Intérêt, conditions nécessaires au déploiement et impact de l'échographie clinique en médecine d'urgence.

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Intérêt, conditions nécessaires au déploiement et impact de l'Échographie Clinique en Médecine d'Urgence.

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1. Introduction :

Les technologies de l'échographie et du Doppler sont utilisées depuis plusieurs décennies en médecine. Son déploiement fut d'abord important dans les services d'imagerie médicale. Certaines spécialités médicales (gynécologie, cardiologie, médecine vasculaire) se sont appropriées ces technologies pour que l'échographie-Doppler devienne une part importante de leur activité voire une « sous spécialité ». Les années 80, 90 et le début des années 2000 ont vu la publication de nombreuses études validant l'intérêt diagnostique de l'échographie réalisée par un clinicien. Par conséquent, l'échographie intégrée à l'examen clinique connait surtout son essor depuis deux décennies. Les spécialités de Réanimation et de Médecine d'Urgence ont été les premières à développer le concept d'échographie clinique transversale. Le déploiement de l'échographie clinique en médecine d'urgence (ECMU) demande quatre conditions : l'existence de preuves scientifiques sur la pertinence diagnostique des techniques utilisées, la disponibilité d'un échographe adapté, la compétence du praticien et l'objectivation de son impact clinique. Après avoir défini le concept d'ECMU, nous décrirons et analyserons l'état d'avancement de ces quatre étapes avant de proposer des perspectives d'évolution de l'ECMU.

2. ECMU : définition

2.1. Sémantique :

Le concept de *point-of-care ultrasonography* (*POCUS*) fut bien défini en 2011 (1). En anglais, il est également appelé *bedside ultrasonography*, *focused ultrasonography* ou *clinical ultrasonography*. En français, le conseil national pédagogique du Diplôme Interuniversitaire d'Échographie et Techniques UltraSonores (DIU ETUS) a renommé le module destiné aux urgentistes en 2014 (initialement appelé Échographie Appliquée à l'Urgence) pour l'appeler Échographie Clinique Appliquée à l'Urgence (ECAU). Enfin, les recommandations formalisées d'experts (RFE) de la Société Française de Médecine d'Urgence (SFMU) publiées en 2016 utilisaient le terme d'ECMU (2). Nous utiliserons ce terme pour se référer à la *POCUS* réalisée en médecine d'urgence, et utiliserons le terme « échographie clinique » pour décrire le concept général.

2.2. Concept d'échographie clinique :

Le concept d'échographie clinique est né de l'observation de l'utilisation de l'outil échographique par des cliniciens issus de nombreuses spécialités (1). Les caractéristiques d'une échographie clinique sont (1) :

- Une échographie réalisée au lit du patient ;
- Une échographie réalisée par le médecin clinicien riche de la connaissance du contexte et de l'examen clinique ;
- Dont les résultats sont immédiats ;
- Dont les résultats sont souvent de type binaire : oui ou non ;
- Qui peut être répétée, en particulier pour permettre le monitorage du patient.

Trois types d'applications de l'échographie clinique sont décrites : pour le dépistage, diagnostique et procédurale.

2.3. Particularités de l'ECMU :

La première particularité de l'ECMU est que l'échographie ne sera pas réalisée « au lit du patient » mais « sur les lieux ». Les prises en charges de médecine d'urgence peuvent concerner des patients sur la voie publique, dans leur domicile, durant un transport ou en conditions hospitalières. Si certaines techniques dans certaines conditions permettent d'affirmer ou d'infirmer un diagnostic, le bénéfice de l'ECMU est plutôt d'ajouter un argument permettant d'améliorer la pertinence diagnostique du clinicien (3). Pour décrire les conditions définissant une ECMU, les RFE de la SFMU de 2016 ont repris les caractéristiques de l'échographie clinique en y ajoutant deux point (2) :

- « Nécessite des images cibles ou diagnostiques sans équivoque dans le contexte clinique » ;
- « Se réalise dans un temps court compatible avec celui de l'urgence vitale » ;

Ce qui caractérise l'ECMU serait donc le fait de se baser sur des techniques de réalisation simples et rapides.

Dans la description de la POCUS (1), les types d'applications qui semblent intéresser la médecine d'urgence sont diagnostiques et procédurales. L'*Amercian College of Emergency Physicians* (*ACEP*) décrit dans ses *guidelines* de 2017 cinq champs d'applications (4) :

- *Resuscitative* : ECMU réalisée durant une réanimation, un arrêt cardio-respiratoire (ACR) par exemple. L'individualisation de ce champ d'application met en avant l'expertise nécessaire des médecins urgentistes pour la prise en charge initiale des détresses vitales et de l'ACR ;
- *Diagnostic* ;
- *Procedural guidance* ;
- *Symptom or Sign Based* : ECMU réalisée dans un contexte symptomatologique particulier comme la dyspnée ou la douleur thoracique. Individualiser ce champ d'application en médecine d'urgence est d'une importance majeure. Il permet d'insister sur le caractère multi-organique ou transversal de l'examen. Une des caractéristiques de la médecine d'urgence est sa transversalité. Le médecin urgentiste est confronté à des situations cliniques impliquant plusieurs organes ou systèmes. Si l'examen clinique d'un patient dyspnéique ne se limite pas à l'évaluation pulmonaire, les techniques d'ECMU utilisées ne doivent pas se limiter à un organe cible. Ainsi, chez les patients en détresse respiratoire par exemple, l'association de l'échocardiographie à l'échographie pulmonaire a montré sa supériorité à l'utilisation de l'échographie pulmonaire seule (5).
- *Therapeutic and Monitoring* : ECMU réalisée pour surveiller l'efficacité d'un traitement mis en place ou l'évolution d'un patient traité. Ainsi, le monitorage précoce de l'efficacité des thérapeutiques mises en place sera permis comme lors de l'instauration d'une séance de ventilation non invasive (VNI) dans la prise en charge de l'œdème aigu du poumon (OAP) cardiogénique en médecine préhospitalière (6).

L'ECMU peut donc être définit comme l'utilisation d'une technique échographique simple et rapide, réalisée par le médecin urgentiste en charge du patient, sur les lieux de la prise en charge, et dont les résultats sont immédiats et souvent binaires. Ces champs d'applications sont le guidage de gestes invasifs et l'amélioration de la pertinence diagnostique par une utilisation transversale des différentes techniques, en particulier afin de guider une réanimation ou de monitorer un patient aigu.

2.4. Place de l'ECMU dans le raisonnement diagnostique :

Un modèle de raisonnement diagnostique couramment décrit est que le médecin urgentiste émet des hypothèses à partir de l'examen clinique et confirme ou infirme chacune d'entre elle grâce aux résultats des autres outils diagnostiques (raisonnement hypothético-déductif) (7). Nous avons voulu étudier les déterminants du poids de l'argument « ECMU » dans le raisonnement clinique. En effet, réaliser une ECMU mais n'accorder que peu d'importance à son résultat est probablement une perte de temps. Nous avons choisi comme sujet d'étude l'échographie pulmonaire dans la dyspnée. Premièrement, parce que c'est un des contextes cliniques dans lequel le niveau de preuve de la pertinence diagnostique de l'ECMU est la plus élevée. Donc, le poids des résultats de l'ECMU dans le raisonnement diagnostique devrait être majeur. Deuxièmement, parce que le problème de la dyspnée est complexe : si un bon diagnostic est associé à une meilleure survie (8), les causes sont souvent mixtes. Nous avons considéré qu'il y avait trois niveaux d'hypothèses diagnostiques cliniques : les hypothèses fortes (niveau de probabilité > 7/10), les faibles (niveau de probabilité < 3/10) et les modérées (niveau de probabilité compris entre 3 et 7/10 inclus). Nous avons appelé ces probabilités modérées, des hypothèses incertaines. Cette catégorie d'hypothèses nous a particulièrement intéressé car il est probable que les hypothèses fortes entrainent la mise en place d'un traitement spécifique, que les hypothèses faibles n'entrainent pas de mise en place de traitement spécifique et que les hypothèses incertaines posent le problème de la mise en place du traitement spécifique au clinicien. Nous avons donc réalisé une étude multicentrique, randomisée, en France et au Maroc, basée sur la résolution de cas cliniques complexes de dyspnée. L'objectif principal de cette étude était d'évaluer le nombre d'hypothèses diagnostiques incertaines proposées par des médecins urgentistes selon les informations dont ils disposaient pour résoudre les cas cliniques (selon trois possibilités : contexte - examen clinique, échographie pulmonaire ou les deux). Les réponses de 76 médecins ont été analysées (228 cas cliniques résolus). Le nombre moyen d'hypothèses diagnostiques incertaines était, respectivement lorsque les médecins avaient les données cliniques, échographiques et les deux : 2,9 ± 1,8, 2,2 ± 1,7, 2,2 ± 1,8 ($p = 0,02$). Les seules variables liées au nombre d'hypothèses incertaines étaient d'avoir accès aux données échographiques et la fréquence d'utilisation de l'ECMU. Une fréquence élevée d'utilisation de l'échographie diminuait le nombre de diagnostics incertains. Notre étude a confirmé que l'ECMU diminuait le nombre de diagnostics incertains. Notre principal résultat était qu'une fréquence d'utilisation élevée de l'ECMU était associé à une diminution du nombre de diagnostics incertains formulés. Il existe donc un cercle vertueux : plus le médecin urgentiste pratiquera l'ECMU, plus, quand il l'utilisera, elle aura un impact sur son diagnostic, et vice versa. Enfin, compte tenu des preuves sur l'échographie pulmonaire dans la dyspnée, le poids des données échographiques dans la prise de décision aurait dû être plus important. Des solutions, impliquant la motivation, doivent donc être trouvées afin que les praticiens que l'on forme à l'ECMU pratiquent le plus possible et tiennent compte des résultats dans leurs prises en charge. L'explication du cercle vertueux, décrit précédemment, aux étudiants durant leur enseignement semble une première étape.

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Integration of lung ultrasound in the diagnostic reasoning in acute dyspneic patients: A prospective randomized study

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ABSTRACT

Introduction: Misdiagnosis in acute dyspneic patients (ADP) has consequences on their outcome. Lung ultrasound (LUS) is an accurate tool to improve diagnostic performance. The main goal of this study was to assess the determinants of increased diagnostic accuracy using LUS.

Materials: Multicentre, prospective, randomized study including emergency physicians and critical care physicians treating ADP on a daily basis. Each participant received three difficult clinical cases of ADP: one with only clinical data (OCD), one with only LUS data (OLD), and one with both. Ultrasound video loops of A, B and C profiles were associated with the cases. Which physician received what data for which clinical case was randomized. Physicians assessed the diagnostic probability from 0 to 10 for each possible diagnosis. The number of uncertain diagnoses (NUD) was the number of diagnoses with a diagnostic probability between 3 and 7, inclusive.

Results: Seventy-six physicians responded to the study cases (228 clinical cases resolved). Among the respondents, 28 (37%) were female, 64 (84%) were EPs, and the mean age was 37±8 years. The mean NUDs, respectively, when physicians had OCD, OLD, and both were 2.9±1.8, 2.2±1.7, 2.2±1.8 ($p = 0.02$). Ultrasound data and ultrasound frequency of use were the only variables related to the NUD. Higher frequency of ultrasound use by physicians decreased the number of uncertain diagnoses in difficult clinical cases with ultrasound data (OLD or associated with clinical data).

Conclusion: LUS decreases the NUD in ADP. The ultrasound frequency of use decreased the NUD in ADP clinical cases with LUS data.

1. Introduction

Point of Care Ultrasound (POCUS) is a clinical tool [1] used in emergency medicine [2-4]. Lung ultrasound is a POCUS application characterized by very good accuracy and far better than radiology [5-9] or auscultation [9]. A POCUS diagnostic evaluation, mainly based on a lung ultrasound (LUS) of patients admitted for acute dyspnea, is concordant with complete diagnostic care and is much faster [10].

According to the American College of Emergency Physicians (ACEP), the first three steps of emergency ultrasound competency are the recognition of indications and contraindications, image acquisition, and image interpretation [11]. The last step must be able to integrate POCUS into individual patient care plans and management [11]. To achieve this, physicians must know the accuracy of the ultrasound technique used. As an accurate POCUS technique, LUS should be easily integrated by physicians into their clinical reasoning. However, physicians also reason with other clinical arguments, e.g., past and recent medical history and clinical signs. The decision weight of LUS in diagnostic reasoning is probably different according to each physician. A mechanism of POCUS-added value is a reduction of the number of possible diagnoses [12] and an improvement of diagnostic probability [13]. The improvement of diagnostic probability reduces the number of uncertain diagnoses (NUD). The certainty level is important to allow the decision to treat.

We hypothesized that the decision weight of LUS in diagnostic reasoning is different according to the ultrasound frequency of use and

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Table 1
Available data according to group

	Clinical Case 1 Acute cardiogenic pulmonary edema	Clinical Case 2 Pneumonia	Clinical Case 3 Chronic obstructive pulmonary disease
Group 1	Clinical data and ultrasound	Ultrasound only	Clinical data only
Group 2	Clinical data only	Clinical data and ultrasound	Ultrasound only
Group 3	Ultrasound only	Clinical data only	Clinical data and ultrasound

the physician's medical experience. The primary aim of our study was to identify the determinants of increasing diagnostic accuracy due to lung ultrasound in complicated clinical cases of acute dyspnea.

2. Materials and methods

2.1. Materials

This multicentre, prospective, randomized study was conducted from May 2016 to July 2016. All participants consented to the study. Physicians included were Emergency Physicians (EP) and Critical Care Physicians (CCP). To participate in the study, all physicians had to provide care for patients with acute dyspnea on a daily basis, had formal pulmonary ultrasound training, and practice regularly. Physicians were contacted by email. We proposed to enrol doctors through three professional networks: the Winfocus France group, the "*Comité Urgence*" of the "*Société Francaise d'Anesthésie et Réanimation*" (*SFAR*), and emergency physicians (EP) of the south-east of France hospitals.

Four experts (3 EP, 1 CCP) defined three clinical cases scenario of acute dyspnea that were considered as difficult. Clinical case 1 involved a 45-year-old patient with unknown alcoholic heart disease admitted for acute dyspnea during a transition to atrial fibrillation secondary to cutaneous sepsis. Clinical case 2 described acute dyspnea in a male octogenarian with a past medical history of chronic bronchitis and chronic heart failure. Clinical case 3 described acute dyspnea in a female octogenarian known with chronic obstructive pulmonary disease (COPD) and chronic heart failure. The clinical data included a history of present illness, pertinent past medical history, and all clinical examination data. Four LUS videos were associated with each of the three clinical cases (right base, right apex, left base, and left apex). These videos were made in three patients just after a CT scan performed by a LUS expert. The videos of clinical case 1 were those of acute cardiogenic pulmonary edema (ACPE, bilateral B profile), case 2 videos showed left base pneumonia (posterolateral alveolar and pleural syndrome: PLAPS), and clinical case 3 videos were bilateral A profile with lung sliding. These ultrasounds exams were all performed with a pocket-sized ultrasound system (V-Scan Dual Probe©, GE Healthcare, Milwaukee, Wisconsin, USA). Once consenting to participation in the study, the physicians were randomized into three groups, one for each clinical case (Table 1).

2.2. Aims

The main objective of this study was to identify the determinants of increasing diagnostic accuracy due to LUS. The primary endpoint was the number of considered uncertain diagnoses. There was a maximum of eight possible diagnoses: ACPE, infectious pneumonia, COPD exacerbation, pneumothorax, neoplastic acute dyspnea, acute asthma exacerbation, pulmonary embolism, and metabolic acute dyspnea. Physicians had to evaluate the diagnostic probability from 0 (unlikely definitely not diagnosis) to 10 (definite diagnosis) for each. The number of diagnoses considered possible was the number of diagnoses with a value different from 0. The NUD was the number of possible diagnoses with a value between 3 and 7, inclusive. Our hypothesis was the NUD would be lower with ultrasound data but influenced by ultrasound frequency of use. The secondary aims were to verify that LUS reduces the number of possible diagnoses in acute dyspnea clinical cases and to find if these possible diagnoses are influenced by ultrasound frequency of use or the physician's medical experience.

2.3. Collected data

Data collected on each respondent included their age, gender, clinical experience, specialty (emergency or critical care), main activity (emergency medicine or critical care), LUS training during their initial training, and their frequency of use of ultrasound. Each of the eight possible diagnoses had to be scored according to an assessed diagnostic probability from 0 to 10. Only complete responses were included in the study.

2.4. Statistical analysis

Quantitative data are expressed as mean ± standard deviation (SD) or median with 25th and 75th percentiles ([25th percentile–75th percentile]) according to the variable distribution. Qualitative variables are expressed as frequency with percentage. Comparison of quantitative variables among the different groups was performed by an overall analysis of variance (ANOVA). When conditions of validity of this test (normal distribution, equality of variances) were not verified,

Table 2
Respondents' characteristics
SD: Standard Deviation

		All respondents $n = 76$	Group 1 $n = 25$	Group 2 $n = 22$	Group 3 $n = 29$	p
Age (years) Mean ± SD or Median [Q25; Q75]		37 ± 8	34 [30; 38]	36 [33; 45]	33 [31; 39]	0.37
Gender: female n (%)		28 (37%)	13 (46%)	7 (25%)	8 (29%)	0.15
Clinical experience (year) Mean ± SD or Median [Q25; Q75]		8 ± 7	6 [2; 9]	7 [4; 15]	3 [2; 10]	0.35
Speciality: emergency n (%)		64 (84%)	22 (34%)	17 (27%)	25 (39%)	0.56
Principal activity: emergency n (%)		67 (88%)	23 (34%)	19 (29%)	25 (37%)	0.76
Initial ultrasound training n (%)		40 (53%)	15 (37%)	10 (26%)	15 (37%)	0.60
Ultrasound frequency use n (%)	<1/week	21 (47%)	9 (43%)	5 (24%)	7 (33%)	0.52
	Between once a week and once a month	36 (28%)	11 (31%)	9 (25%)	16 (44%)	
	Everyday	19 (25%)	5 (26%)	8 (42%)	6 32%)	

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Table 3
Factors associated with the number of uncertain diagnoses
SD: Standard Deviation; OR: Odds Ratio; CI: Confidence Interval

		Number of uncertain diagnoses Mean ± SD	Univariate analysis	Multivariate analysis	
			p	OR (CI95%)	p
Available data	Clinical only	2.9 ± 1.8	0.02		
	Ultrasound only	2.2 ± 1.7		0.48 (0.27–0.84)	0.01
	Clinical and ultrasound	2.2 ± 1.8		0.47 (0.27–0.83)	0.01
Age	Under 35 years	2.6 ± 1.8	0.18		
	35 to 50	2.2 ± 1.8		0.85 (0.47–1.51)	0.57
	Over 50	2.7 ± 1.9		1.47 (0.34–6.36)	0.60
Clinical experience	<12 years	2.3 ± 1.7	0.17		
	Between 12 and 20 years	2.7 ± 1.2		0.60 (0.26–1.39)	0.23
	>20 years	3.7 ± 0.6		1.00 (0.19–5.34)	0.99
Ultrasound frequency use	<1/week	2.7 ± 1.6	0.04		
	Between once a week and once a month	2.5 ± 1.8		0.84 (0.47–1.48)	0.54
	Everyday	2.1 ± 1.9		0.61 (0.32–1.19)	0.15
Clinical case	ACPE case	2.6 ± 1.8	0.16		
	Pneumonia case	2.1 ± 1.7		0.61 (0.34–1.06)	0.08
	COPD case	2.7 ± 1.9		1.07 (0.61–1.87)	0.82

nonparametric tests (Wilcoxon test or Kruskal–Wallis test if multiple classes) were used. The relationship between two variables was tested by the Chi square test or by the Fisher exact test when Chi square conditions of application (theoretical numbers <5) were not met. We performed a multivariate analysis to assess the independent factors on the NUD. Variables with a significance level of at least 0.2 were included in the linear model. Concerned quantitative variables were converted to classes according to their distribution. The significance level was set at 5% for all tests used. Statistical analysis was performed under R 3.3.3 (2017, R Foundation for Statistical Computing, Vienna, Austria).

3. Results

3.1. Participants

One hundred and seven physicians responded to the questionnaire. Of those, 31 (29%) were excluded as incomplete: 9 (29%), 10 (32%), and 12 (39%), respectively, in groups 1, 2, and 3. A total of 76 (71%) responses were analyzed (228 clinical cases resolved). These 76 physicians worked in 22 different centers in France and Morocco. The numbers of complete responses per group were: 25 (33%), 22 (29%), and 29 (38%), respectively, in groups 1, 2, and 3. Respondents' characteristics are listed in Table 2.

3.2. Primary outcome

For all clinical cases, the mean NUD was 2.9 ± 1.8 when responders had only clinical data, 2.2 ± 1.7 when they had only ultrasound, and 2.2 ± 1.8 when they had access to both ($p = 0.02$, Table 3, Fig. 1). Only the frequency of ultrasound use was significantly related to the NUD in the univariate analysis (Table 3, Fig. 2). The results of all variables included in the multivariate analysis are shown in Table 3.

3.3. Secondary outcomes

The mean number of diagnoses was 6.2 ± 1.9 when respondents had only clinical data, 4.8 ± 2.3 when they had only ultrasound, and 5.0 ± 2.0 when they had access to both ($p < 0.01$, Fig. 1). These numbers, respectively, for physicians in practice for <12 years, between 12 and 20 years, and >20 years were 5.6 ± 2.1, 4.1 ± 2.1, and 5.1 ± 2.0 ($p < 0.01$). These results and the number of diagnoses according to experience and available data are shown in Fig. 3. The number of possible diagnoses was 6.0 ± 1.7 for physicians who used ultrasound less than once a week, 5.3 ± 2.1 for those who used ultrasound between once a week and once a month, and 4.7 ± 2.5 for daily users ($p < 0.01$, Fig. 2).

4. Discussion

4.1. Main results

Our study showed that higher frequency of ultrasound use by physicians decreased the NUD in difficult clinical cases with ultrasound data (Table 3, Fig. 2). When physicians had ultrasound data (only or with clinical data) and a longer practice history there were fewer uncertain diagnoses (Fig. 2). The weight of LUS images in diagnostic reasoning seems more important to the daily practitioner. We can hypothesize that the weight of ultrasound images in treatment decision-making is also proportional to the frequency of ultrasound use. Indeed, daily ultrasound practitioners are probably more inclined to rely on ultrasound findings. However, this result can be one of the arguments used to

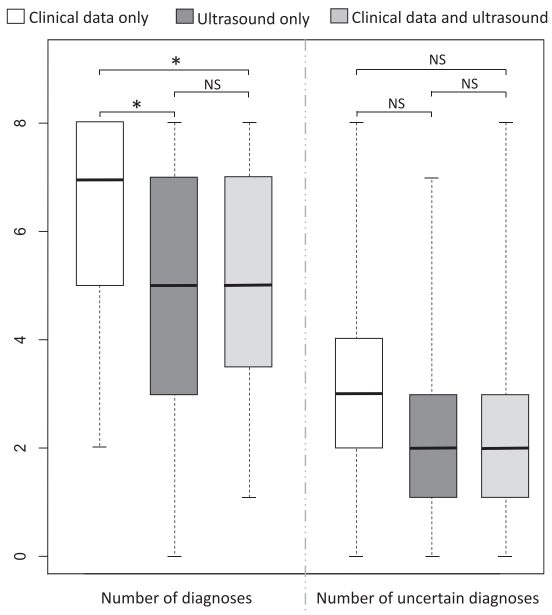

Fig. 1. Number of diagnoses and number of uncertain diagnoses according to available data. NS: Not Significant, $p > 0.2$; "*": $p < 0.05$.

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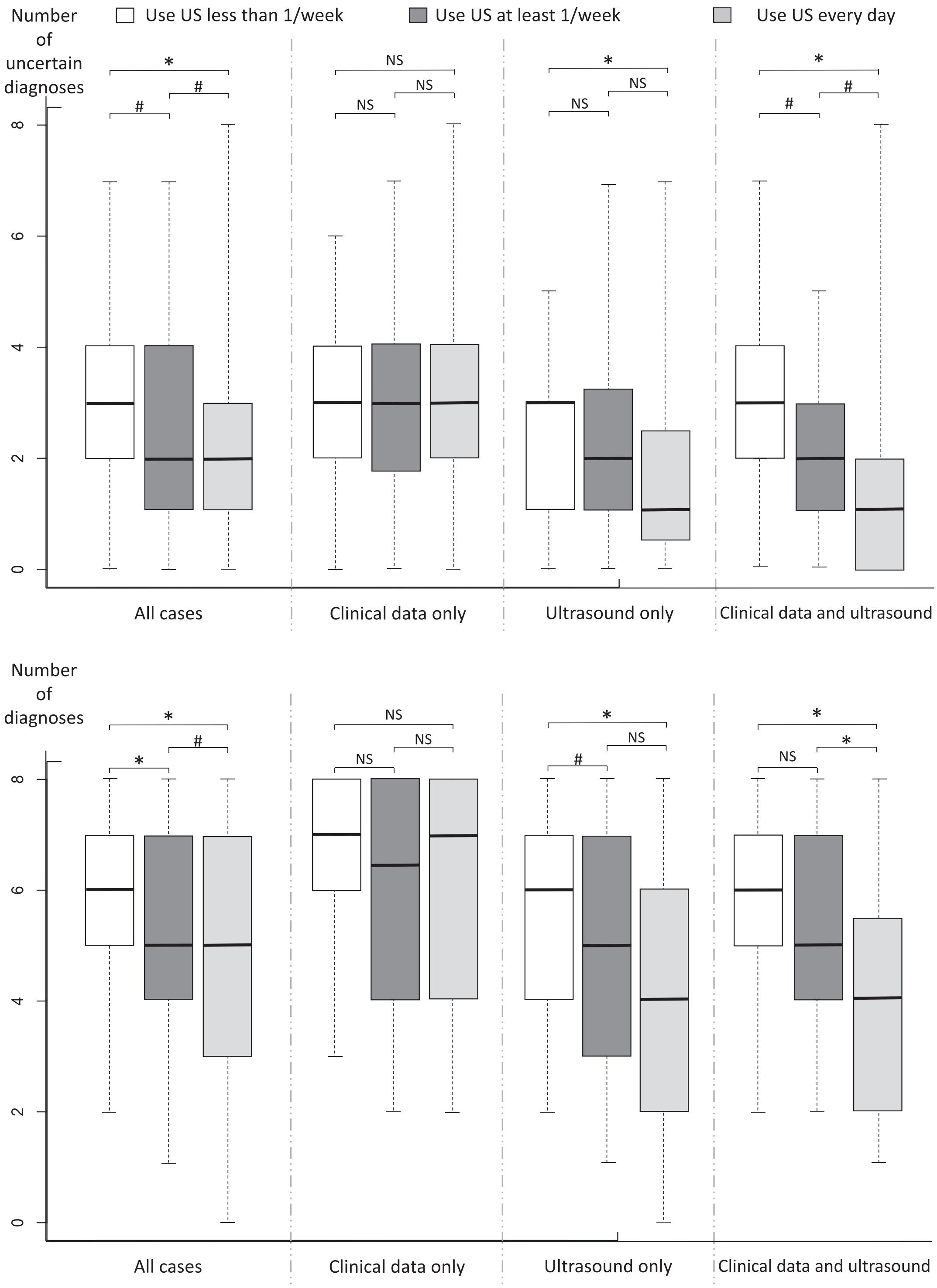

Fig. 2. Number of diagnoses and number of uncertain diagnoses according to available data and ultrasound use frequency. US: Ultrasound; NS: Not Significant, $p > 0.2$; "#": $0.05 < p < 0.2$; "*": $p < 0.05$.

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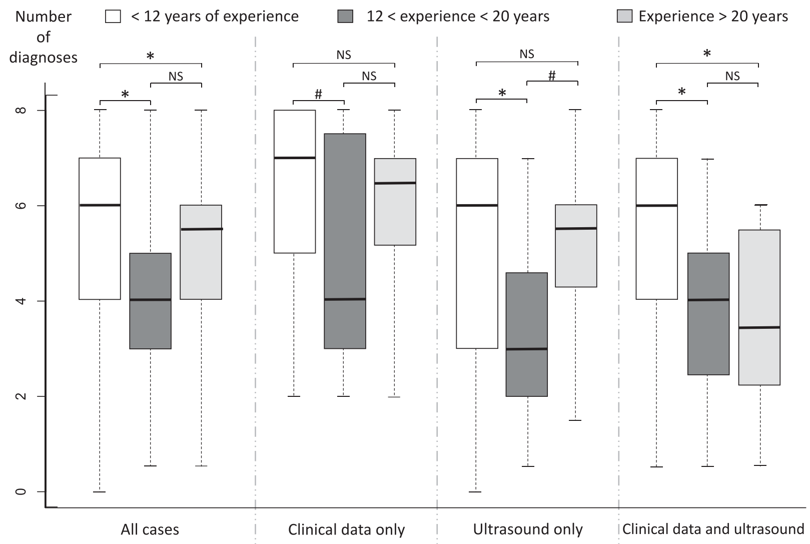

Fig. 3. Number of diagnoses according to available data and clinical experience NS: Not Significant, $p > 0.2$; '#': $0.05 < p < 0.2$; '*': $p < 0.05$.

explain the contrast between current science data on accuracy and ultrasound deployment in emergency medicine. Some studies show POCUS accuracy [5,8,9,14] while others show clinical impact [15,16]. Furthermore, many of POCUS important clinical studies date most than 20 years [17-20]. Paradoxically, the number of actual practicing EPs is not a majority worldwide [2-4]. If an EP does not practice every day, then POCUS becomes probably technically more difficult for them; thus, they assign less weight to the ultrasound result in their decision-making. A difficult or unreliable tool may seem a waste of time [21]. Thus, ultrasound learning must include daily practice for gesture learning and integrating ultrasound into their diagnostic reasoning. In this study, we chose the NUD as the primary endpoints because diagnoses judged possible with a clinical probability lower than three are diagnoses that the physician could not exclude, but that he will not treat. Diagnoses with intermediate clinical probabilities are those for which the physician will have difficulty making a treatment decision. Thus, the reduction of diagnoses with intermediate probabilities is probably a good indicator of the diagnostic accuracy that helps the physician in his daily practice. Dyspnea and LUS were chosen for this study because a misdiagnosis has consequences on the outcomes of dyspneic patients [22]. Lung ultrasound is also a very good tool for dyspneic patients [5-9,14]. Because POCUS alone can make a diagnosis with good concordance to complete diagnostic care in dyspneic patients [10], the weight of LUS in diagnostic reasoning should be major. The only factor independently linked to the NUD in difficult clinical cases is the presence of clinical data (Table 3). The fact that ultrasound increases diagnostic relevance is concordant with other studies [12,13,23]. The fact that ultrasound was the only factor independently linked in the multivariate analysis shows the importance of POCUS.

Similarly, the number of possible diagnoses was lower with ultrasound data than with clinical data only (Fig. 1). This expected result [12] allows us to verify that the methodology used shows results commonly accepted in the literature. An increase on ultrasound frequency of use decreased the number of possible diagnoses (Fig. 2). Physician experience also influenced the number of possible diagnoses. It is interesting to see that this was not true when physicians had clinical data only but it was when they had ultrasound and clinical data. This result is concordant with the literature about clinical decision-making in emergency medicine: Novice physicians tend to disregard information that contradicts their main hypothesis [24]. Experienced clinicians used more hypothetical deductive reasoning; thus, when experienced physicians have one more argument they reduce the number of possible diagnoses.

4.2. Limits

First, our study is based on physicians' diagnostic reasoning to solve theoretical clinical cases. It is possible that the weight of each argument is different in true clinical situations. Second, physicians may have understood the aim of the study. If this was the case, then physicians more believing in ultrasound could be very vigilant when they had ultrasound data and less when they had only clinical data. Finally, the weight of ultrasound in clinical reasoning was judged using ultrasound video loops. Perhaps physicians' confidence in ultrasound is better when they perform the exam. To reduce the importance of this bias, we have chosen typical ultrasound syndromes and the same may be true for clinical data.

5. Conclusion

For safety reasons, EPs tend not to fully confirm or eliminate hypotheses only on their clinical examination [24]. Our study confirms that POCUS decreases the number of possible and uncertain diagnoses in the "in vitro" model employed. Our main result is that ultrasound frequency of use decreased the NUD in difficult acute dyspnea clinical cases with LUS data. Given the accuracy evidence for POCUS, the weight of ultrasound data in decision-making should be more important. Therefore, it must be emphasized during training that daily ultrasound use is necessary for optimal diagnostic gain.

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Competing interests

Xavier Bobbia declares a competing interest as an ultrasound teacher for GE (GE MEDICAL SYSTEMS ULTRASOUND) customers. The other authors state they have no competing interests.

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3. ECMU : les preuves

3.1. Techniques d'ECMU diagnostiques :

3.1.1. Principales applications décrites en médecine d'urgence :

Les études diagnostiques princeps qui ont décrit les techniques d'ECMU actuellement utilisées ont principalement été publiées dans les années 90 et le début des années 2000. Pour un certain nombre, des méta-analyses ont permis d'en préciser la pertinence.

3.1.1.1. Échocardiographie :

Les publications montrant l'intérêt de l'échocardiographie en médecine d'urgence remontent au début des années 2000. L'échocardiographie trans-thoracique (ETT) a montré son utilité pour identifier des anomalies cardiaques non diagnostiquées par l'examen clinique (9), mais surtout, pour identifier la cause cardiaque d'un état de choc avec des sensibilités (Se) et spécificités (Sp) proches de 100% (10). De nombreux articles précisant l'intérêt diagnostique de l'ETT avec mesures Doppler ont suivi. En particulier pour objectiver la participation cardiaque dans une dyspnée (11), montrant des Se et Sp de 80 à 90% (12). Enfin, la pertinence de l'échocardiographie dans l'ACR est décrite depuis 1997 (13).

3.1.1.2. Échographie pulmonaire :

Les premières études descriptives sur l'échographie pulmonaire ayant eu un impact sur le développement de la technique ont été publiées par le Dr R Targhetta au début des années 90 (14-16). Le Dr D Lichtenstein a ensuite montré la pertinence de cet examen chez les patients aigus dyspnéiques (17-19). Depuis, des méta-analyses ou des études avec de larges échantillons ont décrit la pertinence diagnostique de l'échographie pulmonaire pour les principales causes de dyspnées aux urgences : pneumothorax (Se 91%, Sp 98%, (20)), OAP cardiogénique (Se et Sp 97%, (21)), pneumopathie (Se 85%, Sp 93%, (22)) ou pleurésie (Se 94%, Sp 98%, (23)).

3.1.1.3. Échographie des voies urinaires :

La mesure du volume vésical par échographie a montré son excellente corrélation avec le volume observé par vidange après sondage depuis plus de 25 ans (24). De plus, les Se et Sp du médecin urgentiste pour diagnostiquer une hydronéphrose chez des patients présentant une douleur du flanc sont comprises entre 80 et 90% (25).

3.1.1.4. Doppler trans-crânien (DTC) :

Le DTC a montré sa capacité à dépister une hypertension intracrânienne post traumatique chez les patients traumatisés crâniens graves admis en réanimation (26). En médecine d'urgence, cette technique a une Se de 80% et une Sp de 79% pour prédire les aggravations neurologiques secondaires à un traumatisme crânien léger ou modéré (27).

3.1.1.5. Échographie de compression veineuse des membres inférieurs :

En 1989, Lensing et al publiaient dans *the New England Journal of Medicine* que la pertinence diagnostique d'un test, consistant en la vérification de la compressibilité de la veine poplitée et fémorale, avait une Se de 99% et une Sp de 91% pour le diagnostic des thromboses veineuses profondes (TVP) des membres inférieurs (28). En 2015, la méta-analyse de West et al décrivait une Se de 96% et une Sp de 97% (29).

3.1.1.6. Échographie contextuelle :

Le concept d'échographie contextuelle est une situation clinique dans laquelle l'ECMU va être utilisée de façon transversale (applications de techniques ciblées sur plusieurs organes). Les contextes dans lesquels la littérature est la plus abondante sont trois situations d'urgences vitales : le patient traumatisé grave (PTG), le patient hypotendu ou en état de choc et le patient dyspnéique ou en détresse respiratoire.

3.1.1.6.1. Échographie du patient traumatisé grave :

L'échographie clinique du PTG a été décrite par les acronymes de FAST (*Focused Abdominal Sonography for Trauma* (30) puis *Focused Assessment for the Sonographic examination of the Trauma Patient* (31)), EFAST (*Extended Focused Assessment With Sonography For Trauma* (32)) ou encore pFAST (*prehospital Focused Abdominal Sonography for Trauma* (33)). Son principe de base est de rechercher un épanchement dans les séreuses chez un PTG. Les Se et Sp sont supérieures à 95% à l'exception de la Se pour la recherche d'un épanchement péritonéal qui est inférieure à 90% (34). Sa pertinence est montrée en conditions préhospitalières (33, 35) et la réalisation de la FAST à l'accueil d'un PTG entraine une très grande majorité de décisions thérapeutiques appropriées (36).

3.1.1.6.2. Échographie du patient en état de choc :

De nombreuses études ont montré l'intérêt diagnostique de l'ECMU dans la prise en charge des états de choc non traumatique. En particulier de faire un diagnostic plus précis (37, 38) et plus rapide (37, 39).

3.1.1.6.3. Échographie du patient dyspnéique :

La capacité de l'ECMU à permettre un diagnostic étiologique plus souvent correct est montré (40, 41). L'ECMU, réalisée en 24 min à l'admission des patients dyspnéiques a montré sa bonne corrélation avec le diagnostic final d'une prise en charge demandant 186 min en moyenne (42).

3.1.2. Recommandations :

3.1.2.1. Recommandations transversales sur l'ECMU :

Les sociétés savantes de médecine d'urgence de plusieurs pays développés ont publié leurs propres recommandations sur la pratique de l'ECMU (2, 4, 43). En France, la SFMU a choisi de recommander l'utilisation de l'ECMU en deux étapes par des RFE sur un premier (2) et deuxième niveau de compétence (44). Les recommandations fortes (« il faut », « il est recommandé ») issues de ces deux RFE peuvent se résumer à :

- Échocardiographie :
  - Niveau 1 : Évaluation visuelle de la fraction d'éjection du ventricule gauche (FEVG), diagnostic d'épanchement péricardique, de dilation du ventricule droit (VD) et analyse des variations respiratoires de la Veine Cave Inférieure (VCI) ;
  - Niveau 2 : Reconnaissance des anomalies de contractilité segmentaires du VG, d'une tamponnade péricardique, de signes de cœur pulmonaire aigu (CPA), d'une pathologie valvulaire sévère, identification d'un trouble diastolique sévère du VG, évaluation des pressions de remplissage du VG, du débit cardiaque par calcul de l'intégrale Temps Vitesse sous aortique (ITVao) et de la réponse à une expansion volémique ;
- Échographie pulmonaire (Niveau 1) : Diagnostic de pneumothorax, pleurésie, condensation et syndrome interstitiel.
- Échographie abdominale :
  - Diagnostic d'épanchement péritonéal (Niveau 1) ;
  - Échographie des voies urinaires (Niveau 1) : Diagnostic d'hydronéphrose, de rétention aigue d'urine et visualisation d'un cathéter de Foley intra-vésical.
  - Diagnostic d'anévrysme de l'aorte abdominale (Niveau 1) ;
  - Échographie obstétricale : Présence d'un sac gestationnel et d'une activité cardiaque (Niveau 2) ;
- Échographie vasculaire :

- Diagnostic de TVP des membres inférieurs par compression veineuse (Niveau 1) ;
- DTC chez le patient traumatisé crânien (Niveau 2).

- ECMU contextuelle : les RFE préconisent que le médecin urgentiste soit capable d'utiliser l'ECMU dans les contextes du PTG, de la dyspnée, de l'état de choc et de la douleur thoracique.

3.1.2.2. Recommandations spécifiques par technique :

Il existe plusieurs recommandations internationales sur l'utilisation de l'ECMU par technique, sur l'échographie pulmonaire (45) et cardiaque (46, 47) notamment. Cependant, il est intéressant de noter un phénomène montrant l'implantation de l'ECMU : la présence de ces techniques d'échographies recommandées dans les référentiels de chaque pathologie. Ainsi, par exemple, la réalisation du DTC est recommandée par les dernières RFE françaises sur les traumatismes crâniens graves (48). De même, la réalisation d'une échographie pulmonaire est citée dans certains *guidelines* sur l'insuffisance cardiaque aigue (49) et la réalisation d'une échographie est à envisager dans l'ACR selon les dernières recommandations de l'*European Resuscitation Council* (ERC) (50).

3.1.3. Recherche d'un outil d'aide au triage des détresses respiratoires : les courses diaphragmatiques.

Devant le nombre de patients à prendre en charge et l'hétérogénéité des niveaux de gravités rencontrés, le triage est un élément essentiel de la médecine d'urgence. L'utilisation de l'ECMU comme outil de triage a déjà été décrit. Le triage peut viser à prédire une consommation de moyens ou une évolution (gravité). La prédiction de l'aggravation neurologique secondaire des traumatisés crâniens légers et modérés par le DTC (27) est un bon exemple d'outil de triage permettant au médecin urgentiste de proposer, ou non, un niveau de surveillance et de monitorage élevé.

Nous nous sommes intéressés à un outil permettant d'évaluer la dysfonction diaphragmatique chez les patients en état de détresse respiratoire. Le constat était que l'évaluation clinique (voir gazométrique initiale) est parfois prise à défaut pour prédire le besoin de recours à une technique de ventilation chez les patients admis pour détresse respiratoire aiguë. On sait que chez ces patients, l'épuisement respiratoire est principalement dû à la fatigue du muscle respiratoire principal, le diaphragme (51). En réanimation, la dysfonction diaphragmatique est définie et évaluable par échographie grâce à la mesure des courses diaphragmatiques (CD) (52).

Le dépistage de dysfonctions diaphragmatiques permet de prédire des difficultés de sevrage ventilatoire des patients de réanimation (53). A notre connaissance, aucune étude n'existait sur la mesure des CD chez les patients en détresse respiratoire. Notre idée était donc d'observer si la dysfonction diaphragmatique pouvait être dépistée par échographie chez ces patients. Méthodologiquement, la première étape était de vérifier si la mesure des CD était faisable et reproductible dans ce contexte (patient assis ou demi-assis, fréquence respiratoire élevée, utilisation des muscles abdominaux). Nous avons réalisé une étude observationnelle prospective dont l'objectif principal était d'analyser la reproductibilité inter-observateur de la mesure des CD chez les patients admis aux urgences en état de détresse respiratoire aiguë. Les objectifs secondaires consistaient à évaluer la faisabilité et la reproductibilité intra-observateur. Enfin, à titre d'objectif exploratoire, nous avons analysé si la valeur des CD était associée à un recours à une technique de ventilation non invasive (VNI) durant les 4 premières heures de prise en charge. Nous avons inclus 24 patients. Les principaux résultats de cette étude étaient que la faisabilité était de 96% à droite et de 67% à gauche. La concordance inter-observateur était de 0,80 (IC95% [0,59 ; 0,91] ; différence moyenne -0,07 ± 0,48 cm) à droite et 0,59 (IC95% [0,19 ; 0,82] ; différence moyenne, 0,30 ± 0,91 cm) à gauche. Pour des valeurs de CD droites inférieures à 2,3 cm, la concordance inter-observateur entre les mesures était de 0,92 (IC95% [0,78 ; 0,97]. La concordance intra-observateur était de 0,89 (IC95% [0,81 ; 0,94] ; différence moyenne 0,02 ± 0,35 cm) à droite et 0,90 (IC95% [0,82 ; 0,95] ; différence moyenne -0,06 ± 0,45 cm) à gauche. Aucun patient ayant une CD droite supérieure à 2 cm n'a eu besoin de VNI. Nous en avons donc conclu que la mesure des CD droites était faisable et avait une bonne reproductibilité chez les patients admis aux urgences pour un état de détresse respiratoire aiguë. La corrélation observée sur ce faible échantillon entre valeurs des CD et le recours à une technique de ventilation semble prometteuse.

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Diagnostics

Diaphragmatic excursion measurement in emergency patients with acute dyspnea: toward a new diagnostic tool?

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ABSTRACT

Introduction: During acute dyspnea (AD), respiratory exhaustion is mainly due to diaphragm fatigue. The primary objective was to validate interobserver reproducibility of diaphragmatic excursion (DE) in emergency department (ED) patients admitted for AD. The secondary objectives were to assess the feasibility of DE measurement and intraobserver reproducibility. Finally, we examined whether the DE value was associated with a need for noninvasive ventilation (NIV).
Materials: This was a monocentric, prospective, technical reproducibility study. Adult patients in spontaneous ventilation admitted for AD were included. Two operators carried out 2 consecutive diaphragm excursion measurements each on the right and left hemidiaphragms.
Results: Twenty-four patients were analyzed. The feasibility was 96% on the right and 67% on the left. The interobserver concordance between the 2 measures was 0.80 (95% confidence interval [CI], 0.59-0.91) (average difference, -0.07 ± 0.48 cm) on the right and 0.59 (95% CI, 0.19-0.82) (average difference, 0.30 ± 0.91 cm) on the left. For right DE values inferior to 2.3 cm, the interobserver concordance between measures was 0.92 (95% CI, 0.78-0.97). The intraobserver concordance was 0.89 (95% CI, 0.81-0.94) (average difference, 0.02 ± 0.35 cm) on the right and 0.90 (95% CI, 0.82-0.95) (average difference, -0.06 ± 0.45 cm) on the left. When the DE was greater than 2 cm, no patient required NIV.
Conclusion: Diaphragmatic excursion measurement of the right diaphragm is feasible, with good interobserver and intraobserver reproducibility in ED patients admitted for AD. When the DE value is greater than 2 cm at admission, no subsequent NIV is required.

1. Introduction

The emergency physician's role is to provide appropriate initial therapy and direct patients to specialized departments according to their pathology and its severity. Admissions for acute dyspnea (AD) are common in emergency departments (EDs) and may have many etiologies [1,2]. Acute dyspnea admissions are mainly related to acute heart failure [3], acute exacerbation of chronic obstructive pulmonary disease (COPD), and severe pneumonia [1,2]. In patients with AD, respiratory exhaustion is mainly due to fatigue of the main breathing muscle, the diaphragm [4]. The emergency physician's care involves correction of hypoxemia and/or hypercapnia and adapt treatment according to the diagnosis. Independent of the diagnosis, the use of invasive (MV) or noninvasive (NIV) mechanical ventilation is based on clinical and biological criteria. Noninvasive ventilation is frequently used in EDs [5] and is recommended in the management of acute exacerbation of COPD and acute heart failure [6–8]. This allows, among others things, to reduce breathing work and respiratory exhaustion [9]. In contrast, patients with respiratory exhaustion will always need ventilation support. Late diagnosis of respiratory exhaustion is probably damaging to patients.

Emergency clinical ultrasonography (US) is increasingly used in EDs as a tool to diagnose or evaluate the effectiveness of initial care [10]. In the intensive care unit, decrease of diaphragmatic excursion (DE) among ventilated patients is defined as diaphragmatic dysfunction [11–13]. Diaphragmatic excursion analysis by M-mode US can predict an extended or a difficult MV [13] weaning [11]. Among unventilated patients, this measure is useful to evaluate diaphragmatic fatigability

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[14–16]. The feasibility and reproducibility of DE have been validated in healthy people [17]. This measure could be very useful as a diagnostic for respiratory exhaustion and as an instrument for prognosis evaluation. Some diaphragmatic electromyographic studies suggest that respiratory distress chronology begins with diaphragmatic fatigue, with increase in respiratory rate followed by alternate thoracoabdominal breathing and paradoxical abdominal breathing and, finally, an increase in $Paco_2$ associated with a decrease in minute ventilation and worsening of respiratory acidosis [4].

To date and to the best of our knowledge, no study has focused on DE analysis among AD patients admitted in ED. Diaphragmatic excursion measurement could be useful when it allows a fast and simple evaluation of diaphragmatic fatigue that is predictive of the need for mechanical ventilation. The primary objective of this study was to validate interobserver reproducibility of DE measurements. The secondary objectives were to assess the feasibility of DE measurement and intraobserver reproducibility. We also looked at whether the DE value was associated with a need for NIV during the first 4 hours.

2. Materials and methods

2.1. Materials

This single-center, prospective, technical reproducibility study was conducted from August 2013 to January 2014. The study population comprised patients attending the ED of University Hospital of Nîmes. The study protocol was approved by the Committee on Human Research South Mediterranean III (CPP-2012.09.08 bis), and written informed consent was obtained from all patients. The protocol was registered at ClinicalTrial.gov (NCT 01743105).

Patients were included if they were admitted in ED for AD as defined by the association of 1 clinical criterion (respiratory rate >25/min and/or signs of respiratory distress) and hypoxia (SpO_2 <90%) or hypercapnia (pH < 7.35 and $Paco_2$ >45 mm Hg). All included patients were in spontaneous ventilation (absence of ventilation assistance) and were older than 18 years. Patients were not included if (1) they were suffering from a neurologic or neuromuscular disorder modifying diaphragm function without any decompensation, (2) they were admitted with AD requiring immediate mechanical ventilation (not allowing 2 US measures), or (3) they were admitted with current respiratory support therapy.

2.2. Aims

The primary objective of our study was to validate interobserver reproducibility of M-mode diaphragmatic US in patients with AD admitted in ED. Secondary aims were to evaluate the practicability of DE, the required time to perform the measures, and the intraobserver reproducibility of DE measurements. The exploratory objectives were to assess a potential association between DE values and the necessity, or futility, of NIV during the subsequent 4 hours and evaluate if some DE values seem to be associated with better interobserver reproducibility.

2.3. Measurements

Study participants had a diaphragmatic ultrasound in addition to usual care. The test was discontinued if the patient required respiratory support during this procedure. Two different operators, including the physician in charge of patient on admission in ED, carried out consecutive measurements for each study patient. The second operator performed the measures blinded from results of the first operator and the patient's records. Each operator carried out 2 consecutive diaphragm excursion measurements for both the right and left hemidiaphragms. Operators were timed in their measurements. *Feasibility* was defined as the ability to record a measure. All operators were trained as defined by an emergency clinical ultrasound university diploma. Moreover, they received a short specific training consisted of a lecture in PowerPoint format about DE measurement and practice: 1 measure on healthy volunteers and 1 on real patients with AD.

Ultrasound evaluation was performed using the technique described and validated as the anterior approach [17]. Patients were in a semisitting position. The operators placed the probe in the subcostal or lower intercostal region between the medioclavicular line and the anterior axillary line for the right diaphragm and between the midaxillary and anterior axillary lines for the left diaphragm. They used the liver or the spleen as a window for each right and left hemidiaphragms, respectively [17]. The probe was oriented in medial, cranial, and dorsal views [17]. Initial US evaluation used the 2-dimensional mode to select the best exploration line of each hemidiaphragm. Then, the operators switched to M-mode tracing when they managed to achieve an angle of more than 70° between the uppermost part of the diaphragm and the analysis axis in the most cranial part of the diaphragm. During inspiration, diaphragm movement toward the probe enabled M-mode tracing [12,17]. The image was stored when 6 measurements were recorded. *Diaphragmatic excursion* was defined as the measure in centimeters between the maximal inspiratory and expiratory position of the diaphragm. All tests were performed with the same ultrasound scanner (Vivid S6; GE Healthcare, Medical System Israel Ltd, Tirad Carmel, Israel) and the same phased array probe (1.3-3.3 MHz).

2.4. Sample size

In the absence of data on DE values in this specific population of patients with AD, we considered DE measurements to be equivalent to those from ventilated patients, both in magnitude and variability [11]. Twenty-two subjects were required to demonstrate a concordance correlation coefficient of 0.90 with a confidence interval (CI) of 95% and whose lower limit is superior than 0.80. To be conservative, we decided to include at least 25 subjects in this study.

Table
Patients' characteristics and care

Inclusion characteristics	Patients, n = 24
Female	13 (54%)
Age	80 (60-88)
BMI	26 (24-29)
Comorbidities	
COPD	6 (25%)
Asthma	3 (13%)
Heart failure	10 (42%)
Pulmonary embolism	3 (13%)
Clinical parameters	
SBP (mm Hg)	129 (109-139)
DBP (mm Hg)	71 (59-84)
HR (/min)	102 (88-120)
RR (/min)	29 (28-32)
SpO_2 (%)	89 (73-92)
Biological parameters	
pH	7.38 (7.29-7.43)
$Paco_2$ (KPa)	6.01 (5.02-7.12)
Pao_2 (KPa)	13.76 (7.89-19.33)
HCO_3- (mmol/L)	24.5 (21.3-27.0)
First final diagnosis	
Acute pulmonary edema	10 (42%)
Acute exacerbation of COPD	6 (25%)
Pneumonia	5 (21%)
Severe acute asthma	3 (13%)
Combined diagnosis	5 (21%)

Data are expressed as number (percentages) or median (25th-75th percentile). Combined diagnosis: at least 2 diagnoses.
Abbreviations: BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate; RR, respiratory rate.

2.5. Statistical analysis

Quantitative data are expressed as mean ± SD or median with 25th and 75th percentiles (25th-75th percentile) according to the variable distribution. Qualitative variables are expressed as frequency with percentage.

The interobserver reproducibility was estimated through a generalized concordance correlation coefficient (ρ_c) between the first measure of the 2 evaluators [18] with its 95% CI. The intraobserver reproducibility was estimated through a generalized concordance correlation coefficient (ρ_c) between the 2 measures of each evaluator. Reproducibility and bias between the 2 compared measures were evaluated by the Bland-Altman method as well [19].

3. Results

3.1. Participants

Twenty-seven patients were enrolled during the study period. Three were excluded from the study: 1 for withdrawal of consent, 1 for duplicate inclusion, and 1 for refusing their data afterwards. The baseline characteristics (inclusion characteristics, clinical and biological parameters, and diagnoses of the 24 participants) are shown in the Table. One patient died during the first 4 hours of care. Seventeen evaluators performed the US during the study. Median previous experience of the evaluators performing US was 2 years [1–4].

3.2. Primary outcome—interobserver reproducibility of DE measurements

Median right DE values were 1.75 cm (1.53-2.82 cm) for evaluator 1 and 1.82 cm (1.57-2.35 cm) for evaluator 2 during the first measure. The concordance between these 2 measures was 0.80 (95% CI, 0.59-0.91). The Bland-Altman graph (Fig. 1A) shows an average difference (evaluator 2 − evaluator 1) of −0.07 ± 0.48 cm.

Median left DE values were 1.77 cm (0.67-2.50 cm) for evaluator 1 and 1.59 cm (1.07-2.26 cm) for evaluator 2 during the first measure. The concordance between these 2 measures was 0.59 (95% CI, 0.19-0.82). The Bland-Altman graph (Fig. 1B) shows an average difference of 0.30 ± 0.91 cm.

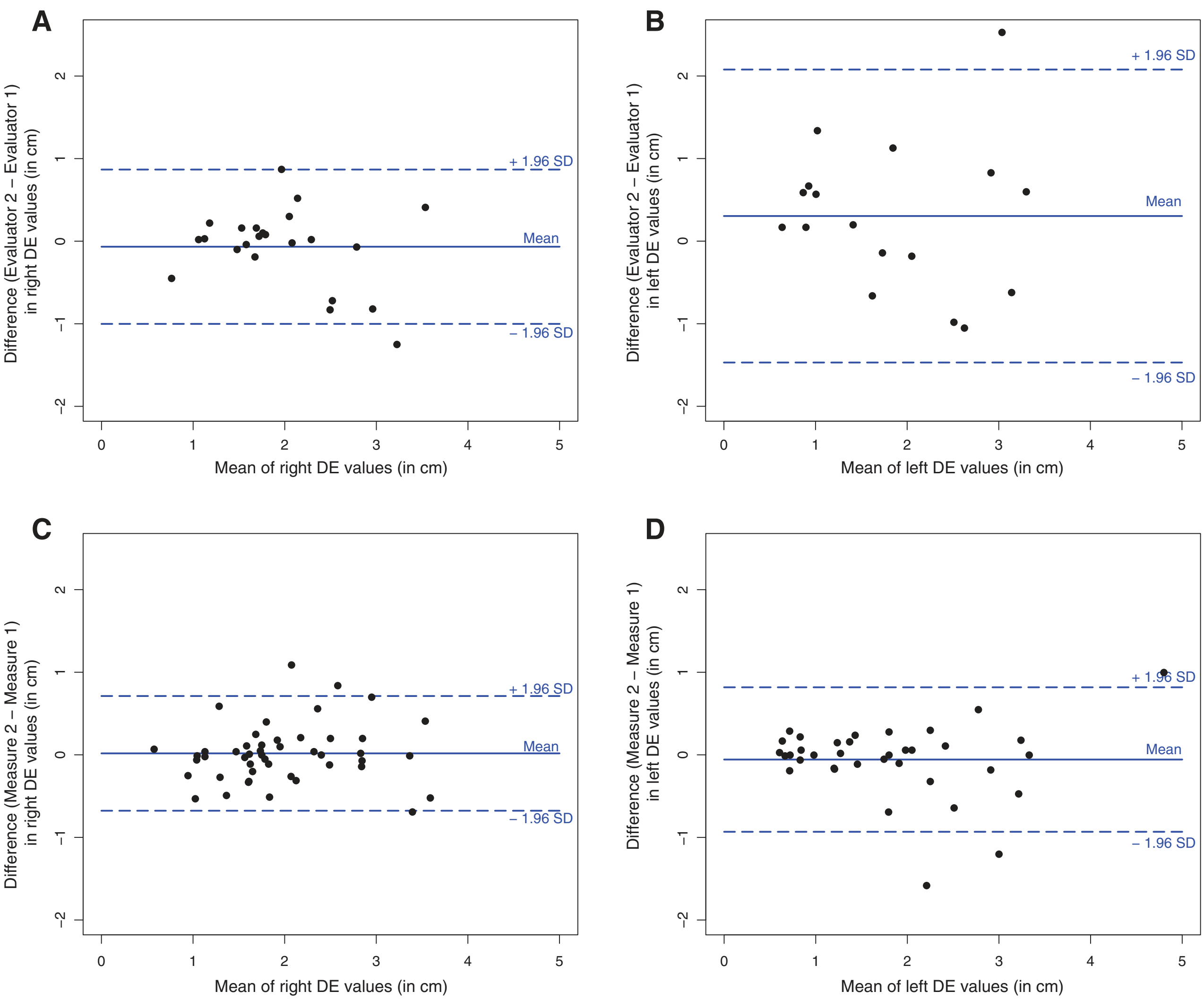

Fig. 1. Bland-Altman graphs to assess interobserver and intraobserver reproducibility. A, Interobserver reproducibility of right DE values. B, Interobserver reproducibility of left DE values. C, Intraobserver reproducibility of right DE values. D, Intraobserver reproducibility of left DE values.

3.3. Secondary and exploratory outcomes

3.3.1. Practicability assessment and time required for DE measurement

Diaphragmatic excursion was successfully measured in 23 patients (96%) and 16 patients (67%) on the right and left sides, respectively. Among the 96 total ultrasounds performed, 94 (98%) could be carried out on the right side, whereas only 77 (80%) could be done on the left. The 2 evaluators could not perform ultrasounds on the right side for 2 patients or the left side for 19 patients.

The median time required per operator between the beginning of the first measurement and the end of the second measurement was 3.5 minutes (2-5 minutes).

3.3.2. Intraobserver reproducibility of DE measurements

Considering overall measures performed by the 2 evaluators, median right DE values were 1.77 (1.53-2.40 cm) for the first measure and 1.81 cm (1.49-2.62 cm) for the second measure. The concordance between these 2 measures was 0.89 (95% CI, 0.81-0.94). The Bland-Altman graph (Fig. 1C) shows a mean difference (evaluators 1 and 2: measure 2 − measure 1) of 0.02 ± 0.35 cm.

Considering overall measures performed by the 2 evaluators, median left DE values were 1.66 cm (0.81-2.41 cm) for the first measure and 1.45 cm (0.87-2.19 cm) for the second measure. The concordance between these 2 measures was 0.90 (95% CI, 0.82-0.95). The Bland-Altman graph (Fig. 1D) highlights a mean difference (evaluators 1 and 2: measure 2 − measure 1) of −0.06 cm (±0.45 cm).

3.3.3. Interobserver reproducibility for right DE inferior to 2.3 cm

For interobserver reproducibility, we decided to study right DE only due to its better feasibility. A difference was observed for DE values inferior to 2.3 cm. Indeed, evaluators 1 and 2 observed values corresponding to 1.65 cm (1.11-1.77 cm) and 1.67 cm (1.29-1.83 cm), respectively. The concordance between these measurements was 0.92 (95% CI, 0.78-0.97).

3.3.4. Association between DE values and necessity of mechanical ventilation in the first 4 hours of emergency care

Seven patients (30%) required NIV during the first 4 hours of care; however, no patients required MV. The distributions of right DE values (evaluator 1; measure 1) according to the requirement of NIV are shown in Fig. 2.

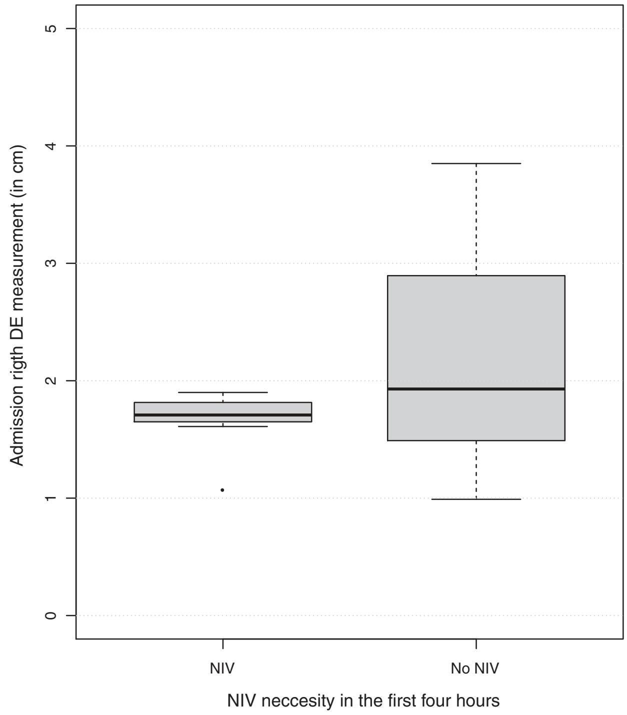

Fig. 2. Box plot of the distribution of right DE values according to the necessity of mechanical ventilation (NIV) in the first 4 hours.

4. Discussion

4.1. Main results

Our study showed that reproducibility of interobserver diaphragmatic excursion measurements in patients with acute respiratory distress is acceptable on the right, but not on the left side (concordance coefficients, 0.80 and 0.59, respectively). Similarly, feasibility was excellent on the right, but not on the left side (96% and 67%, respectively). Interobserver concordance was even better (0.92) for smaller values (right DE inferior to 2.3 cm) but remained lower than reported in intensive care patients in the supine position [11] or in healthy subjects [17].

These results can be explained by the difficulty in performing such measurements in emergency care conditions (sitting or half-sitting, patient with tachypnea, using abdominal wall muscles). Boussuges et al [17] showed DE measurements to be more feasible during “quiet breathing” than “deep breathing” due to lung descent interfering with DE measurements and, more significantly, on the left DE measurement because the splenic window is smaller than the hepatic one. Second, the fact that reproducibility seems better when DE values are low suggests that patients with diaphragmatic fatigue probably have uniform breathing movements and those who are not exhausted could have irregular amplitude breathing movements.

Intraobserver reproducibility was better for measurements on both side (concordance is 0.89 on right and 0.90 on left). These values are close to the greatest interobserver concordance.

The measurement of DE appears well adapted to emergency care as the average time to perform DE measurements is low (3.5 minutes for 2 measures on both sides), which corresponds to usual emergency clinical ultrasound techniques [20].

Finally, the present results show that when the DE value was higher than 2.3 cm at admission, no subsequent NIV was required (Fig. 2). Therefore, a high DE value could be considered as a severity triage index for patients admitted in ED with AD. When DE was less than 2 cm, some patients required NIV, whereas other patients did not. Therefore, a low DE value cannot be considered as respiratory fatigue.

4.2. Limitations

The main limitation of this study is that it is a single-center design. Diaphragmatic excursion measurement techniques used with healthy subjects or intensive care patients in supine position were applied to patients in respiratory distress in a semisitting position. Our study was carried by 17 emergency physicians regularly practicing emergency clinic ultrasound, but with a wide range of experience with this practice. They all received short training on DE measuring; however, as the learning curve for this technique is not known, it is possible that our results can be improved by longer training. Finally, even if the present results suggest a potential interest for diaphragmatic ultrasound as a prognostic tool during acute dyspnea, the study is underpowered to confirm such a hypothesis. Therefore, these results must be confirmed by a larger, multicenter study.

5. Conclusion

In emergency patients admitted in ED for AD, right DE measurement is feasible, with good interobserver and intraobserver reproducibility.

This procedure could help identify patients with a low risk of secondary respiratory deterioration.

Competing interests

XB declares a competing interest as an ultrasound teacher for GE (GE Medical Systems Ultrasound) customers. The other authors state they have no competing interests.

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3.2. Écho-guidage :

La littérature sur l'écho-repérage et l'écho-guidage de gestes invasifs en médecine d'urgence et réanimation semble converger vers un constat : pour viser et toucher une cible, il vaut mieux voir la cible. L'utilité d'une technique d'écho-guidage doit plutôt prendre en compte les paramètres suivants : le taux d'échec et de complications de la méthode anatomique, la faisabilité de la technique écho-guidée et le bénéfice de son utilisation.

- Ponctions vasculaires :
    - Cathéters veineux centraux (CVC)

Compte tenu du taux d'échec et de complication, une des premières applications décrite pour guider les gestes invasifs en médecine d'urgence et en réanimation était la pose de CVC. La méta-analyse de Hind et al publié en 2003, qui étudiait l'impact de l'écho-repérage et de l'écho-guidage sur la mise en place de CVC au niveau des trois sites (jugulaire interne, sous clavier et fémoral), concluait déjà que la technique écho-guidée était plus rapide et plus sûre que la méthode anatomique (54). En 2015, les recommandations françaises sur l'utilisation de l'échographie lors de la mise en place des accès vasculaires préconisaient d'écho-guider toutes les procédures de mise en place de CVC (55).

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    - Ponctions artérielles radiales

La première application d'écho-guidage qui fut décrite pour la ponction de l'artère radiale était pour la mise en place de cathéters artériels. En 2011, une méta-analyse confirmait le bénéfice significatif de l'écho-guidage dans cette application (56). L'écho-guidage des cathéters artériels est préconisée par les recommandations françaises sur l'utilisation de l'échographie lors de la mise en place des accès vasculaires (55) comme par les recommandations sur le premier niveau de compétence d'ECMU (2).

Peu de cathéters artériels sont néanmoins posés dans les structures d'urgences (SU). A contrario, la ponction artérielle radiale pour la réalisation de gaz du sang artériels (GDSA) est fréquente. Les problématiques principales des GDSA radiaux sont un taux d'échec d'environ 10% et la douleur engendrée (57). Nous avons voulu observer l'utilité de l'écho-guidage dans cette indication en réalisant une étude randomisée prospective dont l'objectif principal était de comparer le nombre de tentatives requises pour la réalisation d'un GDSA radial entre la technique anatomique et écho-guidée. Les objectifs secondaires étaient de comparer le temps de réalisation, la douleur, la satisfaction du patient et du médecin. Nous avons analysé 72 patients. Notre résultat principal était que le nombre de tentatives était augmenté avec écho-guidage : 2,3 [1 ; 3] vs 1,7 [1 ; 2], p = 0,02. L'échographie augmentait également le temps de réalisation du geste : 132 [50 ; 200] vs 55 [20 ; 65] secondes (p < 0,01), sans différence significative sur la douleur, la satisfaction du patient et du médecin. Notre conclusion était que l'écho-guidage n'avait pas d'intérêt pour la ponction de l'ensemble des GDSA. Ce constat nous a paru lié au taux d'échec (ou nombre de ponctions) faible avec la technique anatomique pour une population non sélectionnée.

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Original Contribution

Ultrasound guidance for radial arterial puncture: a randomized controlled trial☆,☆☆

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A R T I C L E I N F O

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A B S T R A C T

Study Objective and Background: Arterial puncture for blood gas analysis is a frequent procedure and could be difficult in the emergency setting. The aim of the study was to compare ultrasonographically guided arterial radial puncture vs conventional sampling.
Materials and Methods: This is a prospective, randomized study. The inclusion criteria are all patients needing arterial blood gas at admission in the emergency unit. The exclusion criteria are the following: Hallen test positive, local sepsis, local trauma, known sever local arteriopathy, refusal of consent by the patient, participation in another study, and cardiac arrest. Patients were randomized into 2 groups: radial arterial puncture obtained through an ultrasonographically guided technique (group 1) or radial arterial puncture by conventional method (group 2). The main objective is the number of attempts after enrollment. The secondary objectives are time to success, patient satisfaction and pain, and physician satisfaction. Immediate complications were collected. Groups were compared with nonparametric analysis.
Results: The data were usable for 72 of 74 patients included. Lung disease (acute exacerbation of chronic obstructive pulmonary disease and pneumonia) at 45% (n = 32) and suspicion of pulmonary embolism in 31% (n = 22) were the most common reasons. Demographics data were comparable in the 2 groups. In group 1, the number of attempts significantly increased (2.35 [1-3] vs 1.66 [1-2] [P = .017]), and the sample was 2.4 times longer (132 seconds [50-200] vs 55 [20-65] [P < .01] by standard method). There was no significant difference in terms of pain (visual analog scale [VAS], 3.6 [2-5] for both groups [P = .743]), patient satisfaction (VAS, 7.2 [5-9] vs 6.8 [5-9] [P = .494]), and physician satisfaction (VAS, 6.0 [3.5-8] vs 6.9 [5-9] [P = .233]). No immediate complications were found in the 2 groups.
Conclusion: Ultrasonographically guided arterial puncture increases the number and duration of implementations. This technique, however, does not alter the patient's pain, the number of immediate complications, or patient and physician satisfaction.

1. Introduction

1.1. Background

Arterial puncture for blood gas analysis is a very common procedure in medicine ward [1], intensive care unit, or emergency department (ED). In our ED, 8% to 12% of patients benefit from arterial blood gas, although many institutions are using lesser arterial blood gases analysis, especially with new and less invasive devices [2]. Blood gas analysis is helpful for precise diagnosis and monitoring of many diseases such as thromboembolism disease [3], respiratory disease in decompensation [4,5] or not, prehospital [6] and hospital [7] ventilated patients, disturbances of the acid-base balance, or carbon monoxide poisoning [8]. The sampling technique has been described in the 19th century [9] and has been updated since. After skin disinfection with an antiseptic solution, there is a detection of the artery by palpation and the introduction of a needle with a spontaneous influx of blood pressure in the syringe [10]. Because of its simplicity, the preferred way is the radial access rather than the femoral or axillary artery [11]. This procedure is not totally safe. Although they are rare (<1% for catheters [12]), it can lead to vascular complications (pseudoaneurysm, hematoma… [13]); this procedure induces pain [14], associated with a high

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☆☆ BX, GGR conceived the study, designed the trial, supervised the conduct of the trial and data collection; BX,GGR,PS,PBR,BJM undertook recruitment of patients; GGR, MA,CPG managed the data ; DLCJE,LJY controlled the quality and chaired the data oversight committee; XB,ML provided statistical advice on study design; ML,MA analyzed the data; GGR drafted the manuscript; All authors contributed substantially to its revision; GGR takes the responsibility for the paper as a whole.

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number of attempts and failures [1]. Various approaches have been studied to reduce the pain associated with the use of this method, such as anesthetic cream EMLA® type [15,16], but few results have been obtained.

1.2. Importance

The use of ultrasonography (US) as a tool for insertion of central venous catheters has been well established, generally showing increased success and decreased rates of complications [17,18].

In peripheral venous catheterization, US has shown encouraging results in terms of the number of attempts, time to success, and the number of complications [19,20]. This experience could be applied to arterial puncture.

However, there are only 3 studies evaluating the value of US in the implementation of arterial catheter [21–23]. To the best of our knowledge, there is no published study on arterial samples guided by US.

1.3. Goals of this investigation

The goal of this study was to compare US-guided arterial sampling vs conventional technique during a 1-month period in the emergency ward.

We conducted a prospective randomized trial in the ED during 1 month. Our primary end point was the number of attempts that were required for successful sample. Secondary end points were time to success, patient satisfaction and pain, and physician satisfaction. The hypothesis was that there would be a clinically significant difference in the number of attempts required for success of a radial artery sample with US technique vs non-US technique.

2. Materials and methods

2.1. Study design and setting

This was a prospective, nonblinded, randomized trial comparing a US-guided radial artery sample with non–US-guided radial artery sampling. The study was performed at the University Hospital of Nimes, France, an urban tertiary care university teaching hospital with approximately 70 000 ED patient visits per year. Data were collected on consecutive patients who presented between August 15, 2010, and September 30, 2010. This study was approved by the French Agency for the Safety of Health Products (AFSSAPS-2010-A00714-35) and the Committee on Human Research South Mediterranean III (CPP – 2010.07.06 bis).

2.2. Selection of participants

Patients were admitted in the ED at their own request, after a call to the emergency call center, after request of their physician or prehospital medical decision. After clinical examination by an emergency physician, if an arterial sampling for diagnostic (thromboembolism disease [3], acute respiratory disease [4,5] disturbances of acid-base balance, or carbon monoxide poisoning [8]) or for mechanical ventilation monitoring (prehospital [6] and hospital ventilated patients [7]) was indicated by the attending physician, patient could be included, and a physician investigator was called.

Patients became eligible for the study if they were at least 18 years old, required a radial artery sample, and free, informed, and signed consent was given and recorded. Patients were excluded from the trial if they were in cardiac arrest, pregnant or lactating, refused to give consent, or were participating in another study. We also excluded situations where radial arterial sample was prohibited: Hallen test positive, local trauma of 2 wrists, or known severe local arteriopathy.

Emergency physicians were allowed to enroll patients around the clock. Patients were eligible to participate only once in this trial.

Of the 22 attending physicians in the ED before the start of the trial, 9 physicians did not participate because they had no accrediting degree or sufficient experience in the technical mastery of gesture. The other 13 physicians were all graduates of accredited SFMU (French Society of Emergency Medicine) in which a theoretical and practical training of the gesture was taught. In addition, the use of US for radial arterial puncture was a current procedure in our emergency service. To avoid any confusion, 3 hours of simulator training was given before the start of the study. There were no specific data managers, and data were collected by physicians.

2.3. Methods of measurement

After enrollment, patients were randomized. A simple (unrestricted) randomization algorithm was used. The computer simultaneously created a time stamp in the research database, which represented the time of enrollment and designated the group in which the patient was (US-guided [group 1] or not [group 2]).

Ultrasonographically guidance was performed in real time, with a GE Vivid S6 machine with a 10-MHz linear transducer (General Electric Company, Fairfield, CT). After skin disinfection by local antiseptic and development of sterile gel at the puncture site, a timer was started. Physicians spotted the radial artery by ultrasound with different modes (2B mode, color flow mode, and pulse wave mode) and centered it in the middle of the monitor. At this time, they introduced the syringe at 70° with respect to the probe, in the center of it.

The standard method (or no US guidance method) was performed only by the attending emergency physician. After skin disinfection by local antiseptic, the timer was started with the first skin contact for palpation to spot the radial artery. Once the artery was identified, the physician introduced the syringe at 70°.

For the 2 arms, a successful attempt was defined as blood return and the timer was stopped. One attempt corresponded to one break in the skin.

After sampling, data were collected: age of patient, sex of patient, body mass index, systolic blood pressure, numbers of attempts, pain, patient satisfaction, physician satisfaction, complications, and duration.

One visit was necessary for this trial. Following the data collection necessary for this study, the end of the test was completed.

2.4. Primary data analysis

The principal end point was the number of attempts required for effective blood gas sampling. Secondary end points were patient and physician satisfaction (0-10 scale) and patient pain (0-10 scale). Immediate complications in the emergency ward were also recorded.

2.4.1. Number of subjects

Sample size was calculated according to the trial of Shiver et al [23] who found a success rate of 50% in the first attempt of radial catheterization in non–US-guided group and a success rate on the first attempt of 87% in the group "with ultrasound guidance." To show a difference on the first attempt by 37% between the 2 groups with a 2-tailed α risk of .05 and a power of 90%, the number of subjects to include was 62. In a conservative spirit, we increased that number by 20%.

2.4.2. Statistical analysis

Qualitative variables were compared using a χ^2 test. Alternatively, if the conditions of realization of this test were not met, Fisher exact test was used. Quantitative variables were compared between the 2 groups: in case of Gaussian variables, a Student *t* test or analysis of variance, and in case of non-Gaussian variables, a Wilcoxon-Mann-Whitney test. The statistical results were presented as means ± SDs for quantitative variables whose distribution is Gaussian, mean and 95% confidence intervals antiprocessed for variables whose distribution is Gaussian after transformation, and median and interquartile ranges for other variables.

For qualitative variables, numbers and percentages involved were presented. A difference was considered statistically significant when the degree of significance of the test is less than or equal to 0.05. The data were analyzed using SAS statistical software version 9.0 (SAS Institute, Cary, NC).

3. Results

A total of 74 patients were eligible for our trial during the study period. Two were excluded because of default data of important information. Seventy-two patients were randomized to the 2 groups (Fig. 1). Thirty-seven patients were randomized to group 1 (US-guided), and 35 were randomized to group 2 (non–US-guided). Baseline demographics are shown in Table 1. There were no statistical differences in demographic data between the groups. Reasons for blood gas sampling are represented on Fig. 2.

Table 1
Baseline patient characteristics

Characteristics	US group (n = 37)	No US group (n = 35)	*P*
Age, y, mean (SD)	69 (56-82)	71 (61-85)	.226
Female, n (%)	68% (n = 25)	51% (n = 18)	.100
Weight, kg (SD)	79 (67-95)	75 (60-83)	.095
Size, cm (SD)	167 (160-175)	163 (160-172)	.619
Body mass index (SD)	28 (24-31)	26 (22-29)	.146
Radial artery palpable (%)	97% (n = 33)	86% (n = 32)	.360
Gas blood sampling antecedent (%)	47% (n = 15)	39% (n = 13)	.700
Underlying vascular pathology (%)	46% (n = 16)	43% (n = 16)	.353

3.1. Number of attempts

In group 1, a median of an additional 2.35 (1-3) attempts was required before gas blood samples. In group 2, a median of 1.66 (1-2) further attempts were required; $P = .017$.

3.2. Time to success

In group 1, the time to obtain a successful radial arterial sample was 132 seconds (50-200) vs 55 seconds (20-65) in group 2; $P < .01$.

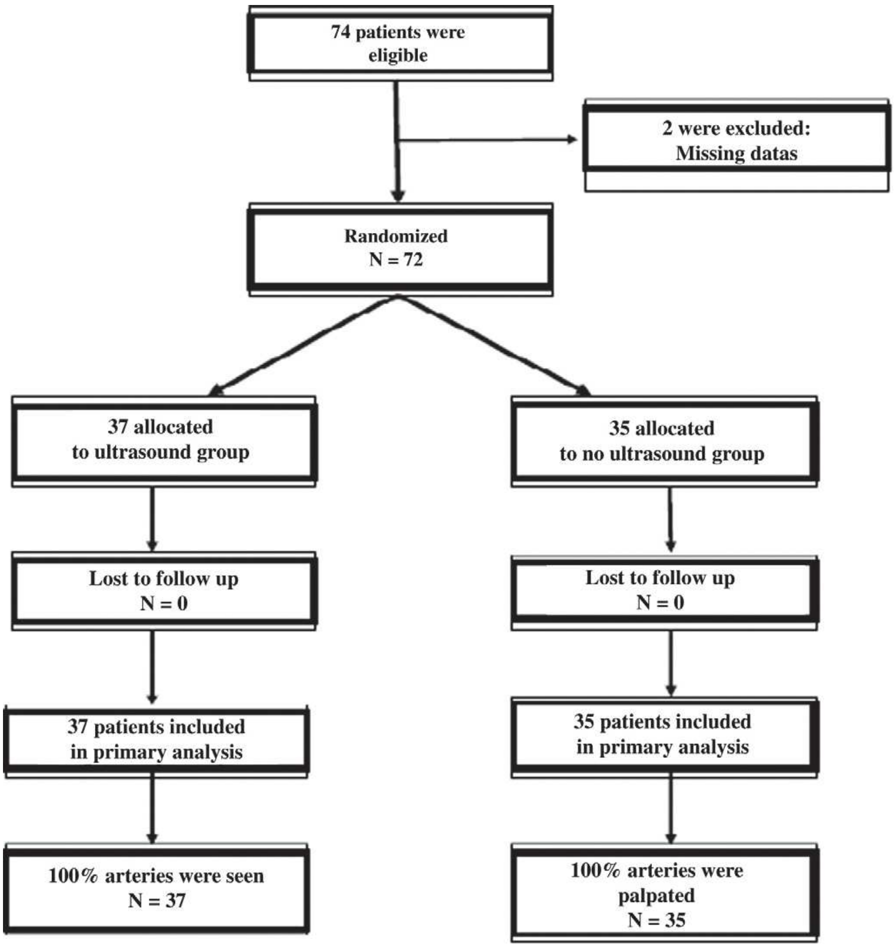

Fig. 1. CONSORT diagram summarizing inclusion, allocation, and follow-up.

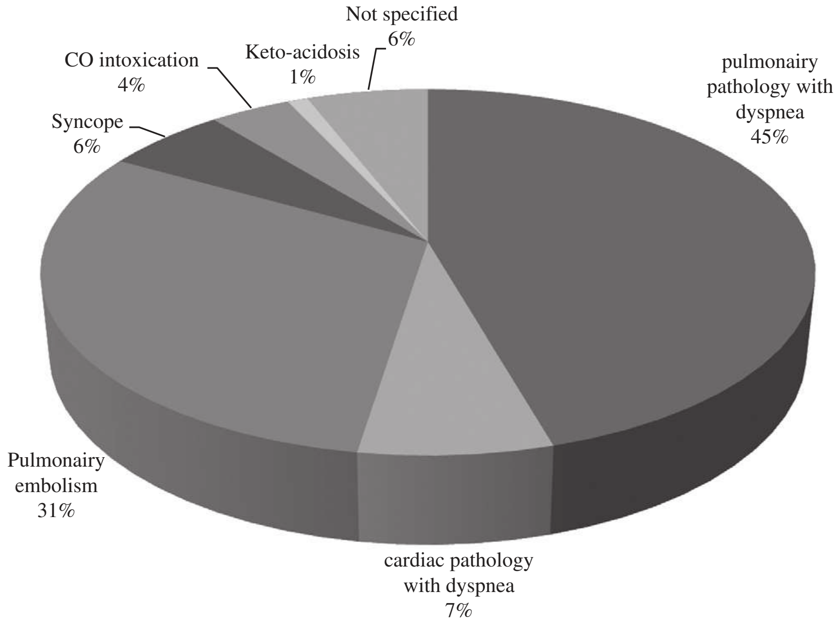

Fig. 2. Reasons for arterial sample.

3.3. Patient pain and satisfaction data

The median Likert score was 3.6 (2-5) for the pain and was 7.2 (interquartile range [IQR], 5-9) for the satisfaction in group 1. In group 2, the mean score was 3.6 (IQR, 2-5) for the pain and was 6.8 (IQR, 5-9) for the satisfaction. There was no significant difference between the 2 groups.

3.4. Physician satisfaction

The median Likert score was 6.0 (3.5-8) in group 1 and 6.9 (5-9) in group 2. There was no significant difference between the 2 groups ($P = .228$).

There were no complications recorded in either group.

4. Limitations

Absence of an observational training period for physicians was the major limitation. In fact, we have considered that physicians participating in the trial had an adequate education and training to use US.

One limitation of the trial is that we did not have sufficient sample size to test variations in success among different physician providers. The population of physicians was not homogeneous, and the sample was too small to compare trained physicians and novice physicians. We do not have an adequate number of patients to evaluate differences between physicians with regard to level of training. The significant diversity of physician skill and practice is clearly a difficulty in the analysis of our study. The only way to correct this bias could have been a larger sample of practitioner over several centers or a period of training with implementation and analyze of the learning curve before starting such study. To confirm the present study, further studies should take into account these specific methodological points. However, our goal was not to assess whether a subgroup of highly trained physicians can perform this technique better than a less skilled subgroup.

Finally, we observed an underestimation of the total time of achievement in ultrasound because the study ignored the displacement and the tensioning of the ultrasound unit Vivid S6. The machine installation procedure increases the duration of completion of 3 to 5 minutes. This longer time does not have significant impact on routine practice. Moreover, this technique could be of particular interest in case of difficult puncture, although this hypothesis was not specifically tested in the present study.

Evaluation of immediate and remote complications was impossible because the sample was too weak.

5. Discussion

The present study shows that, unexpectedly, US-guided arterial puncture for blood gas analysis in the emergency ward significantly increased the puncture number and procedure duration. Pain and patient satisfaction, however, were not altered by using the US technique (Table 2).

Table 2
Number of attempts, time to success, patient satisfaction, patient pain, and physician satisfaction among patient requiring gas blood sampling randomly assigned to US or no US

Characteristics	US used?	n	Mean	95% CI Of mean	Median	Median difference	*P*
No. of attempts	Y	37	2.35	1.5-3.3	2 (1-3)	1 (0-1)	.017
	N	35	1.66	1-2.3	1 (1-2)		
Time to success (s)	Y	37	132	78	87 (50-200)	52 (30-135)	<.01
	N	35	55	27	35 (20-65)		
Patient satisfaction	Y	37	7.2	6-8.4	8 (5-8)	0 (0-1)	.494
	N	35	6.8	5.4-8.2	8 (5-8)		
Patient pain	Y	37	3.6	2.4-4.7	3 (2-5)	0 (0-0)	.743
	N	35	3.6	1.2-3.9	3 (2-5)		
Physician satisfaction	Y	37	6.0	4.7-7.4	7 (4-8)	0 (1-1)	.228
	N	35	6.9	5.8-8	7 (5-9)		
No. of failure	Y	37	0				
	N	35	0				

Sampling arterial blood gas is a common procedure in the ED, and one that typically is accomplished without difficulty. In the present trial, a large number of blood gases were sampled in suspected pulmonary embolism (PE) (31%). This proportion explains the high number of sample in our ED. The use of blood gases is not routinely recommended by recent guidelines of the American scientific societies [24] and the European Society of Cardiology [25]. Despite that, it was largely demonstrated in various fields that physicians poorly apply recommendations. Then, the high use of arterial blood gas for PE diagnosis in our study is probably related to a poor knowledge of such recommendations.

However, some previous studies to these recommendations, earlier also the more systematic use of D-dimer and the angio-computed tomography, show that PE is generally associated with hypoxemia, but up to 20% of patients with PE have a normal arterial oxygen pressure (Pa_{O_2}) and a normal alveolar-arterial oxygen gradient [D(A-a)O_2] [26]. Others trials show a correlation of computed tomography pulmonary artery obstruction index with blood gas values [27].

Nevertheless, the conventional procedure can generate pain and dissatisfaction for the patient by a large number of skin breaks and a prolonged period of realization. It would be interesting to develop a method allowing a reduction of the number of attempts, the time for the procedure, and discomfort.

Because of the success of US for placing internal jugular vein [28–32], subclavian vein [18,33], or femoral vein [34–36] central lines, Shiver et al [23] investigated its use in the placement of arterial access. This group was able to demonstrate that US-guided technique patients underwent fewer placement attempts (1.2 vs 2.2, difference 1; $P = .001$), shorter time for arterial line placement, and fewer sites required for successful placement as compared with the conventional technique.

In the case of vascular access being more difficult for children, Ganesh et al [22] had demonstrated in a randomized study of 152 children that US was useful to decrease the time or the number of attempts for radial arterial cannulation. Analogous results were found by Gratix et al [21], although this trial included only 15 patients, and there was no control group.

Similar results were shown in the case of venous peripheral access. Keyes et al [37] demonstrated that US-guided technique allowed successful cannulation in 91% of the difficult intravenous access patients in the deep brachial or basilic vein. There was no control or comparison group in this trial. In 2007, Bauman et al [20] showed that, after following a brief ultrasound training for peripheral venous access, there was a similar success rate but ultrasound had significantly improved the speed of the procedure and patient satisfaction with fewer skin punctures and complications. However, Stein et al [38] showed in 2009 that the superiority of US-guided peripheral intravenous cannulation is not supported by a randomized trial.

Recommendations were published in 2011 by Troianos et al [39] concerning US-guided cannulation. For central vein (femoral, subclavian, and internal jugular) catheter placement, US have been found useful by the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists. This same council does not recommended routine real-time ultrasound use for the arterial cannulation in general. However, for radial artery, based on the meta-analysis of Shiloh et al [40], there is a category A, level 1 support for the use of US to improve first-pass success.

In 2012, a conference report and expert panel published evidence-based recommendations on US-guided vascular access [41]. Although there are some topics that still need to be defined such as education, training, and accreditation, given the evidence from the literature and based on voting results, ultrasound guidance has to be suggested as the method of choice for any kind of vascular cannulation given its higher safety and efficacy.

However, there are no recommendations about blood gas samples. We only find a case report published in Respiratory Care: US facilitate arterial sample in a 35-year-old woman with difficult vascular access [42].

To summarize, many trials found interest in the use of ultrasound for vascular cannulation, but none was interested in arterial blood gas samples. In the light of this previous work, we should observe a decrease in the number of attempts and in the time of realization and better satisfaction. Unfortunately, we did not observe such expected results, and we demonstrated that US technique was inferior to the conventional technique.

Ultrasonographically guided technique is unnecessary for blood gas samples for the common emergency population because it does not decrease the number of attempts. We also can declare that US are an obstacle to sample arterial blood in radial position because they increase the time of procedure. Unlike the radial arterial cannulation [39,40], we do not recommend routine real-time US for blood gas sampling.

Nevertheless, we showed that all radial arteries (100%, $n = 37$) were seen using US. So, we can suggest that this technique could be useful if the puncture is difficult or impossible. However, it would be necessary to complete this study by a randomized trial selecting difficult punctures, after 2 failures of palpation technique or nonpalpable arteries.

In conclusion, the present studies unexpectedly showed that US guidance does not help arterial puncture for blood gas analysis in a general population of emergency patients. The role of US guidance in the case of difficult puncture needs to be clarified.

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- Voies veineuses périphériques (VVP)

La problématique de la pose de VVP est comparable à celle du GSA radial : technique qui engendre peu de complications, qui présente un taux d'échec faible en routine mais pour laquelle certains patients sont très difficiles. Ainsi, l'écho-guidage améliore le taux de succès de pose de VVP chez les patients difficiles mais pas chez ceux susceptibles d'avoir un accès facile (58). Les RFE de la SFMU de 2016 préconisent que l'urgentiste soit capable de réaliser un écho-guidage pour la mise en place des voies veineuses périphériques (2).

- Autres ponctions :

L'écho-repérage ou l'écho-guidage ont également prouvé leur bénéfice sur d'autres ponctions couramment utilisées dans les SU : diminution du taux d'échec des ponctions lombaires (59), diminution du taux de pneumothorax secondaires aux ponctions pleurales (60), ou encore diminution du taux d'échec (61) et de complications (60) des ponctions d'ascite. Les RFE de la SFMU recommandent que les médecins urgentistes soient capables de réaliser un écho-guidage des ponctions d'ascites et des anesthésies loco-régionales, et un écho-repérage des ponctions pleurales et de la mise en place des cathéters sus-pubiens (2, 44).

3.3. Conclusion :

Les preuves montrant que les techniques diagnostiques d'ECMU sont pertinentes sont déjà anciennes et nombreuses. De même, beaucoup de preuves montrant le bénéfice de l'écho-guidage existent. Beaucoup de ces publications étant issues de réanimation, des études en contexte d'urgence et sur des applications spécifiques de médecine d'urgence sont encore à envisager.

4. Équipement :

4.1. État des lieux :

La présence de nombreuses preuves scientifiques sur la pertinence de l'ECMU a entrainé son implantation progressive dans les SU. La disponibilité d'un échographe est une condition nécessaire à la pratique de l'ECMU. Nous avions réalisé une étude nationale en 2011 pour connaitre le taux d'équipement des SU françaises (62). Les SU hospitalières publiques avaient la disponibilité d'un échographe dans 52% des cas, 9% pour les SU préhospitalières. Nous avions souligné que dans près d'un tiers des services d'urgences, qui avaient la disponibilité d'un échographe, le dispositif n'était pas stationné dans le service. Les RFE de la SFMU de 2016 sur l'ECMU ont préconisé la présence d'un échographe dédié dans chaque service d'urgence et la disponibilité d'un échographe pour chaque unité mobile hospitalière (UMH) (2). Nous avons donc voulu refaire l'état des lieux de la disponibilité d'échographes dans les SU françaises 5 ans après la première étude et l'année de la publication des RFE. Trois cent vingt-huit (84%) services ont répondu au questionnaire : 179 (86%) services d'urgence et 149 (82%) services mobiles d'urgence et de réanimation (SMUR). Le taux de disponibilité était passé de 52% en 2011 à 71% (IC95% [64 ;78]) en 2016 ($p < 0{,}01$) dans les services d'urgences et de 9% à 28% (IC95% [21 ; 35]) ($p < 0{,}01$) dans les SMUR. Le taux d'échographes exclusivement dédiés aux urgences était alors de 76%. L'accès à un échographe avait donc significativement augmenté entre les deux périodes. Le fait que plus des deux tiers des services d'urgences soient déjà équipés l'année de la publication des premières recommandations françaises montre le coté tardif de cet événement (15 ans après les premières recommandations de l'ACEP (63)). Si il est possible de se satisfaire de cette évolution, le taux brut de services équipés restait insuffisant, en particulier en préhospitalier. Cependant au niveau international, ce taux d'équipement semblait intermédiaire, entre, par exemple, deux études publiées en 2015 : une aux états unis d'Amériques rapportant un taux d'équipement à 47% (64), et une réalisée dans les services d'urgences ruraux d'Ontario (Canada) où ce taux était de 95% (65).

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Anaesthesia Critical Care & Pain Medicine

Original Article

Changes in the availability of bedside ultrasound practice in emergency rooms and prehospital settings in France

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ABSTRACT

Objective: Ensuring the availability of ultrasound devices is the initial step in implementing clinical ultrasound (CUS) in emergency services. In France in 2011, 52% of emergency departments (EDs) and only 9% of mobile intensive care stations (MICS) were equipped with ultrasound devices. The main goal of this study was to determine the movement of these rates since 2011.

Methods: We conducted a cross-sectional, descriptive, multicentre study in the form of a questionnaire. To estimate the numbers of EDs and MICS equipped with at least one ultrasound system with a confidence level of 95% and margin of error of 5%, 170 responding EDs and 145 MICS were required. Each service was solicited three times by secure online questionnaire and then by phone.

Results: Three hundred and twenty-eight (84%) services responded to the questionnaire: 179 (86%) EDs and 149 (82%) MICS. At least one ultrasound machine was available in 127 (71%, 95% CI [64; 78]) EDs vs. 52% in 2011 ($P < 0.01$). 42 (28%, 95% CI [21; 35]) MICS were equipped vs. 9% in 2011 ($P < 0.01$). In 97 (76%) EDs and 24 (55%) MICS, less than a half of physicians were trained. CUS was used at least three times a day in 52 (41%) EDs and in 8 (19%) MICS.

Conclusion: Our study demonstrates improved access to ultrasound devices in French EDs and MICS. Almost three-quarters of EDs and nearly one-third of MICS are now equipped with at least one ultrasound device. However, the rate of physicians trained per service remains insufficient.

1. Introduction

Clinical ultrasonography (CUS) is now integrated into the diagnostic tool-kits of many medical specialties [1]. The American College of Emergency Physicians (ACEP) defined 'clinical ultrasound' as follows: "CUS is a diagnostic tool, providing clinical information that would not have been obtained by the inspection, palpation, auscultation or any other component of patient's physical examination. This is a separate diagnostic tool, not a component or extension of the physical examination" [2]. Since validation of the FAST protocol (Focused Assessment with Sonography for Trauma) [3], many applications were described and/or recommended, e.g. lung ultrasound [4,5], focused cardiac ultrasound [6], diagnosis of intrauterine pregnancy [7,8], of abdominal aortic aneurysm, of deep venous thrombosis [9], of hepatobiliary and urinary tract pathologies [10], transcranial Doppler [11,12] and others. The French Society of Emergency Medicine (SFMU) has recently issued its first national guidelines on emergency CUS [13].

Several studies suggest that CUS enables therapy optimisation in prehospital settings during the evaluation of traumatic injuries [12,14]. Other studies suggest prehospital usefulness of CUS in evaluation of dyspnoea, chest pain, abdominal trauma and in invasive procedures guidance [15–17]. International recommendations now include CUS in cardiopulmonary resuscitation

Abbreviations: CUS, clinical ultrasound; EDs, emergency departments; MICS, mobile intensive care stations; ACEP, American College of Emergency Physicians; FAST, Focused Assessment with Sonography for Trauma; SFMU, French Society of Emergency Medicine; FOAM, Free Open Access Medical Education; ERC, European Resuscitation Council; ASE, American Society of Echocardiography; CPR, cardiopulmonary resuscitation; PEA, pulseless electrical activities.

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algorithms [18]. Several randomised controlled studies are underway to evaluate the real contribution of CUS in prehospital settings [19–21].

A first study conducted in 2011 in France showed an availability rate of ultrasound devices of 52% in emergency departments (EDs) and only 9% in mobile intensive care stations (MICS) (22). We decided to check those rates after five years, at the time when the French recommendations were published. The main objective of our study was to determine the evolution of availability rates between 2011 and 2016 in France for both in-hospital and pre-hospital emergency settings. Secondary objectives were to determine the number of ultrasound devices available in each ward, type and number of practitioners trained in CUS and, finally, main clinical applications.

2. Methods

2.1. Objectives of the study

We conducted a cross-sectional, descriptive, multicentre study in the form of a questionnaire. The centres surveyed in this study were all EDs in public and private hospitals as well as all MICS in mainland France and overseas territories.

The primary objective of our study was to determine the numbers of EDs and MICS equipped with ultrasound devices after five years. The primary endpoint was availability or not of one or more ultrasound device in each service.

Secondary objectives were to determine the number of devices available, the types of device used, the number of practitioners trained in ultrasonography and the main clinical applications. To judge the latter, we interviewed centres on all applications listed in the SFMU recommendations published in 2016 [13]. Their analysis was conducted after having designed eight clinical categories (serous effusion, abdominal ultrasound, echocardiography, lung ultrasound, venous ultrasound, musculoskeletal ultrasound, paediatric ultrasound, ultrasound guidance and interventional ultrasound) and five critical scenarios (shock state, dyspnoea, chest pain, cardiac arrest and severe trauma).

2.2. Statistical requirements

The sample of interviewed EDs was established from hospitals listed on the website of the Fédération Hospitalière de France (http://www.fhf.fr). We estimated an expected proportion of EDs equipped with at least one ultrasound machine to be 75%. To calculate an equipment rate with a confidence level of 95% and margin of error of 5%, we needed 170 respondent EDs from a total of 414. By setting the response rate goal at 85%, we had to examine 200 EDs. As a precaution, we examined 208 EDs, representing 50% of all EDs.

The list of interviewed MICS was established from the website of SAMU–Urgence de France (http://www.samu-de-france.fr). We estimated an expected proportion of MICS equipped with at least one ultrasound machine to be 30%. To calculate an equipment rate with a 95% confidence level and margin of error of 5%, we needed 145 respondent MICS from a total of 264. By setting the response rate goal at 85%, we had to examine 171 MICS. As a precaution, 181 MICS were examined, representing 68% of all MICS.

2.3. Development of the study

The study inclusion period was from May to July 2016. The services were solicited three times by email to complete a secured online questionnaire. Non-responders were additionally contacted by phone after the third email reminder.

Table 1
Answering hospitals' characteristics.

	EDs, $n = 179$	MICS, $n = 149$
Type of hospital, n (%)		
General hospital	158 (88)	132 (88)
University hospital	21 (12)	17 (12)
Rate of physicians per service, n (%)		
< 5	24 (13)	19 (13)
6–15	95 (53)	77 (51)
16–25	42 (23)	37 (25)
26–35	10 (6)	6 (4)
> 35	8 (5)	10 (7)
EDs: visits rate per year, n (%)		
< 16000	46 (26)	
16000–26000	45 (25)	
26001–40000	45 (25)	
> 40000	43 (23)	
MICS: interventions rate per year, n (%)		
< 500		24 (16)
500–1500		57 (38)
> 1500		60 (40)
N/A		8 (6)

EDs: emergency departments; MICS: mobile intensive care stations.

2.4. Statistical analysis

Quantitative variables were expressed by their mean values and standard deviation or median values followed by 25th and 75th percentiles (interquartile range). Qualitative variables were expressed by their numbers and percentages. Comparison of quantitative variables among the different groups was performed by the student test. When conditions of validity of this test (normal distribution, equality of variances) were not verified, nonparametric tests (Wilcoxon test or Kruskal–Wallis test if multiple classes) were used. The relationship between two variables was tested by the Chi^2 test or by the Fisher exact test when the Chi^2 conditions of application (theoretical numbers < 5) were not met. The significance level was set at 5% for all tests used. Statistical analysis was performed under R 2.9.2 (R Development Core Team, 2009, R Foundation for Statistical Computing, Vienna, Austria).

3. Results

Three hundred twenty-eight (84%) services answered the questionnaire: 179 (86%) EDs and 149 (82%) MICS. Characteristics of responding services are described in Table 1.

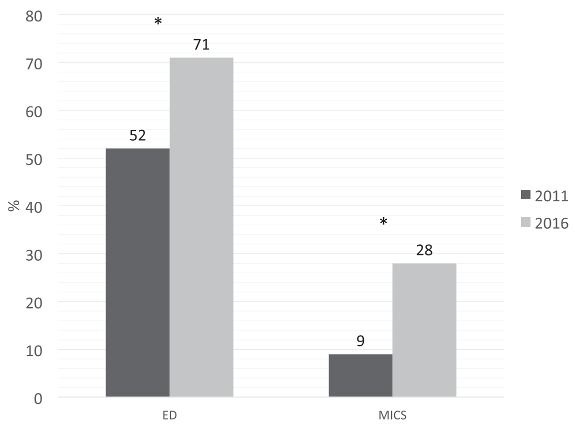

Fig. 1. Availability rate of at least one US device in ED and MICS: 2016 vs. 2011. * $P < 0.001$; EDs: emergency departments; MICS: mobile intensive care stations; US: ultrasound.

Among the 179 ED that responded, at least one ultrasound machine was available in 127 EDs (71%, 95% CI [64; 78]) vs. 52% in 2011 ($P < 0.01$). Among the 142 responding MICS, at least one ultrasound machine was available in 42 (28%, 95% CI [21; 35]) vs. 9% in 2011 ($P < 0.01$). Results are summarised in Fig. 1. In unequipped services, there was an ongoing purchase project of ultrasound equipment in 17 (33%) EDs and 34 (32%) MICS.

In services equipped with at least one ultrasound device, whether ED or MICS, the median number of devices was 1 ± 0.4. In 96 (76%) EDs, the unit was exclusively dedicated to the service (57% in 2011). Ultrasound was used at least three times a day in 52 (41%) EDs and 8 (19%) MICS.

Doctors' training rates among EDs and MICS are described in Table 2. In 101 (80%) EDs and 36 (83%) MICS, there was at least one emergency physician (EP) who had followed a long academic course. In 56 (44%) EDs and 28 (76%) MICS, some EPs had followed short WINFOCUS courses.

Data on the main clinical applications performed in the EDs and in prehospital settings are described in Fig. 2.

Table 2
Rate of CUS-trained physicians in EDs and MICS.

	EDs, $n = 127$	MICS, $n = 44$
Rate of CUS-trained physicians, n (%)		
$< 25\%$	54 (42)	8 (19)
25–50%	43 (34)	16 (36)
51–75%	15 (12)	13 (29)
$> 75\%$	15 (12)	7 (16)

EDs: emergency departments; MICS: mobile intensive care stations; CUS: clinical ultrasound.

4. Discussion

4.1. Main results

Results of our study are showing that from 2011 to 2016, the number of French emergency services equipped with ultrasound increased in both EDs (52% vs. 71%; $P < 0.001$) and MICS (9% vs. 28%; $P < 0.001$) [22]. Although few studies are available on access to clinical ultrasound in emergency services, our study lies in the intermediate position in international literature. In a study gathering data from five American states and published in 2015, the presence of an ultrasound machine was of 113 EDs (47%) of 242 [23]. In contrast, a Canadian study published the same year showed that 103 (95%) of 108 rural EDs in Ontario benefited from a dedicated ultrasound machine [24]. Many local or national factors could likely explain these disparities. Our results are encouraging as more than two-thirds of EDs and more than one-quarter of MICS got equipped at the first SFMU recommendations issued.

In France, recent guidelines posted by SAMU–Urgence de France categorise the presence of a portable ultrasound device within MICS as "essential" [25]. The increase of procurement rate of ultrasound machines in MICS (mostly pocket-size) is a positive signal. Only half the services that reported to be equipped with ultrasound declared that the device was used more than three times a day. This under-use, in contrast with the amount of eligible patients, might be explained by a low rate of trained doctors and the absence of French recommendations. Increased numbers of EDs equipped with an ultrasound device is associated with an increased number of EDs where the machine is solely dedicated to the service: from 57% in 2011 [22] to 76% in the present study. These data seem important because equipment shared by different

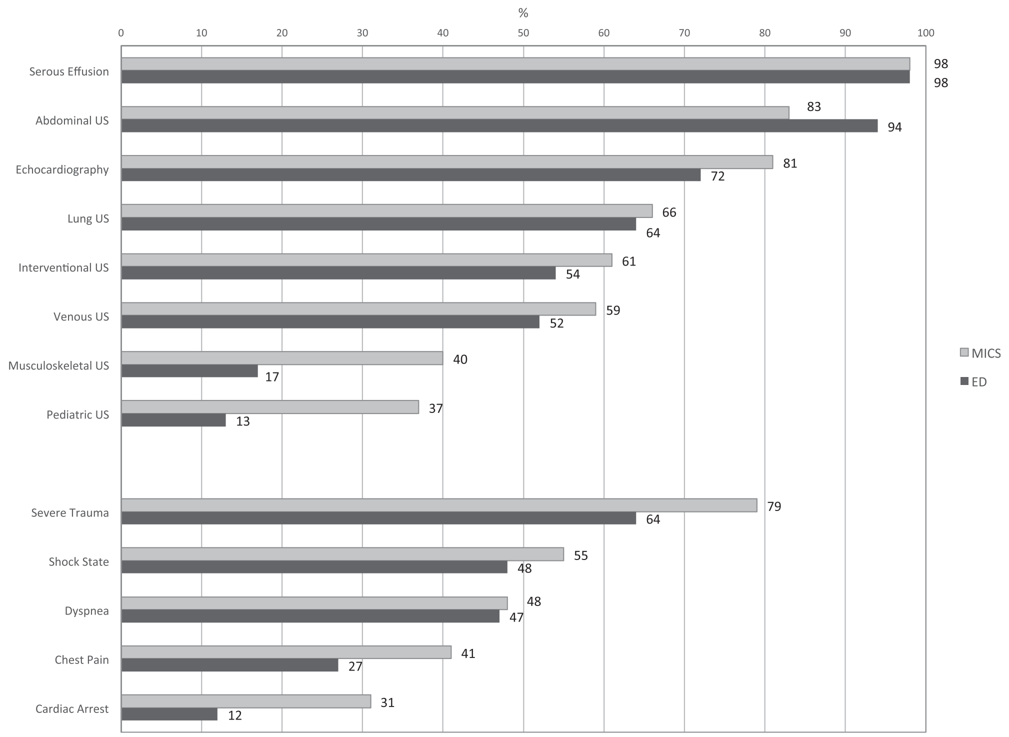

Fig. 2. Main clinical US applications in EDs and MICS. EDs: emergency departments; MICS: mobile intensive care stations; US: ultrasound.

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services can induce a loss of time for device retrieval, thereby presenting a barrier to its use in EDs. The number of equipped services should continue to increase as 33% of EDs and 32% of MICS not equipped have reported a short-term project to purchase an ultrasound device.

Whether pre- or in-hospital CUS, its overall quality is directly related to the training, skills and experience of EP [21,26,27]. In our study, less than half of the medical team was trained in 76% of EDs and 54% of MICS. In a majority of services surveyed, at least one doctor had followed relevant academic education (83% for emergency services and 80% in prehospital).

In 2016, the French Society of Emergency Medicine published for the first time its recommendations on prerequisites necessary for the practice of basic level CUS [13]. Thus, we wanted to determine the fields of application (Fig. 2). Comparing, respectively, EDs with MICS, clinical categories where CUS was used were, from most to least frequent: detection of serous free fluid (98% vs. 98%), abdominal ultrasound (94% vs. 83%), focused cardiac ultrasound (72% vs. 81%) and lung ultrasound (63% vs. 66%). Similarly, critical scenarios where CUS was used were, from most to least frequent: trauma patients (64% vs. 79%), shock state (48% vs. 55%) and acute dyspnoea (47% vs. 48%). History might explain these results: FAST is one of the oldest applications [3], with proven added value in clinical practice [28]. They also show there was a particular interest for EPs to integrate CUS in the algorithm of shock state management. Indeed, a 2013 study confirmed the capacity of CUS to increase clinical effectiveness in terms of etiological diagnosis and treatment precision [29]. As it has recently and again been demonstrated, there is a benefit to use CUS during invasive procedures such as placement of central venous catheters [30]. In our study, CUS was used only in 54% of ED vs. 61% of MICS for procedural guidance. Lack of education, skills or availability of ultrasound devices might explain these results. A critical scenario in which ultrasonography was least used was cardiac arrest management. Although the European Resuscitation Council (ERC) [18], ACEP and American Society of Echocardiography (ASE) recommend its use during CPR, CUS has been used only in 12% of EDs and 31% of MICS. The practices of EPs must evolve. Practitioners should improve their skills through specific training to conform to new recommended algorithms for cardiac arrest management in both in-hospital and prehospital settings.

4.2. Limitations

First, our study is a survey. There is one possible reporting bias. If it is probably negligible for the main purpose (ultrasound equipment), then it is possible for the secondary objectives. The main limitation is that the results on the types of training followed and the practiced applications are cast for each medical team's unit and not by individual physicians.

5. Conclusion

Our study shows a clear 5-year increase (2011–2016) in the number of French EDs and MICS with access to ultrasound equipment for EPs. Almost three-quarters of EDs and nearly one-third of MICS are now equipped. This is clearly a positive sign for improving patient management. Moreover, it is in line with the latest recommendations published in this field by both French and international scientific societies.

Nevertheless, the rate of trained physicians per service remains inadequate as the number of CUS applications remains too limited compared with the guideline's suggested scope.

Disclosure of interest

Xavier Bobbia declares a competing interest as an ultrasound teacher for GE (GE MEDICAL SYSTEMS ULTRASOUND) customers. The other authors declare that they have no competing interest.

Ethical statement

This observational study was approved by the institutional review board (IRB) (Nîmes, France, 16/01-04).

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The authors acknowledge all the EPs who responded to our survey.

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4.2. Intérêt des échographes de poche :

Tous les échographes ne sont pas adaptés à la pratique de l'ECMU. Comme nous l'avons vu dans sa définition, l'ECMU se pratique sur les lieux de la prise en charge du patient. En médecine d'urgence hospitalière, cela peut vouloir dire dans des salles de consultations, dans des chambres ou dans des salles de soins (type salle d'accueil des urgences vitales (SAUV)), mais dans toutes les conditions possibles en préhospitalier. Un échographe lourd ou encombrant n'est pas adapté à cette pratique. De plus, nous avons vu que l'ECMU se caractérise par des techniques simples et rapides. Pour réaliser une technique échographique demandant 3 minutes de réalisation, l'allumage d'un échographe qui en demande 2 n'est pas adapté. De même, une interface complexe ou la nécessité de plusieurs paramétrages pour débuter l'examen ne le sont pas plus. Enfin, le fait de devoir chercher le dispositif dans le service est également un frein à la pratique de l'ECMU. L'échographe idéal pour la plupart des applications semble donc être un échographe au temps d'allumage très court, avec une interface simpliste et que le médecin a toujours sur lui. C'est le concept des échographes de poche (*pocket-sized* en anglais). La miniaturisation des échographes et l'amélioration de la qualité d'image a permis aux industriels fabriquant des échographes de concevoir des dispositifs qui paraissent particulièrement adaptés à l'échographie clinique. Ces dispositifs ont renforcé l'idée de stéthoscope échographique. En France, leur déploiement en médecine d'urgence a été surtout marqué par la mise sur le marché en 2009 d'un dispositif : le Vscan (Vscan™; GE Healthcare, Milwaukee, Wisconsin, USA). Sa version initiale avait une seule sonde (cardiaque) puis une version avec deux sondes (cardiaque et vasculaire) a été proposée. Le développement des échographes de poche en cardiologie a même entrainé la publication de recommandations sur leur utilisation par l'*European Association of Echocardiography* (ESA) (66). En médecine d'urgence, la diffusion de ce type de dispositif semble encore limitée : dans une étude que nous avons réalisé en 2014 dans 50 SU françaises, seulement 6% des échographies étaient réalisées avec un échographe de poche (67). Nous avons voulu tester le Vscan dual probe™. D'abord, nous avons voulu tester la qualité des images obtenues. Nous avons étudié une application dans laquelle le choix de la sonde est laissé au jugement du praticien par les recommandations (45) : l'échographie pulmonaire. En effet, si beaucoup d'études sur l'échographie pulmonaire ont été conduites avec une sonde micro-convexe (17-19, 68) (dont très peu de services cliniques disposent), aucune n'avait comparé différentes sondes pour réaliser une échographie pulmonaire. Nous avons réalisé une étude observationnelle prospective dont l'objectif principal était de comparer la concordance diagnostique entre l'échographie pulmonaire obtenue grâce à 5 sondes différentes et la tomodensitométrie chez des patients pris en charge pour un état de détresse respiratoire aiguë.

Nous avons voulu analyser ces concordances en fonction de l’expérience du médecin qui interprétait l’examen (interne en début d’apprentissage, médecin pratiquant la technique et expert). Les 5 sondes choisies étaient les 3 habituellement présentes sur un échographe conventionnel (cardiologique, abdominale et vasculaire) et les deux sondes de l’échographe de poche (cardiaque et vasculaire). Cent échographies ont été analysées. Les principaux résultats étaient que la sonde cardiaque de l’échographe conventionnel et la sonde linéaire de l’échographe de poche avaient les meilleures concordances avec le scanner (coefficient Kappa = 0,75 IC95% [0,54 ; 0,96] et 0,62 IC95% [0,37 ; 0,86] respectivement) mais uniquement pour les experts et les médecins formés. L'accord était toujours mauvais pour les internes. Nous avons conclu que la sonde cardiaque de l’échographe conventionnel et la sonde linéaire de l’échographe de poche semblaient être les plus adaptées à la pratique de cet examen. Pour la sonde cardiaque de l’appareil conventionnel nous avons émis l’hypothèse que ces résultats étaient dus au fait qu’il s’agissait d’une sonde haut de gamme de type matricielle. Pour la sonde linéaire de l’échographe de poche, nous pensons que sa performance est due à la « pureté » de l’image obtenue. En effet, l’échographie pulmonaire est, en bonne partie, basée sur l’interprétation d’artéfacts. Or, les échographes conventionnels possèdent de nombreux outils informatiques pour éliminer les artéfacts afin d’améliorer la qualité d’image (filtres, compression etc...). L’association d’une sonde à haute fréquence (vasculaire), donc avec la meilleure discrimination spatiale, avec un échographe pauvre en outils de post-traitement d’image semble permettre une image pulmonaire de qualité. Le fait qu’une sonde d’un échographe de poche soit performante pour la réalisation de l’échographie pulmonaire est important. L’échographie pulmonaire est une part importante de l’ECMU et le fait de pouvoir la réaliser avec un échographe ergonomique peut aider à son déploiement, même en médecine d’urgence préhospitalière.

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Brief Report

Assessment of five different probes for lung ultrasound in critically ill patients: A pilot study

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ABSTRACT

Introduction: The present study was aimed at comparing the diagnosis concordance of five echo probes of lung ultrasound (LUS) with CT scans in intensive care and emergency patients with acute respiratory failure.
Materials: This prospective, observational, pilot study involved 10 acute patients in whom a thoracic CT scan was performed. An expert performed an LUS reference exam using five different probes: three probes with a high-quality conventional echo machine (cardiac phased-array probe, abdominal convex probe, linear probe) and two probes (cardiac and linear) with a pocket ultrasound device (PUD). Then, a trained physician and a resident performed 'blinded' analyses by viewing the video results on a computer. The primary objective was to test concordance between the blinded echo diagnosis and the CT scan.
Results: In the 100 LUS performed, the phased-array probe of the conventional machine and linear array probe of the PUD have the best concordance with the CT scan (*Kappa* coefficient = 0.75 [CI 95% = 0.54–0.96] and 0.62 [CI 95% = 0.37–0.86], respectively) only for experts and trained physicians. The agreement was always poor for residents. Convex (abdominal) and linear transducers of conventional machines and the phased-array transducers (cardiac) of PUD have poor or very poor agreement, regardless of the physician's experience.
Conclusion: Among the probes tested for LUS in acute patients, the cardiac probe of conventional machines and the linear probes of PUDs provide good diagnosis concordance with CT scans when performed by an expert and trained physician, but not by residents.

1. Introduction

International guidelines recommend the widespread use of LUS in ICUs and emergency departments (EDs) [1,2]. Most of the early studies focusing on LUS in the ICU and emergency department (ED) were performed using a 5 MHz micro convex probe [3-10]. However, the 5 MHz micro convex probe is rarely available on conventional echo machines (CEMs) [1]; thus, the 1–3 MHz convex transducer (abdominal probe) has been used to perform LUS with a good agreement [11,12]. In the ICU, physicians also use phased-array (cardiac) and linear array transducers to perform LUS as the majority of echo machines are equipped with such probes [1,12]. The International Liaison Committee for point-of-care LUS reported few recommendations for optimal echo probes [1]. These recommendations only mentioned that the 5 MHz micro convex probe should preferably be used to assess the presence of pneumothorax in adults, although physicians could still choose other transducers (phased-array, convex, linear) based on their experience and the clinical setting [1,12]. To our knowledge, no study has compared the accuracy of various echo transducers for LUS.

The primary endpoint of the present study aimed to assess the diagnosis concordance between thoracic CT scan and five different transducers used to perform LUS, according to physician experience. The secondary end point aimed to compare the diagnosis concordance of the five probes for the following pulmonary syndromes: normal

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lung, pleural effusion, alveolar-interstitial syndrome, pneumothorax, condensation, association of condensation and pleural effusion. Finally, experts subjectively rated the quality of each LUS image by using a visual analogue scale (VAS) ranging from 0 (no image) to 10.

2. Materials and methods

2.1. Materials

2.1.1. Ethics approval

The present prospective, observational pilot study was conducted in the ICU of Nîmes University Hospital (France) from January to October 2015. The study was approved by the Institutional Review Board of Nîmes University Hospital, France (Reference number: IRB 15/04/02).

2.1.2. Patient selection

Patients admitted in the ICU or the emergency room (ER) and undergoing a thoracic CT scanner were eligible for the present study. Patients under 18 years of age, patients without CT scanner indication and intervals between LUS and CT scanner >6 h were excluded. A certified expert in critical care ultrasound (US) performed an LUS exam, which was considered as the 'reference exam'. A certified expert was defined by the following four criteria: a daily practice of LUS for >10 years, national ultrasonography diploma, institutional referent for LUS and in charge of university ultrasonography teaching.

2.1.3. Study design (Fig. 1)

For the reference (non-blinded) exam, the expert was aware of the CT scan results and took these into account while performing the LUS reference exam. This expert aimed to perform the most optimal LUS images and videos according to his experience and CT scan data in order to maximise the quality of the blinded analysis. The expert subjectively rated the quality of each LUS image by using a VAS ranging from 0 (no image) to 10 (optimal image). The two LUS experts involved had frequent use of both types of ultrasound devices. When one of those experts performed the reference LUS exam, he also analysed the blinded images. Cine loops recorded by medical experts were all de-identified and randomly analysed. Three physicians analysed these blinded cine loops:

- The second medical expert, who had not performed the original LUS imaging.
- An experienced practitioner (ICU) defined as owning an ultrasonography university diploma associated with a daily practice of LUS for more than two years.

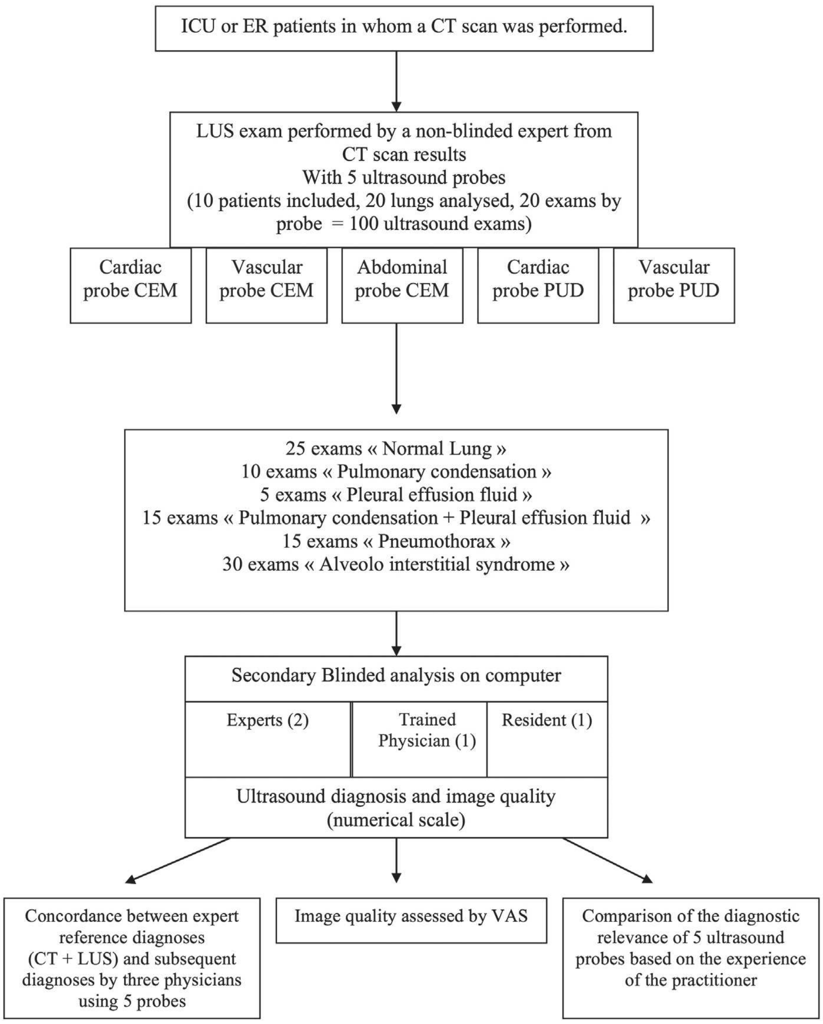

Fig. 1. Study design and flowchart. ICU: Intensive Care Unit; ER: Emergency Room; LUS: lung ultrasound; CT: computerised tomography; CEM: conventional echo machine; PUD: pocket ultrasound device; VAS: visual analogue scale.

Table 1
Diagnosis concordance.
Expressed by *Kappa* coefficient between physician experiences, regardless of transducer type.

	Kappa < 0 Important disagreement	0 ≤ *Kappa* < 0.2 Very weak agreement	0.2 ≤ *Kappa* < 0.4 Weak agreement	0.4 ≤ *Kappa* < 0.6 Medium agreement	0.6 ≤ *Kappa* < 0.8 Good agreement	0.8 ≤ *Kappa* ≤ 1 Excellent agreement
Expert					*Kappa* = 0.63	
Trained physician				*Kappa* = 0.55		
Resident		*Kappa* = 0.18				

- A resident (ED) who followed a theoretical academic LUS training and had a short practical training.

2.1.4. Ultrasound protocol

The non-blinded expert performed a PLUS examination at each lung of each patient. The examination was performed in a lung area where the diagnosis of computed tomography was evident: normal, alveolar-interstitial syndrome, pneumothorax, consolidation, pleural effusion, association of consolidation or pleural effusion. We postulated that such methodology could ensure a perfect concordance between the CT scan and LUS exam. Five probes from two machines, one CEM and one pocket ultrasound device (PUD) were tested for each patient:

- Three probes from a CEM (Vivid S6, GE Healthcare, Medical System Israel Ltd, 4 Haetgar St. Tirad Carmel 39120), considered as a high-quality reference machine:
  - o Cardiac probe Vivid (M4S-RS) sector 1.5–3.6 MHz: CEM cardiac probe
  - o Vascular probe Vivid (9L-RS) superficial probe 3.5–10.0 MHz: CEM vascular probe
  - o Abdominal probe Vivid (4C-RS) convex 1.8–6.0 MHz: CEM abdominal probe

- Two probes from a PUD (Vscan Dual probe, GE Healthcare, Vingmed Ultrasound AS, Standpromenaden 45, 3183 Horten, Norvège):
  - o Cardiac probe Vscan sector 1.7–3.8 MHz: PUD cardiac probe
  - o Vascular probe Vscan M7C linear 6–14 MHz: PUD vascular probe

2.2. Statistical analysis

This was a pilot study, with no previous published data on this specific issue. The statistical analysis was performed with version 9.4 SAS software (SAS Institute, Cary, NC, USA). The normality of quantitative variable distributions was assessed. Statistical results were expressed in mean ± standard deviation. Qualitative variables were expressed in number and associated percentages. To take account of the agreement occurring by chance, Cohen's *Kappa* coefficient was used to measure inter-rater agreement between physician experience, regardless of probe, and to measure concordance between CT scans and LUS performed by five different probes, according to physician experience [13,14]. Chi-square was used to compare the frequencies actually observed in a study to the expected frequencies to see if they are significantly different. The risk of error of the first kind was set at 5%.

3. Results

3.1. Participants

Five (50%) out of the 10 included patients were female (62 ± 16 years old; three patients with body mass index (BMI) between 18 and 24; four patients with BMI between 24 and 30 and three patients with BMI ≥ 30 kg/m^2). Seven patients (70%) had no medical history of heart or lung disease, whereas three patients (30%) had a medical history of chronic obstructive pulmonary disease and two had chronic heart failure as well. The causes of admission were pneumonia (n = 6), acute respiratory distress syndrome (n = 2), pneumothorax (n = 1) and chest trauma (n = 1). Mechanical ventilation was applied in seven patients, whereas three patients were spontaneously breathing.

3.2. Types of pleuro-pulmonary syndrome recorded

Among the 10 studied patients, 20 different lung images could be analysed by five different probes, leading to 100 LUS examinations: Fig. 1.

3.3. Assessment of concordance

The diagnosis concordance between physician experiences is shown in Table 1. The concordance decreases in trained physicians and residents. The diagnosis concordance between CT scans and LUS performed by five different transducers according to physician experience were greater with the CEM cardiac probe and PUD vascular probe (Table 2).

Fig. 2 shows the diagnosis concordance between the CT scan and the five transducers for the six different LUS diagnoses. Table 3 shows the VAS for each transducer, according to physician experience.

4. Discussion

4.1. Main result

The present study compared five different probes for the two types of US machines (CEM and PUD) typically used in acute care conditions for analysing lung images. When compared with CT scans, the concordance increased with the training of the operator. The cardiac probe of CEM and the vascular probe of PUD exhibited greater concordance

Table 2
Diagnosis concordance between CT scans and LUS performed by five different transducers, according to physician experience.
CT: computerised tomography; LUS: lung ultrasound; CEM: conventional echo machine; PUD: pocket ultrasound device. ND: not determined; CI: confidence interval. Green box table: good agreement between the two systems; Orange: medium agreement; Dark orange: weak agreement; Red: very weak agreement.

	Cardiac probe CEM	Vascular probe CEM	Abdominal probe CEM	Cardiac probe PUD	Vascular probe PUD
Expert	0.75 [CI 95%=0.54–0.96]	ND	ND	ND	0.62 [CI 95%=0.37–0.86]
Trained physician	ND	ND	0.44 [CI 95%=0.17–0.70]	0.42 [CI 95%=0.15–0.69]	0.68 [CI 95%=0.44–0.91]
Resident	ND	ND	0.26 [CI 95%=0.01–0.51]	0.05 [CI 95%=−0.17–0.27]	ND

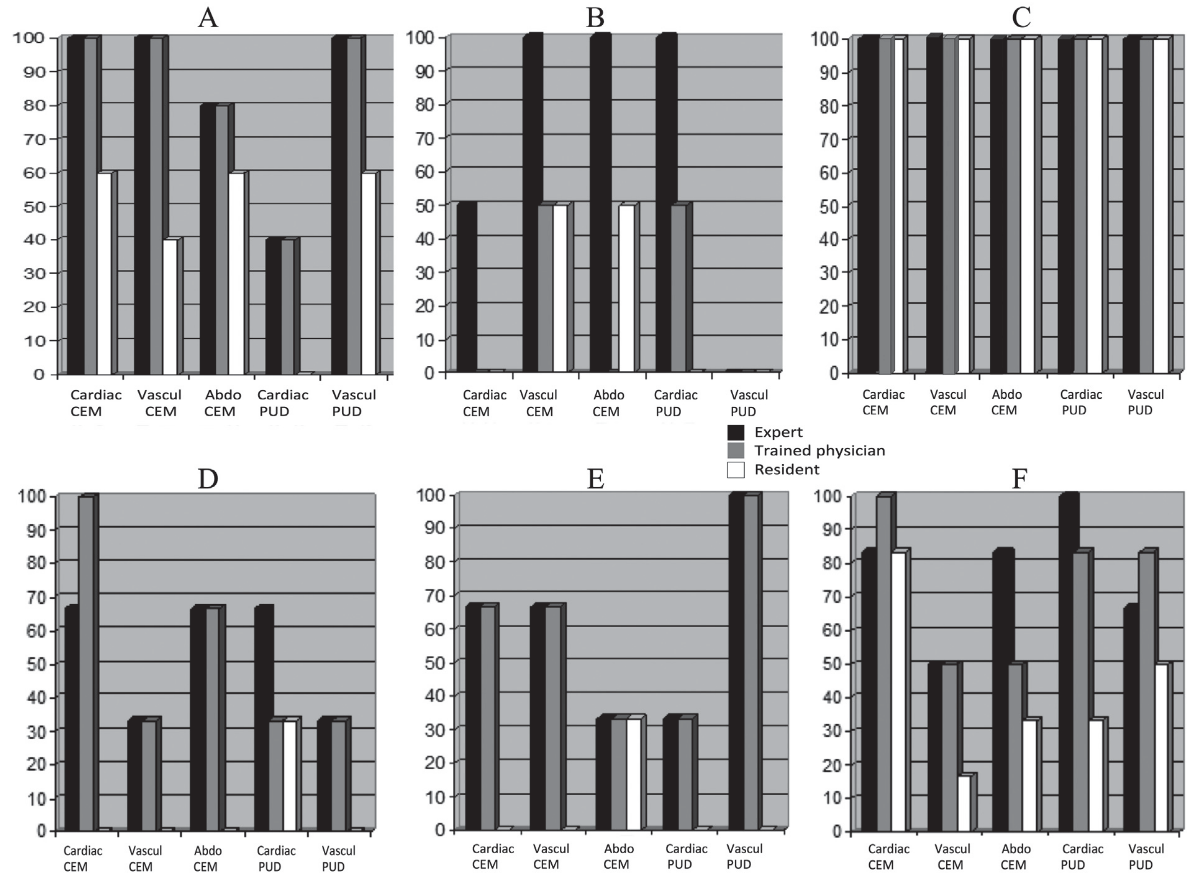

Fig. 2. Comparison of ultrasound probes for the diagnosis of various lung ultrasound syndromes. A: Diagnosis of normal lung; B: diagnosis of pulmonary consolidation; C: diagno pleural effusion fluid; D: diagnosis of association of pulmonary consolidation with pleural effusion fluid; E: diagnosis of pneumothorax; and F: diagnosis of alveolo-inters syndrome (AIS). Black bar: blinded expert operator; grey bar: trained operator; white bar: resident. CEM: conventional echo machine; PUD: pocket ultrasound device; Cardiac: ca transducer; Vascul: vascular transducer. Abdo: abdominal transducer.

with the CT scan, but only for experts and trained physicians. The agreement was weak for residents, whatever the probe. The use of the CEM cardiac probe by experts and trained physicians was associated with better diagnosis concordance with the CT scan, meaning that the CEM cardiac probe can diagnose both superficial and deeper abnormalities. This finding contradicts the recommendations, which doubt the ability of the cardiac probe to diagnose pneumothorax [1]. Despite a bandwidth of 1.5–3.6 MHz, this probe is a matrix transducer, which explains the high quality of images and, therefore, the good results obtained with this probe. This result suggests that echocardiographic exam ca coupled with LUS without changing probes for patients in shock a or respiratory failure. Several studies have shown the interest of c pling cardiac and lung sonography [15,16].

Surprisingly, the vascular probe of the tested PUD showed a good agnosis concordance with the CT scan. First, this probe was associ with an excellent analysis of pleura, particularly in the case of pneu thorax (Fig. 2). Second, this probe is a broad-bandwidth linear a ranging from 3.4 to 8.0 MHz, allowing both superficial and dee

Table 3
Values of visual analogue scale (VAS) per review for each probe and each type of physician.
CEM: conventional echo machine; PUD: pocket ultrasound device; VAS: visual analogue scale, NS: numerical scale. The first line represents VAS values for the reference exam perform a non-blinded expert on the basis of thoracic CT scan results.

	Cardiac probe CEM	Vascular probe CEM	Abdominal probe CEM	Cardiac probe PUD	Vascular probe PUD	All combined pro
Reference exam by non-blinded expert						
NS mean, SD	8.46 ± 1.17	7.22 ± 2.48	7.72 ± 1.35	6.72 ± 2.78	7.01 ± 3.21	7.43 ± 2.37
Expert						
VAS mean, SD	6.27 ± 2.68	6.52 ± 2.10	6.77 ± 2.04	4.9 ± 2.50	6.90 ± 2.33	6.28 ± 2.40
Trained physician						
NS mean, SD	6.65 ± 1.53	6.40 ± 2.23	6.25 ± 1.58	4.05 ± 2.43	6.30 ± 1.71	5.93 ± 2.12
Resident						
NS mean, SD	5.70 ± 1.38	5.55 ± 1.23	5.30 ± 1.34	5.50 ± 1.27	5.80 ± 1.15	5.57 ± 1.26
Pooled data						
NS mean, SD	6.77 ± 2.04	6.43 ± 2.12	6.51 ± 1.81	5.31 ± 2.48	6.50 ± 2.25	6.30

evaluation. The poor concordance of the CEM abdominal probe is not in accordance with the literature [12]. This is probably because we do not often use the convex probe for LUS.

4.2. Originality of the study

To our knowledge, the present study is the first to analyse the reliability of the most common probes for lung imaging used in acute care conditions. The 5 MHz micro convex probe is not typically proposed by manufacturers in CEMs. Therefore, by force of circumstance, the three types of probes tested are used to perform LUS in ICUs and EDs [12]. Moreover, the widespread use of PUDs, available with different probes, raises the question of the most adequate probe for LUS assessment by PUD. Again, no study has compared the probes of such devices with the transducers of CEMs.

4.3. Limits

In the present study, some limitations could be advanced:

- A larger patient and operator sample size may have enabled to show statistical differences between probes. However, this pilot study provides useful data to design further studies on LUS probe performance.
- We did not use the 5 MHz micro convex transducer, which is considered as a reference in LUS; however, this probe is rarely available in ICUs.
- The methodology is not designed for compared in real clinical conditions the accuracy of each probe.
- Blinded operators did not technically perform complete LUS exams as they evaluated the different probes on the basis of short video movies visualised on a computer.

5. Conclusion

Among the two ultrasound devices tested, the present study shows that conventional machine cardiac probes and pocket ultrasound device vascular probes allow a good diagnosis concordance between CT scan and LUS, but only when performed by trained operators.

Competing interests

Only the first author declares a competing interest: XB declares teaching ultrasound for GE (GE MEDICAL SYSTEMS ULTRASOUND) customers. The other authors state they have no competing interests.

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Nous avons également voulu tester la sonde vasculaire de l'échographe de poche dans une autre application de l'ECMU : la compression veineuse des membres inférieurs. Nous avons réalisé une étude prospective interventionnelle dont l'objectif principal était d'évaluer la performance diagnostique de l'échographie de compression veineuse des membres inférieurs réalisée avec un échographe de poche pour diagnostiquer les thromboses veineuses profondes proximales (TVPP). Nous avons inclus et analysé 56 patients. Onze (20%) TVPP ont été diagnostiquées avec l'échographe de poche : 7 (64%) fémorales et 4 (36%) poplitées. L'examen avec l'échographe de poche avait une Se de 100% [72% ; 100%] et une Sp 100% [92% ; 100%]. La valeur prédictive positive (VPP) était de 100% [74% ; 100%] et la valeur prédictive négative (VPN) de 100% [90% ; 100%]. Nous en avons conclu que l'échographie de compression veineuse des membres inférieurs était faisable avec un échographe de poche, et que la borne inférieure de l'intervalle de confiance de la VPN était acceptable.

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Brief Report

Compression with a pocket-sized ultrasound device to diagnose proximal deep vein thrombosis

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ABSTRACT

Introduction: Compression ultrasonography (CUS) is a validated technique for the diagnosis of deep venous thrombosis (DVT), but has never been studied with pocket-sized ultrasound device (PUD). The main objective of this study was to assess the diagnostic performance of CUS made by emergency physicians (EPs) using a PUD.
Materials: This was a prospective, diagnostic test assessment, single-center study. Patients underwent VCU performed by a trained EP with PUD (CUS-PUD) for searching proximal DVT (PDVT) and were then seen by an expert vascular physician who blindly performed a duplex venous ultrasound, which was the criterion standard. CUS-PUD's diagnostic performance was evaluated by sensitivity (Se), specificity (Sp), and positive and negative predictive values (PPV and NPV).
Results: The sample included 57 patients of whom 56 were analyzed. Eleven (20%) PDVT were diagnosed with CUS-PUD: 7 (64%) femoral and 4 (36%) popliteal. The CUS-PUD's Se was 100% [72%; 100%], Sp 100% [92%; 100%]. The PPV was 100% [74%; 100%], and the NPV was 100% [90%; 100%].
Conclusion: CUS-PUD performed with a pocket-sized ultrasound appears to be feasible in emergency practice for the diagnosis of proximal DVT. A study with a larger sample size will have to describe the accuracy.

1. Introduction

Suspected deep vein thrombosis (DVT) is a common presentation seen in the Emergency Department (ED) [1]. Because it can result in pulmonary embolism [1,2], suspected DVT requires a confirmatory test in order to start early treatment. Venous duplex ultrasonography (VDUS) is the criterion standard for diagnosing DVT with a sensitivity (Se) of 96% and a specificity (Sp) from 98 to 100% [3]. This test is subject to material and human constraints (e.g., availability of certified practitioners). When it is impossible to rule out DVT, sometimes anticoagulation treatment is recommended [4], thus exposing patients to its complications, whereas only 23% of them really have DVT [1,3].

Compression ultrasonography (CUS) performed by an emergency physician (EP) is one of the applications of point-of-care ultrasonography (POCUS) [5,6]. It is currently recommended for diagnosis of proximal DVT (PDVT) [7]. CUS consists of compressing the common femoral vein and popliteal vein with the probe [8]. Pomero et al.'s meta-analysis [3] found CUS Se from 70 to 100% (97.6% if considering only high-quality studies) and Sp from 78 to 100% (96.8% in high-quality studies). A recent study confirmed that emergency physicians can obtain a level of competence equivalent to that of radiologists making compression ultrasonography [9]. CUS by EP can be useful in an overcrowded ED due to time savings and avoiding risks of a non-indicated anticoagulation therapy. CUS seems to have a fast learning curve [10]. Lastly, guidelines for DVT diagnosis give three elements to indicate VDUS and anticoagulation: the clinical assessment of pretest probability, D-dimer, and CUS [7].

CUS with portable vascular ultrasonography is pertinent [11]: Se 100% [92%; 100%], Sp 99% [96%; 100%]. The miniaturization of ultrasound devices represents major progress allowing the large-scale development of POCUS [12]. Pocket-sized ultrasound devices (PUD) seem to be particularly adapted at POCUS. Numerous publications have already

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demonstrated their potential use in many emergency ultrasound applications [13-15].

The main objective of our study was to assess the diagnostic performance of CUS made by an EP with a PUD (CUS-PUD) in suspected cases of PDVT (excluding patients with prior history of DVT).

2. Materials and method

2.1. Materials

This prospective, diagnostic test assessment, single-center study was conducted from April 2015–February 2017. The study population comprised patients attending the ED of University Hospital of Nîmes. The study protocol was approved by the Committee on Human Research South Mediterranean III (CPP-2014.07.18) and written informed consent was obtained from all patients. The protocol was registered at ClinicalTrials.gov (NCT02262494). Patients were included if they were admitted to the ED for suspicion of a first DVT. All included patients were older than 18 years, had health insurance, and were not participating in another study. Patients were not included if they had a prior history of venous thromboembolic disease.

2.2. Aims

The primary objective of our study was to determinate diagnostic performance of CUS-PUD in cases of suspected PDVT (except patients with prior history of DVT). Se, Sp, and predictive values of CUS-PUD were calculated. The gold standard was VDUS made by a vascular certified practitioner. Secondary aim was to compare in those patients, diagnostic performance of CUS-PUD depending on clinical assessment of pretest probability (determined by Wells' Criteria).

2.3. Measurements

CUS-PUD observation was made by an experienced EP (defined as owning an ultrasonography university diploma associated with daily practice) with PDU (V-Scan Dualprobe©, GE Healthcare, Milwaukee, Wisconsin, USA). CUS-PUD tests the ability of the ultrasound probe to compress the common femoral vein then popliteal vein on the lower-limb studied. The CUS-PUD was performed as follows (first in femoral then in popliteal): if a venous thrombus was visualized or if the vein was incompressible, then the exam was positive and stopped. If there was no thrombus visualized and if the femoral then popliteal vein were compressible, then the exam was negative. After CUS-PUD, the patient had a VDUS. This exam was performed by physicians blinded to the result from CUS-PUD.

2.4. Sample size

Two hundred and thirty-six patients were required to demonstrate a sensitivity of 95% with a confidence interval of 95% and a lower limit >0.85. Due to difficulty with recruitment, this study was terminated after enrolling 56 patients.

2.5. Statistical analysis

Quantitative data are expressed as the median with 25th and 75th percentiles ([25th percentile; 75th percentile]). Qualitative variables are expressed as frequency with percentages. Diagnostic performance of CUS-PUD (Se, Sp, PPV, and NPV) was estimated with confidence intervals of 95%. The significance level was set at 5% for all tests used. Statistical analysis was performed under R 3.3.3 (2017, R Foundation for Statistical Computing, Vienna, Austria).

3. Results

3.1. Participants

Between April 2015 and February 2017, of 232 patients eligible for recruitment 57 were included (25%). One patient was excluded from the study because he could not receive VDUS. Five EPs participated in the recruitment. Of the 56 patients analyzed, 33 (59%) were women of median age 73 [59–84] years and of BMI 26 [22−30] kg/m^2. The baseline characteristics of the 56 participants (Wells' score and items, clinical probability, anticoagulation) are shown in Table 1. Sixteen (29%) DVTs were diagnosed by VDUS: 11 (69%) proximal and 5 (31%) distal.

3.2. Primary outcome – diagnostic performance of CUS-PUD made with PSU

Eleven (20%) proximal DVT were diagnosed by CUS-PUD: 7 (64%) femoral and 4 (36%) popliteal. Sensitivity and specificity of CUS-PUD were 100% [72%; 100%] and 100% [92%; 100%], respectively. PPV was 100% [74%; 100%] and NPV was 100% [90%; 100%]. As a result of sensitivity and specificity values of 100%, the likelihood ratios were not calculable. No comparative studies based on the clinical assessment of pretest probability could be done due to the CUS-PUD's sensitivity and specificity of 100%.

4. Discussion

4.1. Main results

Our main result was that CUS-PUD seems to be feasible for the diagnosis of PDVT. With a small sample size, our study showed a sensitivity of 100% [72%; 100%], a specificity of 100% [92%; 100%], a PPV of 100% [74%; 100%], and an NPV of 100% [90%; 100%]. The lower limits of the confidence intervals do not allow to correctly judge the accuracy. Diagnostic studies made with conventional ultrasonography [1,3,4,12,16] showed sensitivities and specificities of 95–98% and 96–97%, respectively [3]. Previous studies analyzed samples of 148 patients on average, with low-trained CUS-PUD operators (1 h of exam reading, 1–3 h of training). There is only Magazzini's study [16] with a sample size of 399 patients that had two very well-trained operators: 30-hour course, 6 h of lectures, and 24 h of training under supervision. In this study, CUS-PUD had a sensitivity of 100% and a specificity of 98%. Previous studies included more operators, especially Crisp's investigation (48 operators

Table 1
Patients' characteristics. Data are expressed in median [25th percentile; 75th percentile] or *n* (%).

	Patients N = 56
Wells' criteria	
Localized tenderness along deep venous system	37 (66%)
Swelling of entire leg	34 (61%)
Unilateral pitting edema	25 (45%)
Calf swelling >3 cm compared with asymptomatic calf	20 (36%)
Paralysis, paresis or recent cast immobilization of lower extremity	18 (32%)
Recent bedridden >3 days	14 (25%)
Alternative diagnosis as likely	8 (14%)
Active cancer	7 (12%)
Swollen unilateral superficial veins (non-varicose)	5 (9%)
Wells' score	2 [1; 3]
Clinical pre-test probability	
Low	5 (9%)
Moderate	27 (48%)
High	24 (43%)
Anticoagulation	8 (14%)
Curative	5 (63%)
Preventive	3 (37%)
Oral	5 (63%)
Intravenous	3 (37%)

with 10 min of training for CUS-PUD) that found a sensitivity of 100% and a specificity of 99%. Our results are better. Our sample is smaller and baseline performances are inside the confidence intervals of 95%. Moreover, in our study, the prevalence of DVT was similar to the literature (29% vs. 24%), with Pomero's meta-analysis [3] finding very variable prevalence ranging from 7%–43%. The pretest clinical probabilities of our patients were essentially average too high. These results confirm the representativeness of our sample and allow us to generalize our results.

4.2. Originality of the study

To our knowledge, the validity of compression ultrasonography for diagnosing PDVT performed using a pocket-sized ultrasonography has never been studied. In our study, CUS-PUD for detecting PDVT had the same results as VDUS (Se, Sp, PPV, and NPV were 100%). If the small sample size did not allow a lower bound on the 95% confidence intervals, we showed CUS-PUD seems to be feasible. A study with a larger sample size will have to describe the accuracy.

4.3. Limits

The main limitations of this study are the small sample size and slow recruitment, which was mainly due to material constraints and forced the study's early termination. Finally, the small number of EPs who performed CUS-PUD exposes us to a classification bias because these physicians were probably more invested and trained. Second, the limited number of operators, particularly trained in this POCUS application may also explain those perfect results.

5. Conclusion

CUS is a technique that is reliable and achievable in current ED practice for the diagnosis of PDVT. CUS-PUD performed with a pocket-sized ultrasound appears to be feasible in emergency practice for the diagnosis of proximal DVT. A study with a larger sample size will have to describe the accuracy.

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Competing interests

XB declares a competing interest as an ultrasound teacher for GE (GE MEDICAL SYSTEMS ULTRASOUND) customers. The other authors state they have no competing interests.

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4.3. Conclusion :

L'implantation des échographes dans les structures d'urgence est en cours. Elle est plus avancée dans les services d'urgences que dans les SMUR. La RFE de la SFMU recommandant que chaque SU dispose d'au moins un échographe dédié ne date que de 2016. Les échographes de poche semblent pertinents dans plusieurs indications d'ECMU. Leur diffusion pourrait être une solution pour augmenter la pratique de l'ECMU.

5. Formation :

5.1. État des lieux :

La troisième condition pour pratiquer l'ECMU, après l'existence de preuves et la présence d'un échographe, est l'obtention de compétences par les médecins urgentistes. Deux parties différentes du problème de la formation étaient à résoudre : la formation des nouveaux médecins urgentistes (formation initiale) et la formation des médecins urgentistes déjà en poste (formation continue). Les freins rencontrés par l'ajout de formations d'ECMU dans la formation initiale en France étaient multiples. Premièrement, l'absence de recommandations nationales n'incitait pas les coordonnateurs de DESC à instaurer des formations. Deuxièmement, l'absence ou la rareté de médecins compétents pour enseigner l'ECMU rendait la tâche parfois impossible. Enfin, la perspective de la création d'un diplôme d'études spécialisées (DES) et l'implantation d'un enseignement formalisé d'ECMU dans le programme a découragé les inter-régions qui n'enseignaient pas l'ECMU de le faire peu avant ce grand changement. La conséquence de ces freins est que l'enseignement de l'ECMU aux étudiants inscrits en diplôme d'études spécialisées complémentaires (DESC) en France est très hétérogène selon les différentes inter-régions. Actuellement, un enseignement d'ECMU en deux niveaux de compétences est compris dans l'enseignement du DES de médecine d'urgence. Ainsi, tous les médecins urgentistes titulaires du DES auront été formés à la technique.

Les problèmes liés à la formation continue étaient, en partie, similaires : absence de recommandations nationales et rareté des formateurs compétents. Les autres freins étaient la motivation des médecins urgentistes à se former (également lié à l'absence de RFE), et le nombre de médecins potentiel à former. Depuis le déploiement de l'ECMU, de nombreuses formations complémentaires ont été créées. La formation universitaire jugée comme le *gold standard* en France (2) est le DIU ETUS, mais d'autres diplômes universitaires (DU ou DIU) ont vu le jour. Des formations courtes ont également été créées, organisées par des plateaux de simulations universitaires, des associations à but non lucratif (comme Winfocus France) ou des sociétés à but lucratif (encouragées par les nouvelles règles du développement personnel continu).

Il n'existe pas, à ce jour, d'enquête nationale satisfaisante décrivant le taux de médecins urgentistes formés. Dans les enquêtes que nous avons réalisées en 2011 et 2016 sur l'équipement des SU (62, 69), une partie formation était demandée. Les résultats sont à interpréter avec précaution car un seul médecin par structure répondait. En 2011, la médiane de médecins formés par équipe était de 3 par SU (pour un nombre de médecin le plus souvent compris entre 10 et 20) et 20% d'entre elles n'avaient aucun médecin formé (62). En 2016, 42%

des services d'urgences et 19% des SMUR avaient moins d'un quart de leurs médecins qui avaient bénéficié d'une formation. Seulement 24% des services hospitaliers et 45% des préhospitaliers avaient plus de la moitié de l'équipe formée. Ces chiffres montrent une réelle évolution entre 2011 et 2016 mais rapportés au nombre de médecins urgentistes en France, ils montrent également le nombre important de médecins qu'il reste encore à former. A ceci s'ajoute la nécessité de prévoir des formations de maintien des compétences pour tous.

5.2. Formations recommandées

Les RFE de la SFMU de 2016 précisent qu' « il faut que les médecins urgentistes qui pratiquent l'échographie aux urgences puissent justifier d'une formation » mais n'ont pas tranché sur le type de formation préférentielle : « Il est recommandé que les urgentistes acquièrent leur compétence par une formation universitaire, une formation hospitalière formalisée ou s'inscrivant dans le développement professionnel continu » (2).

5.3. Évaluation d'une formation universitaire :

Un modèle d'évaluation des enseignements couramment utilisé est le modèle de Kirkpatrick à 4 niveaux (70) : le premier est l'évaluation de la satisfaction des étudiants, le second est l'évaluation des connaissances déclaratives ou procédurales acquises (examen final d'un DIU, par exemple), le troisième est l'impact de la formation sur la pratique professionnelle et la quatrième est l'impact sur la performance professionnelle (en médecine ce serait l'amélioration de la qualité des soins). Le troisième niveau d 'évaluation peut donc se résumer pour les formations d'ECMU à la question suivante : est ce que les médecins pratiquent différemment l'échographie après la formation ? Si plusieurs études existent sur l'impact de formations courtes d'ECMU (71-74), peu d'études ont entrepris d'évaluer des formations universitaires longues. De plus, les études sur la formation en ECMU se limitent pratiquement toujours à une évaluation de niveau 2 (acquisition des connaissances) et souvent, réalisées peu de temps après la formation (73, 74).

L'ACEP établit trois étapes dans la formation à l'ECMU : la connaissance des indications et limites, l'apprentissage du geste technique et la reconnaissance des images pathologiques (75). Nous avons émis l'hypothèse que l'apprentissage du geste (connaissances procédurales) et des indications et limites (connaissances déclaratives) étaient liés. La Faculté de médecine de Montpellier-Nîmes dispense des formations à l'ECMU depuis 2009 : dans le cadre de la formation initiale des DESC de médecine d'urgence ou de la formation continue (DIU). Les programmes théoriques sont similaires en durée et en contenu. Les enseignants sont également les mêmes. Nous avons voulu évaluer l'impact de ces formations universitaires avec une évaluation à distance et un niveau 2 et 3 d'évaluation pédagogique. Nous avons réalisé une étude prospective observationnelle dont l'objectif principal était de comparer les résultats d'une évaluation des connaissances déclaratives, à un an, entre deux groupes de DESC ayant bénéficié d'une même formation théorique avec ou sans travaux pratiques (TP). Nos objectifs secondaires étaient de comparer l'impact de cette formation sur le transfert des compétences (niveau 3) selon la présence de TP ou non, ainsi que de comparer les résultats de ces deux niveaux d'évaluation selon le type de formation, initiale ou continue. Quatre-vingt-quatorze (65 %) réponses de médecins formés ont été analysées. La note médiane au questionnaire était de 66 [59 ; 75] sur 100 dans le groupe DESC avec TP, comparé respectivement aux groupes DESC sans TP et formation continue (avec TP) : 68 [64 ; 74] (p=0,35) et 73 [65-82] (p=0,02). Les facteurs indépendants augmentant les connaissances déclaratives étaient le fait d'appartenir au groupe formation continue et la disponibilité d'un échographe durant la formation. La médiane globale du nombre d'ECMU réalisées était de 157 [74 ; 297] sans qu'il n'y ait de différence significative entre les groupes. Enfin, le taux de pratique de l'ECU à un an était de 99 %. Cette étude n'a donc pas montré de différence de connaissances résiduelles ou de pratique de l'ECMU en fonction de la présence de TP dans la formation initiale. Par contre, elle a montré une évaluation de niveau 2 plus satisfaisante chez les médecins en formation continue que ceux en formation initiale. Les deux principales hypothèses pour expliquer ce résultat sont le biais de motivation (la formation initiale est obligatoire, pas le DIU) et la présence d'un contrôle de connaissance à la fin de l'année de formation dans le groupe formation continue (entrainant des révisions des acquis). Notre étude montrait que 99% des médecins ayant bénéficié de la formation pratiquaient l'ECMU un an après. Si le nombre de techniques échographiques utilisées en pratique clinique était hétérogène, ce résultat montre, un très bon impact de cette formation universitaire. Enfin face, à la question permanente de connaitre si la première étape d'un service devrait être de s'équiper en échographe ou de former ses praticiens, notre étude montre que la disponibilité d'un échographe durant la formation semble bénéfique à l'apprentissage.

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ARTICLE ORIGINAL / *ORIGINAL ARTICLE*

Formation universitaire à l'échographie clinique d'urgence : impacts et facteurs déterminants

University Training in Emergency Clinical Ultrasound : Impact and Influencing Factors

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Résumé *Objectifs* : Étudier l'efficacité d'une formation universitaire (FU) en échographie clinique d'urgence (ECU) et ses déterminants.
Méthode : Étude observationnelle, transversale, analytique, multicentrique sous forme de questionnaire envoyé à un an de FU de même contenu théorique : groupe 1 : étudiants en diplôme d'études spécialisées complémentaires (DESC 1) de médecine d'urgence formés avec travaux pratiques (TP) ; groupe 2 : DESC 1 formés sans TP ; groupe 3 : médecins urgentistes inscrits en diplôme interuniversitaire formés avec TP. Étaient évalués : les connaissances déclaratives (questionnaire vrai/faux sur 100), le nombre d'ECU réalisées et le taux de médecins utilisant l'ECU.
Résultats : Quatre-vingt-quatorze (65 %) médecins ont répondu. La note médiane au questionnaire était de 69 [62-77] ; 66 [59-75] dans le groupe 1, comparé respectivement aux groupes 2 et 3 : 68 [64-74] (p=0,35) et 73 [65-82] (p=0,02). Les facteurs indépendants augmentant les connaissances déclaratives étaient le groupe 3 (p=0,01) et la disponibilité d'un échographe durant la formation (p=0,03). La médiane du nombre d'ECU réalisées était de 157 [74-297] ; 164 [75-309] dans le groupe 1, comparé respectivement aux groupes 2 et 3 : 135 [61-202] (p=0,14) et 222 [81-648] (p=0,09). Le taux de pratique de l'ECU à un an était de 99 %.
Conclusion : Une formation universitaire est associée à une pratique de l'ECU par une grande majorité des apprenants. La disponibilité d'un échographe dans le service de l'étudiant, lors de la formation, est souhaitable.

Mots clés Médecine d'urgence · Échographie Clinique · Pédagogie médicale

Abstract *Aims*: Know the impact of university training in emergency point-of-care ultrasound (POCUS) and its determinants.
Procedure: Multicentric analytic observational, cross-sectional survey. A questionnaire was sent, 1 year after a same theoretical training : group 1 : emergency medicine residents trained with hands on training (HOT); group 2 : emergency medicine residents trained without HOT; group 3 : emergency physicians enrolled in a university training with HOT. Declarative knowledges were evaluated with a true-false quiz /100. The transfer was evaluated by the number of POCUS performed since the training and the rate of physicians using the POCUS.
Results: Ninety-four (65 %) physicians responded. The questionnaire median score was 69 [62-77], 66 [59-75] in group 1 vs 68 [64-74] in group 2 (p=0.35), 73 [65-82] in group 3 (p=0.02 vs group 1). The independent factors increasing declarative knowledge were the group 3 (p=0.01) and

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the availability of an ultrasound device during training (p=0.03). The median number of POCUS performed was 157 [74-297], 164 [75-309] in group 1 vs 135 [61-202] in group 2 (p=0.14) and 222 [81-648] in group 3 (p=0.09 vs group 1). POCUS utilization at 1 year was 99%.
Conclusion: University training is associated with POCUS use in the great majority of learners. The availability of an ultrasound device in the student service, during training, is desirable.

Keywords Emergency Medicine · Ultrasonography · Point of Care system · Medical education

Introduction

L'échographie clinique d'urgence (ECU) permet des évaluations simples et rapides modifiant les décisions thérapeutiques et l'orientation des patients [1,2]. Les données concernant les schémas d'enseignements nécessaires sont disparates. Le volume théorique et pratique des formations jugées nécessaires a diminué avec le temps [3-7]. Les principaux déterminants favorisant l'acquisition de connaissances et le transfert de compétences en échographie après formation semblent être l'expérience clinique antérieure, l'entraînement répété et supervisé, ainsi que la pratique [8,9]. Selon l'*American College of Emergency Physicians* (ACEP), deux types de formation sont possibles [10] selon le public concerné : premièrement, la formation initiale dont le programme comprend des travaux pratiques (TP) et la relecture des ECU par un médecin expérimenté. La validation comprend une évaluation des connaissances déclaratives et procédurales : l'interprétation d'images et une quantité d'ECU. En France, si l'acquisition de cette technique est demandée dans le Diplôme d'études spécialisées complémentaires (DESC) de médecine d'urgence, il n'y a aucune référence aux modalités de son enseignement dans le programme national [11]. Deuxièmement, le format américain de la formation continue comporte 16 à 24h d'enseignements théoriques, des sessions pratiques et des examens supervisés. La validation ne comprend que l'évaluation des connaissances procédurales. En France, il existe des formations dites « courtes » (1 à 2 jours, avec alternance d'enseignements théoriques et de TP) et des formations « longues » universitaires, comme les diplômes interuniversitaires (DIU) [12].

Depuis 2009, la Faculté de médecine de Montpellier-Nîmes prodigue des formations à l'ECU en formation initiale (DESC) ou continue (DIU). Les programmes théoriques sont similaires en durée (16 h) et en contenu. Jusqu'en 2013, la formation pratique des DESC comprenait des TP (10 h, comme le DIU) et des stages hospitaliers tutorés spécifiques. Les TP, consistant en des séances d'apprentissage du geste sur sujets sains rémunérés, ont été retirés de la formation des DESC depuis 2014 pour des raisons économiques. Nous avons émis l'hypothèse que la réalisation de TP pouvait avoir un impact sur l'apprentissage, car elle pourrait favoriser la compréhension des éléments théoriques et permettrait d'augmenter la motivation intrinsèque par la prise de conscience de la facilité de réalisation des ECU. Ce gain pourrait aboutir à une meilleure acquisition des connaissances déclaratives et donc une meilleure mémorisation à long terme, voire un meilleur transfert des compétences. Afin d'observer un éventuel impact des TP sur la performance d'une formation universitaire initiale « longue », l'objectif principal de notre étude était de comparer les résultats d'une évaluation des connaissances déclaratives [13] (à un an) entre deux groupes de DESC ayant bénéficié d'une même formation théorique avec ou sans TP (niveau deux d'évaluation des formations selon Kirkpatrick [14]). Nos objectifs secondaires étaient de comparer l'impact (à un an) de cette formation sur le transfert des compétences (évaluée par l'utilisation réelle de l'ECU) selon la présence de TP ou non (niveau trois de Kirkpatrick), ainsi que de comparer l'apprentissage, par les connaissances déclaratives acquises et par le transfert des compétences, selon le type de formation, initiale ou continue.

Méthode

Nous avons réalisé une étude observationnelle, transversale, analytique, multicentrique sous forme d'un questionnaire à un an de la formation reçue. L'ensemble des objectifs et critères de jugements sont représentés dans la Figure 1. La population de l'étude était constituée de médecins urgentistes ayant bénéficié, en 2013 ou 2014, d'une formation à l'ECU de contenu théorique standardisé (16 h). Ces médecins se répartissaient en trois groupes :

- groupe 1 : DESC1 de médecine d'urgence ayant bénéficié d'une formation initiale en 2013 avec alternance enseignements théoriques-TP par thème (abdomen, thorax, vasculaire) et stages hospitaliers spécifiques (4 demi-journées) ;
- groupe 2 : DESC1 de médecine d'urgence ayant bénéficié d'une formation initiale en 2014 sans TP, avec stages hospitaliers spécifiques (4 demi-journées) ;
- groupe 3 : médecins urgentistes seniors ayant bénéficié en 2013 ou 2014 d'une formation continue (DIU) avec alternance cours-TP (même programme que le groupe 1) et stages hospitaliers spécifiques (10 demi-journées).

Le critère de jugement principal (CJP), permettant de juger des connaissances déclaratives, était évalué par un questionnaire vrai/faux comprenant 100 affirmations. Chaque enseignant a réalisé un nombre d'items proportionnel au temps

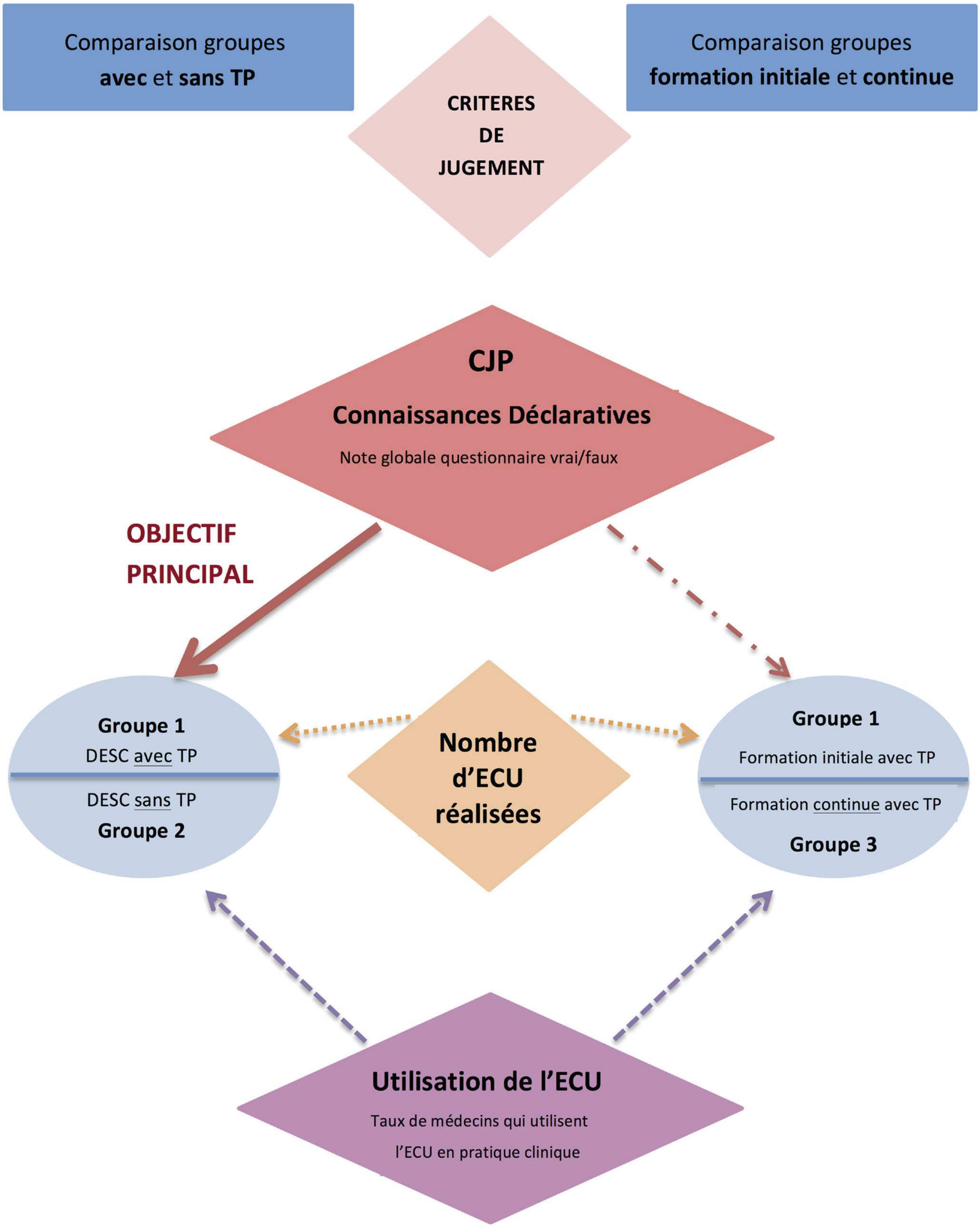

Fig. 1 Critères de jugement et objectifs. Flèches pointillés : objectifs secondaires. TP : travaux pratiques ; CJP : critère de jugement principal ; ECU : échographie clinique d'urgence ; DESC : diplôme d'étude spécialisé complémentaire

d'enseignement de la technique qu'il avait traité. Les connaissances déclaratives étaient évaluées à tous les niveaux : dans leur composante cognitive pure, dans leur composante servant aux connaissances procédurales (interprétation d'images et intégration de résultats d'ECU dans la prise en charge d'un patient) et dans leur composante servant aux connaissances conditionnelles (indications, limites). La note médiane de chaque groupe (CJP) était la médiane du nombre de réponses correctes pour chaque étudiant du groupe. Les critères de jugements secondaires (Fig. 1) permettaient d'évaluer le transfert. Afin de juger du transfert de compétences, nous avons évalué l'utilisation, en pratique clinique, de l'ECU par les étudiants. Les critères de jugements secondaires étaient donc le nombre total d'ECU réalisées depuis la formation et le taux d'étudiants déclarant utiliser au moins une technique seule, en se basant sur leurs résultats dans la prise en charge des patients.

Lors des formations, les TP étaient organisés avec un échographe, un sujet sain et un formateur pour trois ou quatre étudiants étaient proposés. Chaque étudiant a été sollicité par courriel un an après sa formation pour répondre à un questionnaire en ligne. En plus des questions permettant l'évaluation des critères de jugement, une question sur la présence d'un échographe dans leur lieu d'exercice au moment de leur formation et de réception du questionnaire était posée. En cas de non-réponse, deux relances par courriel ont été effectuées. Aucune donnée nominative ou permettant de retrouver indirectement l'identité du répondeur au questionnaire n'a été demandée. Par conséquent, une déclaration à la Commission Nationale de l'Informatique et des Libertés n'était pas requise. Le projet a été présenté à l'Interface de Recherche Bioéthique du CHU de Nîmes et a obtenu un avis favorable (avis IRB 15/ 01.02).

Analyse statistique

Les variables quantitatives étaient exprimées en médianes assorties des 25^{e} et 75^{e} percentiles. Les variables qualitatives étaient exprimées par leurs effectifs et leurs pourcentages. La comparaison des variables quantitatives entre les différents groupes a été réalisée par le test de Student. Lorsque les conditions de validité de ce test (distribution normale, égalité des variances) n'étaient pas vérifiées, le test non paramétrique de Mann-Whitney était utilisé. La relation entre deux variables quantitatives a été analysée par régression linéaire ou corrélation de Pearson selon la normalité des résultats. Le lien entre deux variables qualitatives était testé par le test du Chi2. Les analyses multivariées ont été réalisées grâce à l'utilisation d'un modèle de régression linéaire multivariée. Étaient choisis pour intégrer le modèle, le groupe d'étudiants et tous les facteurs liés au critère de jugement par un $p<0,2$ en analyse univariée. Le seuil de significativité était fixé à 5 % pour tous les tests utilisés. L'analyse statistique a été réalisée avec le logiciel R (R *Foundation for Statistical Computing*, Vienne, Autriche).

Résultats

Au total, 144 médecins ont été formés à l'ECU : 36 (25 %) en formation continue et 108 (75 %) en formation initiale dont 50 (46 %) avec travaux pratiques. Quatre-vingt-quatorze (65 %) médecins ont répondu : 37 (74 %) du groupe 1, 34 (59 %) du groupe 2 et 23 (64 %) du groupe 3 (p=0,24). Le Tableau 1 résume les résultats descriptifs issus des réponses. Soixante et onze (81 %) médecins avaient accès à un échographe au moment de la formation et 79 (89 %) au moment du questionnaire.

Dans la population globale, la note médiane sur 100 obtenue au questionnaire vrai/faux (CJP) était de 69 [62-77]. Les notes médianes dans les deux groupes en formation initiale étaient 66 [59-75] avec TP (groupe 1) vs 68 [64-74] sans TP (groupe 2) (p=0,35). Cette note était de 73 [65-82] en formation continue (groupe 3) (vs groupe 1 : p=0,02). Le nombre médian d'ECU réalisées par les médecins était de 157 [74-297]. Dans les deux groupes en formation initiale, il était de 164 [75-309] avec TP (groupe 1) vs 135 [61-202] sans TP (groupe 2) (p=0,14). Le nombre médian d'ECU réalisées était de 222 [81-648] en formation continue (groupe 3) (vs groupe 1 : p=0,09). Les comparaisons concernant les connaissances déclaratives et le nombre total d'ECU réalisées en fonction des différents groupes et des autres facteurs inclus dans l'analyse multivariée sont présentées dans le Tableau 2. Quatre-vingt-treize (99 %) médecins interrogés déclaraient utiliser au moins une technique d'ECU dans leur pratique. Le médecin déclarant ne pas utiliser l'ECU était issu du groupe 3. Devant ce résultat, aucune analyse comparative n'a pu être réalisée.

Discussion

Notre étude s'intéressait à deux niveaux d'évaluation pédagogique [14] d'une formation à l'ECU : les connaissances déclaratives et le transfert sous la forme de l'impact sur la pratique médicale. Les connaissances déclaratives étaient globalement bonnes (69/100). Nous n'avons pas trouvé d'effet dû à la présence de TP lors de la formation initiale sur ce paramètre. Deux raisons peuvent l'expliquer. Premièrement, l'hypothèse selon laquelle un meilleur apprentissage du geste (réalisation de TP) peut avoir un impact sur les connaissances déclaratives à un an d'une formation n'est pas montrée. L'augmentation de la motivation intrinsèque par la prise de conscience de la faisabilité d'une technique pourrait, cependant, avoir un effet sur l'ensemble de

Tableau 1 Réponses de la population générale au questionnaire.

Connaissances déclaratives à un an	Note médiane sur 100 [Q25; Q75]
Notions générales	75 [50;100]
Échocardiographie	71 [58;79]
Aorte abdominale	75 [50;100]
FAST	62 [41;75]
Compression veineuse	100 [75;100]
Pleuropulmonaire	71 [62;82]
Doppler transcrânien	50 [37;62]
Échoguidage de ponction	75 [75;94]
Voies biliaires	62 [50;75]
Voies urinaires	75 [50;75]
Pelvienne	87 [62;87]
Note globale	69 [62;77]
Nombre d'ECU réalisées	Médiane [Q25;Q75]
Échocardiographie	38 [18;75]
Aorte abdominale	5 [5;5]
FAST	11 [5;38]
Compression veineuse	5 [5;18]
Pleuropulmonaire	5 [5;38]
Doppler transcrânien	5 [0;5]
Ponction veineuse centrale	5 [5;18]
Voies biliaires	5 [0;5]
Voies urinaires	5 [5;18]
Pelvienne	5 [0;18]
Nombre total	157 [74;297]
Techniques d'ECU utilisées	Nombre de médecins utilisant la technique (%)
Échocardiographie	72 (86 %)
Aorte abdominale	56 (62 %)
FAST	79 (88 %)
Compression veineuse	66 (74 %)
Pleuropulmonaire	70 (80 %)
Doppler transcrânien	37 (42 %)
Voies biliaires	42 (46 %)
Voies urinaires	66 (72 %)
Pelvienne	42 (46 %)
Utilisation d'au moins une technique	94 (99 %)

ECU : échographie clinique d'urgence ; FAST : *focused assessment of sonography for trauma*.

l'apprentissage. Deuxièmement, le questionnaire vrai/faux est un outil d'évaluation mettant mal en évidence les écarts de niveaux. Les autres limites de l'étude sont la méthode (questionnaire), qui expose à un biais de représentativité, bien que le taux de réponse global soit satisfaisant (65 %). L'évaluation du nombre total d'ECU est subjective et exposée à un biais de mémoire et de déclaration, les médecins ayant pu avoir tendance à s'éloigner de la réalité selon leur motivation pour l'ECU. L'outil d'évaluation des connaissances déclaratives (questionnaire vrai/faux) n'a pas été testé sur un échantillon de médecins en formation ou d'experts. Enfin, si l'analyse de l'impact d'une formation sur la pratique clinique est un bon niveau d'évaluation pédagogique, le meilleur serait d'analyser l'impact sur les patients (niveau quatre de Kirkpatrick [14]).

Le fait de recevoir la formation à l'ECU dans le cadre d'une formation continue (DIU) était un facteur indépendant de meilleures connaissances déclaratives (p=0,01). Cette constatation est probablement le résultat de la comparaison de deux formations et deux publics différents. Les étudiants en formation initiale ont une obligation de formation dans le cadre de leur cursus. Les médecins s'inscrivent en DIU par motivation et sont probablement déjà convaincus de l'intérêt de l'apprentissage de la technique dans leur pratique. Ces différences de motivations intrinsèques et extrinsèques ont un impact sur les connaissances déclaratives. Les étudiants inscrits en DIU ont bénéficié de plus de stages pratiques (10 demi-journées vs 4 en formation initiale). Ces derniers ont passé et validé un examen théorique et pratique à la fin de la formation, rendant nécessaire une répétition et une intensification des apprentissages, particulièrement en ce qui concerne les connaissances déclaratives. Ce facteur entraîne probablement une mémorisation plus prolongée. Enfin, les inscrits en DIU ont une expérience clinique antérieure supérieure. Ce facteur est connu comme associé à un meilleur apprentissage même chez les internes [9]. Cette donnée ne remet probablement pas en cause la nécessité d'une formation précoce. Si un interne de première année assimile moins l'ECU qu'un interne de dernière année à la fin de la formation, il est probable que le premier soit plus compétent en échographie clinique à la fin de son internat. Le seul autre facteur indépendant lié aux connaissances déclaratives était la disponibilité d'un échographe dans le service de l'apprenant au moment de sa formation (p=0,03). Ceci est un message fort car ce résultat montre qu'il y a bien une relation entre la réalisation d'une technique gestuelle et les connaissances déclaratives. La présence d'un échographe devrait être prise en compte pour planifier l'enseignement de l'ECU qui demande sûrement un certain recul et un niveau de compétence médicale.

Le nombre d'ECU réalisées depuis la formation théorique était satisfaisant mais hétérogène : 157 [74-297]. Cette médiane implique qu'environ un médecin sur deux a réalisé à un an de la formation initiale le nombre d'échographies recommandées par l'ACEP [10]. La présence de TP lors de la formation initiale n'avait pas d'impact sur ce paramètre. Les médecins seniors inscrits en formation continue avaient tendance à en réaliser plus (222 [81;648] vs 164

Tableau 2 Comparaisons des groupes et facteurs associés aux critères de jugement.

Variables	Médiane [Q25;Q75]	Analyse univariée	Analyse multivariée	
		p	OR (IC 95 %)	*p*
Connaissances déclaratives				
Groupe 1	66 [59;75]			
Groupe 2	68 [64;74]	0,35	3,8 (0,8-28,9)	0,12
Groupe 3	73 [65;82]	0,02	16,4 (3,0-135,5)	0,01
Disponibilité échographe lors de la formation				
Non	65 [58;68]			
Oui	71 [63;79]	< 0,01	14,3 (1,3-187,6)	0,03
Nombre total d'ECU faites	157 [74;297]	< 0,01	9,0 (0,9-92,5)	0,06
Nombre d'ECU réalisées				
Groupe 1	164 [75;309]			
Groupe 2	135 [61;202]	0,14	4,6 (0,7-38,8)	0,18
Groupe 3	222 [81;648]	0,09	9,4 (1,1-6,7)	0,05
Disponibilité échographe lors de la formation				
Non	78 [40;158]			
Oui	169 [100;305]	<0,01	2,0 (0,5-9,7)	0,3
Disponibilité échographe lors du questionnaire				
Non	43 [25;65]			
Oui	172 [103;303]	<0,01	15,3 (1,3-162,6)	0,02
Note globale obtenue	69 [62;77]	<0,01	2,7 (0,8-10,8)	0,10

ECU : échographie clinique d'urgence ; OR : odds ratio ; IC : intervalle de confiance.

[75;309] p=0,09). La contrainte des stages hospitaliers obligatoires lors du DIU influe également probablement sur ce résultat. Cependant, il est regrettable que des étudiants encore en cours de formation initiale et disposant majoritairement d'un échographe dans leur terrain de stage ne réalisent pas autant d'examens. Ce point peut être lié au taux de médecins déjà formés dans ces services [15]. Le seul facteur indépendant lié à la quantité d'ECU réalisées était la disponibilité d'un échographe au moment de répondre au questionnaire (p=0,03). Ce résultat logique renforce la validité interne de nos résultats. Que la disponibilité d'un échographe au moment de la formation ait un impact sur les connaissances déclaratives et que celle-ci, un an plus tard, en ait sur le nombre d'échographies réalisées, renforcent l'intérêt de prendre en compte cette disponibilité lors de la formation. Si les étudiants qui ne disposent initialement pas d'un échographe retiennent moins les indications, les limites et l'interprétation mais pratiquent beaucoup lors de l'acquisition du matériel, on peut supposer que l'utilisation de l'ECU puisse être hors des indications et potentiellement délétère pour le patient. Dans notre étude, 99 % des médecins formés déclaraient avoir utilisé au moins l'une des applications de l'ECU pour guider la prise en charge de leurs patients. Ce résultat est satisfaisant et s'il n'est pas surprenant pour les médecins seniors ayant fait la démarche de s'inscrire en DIU, il montre l'efficacité d'une formation initiale universitaire complète. Ce résultat est en accord avec des données canadiennes [16].

Cette étude est la première à étudier l'intérêt et les déterminants d'une formation universitaire à l'ECU en France. À l'aube du DES de médecine d'urgence, la connaissance des modalités d'enseignement permettant le transfert peut orienter l'élaboration des programmes d'enseignement. Si nous n'avons pas montré de lien entre la réalisation de TP et les connaissances déclaratives, une évaluation plus directe du bénéfice attendu (connaissances procédurales et psychomotrices) aurait pu être concluante. L'expérience clinique antérieure, l'entraînement répété supervisé et la pratique sont des facteurs connus comme étant associés à un meilleur apprentissage [8,9]. Le fait que la disponibilité d'un échographe au moment de la formation soit un facteur indépendant de connaissances déclaratives paraît être un résultat primordial de notre étude. Pour les formations continues, il pose la question d'introduire ce critère dans les conditions d'inscription. Pour la formation initiale, ceci serait un argument pour imposer la présence d'un échographe dans les services d'urgence et de réanimation recevant des internes inscrits en DESC, et bientôt DES de médecine d'urgence. Enfin, notre étude est la première à montrer qu'une formation universitaire dite longue peut être associée à l'utilisation de l'ECU dans la pratique quotidienne chez presque tous les étudiants. Ceci conforte l'importance et l'efficacité de ces formations.

Conclusion

Les formations universitaires à l'ECU permettent une bonne acquisition des connaissances déclaratives et un transfert satisfaisant. Notre étude n'a pas montré de relation entre réalisation de travaux pratiques et connaissances déclaratives à un an dans une formation initiale à l'ECU. La présence d'un échographe disponible sur le lieu d'exercice de l'apprenant au moment de la formation augmente les connaissances déclaratives et doit probablement être pris en compte. Quasiment tous les médecins ayant bénéficié d'une formation universitaire longue déclarent utiliser l'ECU pour guider leur prise en charge. Cela confirme l'efficacité et l'impact d'une telle formation.

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Contribution des auteurs : Tous les auteurs ont participé au design de l'étude, en particulier à l'élaboration des critères de jugements. XB a eu l'idée de l'étude. XB, SP, PGC, LM et JELC ont écrit le protocole initial. XB, AM, RGG et LM ont participé à l'écriture du questionnaire. XB, PGC, PM, JL, AM, RGG, LM et JELC enseignent dans les formations évaluées. XB, SP, PM et JL ont participé à la collection des données. XB, SP et EV ont analysé les résultats et écrit la première version de l'article. PGC, PM, JL, AM, RGG, LM et JELC ont corrigé l'article.

Liens d'intérêts et publication antérieure de l'étude : Les auteurs déclarent n'avoir aucun conflit d'intérêt en relation avec cet article. Les auteurs déclarent que l'étude a fait l'objet d'une communication libre médecin lors du congrès Urgences 2016.

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5.4. Évaluation du niveau de formation nécessaire en conditions difficiles :

Plusieurs études ont établi des courbes d'apprentissage du geste concernant les techniques d'ECMU (76, 77). Les résultats sont hétérogènes entre les études et entre les techniques mais en 2009 l'ACEP en a fait une synthèse en préconisant la réalisation de 25 examens supervisés par technique (75). Une des caractéristiques de la médecine d'urgence est le fait d'être exercée dans des conditions parfois difficiles, notamment en médecine préhospitalière. De plus, si les échographes de poche semblent dotés d'une ergonomie particulièrement adaptée à ces conditions, la qualité d'image et la taille de l'écran ont, de suite, entrainé des interrogations sur le niveau de compétence en ECMU nécessaire à leur utilisation. Nous avons voulu évaluer la capacité d'enregistrer des images d'échographie de qualité avec un échographe de poche dans des conditions préhospitalières. Nous avons choisi l'échocardiographie car c'est une technique indiquée dans la prise en charge de pathologies fréquemment rencontrées en SMUR : détresse respiratoire, choc, douleur thoracique. De plus, il était décrit qu'un nombre d'examens proche de 25 suffisait à permettre une acquisition de premier niveau d'échocardiographie (74). Nous avons mené une étude observationnelle prospective uniquement réalisée avec des médecins urgentistes détenteurs d'une formation universitaire d'échographie. L'objectif principal était d'évaluer l'interprétabilité des images d'échocardiographie obtenues en préhospitalier, en utilisant un échographe de poche, en fonction de l'expérience du médecin urgentiste. Nous voulions savoir combien des quatre objectifs de base d'échocardiographie pouvait être jugés avec les images obtenues (évaluation visuelle de la FEVG, recherche d'un épanchement péricardique, d'une dilatation du VD et analyse de la variabilité respiratoire de la VCI). Nous avions défini que les médecins expérimentés étaient ceux qui avaient déjà effectué plus de 50 échocardiographies dans leur vie. Quatorze médecins urgentistes ont participé à l'étude en réalisant 85 échocardiographies. Le nombre médian d'objectifs interprétables était de 3 [1 ; 4] ; 4 [3 ; 4] dans le groupe médecins expérimentés vs 1 [0 ; 2] dans l'autre ($p < 0,01$). En analyse multivariée, seule l'expérience était associée au nombre d'objectifs interprétables. Nous en avons conclu que pour la réalisation des coupes d'échocardiographie, les conditions préhospitalières associées à un échographe de poche demandaient une expérience pratique plus importante que celles habituellement admises.

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ORIGINAL RESEARCH **Open Access**

Does physician experience influence the interpretability of focused echocardiography images performed by a pocket device?

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Abstract

Introduction: The use of focused cardiac ultrasound (FoCUS) in a prehospital setting is recommended. Pocket ultrasound devices (PUDs) appear to be well suited to prehospital FoCUS. The main aim of our study was to evaluate the interpretability of echocardiography performed in a prehospital setting using a PUD based on the experience of the emergency physician (EP).

Methods: This was a monocentric prospective observational study. We defined experienced emergency physicians (EEPs) and novice emergency physicians (NEPs) as echocardiographers if they had performed 50 echocardiographies since their initial university training (theoretical training and at least 25 echocardiographies performed with a mentor). Each patient undergoing prehospital echocardiography with a PUD was included. Four diagnostic items based on FoCUS were analyzed: pericardial effusions (PE), right ventricular dilation (RVD), qualitative left ventricular function assessment (LVEF), and inferior vena cava compliance (IVCC). Two independent experts blindly evaluated the interpretability of each item by examining recorded video loops. If their opinions were divided, then a third expert concluded.

Results: Fourteen EPs participated: eight (57 %) EEPs and six (43 %) NEPs. Eighty-five patients were included: 34 (40 %) had an echocardiography by an NEP and 51 (60 %) by an EEP. The mean number of interpretable items by echocardiography was three [1; 4]; one [0; 2.25] in the NEP group, four [3; 4] in EEP ($p < .01$). The patient position was also associated with interpretable items: supine three [2; 4], "45°" three [1; 4], sitting two [1; 4] ($p = .02$). In multivariate analysis, only EP experience was associated with the number of interpretable items ($p = .02$). Interpretability by NEPs and EEPs was: 56 % vs. 96 % for LVF, 29 % vs. 98 % for PE, 26 % vs. 92 % for RVD, and 21 % vs. 67 % for IVCC ($p < .01$ for all).

Conclusion: FoCUS with PUD in prehospital conditions was possible for EEPs, It is difficult and the diagnostic yield is poor for NEPs.

Keywords: Prehospital emergency care, Echocardiography, Efficiency

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Background

Focused cardiac ultrasound (FoCUS) has been widely recommended in emergency medicine [1–3]. It has been demonstrated that FoCUS facilitates decision-making mainly in a binary (yes or no) fashion [1]. The American Society of Echocardiography (ASE) and the American College of Emergency Physicians (ACEP) define the elements of the FoCUS process [3]: 1. diagnosis and quantification of pericardial effusion (PE); 2. assessment of global cardiac systolic function by evaluation of qualitative left ventricular function (LVF); 3. identification of marked right ventricular dilation (RVD); 4. intravascular volume assessment, especially by assessment of inferior vena cava compliance (IVCC); 5. guidance of pericardiocentesis; 6. confirmation of venous pacing wire placement. Five ultrasound views are recommended [1]: parasternal short axis (PSA), parasternal long axis (PLA), apical four chambers (AFC), subcostal four chambers (SFC), and IVC view. Pocket size ultrasound devices (PUDs) are well adapted to emergency medicine, especially in out-of-hospital conditions. Such devices are less expensive and showed a good diagnostic accuracy compared with conventional machines [4–6]. Additionally, PUDs can favorably influence therapeutic decisions and/or patient orientation in prehospital conditions [7, 8]. Particularly, a favorable impact for echocardiography performed by PUDs has been shown for cardiac arrest [7, 9]. All prehospital patients with symptoms indicating echocardiography should theoretically benefit from faster and more accurate diagnoses. A recent study showed that prehospital echocardiography performed with a PUD was feasible in half of patients and required only a short physician training period [10]. However, the impact of emergency physician (EP) experience on FoCUS accuracy when using a PUD was not reported.

The primary aim of the present study was to compare interpretable items between experienced emergency physicians (EEPs) and non-experienced physicians (NEPs). The second aim was to determine if other variables were associated with the number of interpretable items.

Materials and methods

Materials

The local ethics committee of Nimes Teaching Hospital, France, approved the study (Interface Recherche Bioéthique No. 12/12-03). This monocentric prospective observational study was conducted from December, 2012 to February, 2013 on the mobile resuscitation ambulances of Nimes, France. This unit included 14 trained EPs. The university FoCUS training in emergency medicine involved theoretical teaching and at least 25 echocardiographies performed with supervision. All patients requiring a FoCUS exam in prehospital setting were included. Each patient was informed of the study verbally, as well as by letter, and had an opportunity to withdraw their data. The EP who performed echocardiography was also in charge of the patient's clinical care. Echocardiography was performed using a PUD (Vscan™; GE Healthcare, Milwaukee, Wisconsin, USA).

Aims

The main aim of the present study was to seek correlation between interpretable items (PE, RVF, RVD, and IVCC) by echocardiography and EP experience. The secondary aim was to search for other associated factors of interpretable items. Other aims were to evaluate the quality and interpretability of ultrasound views based on EP experience.

Endpoints

The following data were recorded: age, gender, body mass index (BMI), primary indication of care, respiratory distress state, arterial pressure, shock state, Glasgow coma scale (GCS), mechanical ventilation, echocardiography exam location (home, street, care institution, ambulance, or helicopter), and patient position during examination (supine, 45°, or sitting).

Two groups of physicians were defined: EEP and NEP. The threshold for defining EEP or NEP was more or fewer than 50 echocardiographies already performed, respectively, after initial training [11].

To assess the quality and interpretability of ultrasound views, a five-point scale [12] was used: 1 = no image; 2 = poor and unusable image quality; 3 = usable image quality; 4 = good image quality; and 5 = perfect image quality. A value of three or more defined an interpretable image scan of sufficient quality that it could provide a diagnosis.

Two independent experts blindly evaluated the interpretable items by exams and the interpretability and image quality of the recorded echocardiogram video loops. The first expert was an echocardiography-referent cardiologist at our university hospital. This expert holds an echocardiography university diploma and is a teacher in echocardiography university courses for cardiologists. The second expert was an echocardiography-referent intensivist, who holds an echocardiography university diploma and is a teacher in echocardiography university courses for cardiologists, intensivists, and EPs. If their opinions were divided on the primary endpoint, a third expert made a conclusion (an EP teacher on emergency echocardiography). Experts had no information about the patient or clinical conditions. The video loops were recorded by the EPs and reviewed by the experts on a computer.

Sample size

Our hypothesis was that the mean number of items achieved by NEPs and EEPs would be 1.5 and 2.5, respectively, with a common standard deviation of 1.5 and alpha and beta risk 0.05, so we had to include at least 26 patients per group. As a buffer, we planned to include 20 % more patients, or at least 32 in the smaller group.

Statistical analysis

In all cases, data were examined before analysis to ensure that the assumptions of statistical models were satisfied using Shapiro–Wilk statistics. Data are expressed as mean and standard deviation (SD) or median (25th–75th percentile) depending on their distribution (Gaussian or not). For the comparisons between NEP and EEP, the Student's t-test, Chi square, and Fisher exact tests were performed when appropriate. When a comparison was made to quantitative values of more than two groups with theoretical numbers less than five, subgroups were created. For the multivariate analysis, the dependence of the number of interpretable items (principal end point) on two or more other variables was evaluated by multiple linear regression analysis. The endpoints related to $p < .2$ in bivariate analysis were included in the multiple linear regression analysis. Bivariate correlations among variables were calculated to check for potential multicollinearity. Statistical analysis was performed using R Project (free software foundation, GNU general public license). All p values were two-tailed and $p < .05$ was considered significant. Agreement between the experts was evaluated using Cohen's κ test.

Results

Among the 85 included patients (each patient had one echocardiography evaluated), 34 (40 %) had an echocardiography performed by an NEP and 51 (60 %) by an EEP. Regarding demographics and care, only the patients' positions during examination were significantly different between the NEP and EEP groups (Table 1).

Fourteen EPs participated (experience in emergency medicine averaged six [2; 13] years), eight (57 %) EEPs, and six (43 %) NEPs. The judgements of the experts in interpretability and image quality are shown in Table 2. The third expert was needed to assess the interpretability of echocardiography for 19 (22 %) LVF, 19 (22%) PE, 16 (19 %) RVD, and 21 (25 %) IVCC.

Table 1 Characteristics of the general population and comparison between experienced and novice emergency physician. EEP: experienced emergency physician; NEP: novice emergency physician (almost 50 echocardiographies after initial training); Results expressed in mean (SD) or number (%); BMI: body mass index; GCS: Glasgow coma scale

Characteristics	Missed data	All patients N = 85	Echocardiography by NEP N = 34 (40 %)	Echocardiography by EEP N = 51 (60 %)	p value
Age (years)	7(8 %)	67 (18)	68 (18)	66 (17)	0.65
Women	5 (6 %)	34 (42 %)	14 (41 %)	20 (43 %)	0.98
BMI	6 (7 %)	25 (6)	25 (5)	26 (7)	0.84
Primary indication of care					
Chest pain		44 (52 %)	16 (47 %)	28 (55 %)	
Dyspnea	0	33 (39 %)	15 (44 %)	18 (35 %)	0.63
Syncope		4 (5 %)	1 (3 %)	3 (6 %)	
Cardiac arrest		3 (3 %)	2 (6 %)	1 (2 %)	
Thoracic trauma		1 (1 %)	0	1 (2 %)	
GCS	0	14 (3)	14 (3)	14 (3)	0.85
Systolic arterial pressure (mmHg)	1 (1%)	139 (33)	138 (32)	140 (28)	0.74
Shock state	0	3 (3 %)	2 (6 %)	1 (2 %)	NA
Respiratory distress state	0	20 (24 %)	7 (21 %)	13 (25 %)	0.6
Mechanical ventilation	0	7 (8 %)	4 (12 %)	3 (6 %)	NA
Echocardiography realization location					
Home	1 (1 %)	36 (43 %)	16 (47 %)	20 (40 %)	
Ambulance		36 (43 %)	11 (32 %)	25 (50 %)	0.24
Care institution		10 (12 %)	6 (18 %)	4 (8 %)	
Street		1 (1 %)	0	1 (2 %)	
Helicopter		1 (1 %)	1 (3 %)	0	
Patient position during examination					
Supine	0	30 (36 %)	7 (21 %)	23 (45 %)	0.01
45°		41 (48 %)	17 (50 %)	24 (47 %)	
Sitting		14 (16 %)	10 (29 %)	4 (8 %)	
Duration of echocardiography (s)	0	162 (97)	184 (111)	151 (90)	0.11

Table 2 Interpretability of items, views, and image quality by the two experts

	Expert 1 N = 85	Expert 2 N = 85	Cohen kappa
Interpretable Goals			
Qualitative left ventricular function			.4
Interpretable	62 (73 %)	56 (66 %)	
Normally	37 (60 %)	39 (69 %)	
Moderate*	16 (26 %)	15 (27 %)	
Severe**	9 (14 %)	2 (4 %)	
Pericardial effusion			.56
Interpretable	62 (73 %)	47 (55 %)	
No	56 (90 %)	41 (87 %)	
Yes	6 (10 %)	6 (13 %)	
Right ventricular dilation			.48
Interpretable	55 (65 %)	49 (58 %)	
No	45 (82 %)	45 (92 %)	
Moderate	8 (14 %)	2 (4 %)	
Severe	2 (4 %)	2 (4 %)	
Inferior vena cava compliance			.46
Interpretable	39 (46 %)	34 (41 %)	
0 %	8 (21 %)	9 (26 %)	
1 – 39 %	15 (38 %)	11 (31 %)	
40 – 99 %	11 (28 %)	5 (14 %)	
100 %	5 (13 %)	10 (29 %)	
Image Quality			
Parasternal short axis			
Interpretable	26 (31 %)	22 (26 %)	.83
Mean scale	2 ± 1	1.9 ± 0.9	.81
Parasternal long axis			
Interpretable	41 (48 %)	36 (42 %)	.6
Mean scale	2.3 ± 1	2.2 ± 1	.54
Apical four chambers			
Interpretable	47 (55 %)	52 (61 %)	.64
Mean scale	2.6 ± 1	2.5 ± 0.9	.51
Subcostal four chambers			
Interpretable	34 (40 %)	33 (39 %)	.69
Mean scale	2.6 ± 1.3	2.1 ± 1.1	.62
Inferior vena cava view			
Interpretable	41 (48 %)	36 (42 %)	.6
Mean scale	2.5 ± 1.3	2.2 ± 1	.47

Quality scale: 1 = no image, 2 = poor and unusable image quality, 3 = usable image quality, 4 = good image quality, and 5 = perfect image quality. Interpretable = 3 or more. *Moderate alteration (50 – 30 %), **Severe alteration (<30 %)

The mean number of interpretable items by echocardiography was three [1;4]; one [0;2.25] in the NEP group, four [3; 4] in the EEP group (p < .01). The correlations between interpretable echocardiography items for each exam according to the EP's experience are shown in Fig. 1. LVEF was interpretable in 68 (80 %) patients, PE in 60 (81%), RVD in 56 (66 %), and IVCC in 41 (48 %). Fig. 2 shows interpretability of each echocardiography item, according to the EP's experience.

In bivariate analysis, only one other factor was associated with interpretable items: patient position during examination (supine three [2; 4], "45°" two [1; 4], sitting two [1; 4]; p = .02). In multivariate analysis, only EP experience in echocardiography (EEP or NEP) was associated with the number of interpretable items (p = .02).

Discussion

Main result

Our study shows that, by using a PUD, there is a significant difference in echocardiography items (four [3; 4] vs. one [0; 2.25], p < .01) between most-trained (>50 exams) and less-trained (<50 exams) operators. This result raises a concern on the widespread use of PUD without previous adequate training.

In our study, the good diagnostic performance observed with PUD in trained EPs is consistent with the literature. Pocket ultrasound devices are shown to be effective diagnostic tools in emergency, cardiology, and haemodialysis outpatients [6, 13–15]. Such devices are mainly adapted to some specific diagnoses, such as severe left/right ventricular failure, severe hypovolemia, or large pericardial effusion. Pocket ultrasound devices can be used by less-trained EPs after a specific learning program [13, 14]. In a recent study, Carrié et al. [16] showed that after 30 supervised and goal-oriented examinations, residents could adequately answer clinical questions covered by core applications of emergency ultrasound. Our results suggest that in prehospital clinical practice, a threshold of 50 examinations is preferable.

The first explanation for the present results is that the small screen size and poor prehospital examination conditions present difficulties for NEPs. Thus, it could be hypothesized that exams performed by an NEP take longer than those performed by an EEP. In the present study, EEPs performed good echocardiograms in 2.5 minutes. By contrast, NEPs performed bad exams in 3 minutes. Perhaps they need more time, but do not take it.

In the present report, there is a trend to a higher use of echocardiography in chest pain for EEPs than for NEPs. It could be argued that analyzing chest pain probably implies a more complex echocardiographic analysis than other diagnoses. Particularly, analyses of segmental wall motion abnormalities or aortic disease can be discouraging for novices who are not confident enough.

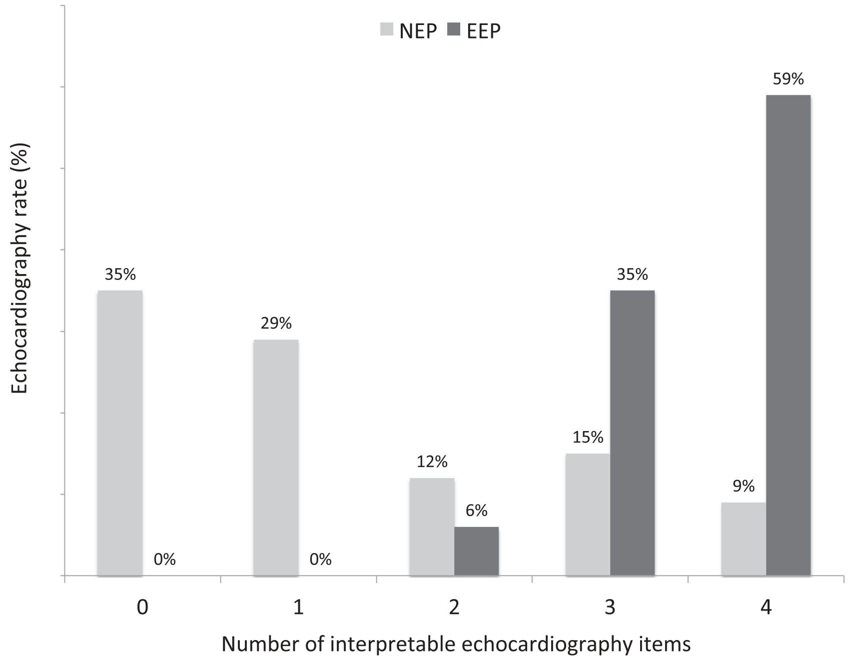

Fig. 1 Number of interpretable echocardiography items for each exam according to physician experience. EEP: experienced emergency physician; NEP: novice emergency physician (almost 50 echocardiographies after initial training); "Echography rate" is the rate of examinations with 0, 1, 2, 3, or 4 interpretable items

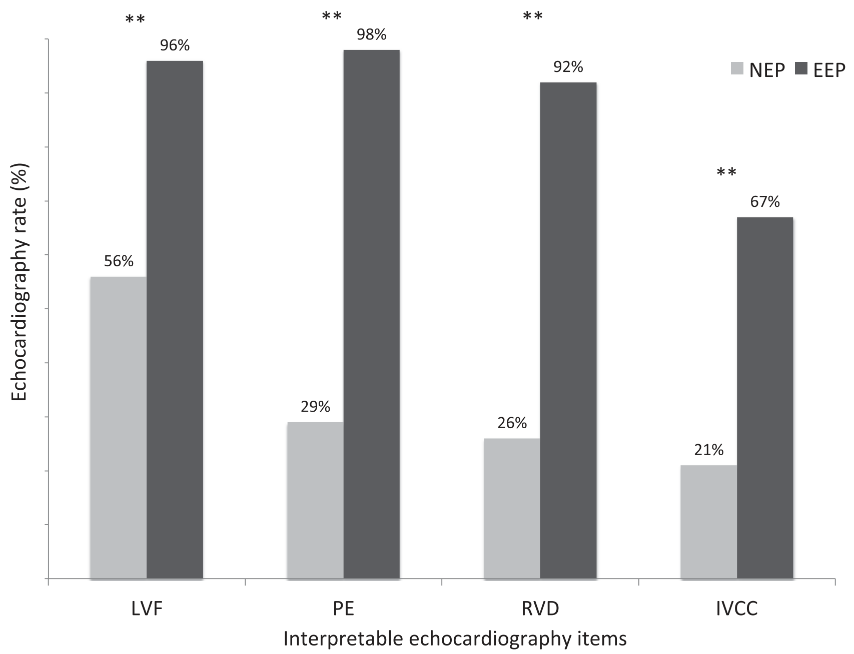

Fig. 2 Interpretable echocardiography items according to physician experience. EEP: experienced emergency physician; NEP: novice emergency physician (almost 50 echocardiographies after initial training); "Echography rate" is the number of examinations in which the item is interpretable; LVF: qualitative left ventricular function; PE: pericardial effusion; RVD: right ventricular dilation; IVCC: inferior vena cava compliance; ** p < .05

There is also a trend to a lower utilization of echocardiography during acute dyspnoea. This could be explained by the fact that EEPs can also use other echo techniques for the diagnosis of dyspnea, especially the lung ultrasound, which is shown to have a high specificity and sensitivity in short-breathing patients [17, 18]. These two issues could lead to a bias. As the differences are not significant, we cannot make a definitive conclusion.

The learning curve of echocardiography is probably slower for PUD than for conventional ultrasound machines. Recent international recommendations state that "*only appropriately trained practitioners should practice FoCUS*" and that exact specifications of skills and appropriate number of supervised and unsupervised scans depend on the specialty of the EP [1]. It can be hypothesized that echocardiography training in the prehospital setting is longer than for conventional echocardiography. We hypothesize that it is learning echocardiography with a PUD that requires more experience. Studies with PUD used by experienced practitioners showed good results: [4, 6]. When training was shorter, results were poorer [10]. These points can be an obstacle for the widespread use of this application because a minority of EPs are trained [19–21]. However, the proportion of emergency physicians experienced in echocardiography is increasing and new generations will likely have better technological skills and will be more rapidly able to use PUD [22].

Originality of the study

In previous studies related to PUD, all examinations were performed by one or two EPs and/or with standardized training [6, 10, 23, 24]. The first originality of the present study is that it evaluates a larger EP population compared with previous studies. This probably helps to generalize the results because the training of EPs in a unit is often heterogeneous.

The second originality of the present study is that the primary endpoint was interpretable echocardiography items. We hypothesize that interpretable items better reflect the clinical usefulness of PUD in the prehospital setting than image quality itself. The most difficult item to record was inferior vena cava compliance (less than one in two). It was earlier reported as a simple item to record and analyze under good examination conditions [13]. One hypothesis for this result is that patients were often not supine, dyspnoeic, or had chest pain. Moreover, only one view (subcostal) shows the inferior vena cava. Therefore, when that view is not possible, the item cannot be analyzed. This reinforces the idea that inferior vena cava imagery is not easy and should be interpreted with caution, especially in spontaneously breathing patients [25]. Other items were easy for EEPs. However, only the estimation of LVEF was possible in more than one in two exams performed by NEPs. Unlike the IVCC, this result is probably because it can be estimated in all views.

Study limitations

The present study has limitations. The first limitation is that it is a monocentric study, affecting the generalizability of the results. The inclusion criteria were set to include each patient requiring echocardiography in the prehospital period. Therefore, patient inclusion was based on the EP's evaluation of the need for a prehospital FoCUS exam. Video loops of echocardiograms were used to make objective assessments. Although common [10, 12], this methodology probably underestimates interpretability. This study supports the conclusion only for interpretability. However, it is likely that diagnostic performance is correlated. Additionally, agreement between the two experts for endpoints was moderate and a third expert was necessary in less than one in four. Finally, the quality of experts could be questioned. The correlation between the experts for interpretable goals was low, whereas the two experts were in accordance for image quality (Table 2). One explanation for such a discrepancy could be that the recorded loops were very short (just a few seconds). This limited duration may decrease the diagnostic accuracy and affect inter-observer variability. To improve this issue, a third expert was mandated and had to intervene in 19 – 25 % of cases.

Conclusion

The present study compared, for the first time, the interpretability of images acquired by highly and less-trained echocardiography emergency physicians using a pocket ultrasound device in a prehospital setting. Less experience by the EP significantly reduces the interpretability of focus echocardiography performed under these conditions. It is likely, therefore, that physician experience affects diagnostic performance. The training of echocardiography physicians appears to be a key issue for using pocket ultrasound devices in prehospital settings.

Abbreviations

FoCUS: Focused cardiac ultrasound; ASE: American Society of Echocardiography; ACEP: American College of Emergency Physicians; PE: Pericardial effusion; LVF: Left ventricular function; RVD: right ventricular dilation; IVCC: Inferior vena cava compliance; PSA: Parasternal short axis; PLA: Parasternal long axis; AFC: Apical four chambers; SFC: Subcostal four chambers; PUD: Pocket size ultrasound device; EEP: Experienced emergency physician; NEP: Non experienced emergency physician; EP: Emergency physician; BMI: Body mass index; GCS: Glasgow coma scale; SD: Standard deviation.

Competing interests

Only the first author (XB) declares a competing interest as an ultrasound teacher for GE (GE MEDICAL SYSTEMS ULTRASOUND) customers: once in 2010, once in 2011, twice in 2012, and twice in 2013. The other authors state they have no competing interests.

Authors' contributions

XB and CP conceived the study, wrote the manuscript, and performed some echocardiography exams. JELC was the director of this research project and participated to the writing of this manuscript. PW and YB performed some echocardiography exams. XB was the responsible of the statistical analysis. PGC, CR, GC, and LM significantly helped to draft the manuscript. CS and LM were the experts. All authors read and approved the final manuscript.

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5.5. Conclusion :

Si des formations courtes ont montré leur capacité à transférer des connaissances procédurales ou théoriques à court terme, des formations universitaires le permettent avec une évaluation 1 an après la formation et entrainent une utilisation de l'ECMU en pratique clinique. La formation à une pratique dans des conditions préhospitalières ou avec des échographes de poche peut demander plus de temps.

6. Impact de l'ECMU :

6.1. Impact déclaratif sur le diagnostic et sur la prise en charge :

Pour avoir un impact sur la qualité des soins des patients, l'implantation d'une technique diagnostique doit entrainer une modification diagnostique et de la prise en charge des patients. La première étape doit, bien sûr, être l'utilisation de l'outil. Nous avons voulu connaitre le taux de patients qui bénéficiait d'une ECMU dans des SU équipées et qui avaient des médecins formés dans leurs équipes. Nous avons réalisé une étude multicentrique prospective « un jour donné ». Cinquante SU ont inclus toutes les ECMUs réalisées un jour donné (24h). Les objectifs principaux de notre étude étaient d'évaluer la prévalence de la réalisation de l'ECMU aux patients pris en charge et d'évaluer son impact sur : le diagnostic, le traitement, l'orientation du patient et la prescription d'examens d'imagerie. Parmi les 4671 patients pris en charge dans les SU participant à l'étude, 229 ECMUs ont été réalisé chez 192 (4%) patients. Aucune ECMU procédurale n'a été pratiquée. Les impacts diagnostiques, thérapeutiques et d'orientation étaient respectivement de 82%, 47% et 85%. Dans 101 cas (44%), l'ECMU a entraîné au moins un changement de prescription d'imagerie. Enfin, 95% des ECMUs réalisées avaient au moins un impact. Donc, en 2014, le taux de patients pris en charge dans une SU équipée d'un échographe et possédant des médecins formés semblait inférieur à 5%. Ce résultat est décevant si on considère le biais de motivation de cette étude (seul des services avec des médecins motivés pour faire l'étude ont été analysés). Par contre, l'impact des ECMUs était très bon. Ces deux résultats sont probablement liés. Si les médecins urgentistes sélectionnent uniquement les patients qui ont un bénéfice potentiel important à la réalisation de l'échographie, l'impact devient artificiellement augmenté. Dans tous les cas cette étude montre que l'ECMU était loin d'être une pratique courante en médecine d'urgence en 2014. Enfin, si nous n'avons pas recueilli le nombre de procédures invasives réalisées dans les services participant, l'absence de réalisation d'ECMUs procédurales apparait comme un signe d'alerte. Cette étude a été réalisée avant la publication des recommandations françaises sur l'écho-guidage des ponctions vasculaires (55) et avant les RFE sur le premier niveau de compétence en ECMU (2). La carence en formations spécifiques semble être le principal frein à l'écho-guidage en médecine d'urgence (78, 79). La diffusion de formations sur l'écho-guidage pourrait être une solution.

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Original Article

The clinical impact and prevalence of emergency point-of-care ultrasound: A prospective multicenter study

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ABSTRACT

Objective: The main objectives of our study were to evaluate the prevalence of emergency point-of-care ultrasound (POCUS) use and to assess the impact of POCUS on: diagnostic, therapeutic, patient orientation and imaging practices.
Methods: This was a one-day, prospective, observational study carried out across multiple centers. Fifty emergency departments (EDs) recorded all POCUS performed over a 24 h period. The prevalence of POCUS was defined as the number of POCUS/number of patients seen in all units. The "diagnostic impact" was defined as a POCUS-induced confirmation or change to the initial clinical diagnosis. The "therapeutic impact" was defined as a POCUS-induced change in treatment. The "orientation impact" was defined as an ultrasound-induced confirmation or change in the initial orientation. The "imaging change" was defined as a radiologic imaging prescription modification.
Results: Two hundred and twenty-nine (5%) POCUS were performed on 192 patients (4%) from among the 4671 patients seen on the study day in the 50 EDs. No ultrasound procedural guidance was given during the study day. The diagnostic, therapeutic and orientation impacts were respectively 82%, 47% and 85%. In 101 cases (44%), POCUS led to at least one imaging change. The clinical value of POCUS, i.e. considering at least one impact and/or imaging change, was assessed at 95%.
Conclusion: This study shows that POCUS is used on a minority of emergency patients. However, when used, it significantly affects diagnostic and therapeutic practices in the emergency setting.

1. Introduction

Accurate diagnoses and treatments are essential in emergency medicine [1]. Point-of-care ultrasound (POCUS) is ultrasonography performed and interpreted by the physician at the bedside [2]. During the last ten years, several guidelines have recommended the use of ultrasound in critical patients [3–7]. Point-of-care ultrasound improves clinical exam performance [8,9]. Emergency POCUS leads to faster and more accurate diagnosis in critical patients [10]. Several applications are described in emergency settings: focused assessment with sonography for trauma (FAST) [11], echocardiography [12], lung ultrasound [4], detection of abdominal aortic aneurysm [13], deep vein thrombosis (DVT) [14], cholecystitis [15], urinary obstruction [16], intrauterine pregnancy [17], or procedural guidance [18–20]. However, in emergency settings, the number of POCUS performed and their global contribution to patient management remain unknown. The primary aim of our study was to evaluate the prevalence of POCUS use among emergency patients. The secondary aims were to assess the impacts of POCUS on diagnostic, therapeutic, patient

Abbreviations: POCUS, point-of-care ultrasound; EDs, emergency departments; FAST, focused assessment with sonography for trauma; DVT, deep vein thrombosis; EP, emergency physicians.

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orientation and imaging practices. Finally, we assessed the factors that may influence the performance of POCUS.

2. Patients and methods

2.1. Study design

This one-day, prospective, observational study was approved by the Institutional review board (IRB) and the Comité consultatif sur le traitement de l'information en matière de recherche dans le domaine de la santé (Paris, France, 14. 051). The IRB waived the need for patient (or relative) consent. Using the results of our previous study [21] and the Winfocus France Group network, we invited French hospitals and pre-hospital emergency departments to participate in the study. Only departments with permanently available ultrasound systems and trained physicians could participate. Fifty emergency departments accepted to participate in the study. The representatives of each unit prospectively collected all ultrasound exams performed in their units over a 24 h period starting at 20 May 2014 at 8 a.m. There was no incentive to perform POCUS that day. During the study period, each operator performing a POCUS completed a case report form. Details on operator training, patient conditions, type of ultrasound and probe, diagnosis, treatment changes and timing of the assessment were reported in the case report form. An organ failure was defined by the presence of hypotension and/or shock state and/or acute dyspnea and/or coma.

The day after the study, each investigator collected the total number of patients admitted to the department.

2.2. Definitions

The prevalence of POCUS was defined as the number of POCUS/ number of patients seen in all units during the study period. The POCUS were classified as "procedural guidance" (ultrasound was used for an invasive procedure) or "diagnostic assessment" in other cases. In the "diagnostic assessment" group, we assessed the clinical value of POCUS by studying imaging changes as well as the diagnostic, therapeutic and orientation impact. An "imaging change" was defined as a radiologic imaging prescription modification (new or cancelled). The "diagnostic impact" was defined as a POCUS-induced confirmation or change of the initial clinical diagnosis. The "therapeutic impact" was defined as a POCUS-induced change in treatment (new treatment, modified doses or terminated). The "orientation impact" was defined as an ultrasound-induced confirmation or change in the initial orientation. Operators determined these POCUS impacts during the management of each patient. For each POCUS, the operator filled in a case report form asking: the impact on the main diagnostic hypothesis (null, confirmation, change), treatment (null, modification or termination of an existing treatment, addition of a new one), orientation (null, confirmation, change) and imaging examination (null, cancellation of a planned imaging examination, addition of a new one).

The "global clinical value" for POCUS was defined as the combination of either the diagnostic, therapeutic, orientation impact or imaging prescription change. The operator classified the quality of images obtained for each procedure as good (full visualisation of structures), average (partial visualisation allowing assessment), or poor (no visualisation or no possible assessment). Only POCUS performed by emergency physicians (EP) were collected. A certified physician was defined as an EP who had had specific training in emergency clinical ultrasound.

2.3. Statistical analysis

Categorical outcomes were characterized by sample size and percentages, and compared using Chi-square or Fisher's exact tests, when appropriate. Data are expressed as means and standard deviations (SD) or medians (25th–75th percentile), depending on their distribution (Gaussian or not). Continuous variables were characterised by their means and standard deviations, and compared by *t*-tests or Wilcoxon rank sum tests, when appropriate. We performed a multivariate analysis to assess the independent factors potentially explaining therapeutic, diagnostic, and orientation impact, as well as imaging change. Variables with a univariate significance level of at least 0.2 were included in the multivariate logistic regression model. Variables were selected with a step-by-step forward–backward model to minimise the Akaike's criterion. The statistical threshold for final significance was 0.05. Statistical analysis was performed using the R-Project statistical programming environment (free software foundation, GNU general public license).

A similar study was conducted simultaneously in intensive care [22]. Some designers are common to both studies.

3. Results

During the study day, 229 (5%) POCUS were performed on 192 (4%) out of 4671 patients seen in the 50 EDs. POCUS were performed in a pre-hospital setting in 32 (14%) cases and in a hospital in 197 (86%) cases. ED and patient characteristics are summarized in Table 1. Image quality was classified as good, average, and poor for 159 (69%), 63 (28%), and 6 (3%) POCUS, respectively. The median duration of POCUS was 180 s (120–300). The examinations most frequently performed with POCUS (> 5%) were echocardiography (69; 30%), focused assessment with sonography for trauma (FAST) (33; 14%), urinary tract (33, 14%), lung (25; 11%), biliary tract (20, 9%) and deep vein thrombosis (16, 7%) (Fig. 1). Twenty-four (10%) POCUS were performed by an EP who practiced clinical ultrasound less than once a month, 36 (16%) less than once a week and 169 (74%) at least once a week. No ultrasound procedural guidance was made during the study day (Fig. 2). The diagnostic, therapeutic and orientation impacts were 82%, 47% and 85%, respectively (Fig. 2). In 101 (44%) cases, POCUS led to at least one imaging change. The clinical value of POCUS, i.e. the percentage of cases with the combination of at least one impact and/or imaging change, was assessed at 95%.

Table 1
Features of emergency departments ($n = 50$) and patients ($n = 197$).

Variables	*n*
Type of hospital	
University hospitals (%)	28 (44)
General hospitals (%)	22 (56)
Number of EP: median (IQR)	22 (15–35)
Trained EP (%)	542 (43)
Management algorithm with POCUS (%)	10 (20)
Number of ultrasound devices: median (IQR)	1 (1–2)
Type of ultrasound device	
Transportable (%)	21 (31)
Portable (%)	42 (63)
Pocket sized (%)	4 (6)
Type of probe	
Phased array (%)	47 (94)
Linear (%)	43 (86)
Convex (%)	42 (84)
Micro convex (%)	5 (10)
Endo vaginal (%)	4 (8)
Patients	
Age: median (IQR)	57 (36–72)
Organ failure (%)	39 (20)
Hypotension and/or shock (%)	22 (11)
Acute respiratory distress (%)	28 (14)
Coma (%)	10 (5)

EP: emergency physician; IQR: interquartile range; POCUS: point-of-care ultrasound.

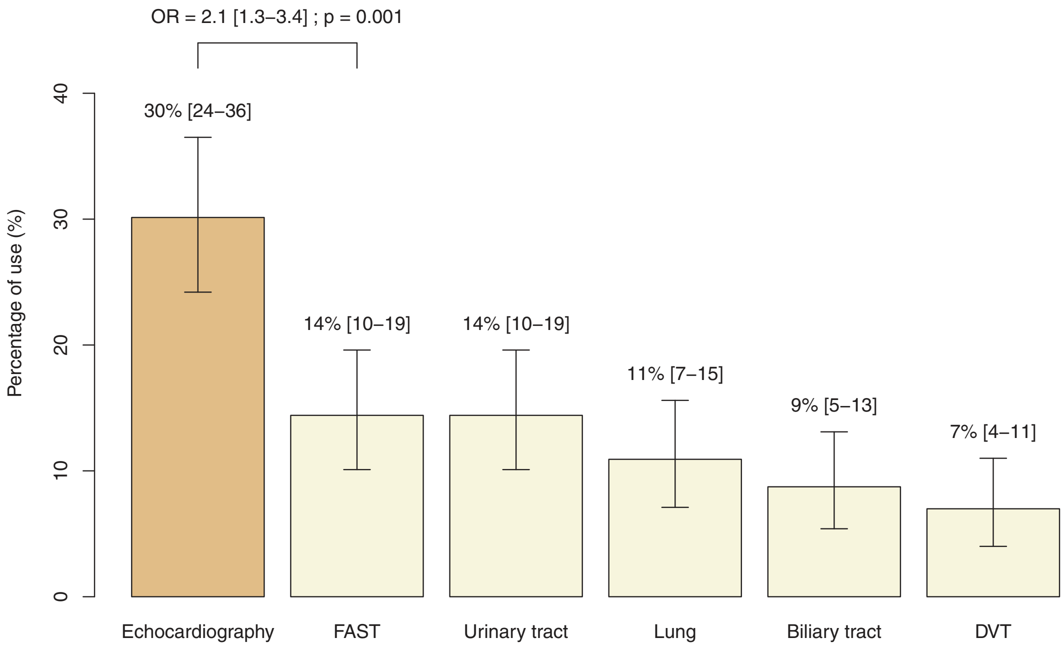

Fig. 1. Most frequent POCUS sites. FAST: focused assessment with sonography for trauma; DVT: deep venous thrombosis.

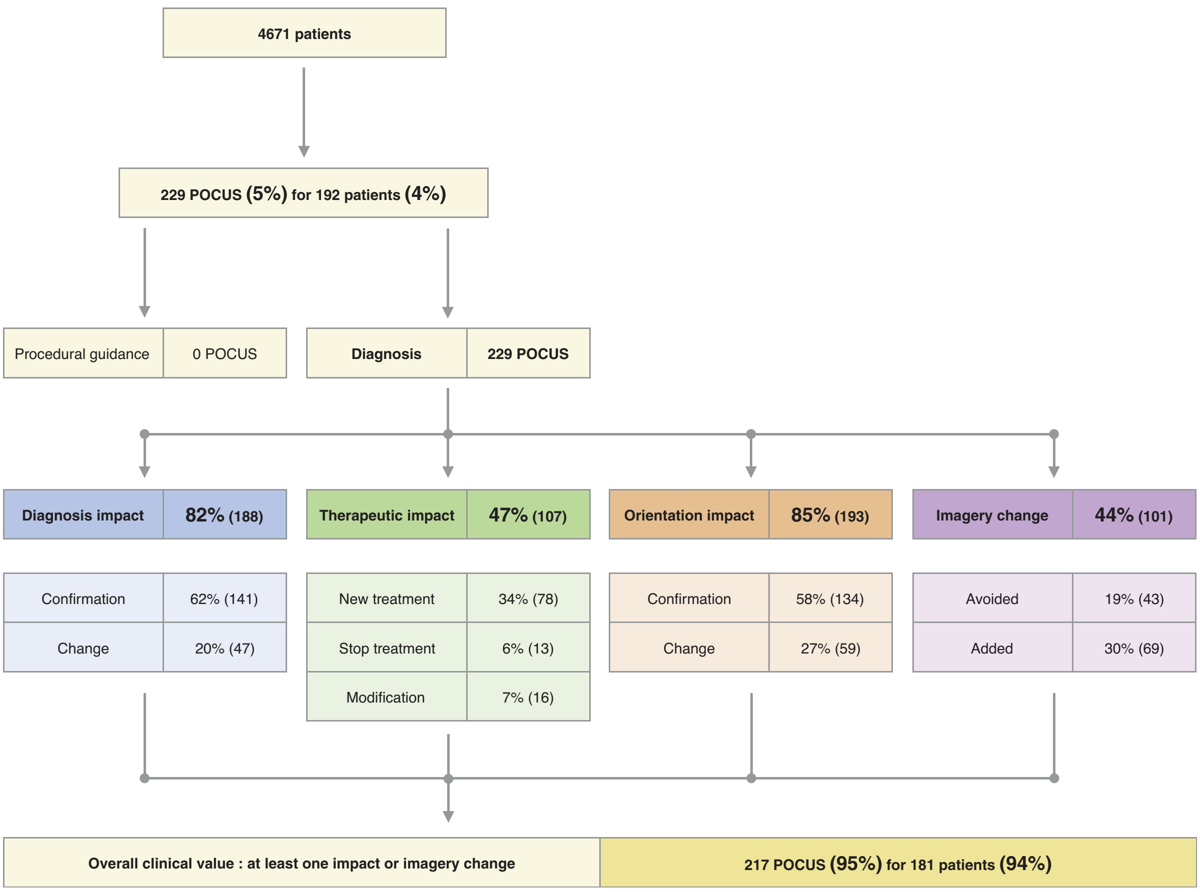

Fig. 2. Flowchart with primary aim, secondary aims and global clinical value of point-of-care ultrasound (POCUS).

The factors associated with diagnostic, therapeutic and orientation impacts as well as imaging changes in the univariate analyses are shown in Table 2. In the multivariate analysis, POCUS made in a university hospital with good quality images were associated with significant changes in diagnostic impact (Table 2). Independent variables associated with therapeutic impact were: POCUS made in a pre-hospital setting, exam performed by an EP with regular use of POCUS at least once a week, the existence of a management algorithm with POCUS in the unit, patient with at least one organ failure, urinary tract ultrasound and FAST exam (Table 2). Echocardiography was associated with significant changes in the orientation impact and good image quality with imaging changes (Table 2).

4. Discussion

4.1. Main results

Our multicenter study covering 50 emergency departments demonstrates a generally low POCUS prevalence (4% of patients have an ultrasound). Nearly half the POCUS have a therapeutic impact and likewise for imaging prescription changes. More than 80% of POCUS have a diagnostic and/or orientation impact. Finally, a large majority (95%) of POCUS has some clinical value.

This study shows that POCUS is rarely used as a daily diagnostic tool (< 5% of admissions). Usually, the two more frequents causes of low POCUS use are the availability of ultrasound devices and EP training [21]. This study shows that in equipped units, trained doctors do not use it for the large majority of patients. There is a possible link between these excellent POCUS performances and its low use. The predictive value of a test is linked to the prevalence of illness. In cases of uncertain clinical diagnosis it is likely that emergency POCUS increases diagnostic accuracy [9]. Therefore, even though EPs perform few POCUS, they probably naturally select patients in whom this technique will be relevant. Another possible explanation of the excellent diagnostic impact in our study is that only POCUS made by emergency physicians were included. A recent study shows that in Denmark, POCUS are usually performed in the ED by other specialists [23]. In intensive care, ultrasounds made by intensivists have more impact [22]. Although this methodology has already been used [22], such good results may be due to the self-judgment of the impacts by operators. An EP who practices POCUS believes in its usefulness and may overestimate the impact of her/his examinations.

On the study day, no ultrasound procedural guidance was recorded. Many procedures have a lower risk of complication or failure when using ultrasound guidance [19,20,24]. Although we did not screen for the number of invasive procedures performed over the study period, it is quite certain that punctures were performed and that ultrasound guidance could have been used. Underuse of ultrasound guidance is well known in emergency medicine [25], even in critical care [22] and anaesthesia [26]. For central venous catheter placement, the perception that ultrasound guidance is too time-consuming is the main barrier for EPs who use POCUS (27%) [25]. Because the benefits [18,19,24] and guidelines [3,4] are clear, the non-use of ultrasound guidance during the study period suggests that promoting ultrasound guidance remains an important challenge for ED teams.

In our study, echocardiography is the most common type of POCUS, even more than FAST. Similar results were recently published in critically ill patients [22]. The development of echocardiography in emergency medicine seems logical. The number of dyspneic, shock and/or thoracic pain patients is high in emergency settings. The use of echocardiography in critical patients is now mandatory [12,27,28]. Echocardiography is the most relevant technique during shock [10]. Because echocardiography is rapid and non-invasive, it is particularly well adapted to the most severe patients. In this study, POCUS performed in patients with at least one organ failure had a higher therapeutic impact (OR = 7, 95% CI [2.5–3.7], $P < 0.01$) than in patients with no

Table 2
Factors associated with an impact or imaging change.

Variables	Univariate analysis			Multivariate analysis	
	Yes: *n* (%)	No: *n* (%)	*P*	OR (95% CI)	*P*
Diagnostic impact					
University Hospital	86 (82)	102 (91)	0.05	0.3 (0.1–0.9)	0.03
Good image quality	130 (86)	57 (95)	0.07	0.2 (0.03–0.8)	0.04
Pre-hospital setting	24 (77)	164 (88)	0.15		
EP POCUS practice at least 1/week	145 (89)	43 (80)	0.08		
Management algorithm with POCUS	48 (77)	121 (89)	0.03		
At least one organ failure	40 (95)	148 (84)	0.07		
POCUS site: biliary tract	15 (75)	173 (88)	0.15		
Therapeutic impact					
Pre-hospital setting	7 (22)	132 (67)	< 0.01	0.2 (0.1–0.8)	0.02
EP POCUS practice at least 1/week	112 (66)	27 (45)	< 0.01	2.3 (1.1–4.9)	0.04
Management algorithm with POCUS	27 (42)	103 (72)	< 0.01	0.3 (0.1–0.7)	< 0.01
At least one organ failure	32 (74)	107 (57)	0.04	7 (2.5–23.7)	< 0.01
POCUS site: urinary tract	28 (85)	111 (57)	< 0.01	4.3 (1.5–16)	0.02
POCUS site: FAST	13 (39)	126 (64)	< 0.01		
Orientation impact					
POCUS site: echocardiography	63 (93)	130 (82)	0.04	2.8 (1.1–8.5)	0.05
Women	105 (89)	87 (81)	0.1		
Imaging prescription change					
Good image quality	79 (50)	20 (32)	0.02	2.3 (1.1–4.9)	0.03
University Hospital	43 (39)	58 (49)	0.11		
Pre-hospital setting	4 (13)	97 (49)	< 0.01		
University certification	77 (42)	23 (53)	0.17		
EP POCUS practice at least 1/week	82 (49)	19 (32)	0.02		
Management algorithm with POCUS	19 (30)	77 (54)	< 0.01		
POCUS site: echocardiography	22 (32)	79 (49)	0.01		
POCUS site: deep venous thrombosis	10 (63)	91 (43)	0.12		
POCUS site: urinary tract	21 (64)	80 (41)	0.01		

POCUS: point-of-care ultrasound; FAST: focused assessment with sonography for trauma.

organ failure. Moreover, echocardiography is the only independent factor associated with orientation impact (OR = 2.8, 95% CI [1.1–8.5], $P = 0.05$). Lung ultrasound was seldom performed during our study. The number of patients who should benefit is, however, high. The diagnostic accuracy of lung ultrasound (LUS) is good [8] and superior to chest radiographs [29]. LUS helps the clinician make the rapid diagnosis of acute respiratory failure [30,31]. Doing LUS with echocardiography results in excellent accuracy [32] without causing patient discomfort [33]. As for procedural guidance, LSU training should be a priority for EPs.

Initial certification is not sufficient. Though all physicians in this study were POCUS certified, the frequency of POCUS use was an independent factor for therapeutic impact. After initial training, ED physicians should pay particular attention to the frequent and regular use of this technique. This result confirms the pivotal role of physician experience in POCUS practice, as recently reported by our group [34].

In this study, emergency POCUS has an impact on the prescription of radiology exams. This confirms that the use of ultrasound at the bedside in critically ill patients significantly reduces the number of radiology exams, as previously reported [35,36]. Certain POCUS techniques have been shown to replace irradiating and expensive exams without increasing adverse events [37]. However, emergency clinical ultrasound should complement normally used tests and not replace them [38]. Surprisingly, in our study, the presence of a management algorithm with POCUS in the unit is an independent factor for low therapeutic impact (OR = 0.3, 95% CI [0.1–0.7], $P < 0.01$). Few algorithms are only based on POCUS techniques [30,39]. Despite the POCUS accuracy, our results suggest that ultrasound is a complementary tool for clinical examination and cannot replace it. Diagnostic algorithms should use both clinical and sonographic criteria. This was well demonstrated in cases of severe pulmonary embolism [40,41]. During severe pulmonary embolism, echocardiography is a good diagnostic tool in case of shock with a high clinical probability of pulmonary embolism. On the other hand, the diagnostic impact of echocardiography is poor during pulmonary embolism with no signs of shock.

Table 3
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4.2. Originality of the study

The first originality of the present study is that it evaluates the prevalence of POCUS in emergency settings in a large number of units. This probably helps generalize the results and brings attention to the too rare use of clinical ultrasound in EDs. The second originality of the present study is the evaluation of to what extent POCUS contributes to patient management. The results show that POCUS is a very helpful diagnostic tool and procedural ultrasound is probably underused. Finally, this study is the first to extensively evaluate the therapeutic and diagnostic impacts of POCUS. The present results are not designed to study the prognostic impact of POCUS. In particular, the link between the use of POCUS and mortality, morbidity or hospitalisation times remains unclear.

4.3. Limitations

The present study has limitations. First, only POCUS events within emergency units that have agreed to participate are represented. This probably represents an intrinsic recruitment bias. Secondly, we conducted the study only in France, affecting the generalisability of the results. Since the study had an open design, the investigators were aware of the study day and this may have encouraged them to use POCUS during that day. This deviation should result in decreased rates of diagnostic and therapeutic impacts, which are high in our study. Operators also determined the POCUS impact on the medical decision and in terms of diagnosis and treatment; POCUS was not compared with a standard of care. Nevertheless, this process has been confirmed in several previous studies [9,10]. Finally, patient outcomes were not analysed.

5. Conclusion

This study shows that POCUS is used in a minority of emergency patients but significantly affects diagnostic and therapeutic practices in emergency settings. Emergency POCUS is also associated with a lower use of radiology exams.

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6.2. Impact pronostique

6.2.1. Concept et difficultés des études pronostiques sur les tests diagnostiques :

La dernière étape pour prouver l'intérêt d'un test diagnostique est de répondre à la question « Est-ce que les patients qui ont bénéficié du test diagnostique vont mieux que ceux qui n'ont pas eu le test ? » (80). Répondre à cette question demande de réaliser des études interventionnelles. Ces études doivent utiliser des critères de jugement admis comme étant des objectifs de prises en charge. La mortalité est le critère le plus communément admis. Montrer qu'un changement de prise en charge entraine une diminution de la mortalité demande que la pathologie ou la symptomatologie étudiée soit grevée d'un taux de mortalité conséquent. Il est donc quasiment impossible de valider, sur ce critère, l'utilisation de tests diagnostiques potentiellement utiles dans des pathologies non ou peu létales. L'autre critère de jugement habituellement admis en médecine d'urgence est la durée d'hospitalisation. Bien qu'on admette le lien entre les deux, ce critère évalue plus la consommation de moyens que le « aller mieux ». De plus, compte tenu de l'évolution des pratiques d'hospitalisations conventionnelles, les études réalisées à des périodes différentes ne peuvent être comparées. Tout ceci explique pourquoi cette dernière étape de l'évaluation des tests diagnostiques ne soit montrée que pour une minorité des tests utilisés en pratique courante. De nombreuses études sur des biomarqueurs (81, 82), ou examens d'imageries (83) recommandées n'ont pas réussi à prouver un bénéfice pronostique à leur utilisation.

6.2.2. Impact pronostique de l'ECMU :

Il n'existe, à ce jour, aucune étude ayant montré un impact pronostique favorable lié à l'utilisation de l'ECMU. Très peu d'études interventionnelles avec un objectif pronostique sont publiées (84) et les revues de la littérature existante ne retrouvent pas de bénéfice patient. C'est le cas pour la FAST en préhospitalier (85), où seul un changement de prise en charge induit a pu être observé (86). Mais c'est le cas également pour l'ensemble des applications d'ECMU préhospitalières chez les patients non-traumatisés (84).
De rares études interventionnelles randomisées existent tout de même. Certaines ont montré que la pratique de l'ECMU pouvait remplacer la réalisation d'examens d'imagerie. C'est le cas dans la colique néphrétique où la réalisation, comme première modalité d'imagerie, d'une ECMU rénale, d'une échographie par le radiologue ou d'un scanner a le même impact sur la survenue d'événements indésirables (87). Dans cette étude, l'ECMU entrainait une irradiation moindre des patients. Un contexte clinique dans lequel l'ECMU semblait pouvoir prouver son efficacité pronostique était l'état de choc. En effet, ce motif de prise en charge est grevé d'un

taux de mortalité important et l'ECMU a prouvé sa bonne pertinence diagnostique dans ce contexte. La prise en charge avec utilisation précoce de l'échographie clinique guide, avec précision, le diagnostic, réduit de manière significative l'incertitude diagnostique des médecins et modifie la gestion et l'utilisation des ressources (38). Une étude récente a cherché à savoir si l'utilisation systématique de l'ECMU pour chercher l'origine des états de chocs indifférenciés non traumatiques apportait un bénéfice sur la sortie vivant de l'hôpital à J30 (88). L'étude multicentrique internationale réalisée sur 270 patients ne retrouvait pas de bénéfice. Plusieurs problèmes méthodologiques peuvent entrainer l'absence de bénéfice dans cette étude. Premièrement, les états de choc étaient indifférenciés mais pas inexpliqués. Seuls les diagnostics évidents (saignement digestif extériorisé par exemple) étaient exclus. Le bénéfice d'un test diagnostique ne peut être montré que dans des situations ou l'examen clinique apporte des hypothèses avec une probabilité non forte. Deuxièmement, l'hypothèse qui a permis le calcul du nombre de sujets nécessaires était présomptueuse. Les auteurs avaient prévu de pouvoir montrer une réduction de mortalité potentielle de 10%. Il est rassurant de savoir qu'il est actuellement difficile de montrer un intérêt pronostique à une technique diagnostique avec 270 patients. Enfin, il est difficile de savoir si le bénéfice de l'utilisation de l'ECMU dans l'état de choc n'est pas plus lié au monitorage adéquat du traitement qu'à l'aide sur le diagnostic étiologique.

7. Perspectives et projets :

Ce texte a comme objectif de faire un état des lieux de l'évolution de l'ECMU au moment de son écriture. Bien qu'il soit toujours difficile de prédire l'avenir, certaines évolutions semblent probables et nous avons fait le choix d'axer la poursuite de notre travail sur l'ECMU par certains thèmes qui nous semblent prioritaires. L'avancement déclaré des projets dans cette partie est valable au moment de l'écriture du manuscrit (septembre 2018).

7.1. Études diagnostiques :

Les études diagnostiques sur les techniques d'ECMU habituellement pratiquées existent déjà. Les perspectives d'études qui pourraient être proposées doivent tenir compte des spécificités de la médecine d'urgence. Une des voies de recherche semblant nécessaire à poursuivre est l'ECMU comme outil de triage. Devant l'importance du triage dans notre spécialité, la recherche permanente d'outils simples et rapides de triage est une priorité. Beaucoup d'applications peuvent s'imaginer. Nous avons réalisé une 2eme étude sur les CD chez les patients en détresse respiratoire. L'objectif principal était de connaitre la pertinence des CD droites sur la prédiction d'un recours à une technique de ventilation chez les patients admis en état de détresse respiratoire. Cent trois patients ont été inclus, les résultats sont en cours d'analyse.

7.2. Écho-guidage :

Nous avons vu que l'écho-guidage ne semble pas avoir d'intérêt pour la réalisation de l'ensemble des GDSA radiaux. Pour les VVP, les études ont montré que l'intérêt de l'écho-guidage ne concernait pas les patients suspects d'être faciles (58). Nous avons émis l'hypothèse qu'il en était de même avec les GDSA radiaux. Nous avons réalisé une étude prospective interventionnelle randomisée sur les GDSA radiaux difficiles. Nous les avons définis comme ceux chez qui deux ponctions ne permettaient pas de succès ou les patients qui n'avaient pas d'artère radiale palpable. Soixante-treize patients ont été inclus. L'étude est soumise et en cours de première relecture.

7.3. Développement d'équipements adaptés :

Le développement d'outils échographiques adaptés à la médecine d'urgence et aux patients pris en charge est une nécessité pour faire évoluer la pratique de l'ECMU et l'adapter aux contraintes cliniques. De plus, la jeune spécialité de médecine d'urgence doit s'approprier certaines techniques d'échographie innovantes.

- Écho-guidage :

Comme nous l'avons vu, l'écho-guidage est probablement sous-utilisé par les médecins urgentistes. Nous avons émis l'hypothèse que l'utilisation d'un échographe de poche pouvait favoriser cette pratique. Pour vérifier la performance du dispositif, nous avons réalisé une étude prospective interventionnelle sur mannequin de simulation comparant la mise en place de VVC avec un échographe conventionnel ou avec un échographe de poche. L'étude est soumise et en cours de deuxième relecture.

Certains fabricants d'échographes ont développé des outils afin de permettre aux praticiens de se repérer en trois dimensions afin d'aider à la ponction sous échographie. Un protocole évaluant cette technique sur un modèle de simulation par des médecins débutants est en cours d'écriture.

- Strain échographie :

Le strain est une technique échographique de développement récent dans laquelle l'échographe peut quantifier les mouvements d'une structure. Il est particulièrement développé en cardiologie pour suivre la fonction VG. Contrairement au Doppler, il n'est pas dépendant de l'angle d'insonation. Sa réalisation nécessitait initialement le traitement des vidéos d'échographies avec un logiciel sur un ordinateur. Sa réalisation est devenue simple depuis la possibilité de le réaliser directement sur l'échographe. Les intérêts d'analyser la fonction ventriculaire gauche en médecine d'urgence sont multiples. Nous avons voulu connaitre l'évolution du strain du VG dans le choc hémorragique. Nous avons réalisé une étude expérimentale sur 18 porcelets anesthésiés. L'étude est soumise et en cours de première relecture.

Le fait que l'échographe puisse quantifier le mouvement de structures pourrait être intéressant pour le diagnostic de pneumothorax par l'ECMU. En effet, le diagnostic échographique est basé sur l'absence de mouvement de la plèvre appelé glissement pleural. Un protocole pour réaliser une étude observationnelle prospective multicentrique est en cours d'écriture.

- Calcul automatique du débit cardiaque :

L'évaluation du débit cardiaque en échographie se fait grâce à la mesure de l'TVao, qui est un reflet du volume d'éjection systolique. Sa mesure bien réalisée est longue : réalisation d'une coupe apicale 5 cavités, recherche du meilleur emplacement pour placer la boite de Doppler pulsé, dessin du contour d'au moins trois complexes et réalisation de leurs moyennes. Comme nous l'avons vu l'ECMU doit se composer de techniques simples et rapides. De plus, la mise en place d'un cathéter veineux central, d'un cathéter artériel et la réalisation de thermodilutions répétées n'est pas une méthode d'évaluation du débit cardiaque adaptée à la médecine d'urgence. Nous avons donc besoin d'outils pertinents, rapides et simples d'utilisation. Ceci afin de respecter les *guidelines* qui recommandent le monitorage du débit cardiaque pendant le remplissage vasculaire des patients en état de choc (89). Un constructeur propose depuis plusieurs mois un dispositif où le médecin n'a qu'à réaliser la coupe apicale 5 cavités et montrer au doigt la cinquième cavité. L'intelligence artificielle fait le reste et la moyenne est calculée à partir de tous les complexes enregistrés pendant 4 secondes. Nous avons voulu comparer la technique manuelle et automatique face à un gold standard : la thermodilution trans-pulmonaire. Nous avons réalisé une étude expérimentale sur 18 porcelets anesthésiés. L'étude est soumise et en cours de deuxième relecture.

7.4. Enseignement :

Le déploiement de la simulation est majeur en médecine d'urgence. Cependant, la grande majorité du bénéfice à pratiquer la simulation a été prouvé en comparant un groupe avec simulation vs un autre sans contrepartie (90). Des simulateurs d'apprentissage d'échographie existent. Il nous a paru évident qu'ils pouvaient prendre une place grandissante dans l'avenir. Nous avons voulu étudier si l'apprentissage des coupes d'échocardiographies était de meilleure qualité lorsque la formation pratique était dispensée sur sujets sains (technique habituelle) ou sur mannequin de simulation. Nous avons inclus 55 étudiants. L'étude est soumise et en cours de première relecture.

Le nombre de fois où un médecin urgentiste est confronté à un contexte clinique dans lequel il doit utiliser une technique d'ECMU est hétérogène selon les techniques. Le problème du maintien des compétence doit être traité, en particulier pour les techniques liées à des situations cliniques peu courantes. Des études permettant de définir les bonnes conditions d'un maintien des compétences devront être mises en place. La place de la simulation pourra être importante dans ce cadre.

7.5. Impact pronostic de l'ECMU :

Il n'existe pas, actuellement, de preuve de l'intérêt de l'utilisation de l'ECMU sur le pronostic des patients pris en charge. Pour tenter d'y parvenir, nous avons choisi le sujet de la dyspnée car l'apport diagnostique de l'échographie pulmonaire y est majeur et la relation entre bon diagnostic et mortalité est prouvée (8). Afin de mettre en place une étude ciblant les patients de médecine d’urgence, nous avons voulu réaliser une étude incluant tous les patients dyspnéiques (et non que les détresses respiratoires) admis en service d’urgence. Comme nous avons voulu inclure toutes les dyspnées, nous n’avons pas choisi la mortalité comme critère de jugement principal mais la durée de séjour hospitalier. Nous avons mené une première étude prospective interventionnelle pilote pour nous permettre de calculer un nombre de sujets nécessaires. Soixante-quinze patients dyspnéiques ont été inclus, randomisés entre un groupe « prise en charge standard » et un groupe « prise en charge standard + échographie pulmonaire systématique ». Les résultats sont en cours d’analyse.

8. Conclusion :

L'ECMU est un outil permettant d'améliorer la pertinence diagnostique du médecin urgentiste et de sécuriser ses procédures. Les preuves actuelles sur sa pertinence légitime sa diffusion. Des recherches doivent être menées sur des techniques spécifiques à la médecine d'urgence, comme des techniques diagnostiques de triage (article 2) ou procédurales de gestes réalisés couramment dans les SU (article 3).

La progression de l'équipement en échographes des SU en France est significative (article 4), bien que ne respectant pas encore les recommandations (au moins un échographe par SU). Grâce à leur ergonomie et à leurs performances (articles 5 et 6), la diffusion des échographes de poche semble être une solution intéressante pour favoriser la pratique de l'ECMU.

Des formations courtes, longues, initiales ou continues existent. Il est actuellement difficile de recommander un cursus bien défini de formation. Les formations universitaires semblent pouvoir avoir un impact significatif sur la pratique de l'ECMU à distance de la formation (article 7). Tous les médecins titulaires du DES de médecine d'urgence auront reçu une formation. Ceci va achever l'implantation de l'outil. L'enseignement aux médecins déjà en poste, mais non encore formé, est un enjeu majeur. Pendant leur formation, les médecins doivent intégrer que seul une pratique régulière permettra un impact sur leurs diagnostics (article 1) et que le cursus de formation pour acquérir les compétences dans des conditions d'exercice préhospitalier ou avec des échographes de poche est plus long (article 8).

L'ECMU modifie les prises en charge par son impact diagnostique, thérapeutique, d'orientation et sur les prescriptions des examens complémentaires (article 9). Cependant, il n'existe actuellement pas de preuves permettant d'affirmer que la pratique de l'ECMU améliore le devenir des patients. Si cela est le cas de la majorité des tests diagnostiques utilisés en pratique clinique, il convient d'axer une partie de la recherche future dans ce sens.

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Résumé

L'échographie clinique en médecine d'urgence (ECMU) devient une pratique intégrée à l'exercice de la spécialité. En France, son utilisation va se généraliser grâce à la formation de tous les nouveaux internes de médecine d'urgence. La pratique de l'ECMU demande l'existence de preuves scientifiques sur la pertinence diagnostique des techniques utilisées, la disponibilité d'un échographe adapté, la compétence de la pratiquer et l'objectivation de son impact clinique. Après avoir définit l'ECMU, ce texte décrit et analyse l'état d'avancement de ces quatre étapes. Les articles inclus dans ce texte s'intègrent dans chacune d'entre elles. Ils ont pour objectif de participer à trouver les solutions permettant le déploiement et l'évolution de l'ECMU. Enfin, des perspectives d'évolutions de l'ECMU sont proposées.

Abstract

Emergency point-of-care ultrasound (EPOCUS) has become an integrated practice in emergency medicine. In France, systematic EPOCUS teaching for all emergency residents will lead to its widespread use. Integrating EPOCUS practice requires four steps: (1) the publication of accurate scientific data; (2) the availability of suitable ultrasound systems; (3) developing the necessary skills; and (4) highlighting its clinical impact. After defining EPOCUS, this manuscript describes and analyzes the progress of these four steps as the articles herein integrate into each. The aim is to find solutions for the deployment and evolution of EPOCUS. Finally, an outlook for future EPOCUS development is proposed.