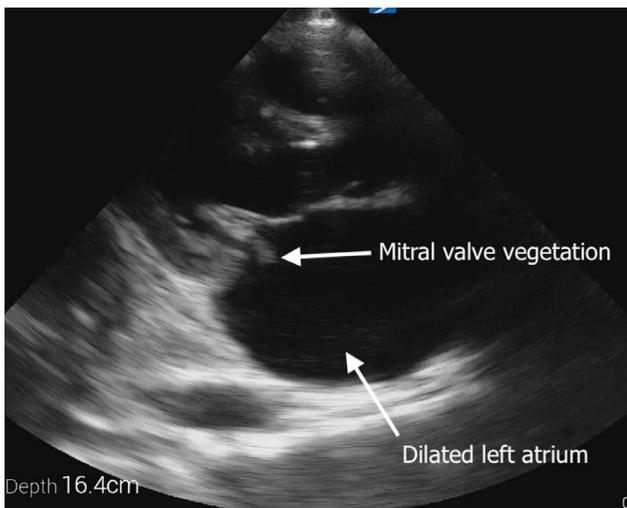


Figure 7. Parasternal long axis view obtained by flight nurses while transporting a patient with sepsis and possible endocarditis. Ultrasound showed a mitral mobile echodensity concerning for vegetation and severely dilated left atrium secondary to regurgitation.

extended in-flight time per transport may allow for an expanded opportunity to perform critical care US.

Conclusion

Our study evaluated the initial learner reactions to an FN critical care US program. Our results suggest that FNs with no prior US experience have the ability to incorporate critical care US modalities into their practice after initial training followed by skill maintenance and continuing education. FNs were more likely to perform US when they expressed lower confidence in their initial patient assessment, and FNs reported that US use often helped to clarify patient assessments.

Appendix 1. Objective Structured Clinical Examination

The goal of this exam is to evaluate the ability to perform the core scans within critical care ultrasound, to explain relevant findings, and to identify how/where to look for pathology.

The exam is broken down into sections by modality. There are two separate grading mechanisms. First, the examinee will need to be able to acquire all of the required views for each modality (which are listed below). It is important to give **no prompting** in regards to which views to obtain, so as to explicitly test what the examinee is able to perform without help. Each view is judged on a 1 to 5 scale.

A score of 1 represents that a view was not obtained.

A score of 2 means a view was obtained but it was not sufficient to evaluate for pathology appropriately.

A score of 3 means the performer was able to obtain a view that is satisfactory; it means the examiner may not be perfect but is able to show enough to make an interpretation. For example, if the user gets a RUQ view on the FAST that has too much depth and a lot of rib shadow, but is still able to see the liver tip, Morrison’s pouch, and above the diaphragm, it warrants a 3. This score is the cutoff for an acceptable view; a score of 2 or lower is a ‘fail’ for that image.

A score of 4 means the view is particularly good. It may have a single issue (too much/too little gain or depth) but is easily interpreted and reviewed and is of notable quality.

A score of 5 means the view obtained had images of textbook-level quality and had no noticeable flaws.

Second, each modality will have a checklist for information the examinee will need to possess about each scan. These are the “critical actions,” and all must be hit properly in order to receive a passing score. For example, the RUQ view of the fast might have check boxes for identifies where free fluid will be in the abdomen, explains how to evaluate for pleural effusion/hemothorax, and correctly identifies liver, kidney, and diaphragm. For this section, **prompting is allowed**. The examinee may simply get the required views, and may need to be asked how they would identify certain things.

E-FAST

Subxiphoid Score: _____

- Identify LV
- Identify RV
- Identify LA
- Identify RA
- Identify Pericardium
- Demonstrate where pericardial fluid would accumulate
- Describe what to look for in tamponade (RA collapse, RV collapse [trampoline man], plethoric IVC)
- Demonstrate how they would evaluate pericardium if SX view impossible to obtain (PSLA)

RUQ Score: _____

- Identify liver
- Identify kidney
- Identify diaphragm
- Identify Morrison's Pouch
- Demonstrate where intraperitoneal fluid will accumulate
- Demonstrate where a pleural effusion/hemothorax would be seen
- Describe what a pleural effusion looks like ([minimum: anechoic fluid. Any other commentary just a bonus], loss of mirroring, spine sign)

LUQ Score: _____

- Identify spleen
- Identify kidney
- Identify diaphragm
- Demonstrate where intraperitoneal fluid will accumulate
- Demonstrate where a pleural effusion/hemothorax would be seen

Pelvis Score: _____

- Identify bladder
- Either identify uterus or (if model male) demonstrate where it would be
- Describe and demonstrate where free fluid would accumulate in both male/female patients

Chest Score: _____

- Identify ribs
- Identify lung pleura
- Describe the main lung findings in pneumothorax (loss of lung sliding AND/OR lung point)

Aorta

Transverse Score: _____ (note: a score of 3 or higher requires evaluation from as proximal as possible through aortic bifurcation)

- Identify aorta
- Identify vertebral body
- Identify Aortic bifurcation
- Measure the aorta (outer to outer wall, anterior to posterior)
- Describe the cutoff of normal (3 cm) for the aorta and the size (5.5 cm) when rupture becomes possible
- Describe appearance of an aortic dissection

Longitudinal Score: _____

- Identify the anterior branching vessels of the aorta (if possible)
- Describe how to best identify longitudinal aorta (rotating over transverse view, anterior branches, goes posterior to liver)

ECHO (note: subxiphoid view is included in testing of FAST and need not be repeated)

Parasternal Long-Axis Score: _____

- Identify LV
- Identify LA
- Identify RV
- Identify Aortic outflow tract
- Identify mitral valve
- Identify aortic valve
- Describe how to evaluate EF subjectively (contraction of ventricle)

Parasternal Short Axis Score: _____

- Identify LV
- Identify RV
- Describe the D sign and explain significance (PE vs. other causes of increased R heart pressure)

Apical Four Chamber Score: _____

- Identify LV
- Identify RV
- Identify LA
- Identify RA
- Describe normal RV to LV size ratio (0.7 or less) and abnormal RV to LV size ratio (greater than 1.0 if severe)

Inferior Vena Cava

IVC View Score: _____

- Identify IVC in long and short axis
- Describe how to evaluate potential volume responsiveness based on IVC collapsibility

Thoracic

Pneumothorax Evaluation Score: _____

- Identify pleura
- Identify lung sliding

Full Lung Evaluation Score: _____

- Identify pleura
- Set depth at appropriate 18 cm
- Describe B lines and their physiologic significance
- Know difference in normal and pathologic B lines (>3 per rib space, extending at least 18 cm)
- Describe where pleural effusion would form

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