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► **To cite this version:**

Laurent Zieleskiewicz, Laurent Muller, Charlotte Arbelot, Pierre-Marie Bertrand, Belaid Bouhemad, et al.. Point-of-care ultrasound in intensive care units: assessment of 1073 procedures in a multicentric, prospective, observational study. *Intensive Care Medicine*, 2015, 41 (9), pp.1638 - 1647. 10.1007/s00134-015-3952-5 . hal-01758771

HAL Id: hal-01758771

<https://hal.umontpellier.fr/hal-01758771>

Submitted on 9 Nov 2018

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Point-of-care ultrasound in intensive care units: assessment of 1073 procedures in a multicentric, prospective, observational study

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Take-home message: In the intensive care unit, the prevalence of point-of-care ultrasound was 55 %. Ultrasound was utilized for diagnostic assessment in 87 % of cases and procedural guidance in 13 % of cases; its use impacted diagnostic and therapeutic strategies in 84 and 69 % of cases. Transthoracic echocardiography and lung ultrasound were routinely performed by intensivists. In contrast, ultrasound guidance for central venous line and arterial catheter placement remains unsatisfactory.

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Abstract Objective: To describe
current use and diagnostic and thera-
peutic impacts of point-of-care
ultrasound (POCUS) in the intensive
care unit (ICU).

Background: POCUS is of growing
importance in the ICU. Several
guidelines recommend its use for
procedural guidance and diagnostic
assessment. Nevertheless, its current
use and clinical impact remain

unknown. **Methods:** Prospec-
tive multicentric study in 142 ICUs in
France, Belgium, and Switzerland.

All the POCUS procedures performed
during a 24-h period were prospec-
tively analyzed. Data regarding
patient condition and the POCUS
procedures were collected. Factors
associated with diagnostic and thera-
peutic impacts were identified.

Results: Among 1954 patients hospi-
talized during the study period,
1073 (55 %) POCUS/day were per-
formed in 709 (36 %) patients.
POCUS served for diagnostic assess-
ment in 932 (87 %) cases and
procedural guidance in 141 (13 %)
cases. Transthoracic echocardiogra-
phy, lung ultrasound, and transcranial
Doppler accounted for 51, 17, and
16 % of procedures, respectively.

Diagnostic and therapeutic impacts of
diagnostic POCUS examinations
were 84 and 69 %, respectively.

Ultrasound guidance was used in 54
and 15 % of cases for central venous
line and arterial catheter placement,
respectively. Hemodynamic instabil-
ity, emergency conditions,
transthoracic echocardiography, and
ultrasounds performed by certified
intensivists themselves were inde-
pendent factors affecting diagnostic
or therapeutic impacts.

Conclusions: With regard to guide-
lines, POCUS utilization for
procedural guidance remains insuffi-
cient. In contrast, POCUS for
diagnostic assessment is of extensive
use. Its impact on both diagnosis and
treatment of ICU patients seems crit-
ical. This study identified factors
associated with an improved clinical
value of POCUS.

Keywords Ultrasound ·
Point-of-care · Diagnosis ·
Treatment · Echocardiography

Introduction

Prompt diagnosis and early treatments are essential in intensive care unit (ICU) patients [1]. During the last few years, several guidelines have recommended using ultrasound for procedural guidance and diagnostic assessment [2–4]. Ultrasound can rapidly provide relevant information at the bedside [5].

As demonstrated in several monocentric studies, transthoracic echocardiography improves the performance of clinical cardiac examination [6–9]. Analogous results were obtained for pulmonary examination. Several studies showed that lung ultrasound performs better than chest radiograph [10, 11] and reduces the need for irradiative procedures [12]. In addition, the use of ultrasound was associated with up to 50 % change of patient management [6–10].

Previous studies defined point-of-care ultrasound (POCUS) as ultrasonography brought to the patient and performed by the provider [13–16]. POCUS aims to avoid delays in diagnosis and treatment initiation [17]. However, in the ICU, the actual levels of POCUS implementation and contribution to patient management remain unknown. The primary aim of our study was to evaluate the prevalence of POCUS use in ICU patients. The secondary aims were to assess the diagnostic performance and therapeutic impact of POCUS in a large cohort of ICU patients. Finally, we assessed the factors that may influence the performance of POCUS.

Materials and methods

Study design

This 1-day, prospective, observational study was approved by the institutional review board (IRB) (Nîmes, France, 13/04-0208/27/2013) and the Commission Nationale de l'Informatique et des Libertés (DE-20146005, 01/30/2014). The IRB waived the need for patient (or relative) consent. Local IRBs in other participating countries also approved the trial with waived consent.

Using several networks including AzuRea and CAR'-Echo, we invited representatives of 160 ICUs to participate to the study. We recruited units from France, Switzerland, and Belgium. The representatives of 142 (89 %) ICUs accepted the invitation. The representatives of each unit prospectively collected all the ultrasound exams that were performed in their units during a 24-h period starting on 11 December 2014 at 8 a.m. There was no incentive to perform POCUS that day. Apart from the local coordinator, the other doctors participating in the trial were not aware of the goals of the trial. During the study, each operator performing an ultrasound examination filled in a case report

form. Details on operator training, patient conditions, type of ultrasound, diagnosis, treatment changes, and timing of assessment were reported in the case report form. The day after the study, each investigator collected the total number of patients hospitalized and the total number of central venous line (CVC) or arterial line (A-line) placements. The case report forms are available in the Electronic Supplemental Material.

Definitions

The prevalence of POCUS was defined as the number of POCUS/number of patients hospitalized in the unit during the study period. The POCUS were classified into “procedural guidance” (ultrasound was used for an invasive procedure) or “diagnostic assessment” in the other cases [13]. We studied diagnostic and therapeutic impact as well as clinical value of POCUS in the “diagnostic assessment POCUS” group. “Procedural guidance POCUS” was excluded from this analysis. The “diagnostic impact” was defined as an ultrasound-induced confirmation or change in the current diagnosis according to the physician who performed the examination. The “therapeutic impact” was defined as an ultrasound-induced change in treatment and/or imaging ordering and/or patient triage according to the physician who performed the POCUS. These variables were determined during the study period. The “global clinical value” was defined as the combination of either the diagnostic impact or therapeutic impact [18]. An emergent ultrasound was defined as a POCUS performed in the first hour after the occurrence of the first clinical sign. We classified POCUS performed at ICU admission, during the hospitalization, during the day shift (from 8 a.m. to 6 p.m.), and during the night shift (6 p.m. to 8 a.m.). The operator classified the quality of images obtained for each procedure as good (full visualization of structures), average (partial visualization allowing assessment), or poor (no visualization or no possible assessment).

A trained physician was defined as a specialist skilled in a given procedure (cardiologists for echocardiography, radiologists for the other types of ultrasound evaluations). For intensivists, a certified physician was defined as an intensivist who received specific training in critical care echography, according to international guidelines [19]. Ultrasound guidance rates for CVC and A-line were defined as the ratio of the total number of CVC or A-line placements divided by the number of ultrasound-guided placements.

Statistical analysis

Statistical analysis was performed using R-Project 3.1 for GNU Linux Ubuntu (Vienna, Austria). For categorical

variables, percentages were computed. Comparisons of percentages were performed with Fisher's exact test. We performed a multivariate analysis to assess the independent factors of therapeutic and diagnostic impact. Variables with a significance level at least 0.1 were included in the logistic regression model. The variables were selected by a step-by-step forward-backward model to minimize the Akaike's criterion. The statistical threshold for final significance was 0.05.

Table 1 Features of intensive care units ($n = 142$) and patients ($n = 709$)

Variables	<i>n</i>
Type of hospital (%)	
University hospitals (%)	98 (69)
General hospitals (%)	44 (31)
Type of ICU (%)	
Polyvalent	95 (70)
Medical	17 (13)
Pediatric	22 (17)
Patients	
Adult patients (%)	603 (85)
Patients younger than 15 years (%)	106 (15)
Shock (%)	393 (43)
Mechanical ventilation (%)	588 (64)
SAPS 2 median (IQR)	45 (32–58)
Timing of POCUS	
Emergent (<1 h after the first clinical sign) (%)	402 (44)
At ICU admission (%)	183 (20)
During night shift (%)	222 (25)
POCUS and procedures	
Disinfection protocol (%)	65 (47)
Management algorithm (%)	29 (20)
Skill level of operator	
Performed by an intensivist (%)	821 (89)
Board-certified operator (%)	752 (81)

ICU intensive care unit, SAPS simplified acute physiology score 2, IQR interquartile range, POCUS point-of-care ultrasound

Results

During the study day, 1073 (55 %) POCUS were performed in 709 (36 %) out of 1954 patients hospitalized in the 142 ICUs. The quality of images was classified as good, average, and poor for 794 (74 %), 236 (22 %), and 43 (4 %) POCUS, respectively. Features of patients and units are summarized in Table 1.

The use of POCUS was aimed at assessing diagnosis in 932 (87 %) cases and procedural guidance in 141 (13 %) cases (Fig. 1). The diagnostic and therapeutic impacts were 84 and 69 %, respectively (Fig. 2). The clinical value combining either the diagnostic impact or the therapeutic impact was assessed at 85 %. With respect to diagnostic impact, the use of POCUS confirmed or changed the diagnosis in 63 and 21 % of cases, respectively. Heart, lung, brain, and miscellaneous other sites represented 51, 17, 16, and 16 % of POCUS, respectively (Fig. 2). Performing POCUS resulted in the initiation of 373 therapeutic interventions, the decision to stop interventions in 73 cases, or not to perform additional examinations in 108 cases (Fig. 1); (Table 2). Hemodynamic interventions including fluid bolus ($n = 115$), fluid depletion ($n = 80$), and catecholamine administration ($n = 43$) were the most prominent POCUS-driven interventions. With respect to 183 central venous line placements and 127 arterial catheter placements, POCUS was used in 99 (54 %) cases and 15 (13 %) cases, respectively.

The factors associated with diagnostic and therapeutic impacts in the univariate analysis are shown in Table 3. In the multivariate analysis, being a certified operator, managing a shocked patient, having a disinfection protocol, and using an algorithm of management were associated with significant changes in the diagnostic impact (Table 3). Being an intensivist, having a daily practice, assessing a child, processing in emergency,

Fig. 1 Flowchart showing prevalence and diagnostic and therapeutic impacts of point-of-care ultrasounds

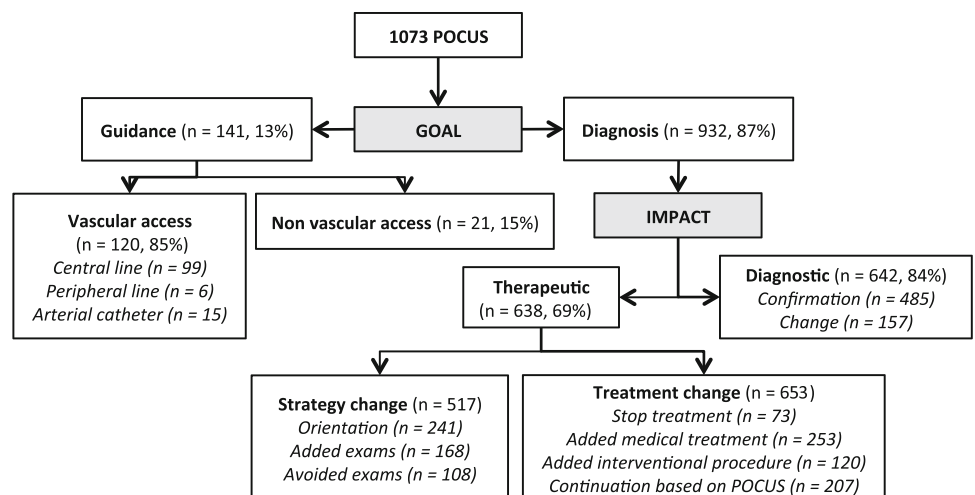


Fig. 2 Rates of point-of-care ultrasound use depending on site

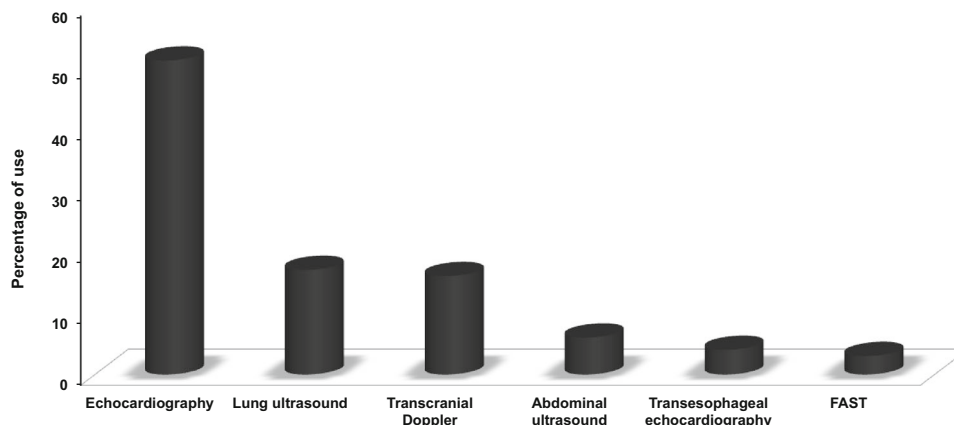


Table 2 Interventions associated with point-of-care ultrasound performance

Intervention	<i>n</i> = 373 (%)
Hemodynamics	
Fluid bolus	115 (31)
Fluid depletion	80 (21)
Catecholamines	43 (12)
Pulmonary artery hypertension treatment	11 (2.9)
Invasive procedures	
Surgery/interventional radiology	13 (3.4)
Chest tube insertion	48 (13)
Medical treatments	
Antibiotics	10 (2.6)
Sedation	6 (1.6)
Mechanical ventilation setting	9 (2.4)
Anticoagulation	7 (1.8)
Others (miscellaneous)	31 (8.3)

working in a university hospital, and transthoracic echocardiography were independent variables associated with therapeutic impact (Table 3).

Discussion

In this large 1-day observational trial we observed that at least one POCUS is performed in one-third of the patients hospitalized in the ICU that day and that it impacted patient management in 85 % of cases.

POCUS was used in 36 % of our patients/day. Even though ICU guidelines recommend a large use of POCUS [2, 4, 19], the prevalence of POCUS use has been poorly described. Only a few monocentric studies assessed the performance of POCUS in ICUs [6, 7, 9, 10, 20]. A previous French survey showed that in the majority of ICUs echocardiography was used about once a day [21]. Interestingly, intensivists performed POCUS in 90 % of cases. This finding confirms the good diffusion of this

technique among intensivists. In addition, more than 80 % of operators were board-certified and used ultrasound on a daily basis.

A diagnostic impact was reported in 84 % of cases. The use of POCUS changed the diagnosis in 21 % of cases, while a suspected diagnosis was confirmed in 63 % of cases. This striking result highlights the emergence of POCUS as a diagnostic tool at the bedside. We did not collect the specific diagnosis. However, as transthoracic echocardiography represented more than 50 % of POCUS, our study underlines that ultrasounds play a key role for the hemodynamic management of ICU patients.

In 69 % of cases, the use of POCUS was associated with interventions including treatment, imagery ordering, and patient triage. In line with the diagnostic impact, most interventions were related to hemodynamics, underlining once again the key role of transthoracic echocardiography. Fluid loading, fluid depletion, and vasopressor administration were among the most frequent interventions. Several studies showed that hemodynamic-related interventions based on echocardiography are efficient [22–25]. Elsewhere, Aliaga et al. reported 54 % of therapeutic changes after chest computed tomography [26]. However, the type of expectations probably differs between POCUS and computed tomography scan.

In our study, cardiac examination was the most common indication for POCUS. Transthoracic echocardiography has been associated with improvement of diagnosis in patients with acute respiratory failure and/or shock [6–8, 27] and is now recommended in guidelines [28]. In our cohort, lung ultrasound was the second most common type of POCUS used. The steep learning curve favors the use of this procedure, which provides interesting information about pleura, parenchyma, and lung aeration state in critical situations [10, 29–31]. Lung ultrasound was associated with reduced requirements for chest radiographs and computed tomography. This shift was associated with a decreased amount of irradiation and medical cost [12, 32]. In recent studies, a global approach combining heart and lung

Table 3 Factors associated with diagnostic and therapeutic impacts

Variable	Univariate analysis			Multivariate analysis	
	Yes <i>n</i> (%)	No <i>n</i> (%)	<i>p</i>	OR (95 % CI)	<i>p</i>
Diagnostic impact					
US certified	464 (86)	178 (78)	0.005	2.0 (1.2–3.1)	0.002
Disinfection protocol	311 (90)	312 (80)	<0.001	2.4 (1.5–3.7)	0.004
Shock	293 (88)	337 (80)	0.05	1.5 (1.0–2.4)	0.01
Management algorithm	136 (75)	487 (87)	<0.001	0.4 (0.3–0.7)	<0.001
Pediatric patient	66 (71)	560 (86)	<0.001		
Adult patient	560 (86)	66 (71)	<0.001		
Emergency US	312 (87)	318 (80)	0.02		
PaO ₂ /FiO ₂ <300 mmHg	268 (86)	354 (82)	0.1		
Therapeutic impact					
Operator: intensivist	579 (71)	55 (55)	0.04	1.7 (1.0–2.9)	0.002
Daily practice of US	509 (71)	124 (61)	0.001	1.8 (1.2–2.7)	0.01
TTE	349 (75)	284 (63)	0.001	1.7 (1.2–2.3)	<0.001
Emergency US	319 (79)	312 (61)	<0.001	2.6 (1.9–3.8)	<0.001
University hospital	430 (65)	180 (79)	0.01	0.6 (0.4–0.9)	<0.001
Pediatric patient	70 (52)	550 (72)	<0.001	0.4 (0.3–0.7)	<0.001
US certified	528 (71)	110 (62)	<0.001		
Ward US	166 (75)	457 (67)	0.03		
Shock	287 (73)	342 (66)	0.03		

OR odds ratio, CI confidence interval, US ultrasound, TTE transthoracic echocardiography

assessment improved diagnostic performance [27, 33]. Thus, one may expect a larger use of this promising technique. The gap between echocardiography and lung ultrasound probably reflects the differences in the penetration rate of the two techniques. Recent guidelines should reduce this gap [2, 34]. In our study, transcranial Doppler was the third most common type of POCUS used. Transcranial Doppler aimed to monitor cerebral hemodynamics, as an alternative or complement to intracranial pressure monitoring [22, 23].

POCUS was used to guide procedures in less than 15 % of indications. Only half of CVC insertions were ultrasound-guided, despite a strong level of evidence and recommendations for using ultrasound guidance during CVC placement [4]. This result is surprising since an ultrasound device was available in all the units. Ultrasound was used in 15 % for the placement of A lines. This procedure is supported by guidelines with a strong level of evidence [35]. Therefore our results show that, in the study group of ICUs, compliance with this recommendation can be improved.

Finally, we identified independent factors associated with the diagnostic and therapeutic impacts. Operator experience (trained or certified physician), disinfection protocol, and presence of shock were associated with increased diagnostic impact. The disinfection protocol may be an indirect marker of appropriate use of POCUS and quality of care. The operator's experience probably reflects a certain level of expertise. With respect to shock management, several studies reported the performance of ultrasound in those patients [21, 26]. In terms of

diagnostic impact, having pre-established therapeutic algorithms was associated with reduced performance. In our opinion, this result reflects the challenge to show the relevance of algorithms in ICU patients [36, 37]. With respect to therapeutic impact, our results showed that being an intensivist, having a routine use of POCUS, and performing an emergency POCUS were associated with an increased impact. Those findings suggest that at the bedside POCUS facilitates the intensivist's decision-making process. This also encourages the development of specific training for intensivists [38]. Unsurprisingly, transthoracic echocardiography also has a stronger therapeutic impact than other procedures. Hemodynamic assessment represented more than half of the interventions, probably explaining these associations.

Our study has several limitations. Although this was not requested, only units with an available ultrasound device participated. This represents probably an intrinsic bias of recruitment. In addition, we conducted the study in Belgium, Switzerland, and France. As we cannot determinate the rate of uptake of POCUS in other countries, it is difficult to determine how our findings are able to be extrapolated elsewhere. As the study was open, the investigators were aware of the study day. Therefore, they may have been encouraged to use the POCUS during the study day. However, this deviation should result in decreased rates of diagnostic and therapeutic impacts, which are high in our study. Moreover, the impact of ultrasound on the medical decision was also determined by the operator. In relation to our aims, the loss of data would have been a bias exceeding that of the non-blinded assessment. In terms of diagnosis

and treatment, POCUS was not compared with a standard of care. Nevertheless, this process was confirmed in several previous studies [6, 7, 10, 11]. Finally, our study was not aimed at assessing the appropriateness of interventions and the patient outcomes. Our goal was to determine the use of POCUS in real life.

Our study clearly shows the high prevalence of POCUS use in ICUs. Moreover, we showed that POCUS is not an observational game but strongly impacts the management of the most critically ill patients. Intensivists acquired adequate skills for using ultrasound at the bedside. Future efforts should stress the placement of intravascular lines using ultrasound.

Acknowledgments Author contributions: Drs Zieleskiewicz and Leone had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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Drafting of the manuscript: Lakhali, Meresse, De Backer, Leone, Allaouchiche, Zieleskiewicz, L Muller, Ichai, Lefrant.

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Members of the CAR'Echo and AzuRea Collaborative Networks

Table 4 presents a list of members of the CAR'Echo and AzuRea Collaborative Networks.

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