ORIGINAL RESEARCH

# Utilization Criteria for Prehospital Ultrasound in a Canadian Critical Care Helicopter Emergency Medical Service: Determining Who Might Benefit


**Domhnall O'Dochartaigh, RN, MSc;[1,2] Matthew Douma, RN, BSN;[3] Chris Alexiu, BSc;[4] Shell Ryan, RN, MN;[2] Mark MacKenzie, MD, CCFP-EM[2,4,5]**

1. Alberta Health Services, Emergency, Edmonton Zone, Alberta, Canada
2. Shock Trauma Air Rescue Society, Edmonton, Alberta, Canada
3. Alberta Health Services, Emergency Services, Royal Alexandra Hospital, Edmonton, Alberta, Canada
4. Department of Emergency Medicine, University of Alberta, Edmonton, Alberta, Canada
5. Alberta Health Services Emergency Medical Services, Edmonton, Alberta, Canada

**Correspondence:**
Domhnall O'Dochartaigh, RN, MSc
Room 1G1-55
Department of Emergency Medicine
University of Alberta Hospital
Edmonton, Alberta, Canada T6G 2B7
E-mail: domhnall.odochartaigh@ahs.ca; dodochartaigh@stars.ca



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**Abbreviations:**
FAST: Focused Assessment with Sonography in Trauma
GCS: Glasgow Coma Score
HEMS: Helicopter Emergency Medical Service
HR: heart rate
IV: intravenous
PHI: Prehospital Index
PHUS: prehospital ultrasound
SBP: systolic blood pressure
SI: shock index


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## Abstract

**Introduction**: Prehospital ultrasound (PHUS) assessments by physicians and non-physicians are performed on medical and trauma patients with increasing frequency. Prehospital ultrasound has been shown to be of benefit by supporting interventions.

**Problem**: Which patients may benefit from PHUS has not been clearly identified.

**Methods**: A multi-variable logistic regression analysis was performed on a previously created retrospective dataset of five years of physician- and non-physician-performed ultrasound scans in a Canadian critical care Helicopter Emergency Medical Service (HEMS). For separate medical and trauma patient groups, the a-priori outcome assessed was patient characteristics associated with the outcome variable of "PHUS-supported intervention."

**Results**: Both models were assessed (Likelihood Ratio, Score, and Wald) as a good fit. For medical patients, the characteristics of heart rate (HR) and shock index (SI) were found to be most significant for an intervention being supported by PHUS. An extremely low HR was found to be the most significant (OR = 15.86 [95% confidence interval (CI), 1.46-171.73]; P = .02). The higher the SI, the more likely that an intervention was supported by PHUS (SI 0.9 to < 1.3: OR = 9.15 [95% CI, 1.36-61.69]; P = .02; and SI 1.3 + : OR = 8.37 [95% CI, 0.69-101.66]; P = .09). For trauma patients, the characteristics of Prehospital Index (PHI) and SI were found to be most significant for PHUS support. The greatest effect was PHI, where increasing ORs were seen with increasing PHI (PHI 14-19: OR = 13.36 [95% CI, 1.92-92.81]; P = .008; and PHI 20-24: OR = 53.10 [95% CI, 4.83-583.86]; P = .001). Shock index was found to be similar, though, with lower impact and significance (SI 0.9 to < 1.3: OR = 9.11 [95% CI, 1.31-63.32]; P = .025; and SI 1.3 + : OR = 35.75 [95% CI, 2.51-509.81]; P = .008).

**Conclusions:** In a critical care HEMS, markers of higher patient acuity in both medical and trauma patients were associated with occurrences when an intervention was supported by PHUS. Prospective study with in-hospital follow-up is required to confirm these hypothesis-generating results.



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## Introduction

Recent studies on prehospital ultrasound (PHUS) demonstrate that ultrasound assessment of medical and trauma patients improved diagnosis, treatment, destination hospital decision making, and initial in-hospital management in both physician-[1,2] and non-physician-conducted scans.[3] Prehospital ultrasound is increasingly used amongst Emergency Medical Services in North America and is gaining popularity with 21% of medical directors responding to a survey considering using ultrasound.[4] It is not currently well-established which patients in the prehospital setting may benefit from PHUS. In order to help guide the practice of PHUS, this study examines patient characteristics to assess if they are associated with occurrences when PHUS supported an intervention.

## Methods

This a-priori planned study uses the same dataset created for "A Canadian five-year retrospective review of physician- and non-physician-conducted PHUS in a Canadian Helicopter Emergency Medical Service [HEMS]."[3] The dataset was assessed for association between previously identified patient characteristics[1,2] and whether an intervention was supported by PHUS or not. Complete details of the data collection can be found in the previously published work.[3] Briefly, a retrospective review was conducted of all physician- and non-physician-conducted PHUS between 2009 and 2014 in a Canadian HEMS. Data were collected on an a-priori created form, and a second data abstractor performed separate data entry on all cases where PHUS was reported to support an intervention.

Inclusion criteria were medical or trauma patients who had a PHUS of the chest or abdomen conducted by the flight crew (physician or non-physician). Types of ultrasound scans included were the Extended Focused Assessment with Sonography in Trauma (EFAST) and the Focused Assessment with Sonography in Trauma (FAST) exams, as well as individual scans of the inferior vena cava, jugular veins, heart, and abdominal aorta. Prehospital ultrasound was performed in "a point of care" manner,[5] where the PHUS image was used by the flight crew to answer a specific binary question to find ultrasound identifiable pathology. In a number of cases, PHUS use was found to support interventions in a number of different ways, and a complete list has been previously described.[3] These included, but were not limited to, the finding of free abdominal fluid supporting a blood transfusion or early hospital notification of a trauma patient who otherwise would not have had a surgeon called; the ruling in or out of a pneumothorax for placement of a needle thoracostomy, if appropriate; the assessment of fluid status to support the provision or withholding of intravenous (IV) fluid, or the initiation of vasoactive medication; and the assessment of cardiac activity to support or cease resuscitation efforts. All PHUS-supported interventions were considered as a single group so as to provide a binary "yes" or "no" primary study variable. The following trauma and medical patient characteristics were assessed for association: sex, age, weight, systolic blood pressure (SBP), heart rate (HR), Glasgow Coma Score (GCS), shock index[6] (SI), and additionally in the trauma cohort only, trauma mechanism (blunt versus penetrating) and Prehospital Index[7] (PHI). Patients were excluded from analysis for ultrasound scans conducted for fetal and tracheal assessment; to assist with IV, central line, or arterial line placement; or if the scan or documentation was incomplete. Ethics approval and a waiver of informed consent was received from the University of Alberta Research Ethics Office (Edmonton, Alberta, Canada) prior to study commencement.

### *Outcome Measures*

The a-priori primary outcome was the strength of any associations (odds ratio [OR]), if any, between patient characteristics and the outcome variable "PHUS-supported interventions." Medical and trauma patients were analyzed separately.

### *Primary Data Analysis*

Multi-variable logistic regression analysis was performed to examine patient characteristics associated with "PHUS-supported interventions" in separate medical and trauma cohorts. In specific terms, PHUS itself was a study design inclusion criterion, and not a component of the regression models. The outcome/dependent variable for the multi-variable logistic regression analysis was "PHUS-supported interventions," which was coded as "no support" = 0 and "yes support" = 1. Thus, a predictor variable OR greater than one indicates a positive contribution to "PHUS-supported interventions" = "yes support." For example, a predictor variable such as SBP 90 to 109 with OR = 2 indicates that patients with a SBP of 90 to 109 are more likely to experience a "PHUS-supported intervention" than those patients with a SBP greater than 109. Analysis was conducted using SAS (version 9.4; SAS Institute; Cary, North Carolina USA). For each patient cohort, modeling consisted of two parts: unadjusted model (the collection of univariable models) and adjusted model (the full multi-variable model).

## Results

### *Characteristics of Study Subjects*

Eligibility assessment of the patient dataset (N = 513) excluded 71 cases. Reasons for exclusion were: sending (non-flight) physician-performed scan (n = 8); IV starts (n = 6); arterial line placement (n = 3); central line placement (n = 33); incomplete scan/documentation (n = 18); fetal scan (n = 2); and trachea scan (n = 1). Included for analysis were 442 cases (143 medical patients and 299 trauma patients).

### *Main Results*

Seven patient characteristics (predictor variables) were examined in the medical cohort and nine in the trauma cohort (Table 1 and Table 2, respectively). All variables were included in the final/adjusted models. Interaction terms were not considered. Both models were statistically significant: three tests (Likelihood Ratio, Score, and Wald) of the global null hypothesis (all coefficients equal to zero) yielded $P < .05$ for both models. The misclassification rate for the medical model was 26.6%, sensitivity (true positive rate) was 67.1%, and specificity (true negative rate) was 79.0%. The misclassification rate for the trauma model was 16.1%, sensitivity (true positive rate) was 46.4%, and specificity (true negative rate) was 95.2%. The Hosmer and Lemeshow goodness-of-fit test suggested that both medical and trauma models had a good fit (Medical: $X^2 = 9.9469$ and P = .6532; Trauma: $X^2 = 8.0950$ and P = .4242).

*Adjusted Model Results for Medical Patients (Table 1)*—The patient characteristics of HR and SI were statistically significantly associated with "PHUS-supported interventions." An extremely low HR was found to have the strongest association (OR = 15.86 [95% CI, 1.46-171.73]; P = .02). For SI, the OR increased with higher SI, indicating that the higher the SI, the more likely that an intervention was supported by PHUS (SI 0.9 to <1.3: OR = 9.15 [95% CI, 1.36-61.69]; P = .02; and SI 1.3 + : OR = 8.37 [95% CI, 0.69-101.66]; P = .09). With respect to SI, for the adjusted (multi-variable) model, inclusion of all other predictors resulted in confounding such that the relationships among levels changed relative to the unadjusted model. In particular, in the adjusted model, the level "0.6 to <0.9" changed to indicate a moderate positive effect (more likely for a "PHUS-supported intervention") from a moderate negative effect (unadjusted OR = 0.81 to adjusted OR = 1.33); the level "1.3 + " continued to indicate a strong positive effect, although it changed to be slightly less than level "0.9 to <1.3;" all values for SI >0.6 indicated a greater likelihood for a "PHUS-supported intervention" relative to SI < 0.6. The GCS was an inconsistent predictor with the range of 9 to 14 reaching significance (OR = 3.80 [95% CI, 1.09-13.22];

| | Unadjusted | | | Adjusted | | |
|---|---|---|---|---|---|---|
| **Patient Characteristic/ Predictor Variable** | **OR** | **95% CI** | **P Value** | **OR** | **95% CI** | **P Value** |
| Female Sex (ref: Male) | 1.47 | 0.74-2.90 | .2726 | 1.38 | 0.58-3.29 | .4740 |
| Age (years) | 1.00 | 0.98-1.02 | .7492 | 1.00 | 0.97-1.02 | .7486 |
| Weight (kg) | 1.01 | 1.00-1.03 | .1108 | 1.01 | 0.99-1.03 | .2408 |
| Systolic Blood Pressure (mm/Hg) | | | **.0017** | | | .2797 |
| <90 | 2.77 | 1.15-6.68 | **.0234** | 0.68 | 0.16-2.95 | .6056 |
| 90-109 | 0.686 | 0.27-1.73 | .4239 | 0.32 | 0.09-1.11 | .0715 |
| 110-139 (ref) | 1 | - | - | 1 | - | - |
| 140 + | 0.33 | 0.11-1.06 | .0623 | 0.60 | 0.16-2.33 | .4610 |
| Heart Rate (pulse/min) | | | **.0076** | | | **.0204** |
| <40 | 24.95 | 3.08-202.09 | **.0026** | 15.86 | 1.46-171.73 | **.0230** |
| 40-99 (ref) | 1 | - | - | 1 | - | - |
| 100-139 | 1.32 | 0.63-2.78 | .4606 | 0.38 | 0.11-1.27 | .1146 |
| 140 + | 4.16 | 0.98-17.66 | .0533 | 1.36 | 0.15-11.99 | .7837 |
| Shock Index | | | **.0006** | | | **.0454** |
| <0.6 (ref) | 1 | - | - | 1 | - | - |
| 0.6- <0.9 | 0.81 | 0.25-2.56 | .7131 | 1.33 | 0.32-5.48 | .6978 |
| 0.9- <1.3 | 3.06 | 0.97-9.66 | .0566 | 9.15 | 1.36-61.69 | **.0230** |
| 1.3 + | 4.73 | 1.42-15.73 | **.0113** | 8.37 | 0.69-101.66 | .0953 |
| Glasgow Coma Scale | | | **.0240** | | | .1992 |
| 2-4 | 2.95 | 1.38-6.33 | **.0054** | 1.59 | 0.62-4.04 | .3336 |
| 5-8 | 1.33 | 0.34-5.24 | .6806 | 1.21 | 0.24-6.17 | .8156 |
| 9-14 | 3.14 | 1.06-9.28 | **.0382** | 3.80 | 1.09-13.22 | **.0359** |
| 15 (ref) | 1 | - | - | 1 | - | - |



**Table 1**. For Medical Patients, Patient Characteristics Associated with "PHUS-Supported Interventions" Multi-Variable Logistic Regression Analysis: Unadjusted Model (all uni-variable models) and Adjusted Model (full multi-variable model)
Note: N = 143; yes support n = 67, 46.85%; no support n = 76, 53.15%.
Abbreviations: CI, confidence interval; OR, odds ratio; Ref, reference level.

P = .035), while low and high GCS did not. The remaining patient characteristics of sex, age, weight, and SBP were found not to be predictive.

*Adjusted Model Results for Trauma Patients (Table 2)*—Patient characteristics of PHI, SI, female sex, and GCS were statistically significantly associated with "PHUS-supported interventions." The greatest effect was seen with PHI, where increasing ORs were seen with increasing PHI (PHI 14-19: OR = 13.36 [95% CI, 1.92-92.81]; P = 0.008; and PHI 20-24: OR = 53.10 [95% CI, 4.83-583.86]; P = .001). Female sex was a moderate predictor (OR = 2.44 [95% CI, 1.05-5.67]; P = .037). For GCS, confounding was noticed in the adjusted model. Lower levels for GCS (<15) indicated, uniformly, a much lower likelihood of a "PHUS-supported intervention." With SI, though the P value for the overall variable was .0662, the OR for "PHUS-supported interventions" was seen to increase with increasing SI values (SI 0.9 to < 1.3: OR = 9.11 [95% CI, 1.31-63.32]; P = .025; and SI 1.3 + : OR = 35.75 [95% CI, 2.51-509.81]; P = .008). The remaining patient characteristics of age, weight, HR, and SBP were found not to be predictive.

## Discussion

Through both uni-variable and multi-variable logistic regression analysis, the characteristics of high patient acuity were associated with a higher likelihood of a "PHUS-supported intervention" to occur.

| | Unadjusted | | | Adjusted | | |
|---|---|---|---|---|---|---|
| **Patient Characteristic/ Predictor Variable** | **OR** | **95% CI** | **P Value** | **OR** | **95% CI** | **P Value** |
| Female Sex (ref: Male) | 1.73 | 0.95-3.14 | .0720 | 2.44 | 1.05-5.67 | **.0374** |
| Age (years) | 1.00 | 0.99-1.02 | .8729 | 1.01 | 0.99-1.03 | .5400 |
| Weight (kg) | 0.99 | 0.98-1.01 | .3803 | 1.00 | 0.98-1.02 | .8928 |
| Systolic Blood Pressure (mm/Hg) | | | **<.0001** | | | .7447 |
| <90 | 11.37 | 5.24-24.68 | **<.0001** | 0.60 | 0.10-3.60 | .5768 |
| 90-109 | 2.04 | 0.87-4.80 | .1020 | 0.83 | 0.29-2.37 | .7271 |
| 110-139 (ref) | 1 | - | - | 1 | - | - |
| 140+ | 0.47 | 0.18-1.21 | .1158 | 0.56 | 0.17-1.83 | .3363 |
| Heart Rate (pulse/min) | | | **<.0001** | | | .0675 |
| <40 | 25.01 | 7.79-80.25 | **<.0001** | 1.38 | 0.20-9.67 | .7463 |
| 40-99 (ref) | 1 | - | - | 1 | - | - |
| 100-139 | 1.82 | 0.97-3.44 | .0632 | 0.51 | 0.17-1.54 | .2343 |
| 140+ | 11.77 | 2.05-67.56 | **.0057** | 5.93 | 0.63-55.75 | .1194 |
| Shock Index | | | **<.0001** | | | .0662 |
| <0.6 (ref) | 1 | - | - | 1 | - | - |
| 0.6-<0.9 | 3.56 | 1.02-12.42 | **.0469** | 3.99 | 0.98-16.27 | .0537 |
| 0.9-<1.3 | 9.80 | 2.69-35.68 | **.0005** | 9.11 | 1.31-63.32 | **.0256** |
| 1.3+ | 68.73 | 17.32-272.70 | **<.0001** | 35.75 | 2.51-509.81 | **.0083** |
| Glasgow Coma Scale | | | **.0002** | | | **.0092** |
| 2-4 | 2.853 | 1.55-5.25 | **.0007** | 0.10 | 0.02-0.47 | **.0038** |
| 5-8 | 0.93 | 0.25-3.47 | .9088 | 0.12 | 0.02-0.83 | **.0316** |
| 9-14 | 0.47 | 0.18-1.22 | .1201 | 0.14 | 0.04-0.53 | **.0038** |
| 15 (ref) | 1 | - | - | 1 | - | - |
| Penetrating Mech. (ref: Blunt)[a] | 1.88 | 0.76-4.64 | .1712 | 1.40 | 0.45-4.40 | .5646 |
| Prehospital Index | | | **<.0001** | | | **.0282** |
| 0-3 (ref) | 1 | - | - | 1 | - | - |
| 4-7 | 2.21 | 0.61-7.99 | .2271 | 2.31 | 0.60-8.92 | .2259 |
| 8-13 | 3.62 | 0.91-14.43 | .0685 | 4.88 | 0.92-26.00 | .0633 |
| 14-19 | 3.78 | 1.01-14.20 | **.0489** | 13.36 | 1.92-92.81 | **.0088** |
| 20-24 | 42.52 | 10.57-171.08 | **<.0001** | 53.10 | 4.83-583.86 | **.0012** |



**Table 2.** For Trauma Patients, Patient Characteristics Associated with "PHUS-Supported Interventions" Multi-Variable Logistic Regression Analysis: Unadjusted Model (all uni-variable models) and Adjusted Model (full multi-variable model)
Note: N = 299; yes support n = 69, 23.08%; no support n = 230, 76.92%.
Abbreviations: CI, confidence interval; OR, odds ratio; Ref, reference level.
[a] Trauma Mechanism (Blunt vs Penetrating).



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In the multi-variable model, HR and SI were significant predictors for medical patients, and PHI, SI, and female sex for trauma patients. In both groups, the highest markers of acuity had the highest association.

For both medical and trauma patients in the unadjusted model, individual patient characteristics of high acuity (low SBP, HR, and GCS) were associated with interventions supported by PHUS. In the adjusted model, this association decreased or was not seen due to the similarities between characteristics and confounding (eg, SI is made up of HR and SBP, so it would be unlikely that either HR or SBP would have a strong association separate to SI). In the medical patient cohort, low HR remained a strong predictor, since this group included patients who were in arrest. What was not predicted was the interesting confounding noted between the unadjusted and adjusted model in trauma patients with a low GCS (2-4). One hypothesis is that while controlling for the predictors of shock and PHI, one group that remains is patients with isolated traumatic brain injuries who might be less likely to have their management supported by a thoracic ultrasound than a hypotensive patient with treatable truncal identifiable injuries or findings. Also not predicted was female sex being associated with "PHUS-supported interventions." One hypothesis for this is that many trauma scans were conducted in-flight on stable male trauma patients that did not result in any supported interventions, which might have increased the effect of those scans conducted on female patients.

The present study results support the findings of previous prehospital ultrasound research. In a medical cohort of patients in arrest and peri-arrest, PHUS was found to affect patient management more often for patients in arrest (89% vs 66%).[8] In a study of well-matched trauma patients, a FAST positive result was associated with a significant difference in time-to-operative intervention compared to a FAST negative or no FAST performed result.[9] Within a physician-staffed HEMS, the use of PHUS within an algorithm for traumatic arrest has been described.[10]

The results of this study support the studied HEMS practice of PHUS use. So as not to delay essential patient transport, an ultrasound scan is only conducted on-scene if the result might reasonably be expected to support the patients' immediate management. Conducting a PHUS en-route is possible and is preferred in many primary scene missions. For interfacility missions (especially trauma), where the median time from injury to receiving hospital arrival has been previously reported as 224 minutes and median flight times are 44 minutes,[11] the decision to rapidly identify any treatable causes of hypotension in the sending facility is preferred.

## Limitations

This study has significant limitations. The value of the support provided by PHUS was not assessed. It was not possible to assess if an intervention would have occurred irrespective of PHUS. Assessment of scan accuracy was not possible as video review or in-hospital follow-up was not available. Only a single organization was studied, so results may not be generalizable. The retrospective nature of this study could lead to bias. Data abstractors were not blinded to the study objectives, and the first abstractor is affiliated with the HEMS program. Mitigating this bias was attempted by using an a-priori data form with defined variables and a second abstractor who was not affiliated with the HEMS program and was blinded to the first abstractors findings.

## Conclusion

In a critical care HEMS, markers of higher patient acuity in both medical and trauma patients were associated with occurrences when an intervention was supported by PHUS. Prospective study with in-hospital follow-up is required to confirm these hypothesis-generating results.

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