LISTE DES ABREVIATIONS

2D: Mode bidimensionel

AUC: Area Under Curve

AUC –ROC: Areas Under Curves - Receiver Operating Characteristic

ARDS: Acute Respiratory Distress Syndrome

CE: Clinical Examination

CP: Contusion Pulmonaire

CT scan: Computed Tomography scan

CXR: Chest Radiography

EC: Examen Clinique

EPulm : Echographie Pleuro-pulmonaire

ER: Emergency Room

FAST: Focused Assessment with Sonography for Trauma examination

HT: Hemothorax

LUS: Lung UltraSonography

LC: Lung Contusion

PTX : Pneumothorax

ROC : Receiver Operating Characteristic

RT : Radiographie Thoracique

SDRA : Syndrome de Détresse Respiratoire Aiguë

TDM : Tomodensitométrie

TLV : Total Lung Volume

TM : Mode Temps Mouvement

VFDs : Ventilator-Free Days

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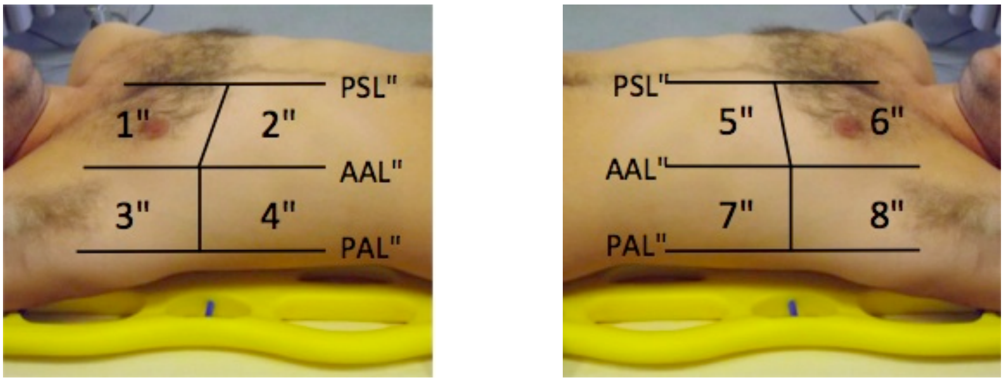
INTRODUCTION

L'échographie pulmonaire est un outil diagnostique en plein essor, particulièrement en traumatologie grave. Si, dans ce contexte, le scanner thoracique est le seul examen diagnostique permettant un bilan exhaustif des lésions pulmonaires et extra-pulmonaires, sa réalisation implique la stabilisation de l'état hémodynamique et/ou respiratoire du patient. En cas d'instabilité persistante, la radiographie thoracique est recommandée, bien que ses performances diagnostiques soient modestes. Aussi l'échographie pulmonaire, alliant simplicité d'exécution (au lit du malade, en moins de 10 minutes) et précision diagnostique, représente-t-elle une perspective séduisante dans ce contexte. Toutefois, sa performance en cas de lésions pulmonaires associées et son intérêt pronostique ont été peu ou pas évalués. Ceci a donc été le sujet d'une étude que nous avons menée au sein du déchocage du CHU d'Angers.

Après un bref rappel sur la sémiologie de l'échographie pulmonaire en traumatologie, nous présenterons cette étude rédigée sous la forme d'un article.

SEMIOLOGIE DE L'ECHOGRAPHIE PULMONAIRE EN TRAUMATOLOGIE

Une analyse échographique complète des poumons est généralement possible chez un patient en décubitus dorsal, d'où son intérêt particulier en traumatologie. On peut diviser chaque hémithorax en 4 zones d'analyse échographique (antéro-apicale, postéro-apicale, antéro-basale, postéro-basale) (figure 1).



PSL, Ligne Parasternale; AAL, Ligne Axillaire Antérieure; PAL, Ligne Axillaire Postérieure.

Figure 1 : Les 4 zones analysées par échographie sur chaque hémithorax

L'utilisation d'une sonde convexe de petite taille et de 5 MHz permet à la fois le positionnement intercostal de la sonde et une bonne analyse du parenchyme pulmonaire. La sonde est en effet placée dans l'espace intercostal, perpendiculairement aux côtes, afin de repérer la plèvre entre les côtes. Le repérage du diaphragme par une analyse crânio-caudale est particulièrement important en traumatologie car il permet de distinguer les épanchements intrathoraciques des épanchements intra-abdominaux. Les épanchements aériques sont retrouvés préférentiellement en zones antérieures, et les épanchements liquidiens ou alvéolo-interstitiels en zones postérieures.

1) **Poumon normal**

Entre les 2 cônes d'ombres représentant les côtes supérieures et inférieures, on distingue à 0.5cm de profondeur environ (chez l'adulte) une ligne hyperéchogène horizontale représentant la **ligne pleurale** (plèvre pariétale accolée à la plèvre viscérale).

Il existe plusieurs signes statiques à rechercher sur le poumon normal :

_ **Les lignes A** : ce sont des lignes horizontales, artéfacts de répétition de la ligne pleurale, de longueur égale ou inférieure à cette dernière (figure 2)

_ **Les lignes B** : également appelées en « queue de comète » ou en « fusées pleurales ». Elles sont construites par la réflexion des ultrasons avec les septa-interlobulaires formés d'un mélange air/ liquide. Elles associent les caractéristiques suivantes : trajet vertical partant de la ligne pleurale sans épuisement jusqu'au bas de l'écran et mouvement synchrone du glissement pleural, effaçant les lignes A (figure 3). Elles sont physiologiques (28 à 30% des sujets sains) si on les retrouve dans les parties déclives (dernier espace sus-phrénique), et si elles sont peu nombreuses (2 par écrans). Elles deviennent pathologiques si elles sont nombreuses (syndrome interstitiel si la distance entre 2 lignes B est de 7mm, lésions de verre dépoli si la distance entre 2 lignes B est de 3mm, ou plus simplement s'il y a 3 lignes B ou plus par écran) ou antérieures.

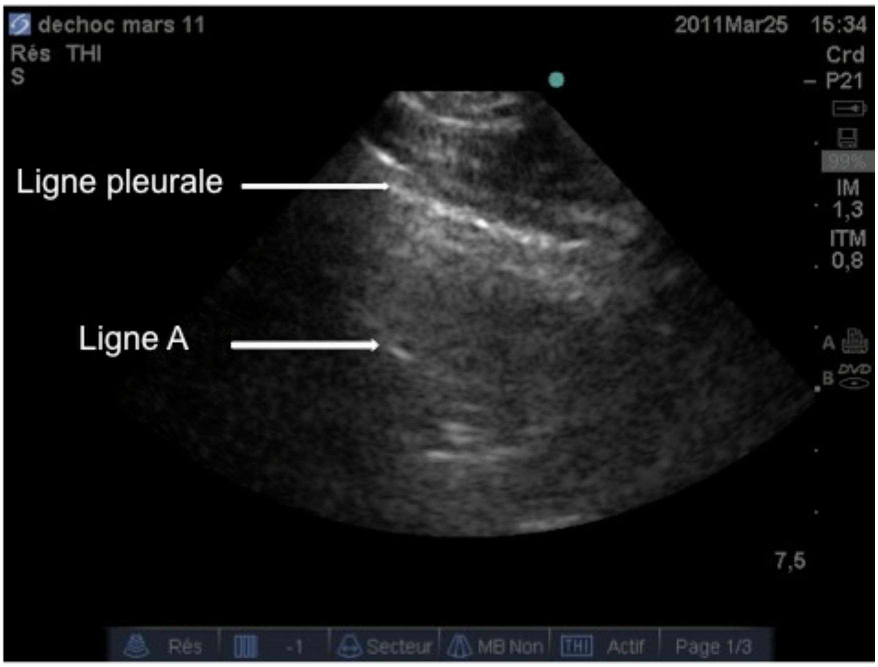


Figure 2: Ligne pleurale et ligne A (flèches)

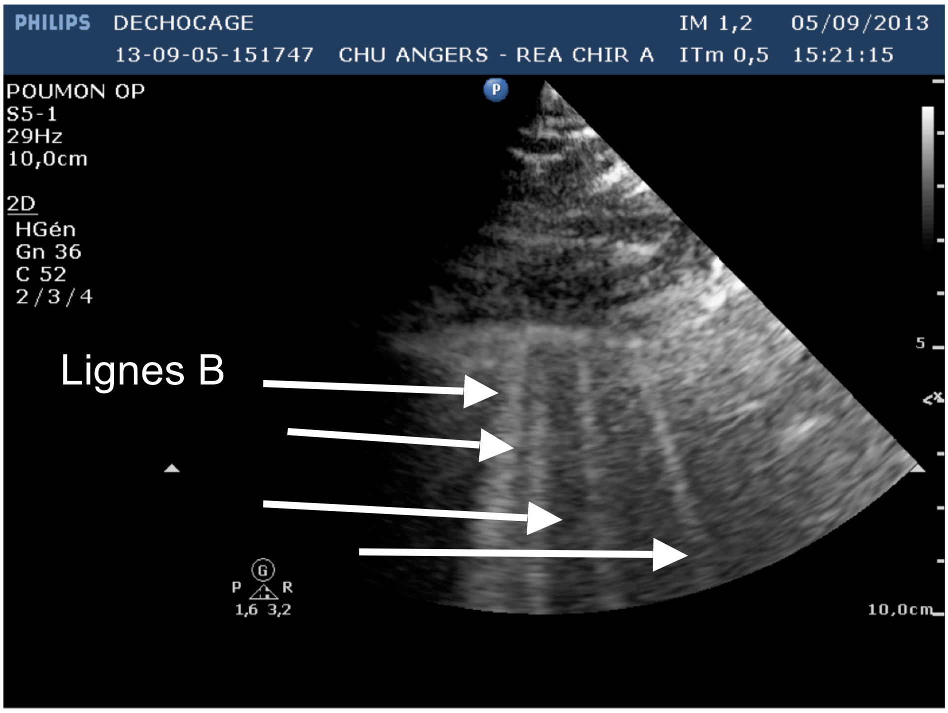


Figure 3 : Lignes B (flèches)

On recherche également en mode bidimensionnel un signe dynamique : le « **glissement pleural** » rythmé par les mouvements respiratoires (mouvements de la plèvre viscérale et du poumon contre la plèvre pariétale). En mode « TM » (temps-mouvement) *le glissement pleural est appelé « **signe du bord de mer** »,* le mouvement du parenchyme pulmonaire donne un aspect "granité" (figure 4).

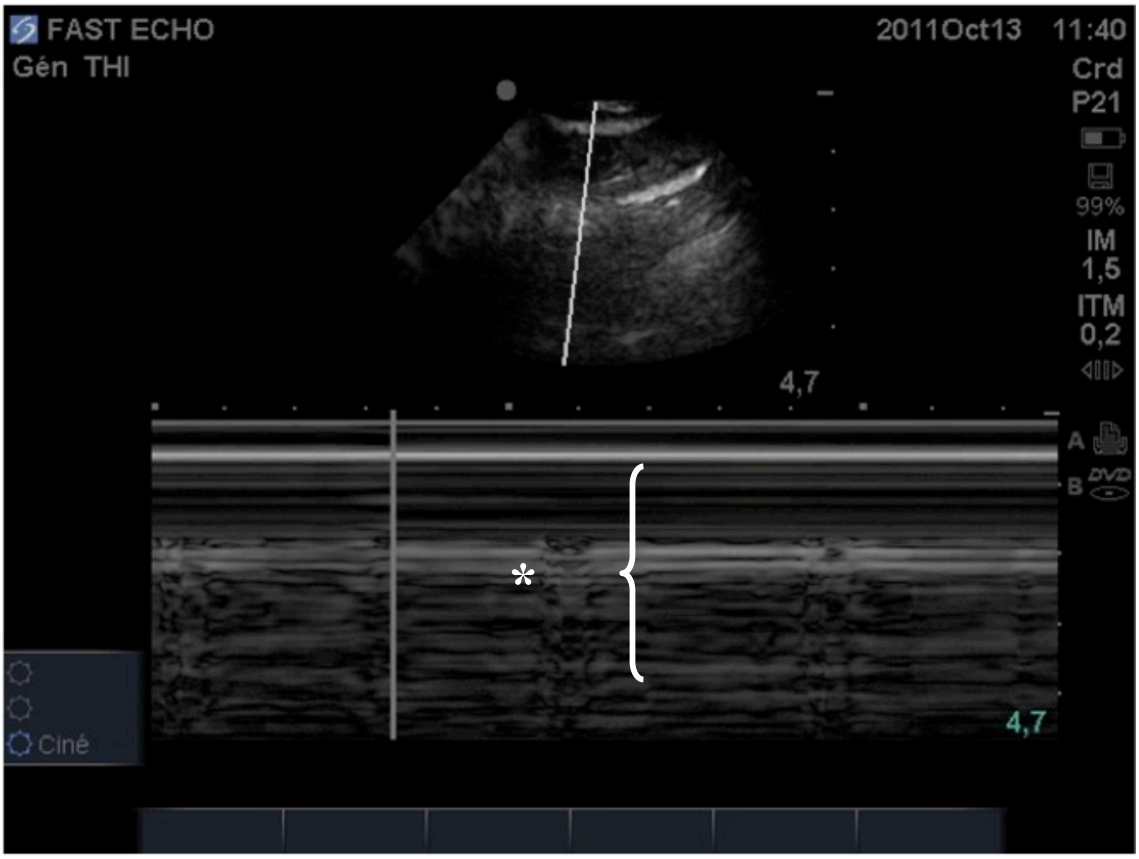


Figure 4 : aspect granité* du parenchyme en mode TM

2) Pneumothorax

Le pneumothorax est identifiable en échographie grâce à plusieurs signes :

_ **L'abolition du glissement pleural :** parfois visible en mode bidimensionnel, en mode TM la disparition du glissement car le poumon n'est plus à la paroi donne un aspect de "code-barre" (figure 5).

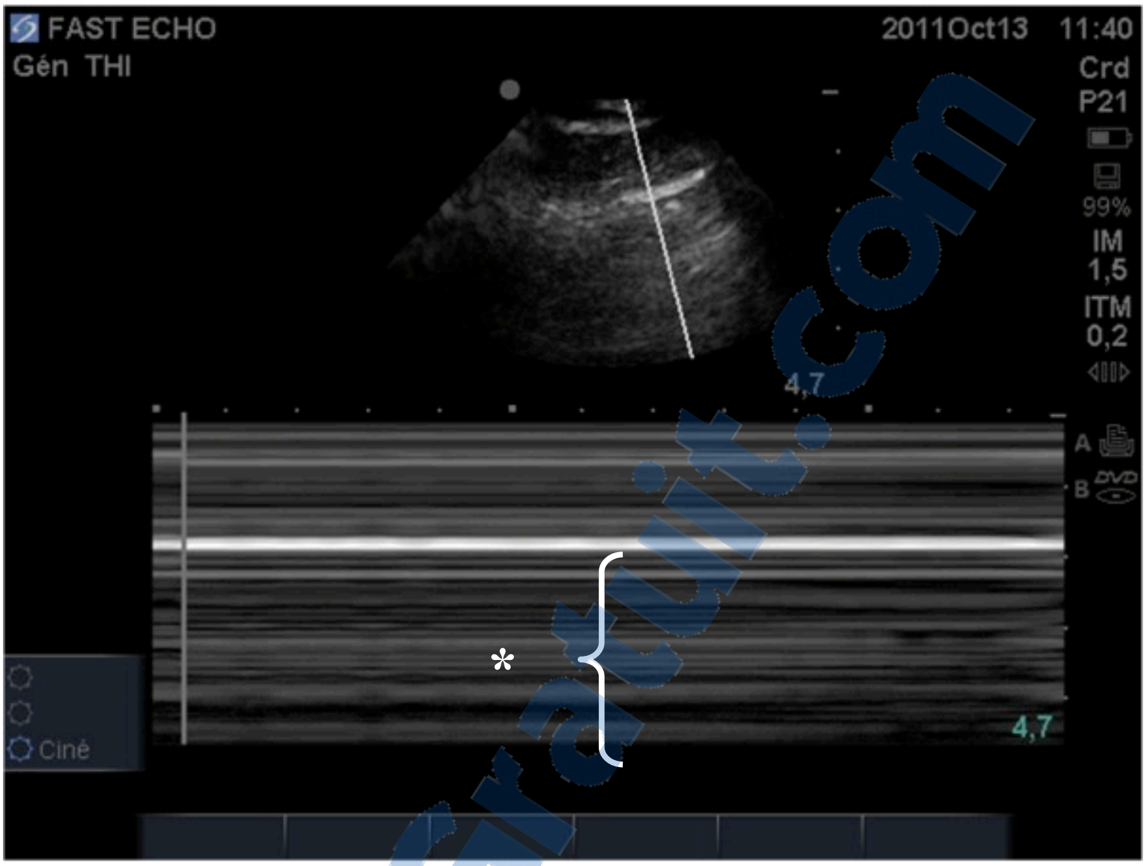


Figure 5: aspect de "code-barre"* en mode TM

_ **Présence des lignes A :** les lignes A sont des artefacts issus de la plèvre, elles sont donc présentes lors d'un pneumothorax.

_ **Absence de ligne B :** les lignes B sont d'origine parenchymateuse, donc absentes lors d'un pneumothorax. La moindre ligne B élimine un pneumothorax à cet endroit.

_ **Présence du point poumon :** il est dû à l'augmentation inspiratoire du volume pulmonaire, qui provoque un accolement temporaire du poumon à la paroi, avec une apparition concomitante de lignes B pouvant effacées les lignes A, et une disparition des lignes B et du glissement pleural à l'expiration (figure 6). Il est généralement absent lors de pneumothorax complet majeur, et présent devant des petits pneumothorax radio-occultes. Une évaluation semi quantitative de la taille du pneumothorax est possible en recherchant les points poumons au niveau de chaque espace intercostal.

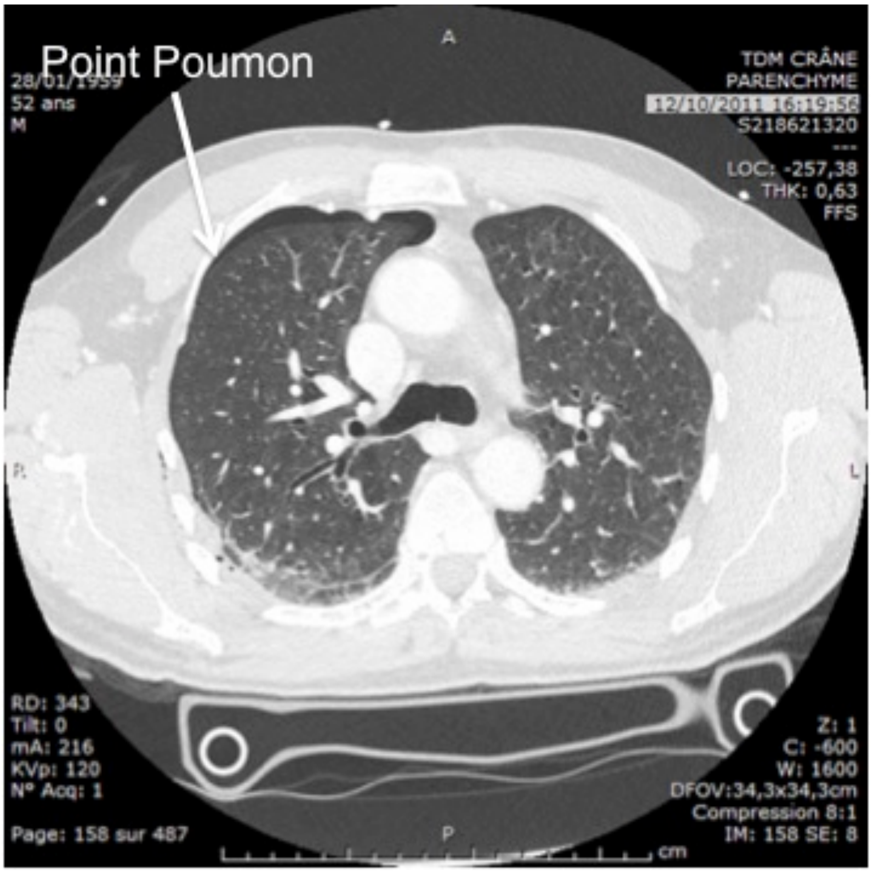


Figure 6 : Point poumon (flèches) à la TDM sur un pneumothorax antérieur

_ **L'absence de "pouls pleural" :** le pouls pleural représente la transmission des battements cardiaques au poumon lorsqu'il n'est pas ventilé (figure 7). Ce signe est absent lors d'un pneumothorax car le poumon n'est pas à la paroi. Par contre, il permet de faire le diagnostic différentiel lors d'une absence de ventilation d'un poumon à la paroi (atélectasie, bradypnée, intubation sélective).

L'échographie permet de guider un drainage pleural, d'évaluer l'efficacité du drainage ou la présence d'un pneumothorax résiduel.

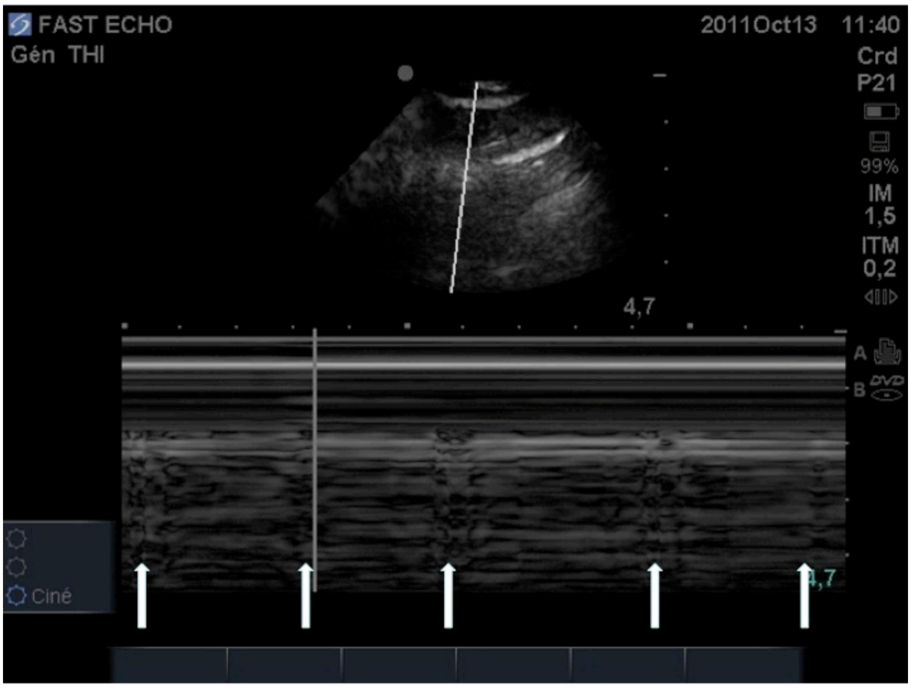


Figure 7: pouls pleural en mode TM (flèches blanches = battements cardiaques transmis)

3) **<u>Hémothorax</u>**

Les épanchements pleuraux liquidiens sont le plus souvent déclives et hypoéchogènes, parfois hétérogènes notamment certains hémothorax (figure 8). Les plus volumineux sont visualisés sur la zone latérale, ceux de faible abondance sont visualisés en postérieur au dessus de la coupole diaphragmatique.

L'analyse échographique est rarement prédictive d'un type d'épanchement, mais un aspect hétérogène et hyperéchogène peut faire évoquer un hémothorax en cours de constitution avec la visualisation d'un caillot frais.

L'échographie permet de plus la quantification des épanchements liquidiens, soit simplement à partir de la distance interpleurale maximum observée (figure 9), soit plus précisément en multipliant la hauteur totale de l'épanchement par son aire transversale (mesurée à mi hauteur de l'épanchement).
L'échographie peut enfin permettre de guider le drainage pleural en visualisant les différentes structures proches du point de ponction.

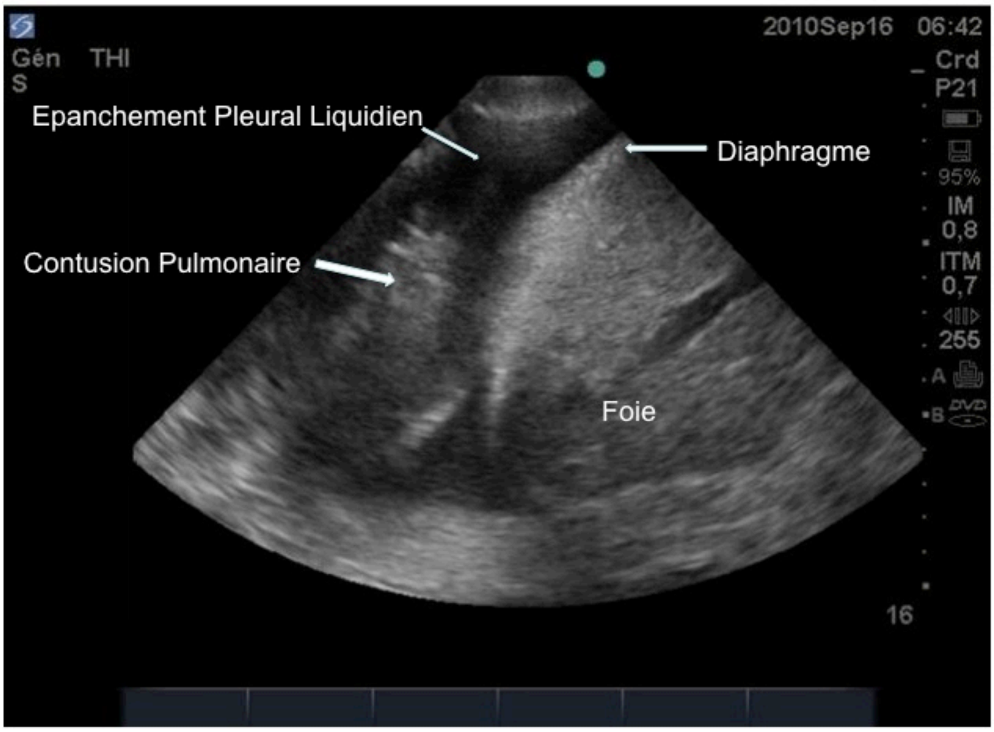


Figure 8 : Hémothorax et contusion pulmonaire

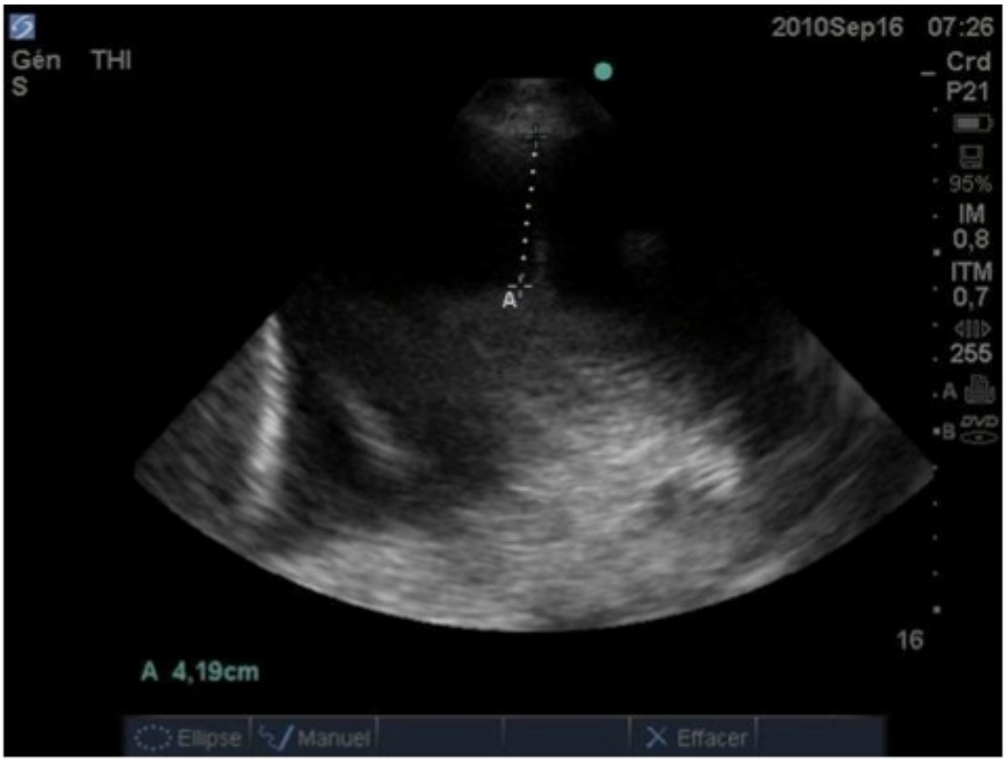


Figure 9: Hémothorax et mesure de la distance interpleurale (pointillés)

4) **Contusion pulmonaire**

A la phase initiale de la contusion pulmonaire, on trouve souvent un aspect de lignes B, explicable par la présence de sang dans les septas inter-alvéolaires et les alvéoles mais sans comblement alvéolaire (figure 10).

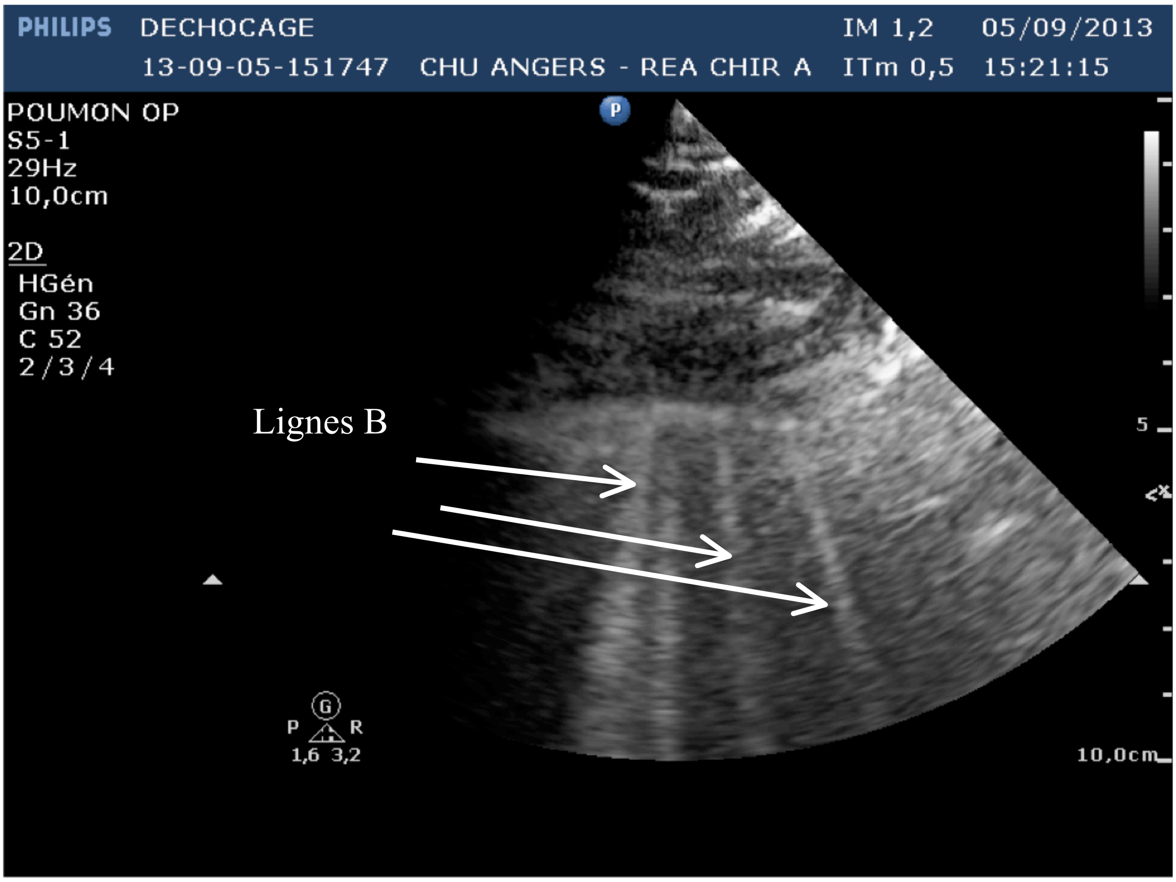


Figure 10 : Aspect de contusion pulmonaire récente avec lignes B (flèches)

Plus tardivement, le comblement alvéolaire par les contusions donne un aspect "hépatisé" ou "condensé" du parenchyme pulmonaire (figure 11).

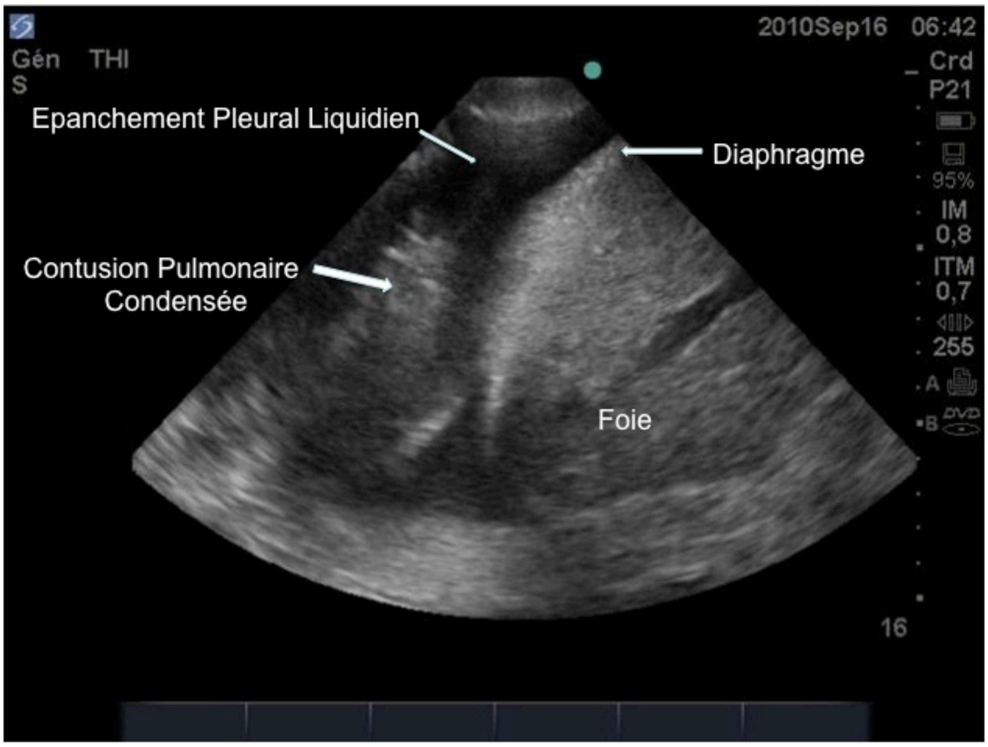


Figure 11 : Contusion Pulmonaire avec aspect « hépatisé » du poumon

Il est possible de trouver au centre des condensations pulmonaires un aspect de bronchogramme aérique (images punctiformes hyperéchogènes). Celui-ci est toujours statique lors d'une atélectasie, il peut être dynamique, c'est-à-dire rythmé par les mouvements respiratoires, au sein d'un foyer de pneumopathie ou de contusion pulmonaire.

Early Ultrasonography for Diagnosing Lung Injuries and Predicting the Occurrence of Acute Respiratory Distress Syndrome in Blunt Trauma Patients

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Abstract (296 words)

Background: Lung contusion is frequently encountered in blunt trauma patients, and its initial extent is associated with the development of subsequent acute respiratory distress syndrome (ARDS). However, measurement of lung contusions volume by computed tomography (CT) scan is not routinely performed, and is not achievable in case of circulatory failure. We tested the hypothesis that initial extent of lung contusion assessed by lung ultrasonography (LUS) could predict the onset of ARDS after blunt trauma.

Methods: We conducted a prospective observational study involving 45 patients admitted to emergency room for blunt trauma and undergoing thoracic CT scan. Each patient underwent clinical examination, chest radiography and LUS in supine position upon arrival at the hospital. The extent of lung contusions on admission was assessed by LUS with chest wall divided into 8 areas. The diagnostic accuracy of combined clinical examination and chest radiography was compared to that of LUS for common lung injuries (i.e. pneumothorax, lung contusion, and hemothorax), with the thoracic CT scan as reference exam. Outcomes included the occurrence of ARDS within the first 72 hours after injury, ventilator-free days by days 28, ICU length of stay, and hospital mortality.

Results: Lung contusion extent assessed by LUS well correlated with thoracic CT scan findings (Spearman coefficient, 0.82, $p<0.05$). The extent of lung contusion on admission assessed by LUS was predictive of the occurrence of severe ARDS within the 72 hours after trauma (AUC=0.87, [95% CI, 0.84-0.90], $p<0.05$). The detection of contusions by LUS in 3 or more areas out of 8 was the best threshold value for predicting the onset of severe ARDS with a sensitivity and specificity of 100%[95% CI; 51-100] and 72%[95% CI; 56-84]. The diagnostic accuracy of LUS was higher than that of combined clinical examination and chest radiography, as shown by their respective areas under the receiver operating characteristic curves (AUC-ROC): 0.81[95% CI, 0.50-1.00] vs 0.74 [0.48-1.00] ($p=0.24$) for pneumothorax, 0.88[0.75-1.00] vs 0.69[0.47-0.92] ($p<0.05$) for lung contusion, and 0.84[0.59-1.00] vs 0.73[0.51-0.94] ($p<0.05$) for hemothorax diagnoses.

Conclusions: LUS on admission identifies blunt trauma patients at risk to develop severe ARDS within the 72 hours after blunt trauma. As LUS is feasible at the bedside, it could allow starting early protective ventilation in patients at risk, even when thoracic CT scan is not achievable.

Key words: Lung Ultrasonography; Chest Trauma; Lung Contusion; Acute Respiratory Distress Syndrome

Introduction

Lung contusion is the most common intrathoracic lesion encountered in blunt trauma patients [1]. Moreover, lung contusion seems to play a key role in the development of subsequent acute respiratory distress syndrome (ARDS) and multiple organ failure [2]. This hypothesis is especially supported by CT scan studies, showing a link between the initial volume of lung contusions and the onset of ARDS [3-6]. However, CT scan measurement of the volume of lung contusions requires 3-dimensional modelling which is not routinely available. Furthermore, the initial phase of severe trauma may cause hemodynamic instability preventing the achievement of an early CT scan. In this context, lung ultrasonography (LUS) could be an attractive alternative, since it is feasible at the bedside and is accurate for diagnosing common lung injuries, including lung contusion [7]. In addition, one study showed a significant correlation between the extent of lung contusion evaluated by LUS and CT scan [8]. We therefore hypothesized that early assessment of lung contusion extent by LUS could predict the occurrence of subsequent ARDS in blunt trauma patients. In addition, we compared the performance of combined clinical examination and chest radiography with that of LUS for diagnosing pneumothorax, lung contusion and hemothorax on emergency room, with the thoracic CT scan as reference exam.

Materials and Methods

Patients

This prospective observational cohort study was conducted from May 2010 to July 2011 in the emergency room of the University Hospital of Angers level 1 trauma center. The Regional Institutional Ethics Committee approved the design of the study and waived requirement for informed consent from the patient (registration 2010/05).

Patients admitted to the emergency room for blunt trauma were enrolled in the study if at least one of the three operators trained on LUS (D.L., G.B. or S.H.) was present, and if thoracic CT scan was achievable. Blunt trauma was defined according to the mechanism of injury and clinical data obtained on admission. Demographic data, physiological parameters, and arterial blood gas measurements on admission were collected. Therapeutic decisions were left to the discretion of the physician in charge of the patient.

Clinical examination and chest radiography

Chest clinical examination (CE), including bilateral inspection, palpation, percussion, and auscultation was done on arrival at the emergency room by the in charge physician, with the patient in supine position. Chest radiography (CXR) was performed at the same time with an

AMX4 portable radiography system (General Electrics). According to the CE and CXR findings, the physician, was asked to write in a dedicated patient file the diagnosis probability of pneumothorax, lung contusion and hemothorax in each lung, using a 4-point scale: 0 = sure of the absence of a lesion, 1 = doubt about the absence of a lesion, 2 = probable presence of a lesion, and 3 = sure of the presence of a lesion.

Lung ultrasonography

LUS was performed immediately after the completion of CE and CXR, using M-Turbo echograph and a 5-1 MHz probe (Sonosite), by one of the three trained operators (D. L., G. B. or S.H.) blinded to the CE and CXR results. Chest wall was divided into 8 areas (figure 1). In each of these areas, sonographic signs of pneumothorax, lung contusion and hemothorax were investigated [9]. Pneumothorax was defined as the absence of lung sliding with A-lines, and by the presence of lung point. Lung contusion was diagnosed by the presence of the following: (1) an irregularly delineated tissue image, which could be a moderately hypoechoic blurred lesion with no change during respiration or hyperechoic punctiform images corresponding to air bronchogram; (2) multiple B-lines. Hemothorax was defined as a dependent collection between the diaphragm and the pleura with inspiratory movement of the visceral pleura from depth to superficies (sinusoid sign). The LUS operator recorded the diagnostic probability of each of these lesions using the same 4-point scale as for the CE+CXR. LUS results could be given to the physician in charge of the trauma patient if patient had abnormal vital signs and required immediate treatment.

Thoracic CT scan

Thoracic CT scan (Optima CT660, General Electrics) was performed from the apex of the chest to the diaphragm, with the patient in supine position. Thoracic CT scans were retrospectively interpreted by a radiologist (C. N.) blinded to the results of the previous investigations (i.e. CE + CXR and LUS). The time between admission on emergency room and thoracic CT scan was recorded. Patients who had a thoracic CT scan before being transferred to our hospital were included in the study if the delay between CT scan and admission was less than 210 minutes. In this situation, only the physician in charge of the patient knew the results of the previous CT scan. Other physicians blinded to these results performed CE + CXR interpretation and LUS. The size of pneumothorax on CT scan was classified as minuscule, anterior, or anterolateral, according to the classification described by Wolfman and colleagues [10]. Lung contusions location on CT scan was described as apical-medial, apical-lateral, medial-basal and/or lateral-basal in each lung. The size of hemothorax was measured based on the equation described by Hazlinger and colleagues [11].

Outcomes

The occurrence of ARDS and/or pneumonia within the first 96 hours after admission, the number of ventilator-free days (VFDs) by days 28, the ICU length of stay, and the in-hospital mortality were recorded. ARDS was defined according to the Berlin recommendations [12]. We defined 3 cumulative categories of ARDS: severe ($PaO_2/FiO_2 \leq$ 100 mmHg), severe to moderate ($PaO_2/FiO_2 \leq 200$ mmHg), and severe to mild ($PaO_2/FiO_2 \leq$ 300 mmHg). Pneumonia was diagnosed as positive bronchoalveolar lavage culture (i.e. BAL culture $\geq 10^4$ colony-forming units per milliliter).

Statistical Analysis

Categorical variables were expressed as frequency and percentage, continuous data were presented as mean and standard deviation or median and interquartile range as appropriate. LUS was compared to thoracic CT scan for assessing lung contusion extent using Spearman rank correlation analysis. Correlation was considered clinically relevant when the correlation coefficient was 0.8 or greater. The link between initial ultrasound extent of lung contusion and the development of ARDS within the 72 hours after admission was tested using area under the receiver operating characteristic curves (AUC-ROC). The Youden index was used to calculate the best threshold value of areas with contusion on initial LUS for predicting ARDS onset.

The diagnostic accuracy of CE + CXR was compared to that of LUS for pneumothorax, lung contusion and hemothorax, using CT scan as the reference exam, and was expressed as sensitivity, specificity, likelihood ratios, and AUC-ROC Demographic data, injury mechanisms, physiological parameters, and arterial blood gas measurements on admission were collected.. The independence between right and left chest walls in the occurrence of each thoracic lesion was tested using Chi2 test.

Statistical analysis was performed using Xlstat 2012 (Addinsoft). P values for overall tests of difference are from Chi2 analysis or Fisher test for categorical variables and Student's *t* test or Mann and Whitney test for continuous variables. Statistical significance was declared when $p < 0,05$.

Results

Patients

During the study period, 219 patients were admitted to our emergency room for blunt trauma. Among them, 50 patients had both a LUS performed on admission by one of the three operators trained in LUS and a thoracic CT scan. Five patients were not included: 1 was under 15 years old, and 4 were transferred from another hospital with a CT scan performed more than 210 minutes before their admission to our emergency room. Figure 2 depicts the flow chart of the study. Table 1 shows the overall characteristics of the 45 patients included. The median [IQR] of the abbreviated injury scale (AIS) for chest was 4[3-4]. Nearly half of the patients required mechanical ventilation at admission. LUS was successfully performed in all patients in less than 10 minutes. The median [IQR] delay from admission to thoracic CT scan was 39[27-67] min.

Diagnostic accuracies

Among the 90 lungs examined, CT scan revealed 30 pneumothorax, 60 lung contusions, and 25 hemothorax. The occurrence of these lesions was similar between the two lungs (17 vs 13 pneumothorax for respectively right and left lungs, p=0,37; 30 vs 30 lung contusions, p=1; 11 vs 14 hemothorax, p=0,48). The diagnostic accuracy of LUS was good, and superior to that of CE + CXR for each of the lesions evaluated. Table 2 and figure 3 show the sensitivity, specificity, likelihood ratios, and AUC-ROC curves of CE + CXR and LUS for each type of lesion.

Initial extent of lung contusions and prediction of ARDS

The extent of lung contusion assessed by LUS on admission was well correlated with thoracic CT scan findings, as shown by the Spearman's coefficient (0.82, $p<0.01$). Among the 41 patients alive at 48 hours, 19 (46%) developed an ARDS within the first 72 hours after trauma. Five (26%) were severe ARDS, 9 (48%) moderate, and 5 (26%) mild. The detection of lung contusions by LUS on 3 areas or more out of 8 was identified as the best threshold value for predicting severe ARDS (sensitivity 100%[95% CI; 51-100], specificity 72%[95% CI; 56-84], AUC=0.87%[95% CI; 0.84-0.90], $p<0.05$). The predictive value of this threshold was lower for severe to moderate ARDS (sensitivity 71%[95% CI; 45-88], specificity 82%[95% CI; 63-92], AUC=0.77 [95% CI; 0.71-0.83], $p<0.05$) and severe to mild ARDS (sensitivity 63%[41-81], specificity 86%[66-96], AUC=0.79%[95% CI; 0.71-0.87], $p<0.05$). These results are reported on figure 4.

Main outcomes

Overall mortality was 18% (Table 1). The mean PaO_2/FiO_2 ratios and the mean tidal volumes on admission were not significantly different between the patients who developed ARDS secondarily and the others (Table 3). Patients with ARDS presented longer duration of mechanical ventilation, longer length of ICU stay, and higher mortality.

Discussion

Lung contusion is the most frequently encountered intrathoracic injury in blunt trauma patients, and is associated with significant morbidity and mortality [1]. Direct damage of the lung tissue causes both local and systemic inflammatory responses that can lead to ARDS and multiple organ failure [2, 13]. The initial size of the lung contusion seems to play a key role in these mechanisms. Indeed, several studies have shown that initial lung contusion volume was predictive of the development of subsequent ARDS or pneumonia [3-6]. Interestingly, Ciesla and colleagues showed a decrease in the incidence of post-traumatic ARDS in a recent decade, probably due in part to the use of protective ventilation [14]. It can therefore be assumed that identification upon admission of patients with extensive lung contusions could allow early intervention as protective ventilation, and thereby affect their prognosis.

As standard chest radiography underestimates the lung contusions in the initial phase of trauma [8, 15], thoracic CT scan has become the reference exam for measuring lung contusion extent [3-6]. However, lung contusion volume measurement by CT scan require specific computer-based algorithm allowing 3-dimensionnal modelling that is not routinely available in emergency setting. Furthermore, severe trauma frequently causes circulatory failure in the initial phase that prevents the achievement of an early CT scan. In this context, LUS appears to be an attractive alternative, since it is feasible at the bedside with a good accuracy for diagnosing lung contusion [7, 8, 15]. However, the ability of LUS to assess the extent of lung contusion has been poorly studied until now. To our knowledge, only the study by Rocco and colleagues addressed this issue on a small cohort [8]. They found a good correlation between LUS and thoracic CT scan for the initial extent of lung contusion, but did not assess its prognostic value.

The present study confirms that LUS is able to accurately diagnose and assess the extent of lung contusion, with a performance superior to that of CE combined to CXR. Furthermore, to our knowledge, this is the first study showing that LUS at the initial phase of trauma can predict the occurrence of subsequent ARDS.

The diagnostic accuracy of LUS was superior to that of CE combined to CXR for the three diagnoses we evaluated. These results are consistent with several previous studies [7, 8, 15-19]. The best diagnostic performance of LUS we observed concerned lung contusion. The assessment of its extent by LUS well correlated with the CT scan findings, which confirms the results of Rocco and colleagues [8]. However, we found a poor sensitivity of LUS for the diagnosis of pneumothorax and hemothorax in comparison with some of these studies [8, 16-19]. A first explanation of these results could be the high incidence of very small lesions in our study. Indeed, 14 pneumothorax out of 26 (33%) were classified as "minuscule" and 10 hemothorax out of 19 (53%) were measured at less than 100 ml by the CT scan. Another explanation could be that we examined three types of lung injuries simultaneously, making the diagnosis more difficult for each. Among the 73 injured lungs assessed in our study, 30 (41%) presented two or three combined lesions. In contrast, most studies on LUS in trauma had examined a lesion at a time [15-19]. Rocco and colleagues examined both lung contusion and hemothorax, but did not specify the size of hemothorax [8]. Interestingly, the only study on LUS to have before we evaluated three lung injuries at the same time has found like us poor sensitivities for pneumothorax and hemothorax diagnosis, respectively 53% and 37% [7]. Finally, it should be noted that all the pneumothorax and hemothorax requiring chest drainage in our study were diagnosed by LUS. Thus, the information provided by LUS seems sufficient to support appropriate therapeutic decisions, as previously described [16-19].

We found a best cut off value of 3 or more areas out of 8 with lung contusion on LUS as predictive of severe ARDS. This result is consistent with the thresholds found in studies using thoracic CT scan as diagnostic tool, ranging from 20% to 24% of the total lung volume [3-6]. However, our prediction threshold has not reached significance, although it is very close, for severe to moderate and severe to mild ARDS. Concretely, when lung contusion was found by LUS on 3 or more areas out of 8, ARDS occurred 77% of the time within the 72 hours. Furthermore, patients developing ARDS experienced longer duration of mechanical ventilation and ICU stay, and above all higher mortality.

In our view, these results could have two important implications. First, lung contusion extent should be assessed routinely in the initial phase of blunt trauma, as part of the "Extended Focused Assessment with Sonography for Trauma" (EFAST) [20, 21]. The development of web-based assessment tools for the EFAST should help in this way [22, 23]. Second, since it is possible identify on admission blunt trauma patients at risk for ARDS, the impact of an early intervention as protective ventilation in these patients needs to be assessed. Indeed, the retrospective study by Ciesla and colleagues had already suggested that protective ventilation could contribute to the reduction of posttraumatic ARDS [2]. In addition, recent data supports the generalization of this strategy prophylactically to almost all mechanical ventilated patients in intensive care [24].

Conclusion

LUS is accurate for diagnosing common lung injuries, and assessing lung contusion extent. Its diagnostic accuracy is higher than that of CE combined to CXR. Furthermore, LUS allows early identification at the bedside of blunt trauma patients at risk for developing severe ARDS within the 72 hours after injury. These results argue for systematic assessment of lung contusion extent by LUS in the initial phase of blunt trauma, as part of the EFAST. The interest of early protective ventilation to prevent the onset of subsequent ARDS in blunt trauma patients at risk needs to be assessed.

Funding/Support

All authors are full time employees of their institution and did not receive any extra financial retribution to perform the present study. Academic resources from our department and institution without any additional grant have supported it.

Conflicts of interest statement

None

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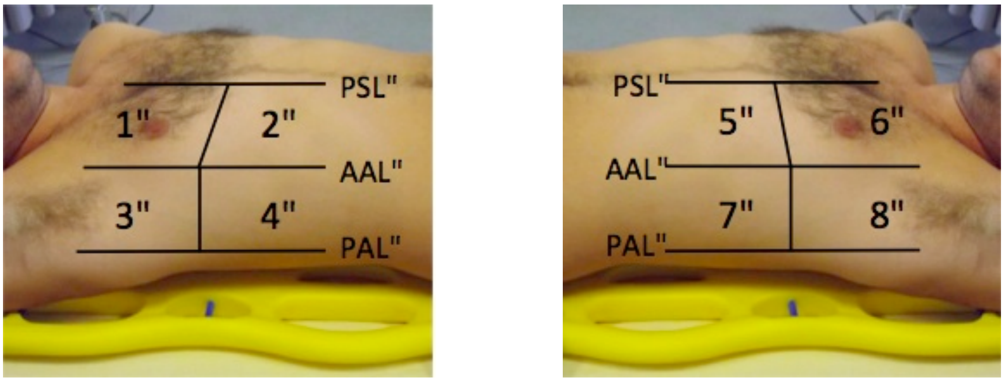
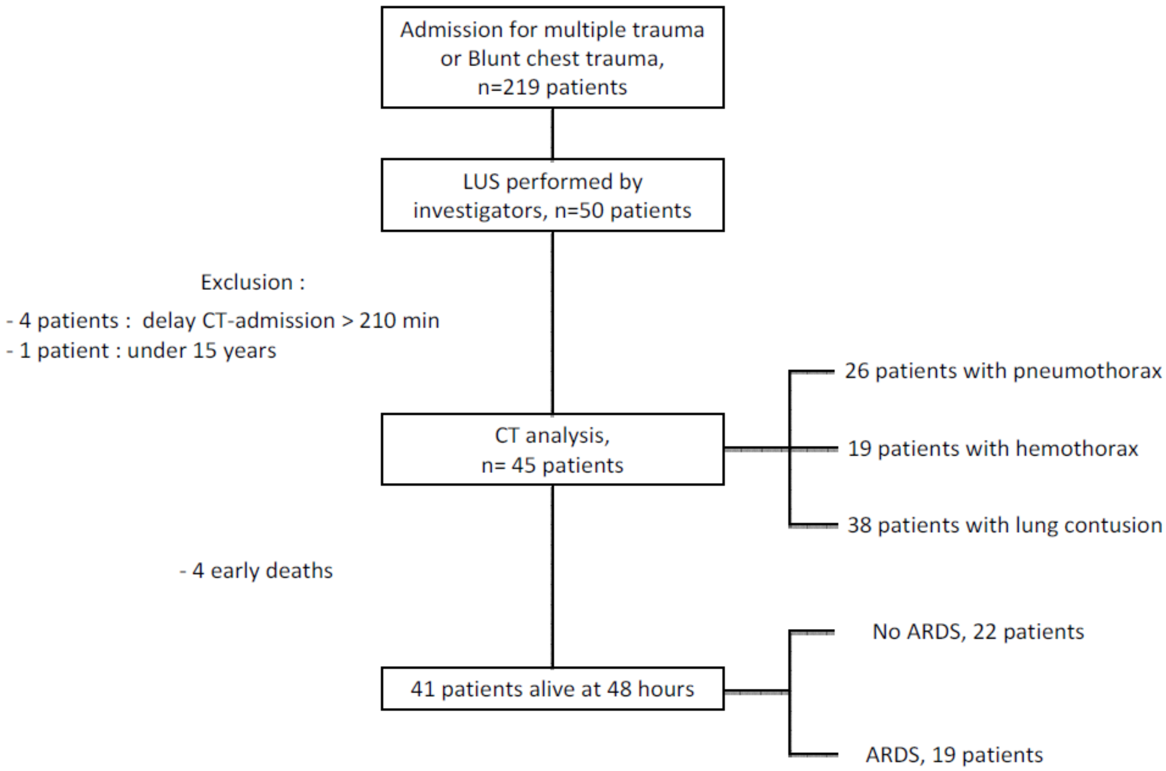
Annexes

Figure 1 - Areas Evaluated by Lung Ultrasonography on Emergency Room



Areas from 1 to 4 on right wall chest and 5 to 8 on left wall chest. PSL, Parasternal Line; AAL, Anterior Axillary Line; PAL, Posterior Axillary Line.

Figure 2 - Flow Chart of the Study



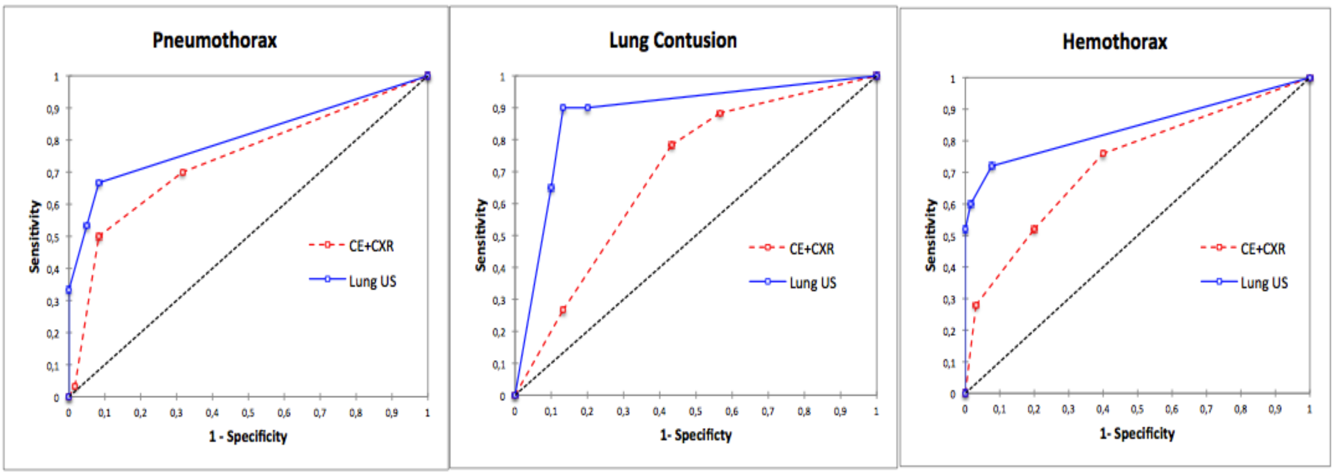
LUS : Lung ultrasonography, CT : Computed tomography, ARDS : Acute respiratory distress syndrome

Table 1 – Overall Patient Characteristics

Patients characteristic	Value (n=45)
Demographics	
Age, years (mean ± SD)	35 ± 16
Male, n (%)	32 (71)
Distribution of injuries	
Head trauma, n (%)	18 (40)
Chest trauma, n (%)	40 (89)
Abdominal trauma, n (%)	21 (47)
Spinal fractures, n (%)	13 (29)
Extremity bone fractures, n (%)	16 (36)
Physiologic parameters on admission	
SBP, mmHg (mean ± SD)	122 ± 30
Heart rate, beats/min (mean ± SD)	93 ± 25
Lactates, mmol/L (mean ± SD)	2,3 ± 1,3
Injury severity measures on admission	
GCS (mean ± SD)	11 ± 4
ISS (median; IQR)	34; 25-48
AIS, chest (median; IQR)	4; 3-4
Patients requiring catecholamines, n (%)	11 (24)
Patients requiring blood transfusions, n (%)	21 (47)
Patients requiring mechanical ventilation, n (%)	22 (49)
Outcomes	
Ventilator-free days by days 28, days (mean ± SD)	21 ± 7
Length of ICU stay, days (median; IQR)	2,5; 1-8,5
Patients developing ARDS, n (%)	20 (44)
Severe, n	5
Moderate, n	10
Mild, n	5
Mortality, n (%)	8 (18)

SBP, systolic blood pressure; ISS, injury severity score; AIS abbreviated injury scale; ICU intensive care unit; ARDS acute respiratory distress syndrome.

Figure 3 - AUC-ROC Curves of Each Diagnostic Method for Common Lung Injuries



AUC-ROC, area under the receiver operating characteristic curve; CE, clinical examination; CXR, chest radiograph; LUS, lung ultrasonography.

Table 2 - Sensitivity, Specificity, Likelihood Ratios and AUC-ROC of Each Diagnostic Method

	CE + CXR	Lung US
Pneumothorax (n=30)		
Sensitivity, %	50	53
Specificity, %	92	95
Positive likelihood ratio	6,0	10,7
Negative likelihood ratio	0,5	0,5
AUC-ROC, mean, 95% CI	0,74 (0,48-1)	0,81 (0,50-1)
Lung Contusion (n=60)		
Sensitivity, %	78	90
Specificity, %	57	87
Positive likelihood ratio	1,8	6,8
Negative likelihood ratio	0,4	0,1
AUC-ROC, mean, 95% CI	0,69 (0,47-0,92)	0,88 (0,76-1)
Hemothorax (n=25)		
Sensitivity, %	52	60
Specificity, %	80	99
Positive likelihood ratio	2,6	39,0
Negative likelihood ratio	0,6	0,4
AUC-ROC, mean, 95% CI	0,73 (0,51-0,94)	0,84 (0,59-1)

AUC-ROC = area under the receiver operating characteristic curve; CE=clinical examination; CXR= chest radiograph.

Figure 4 - Correlation Between Lung Contusion at Initial LUS and ARDS Within the 72 Hours

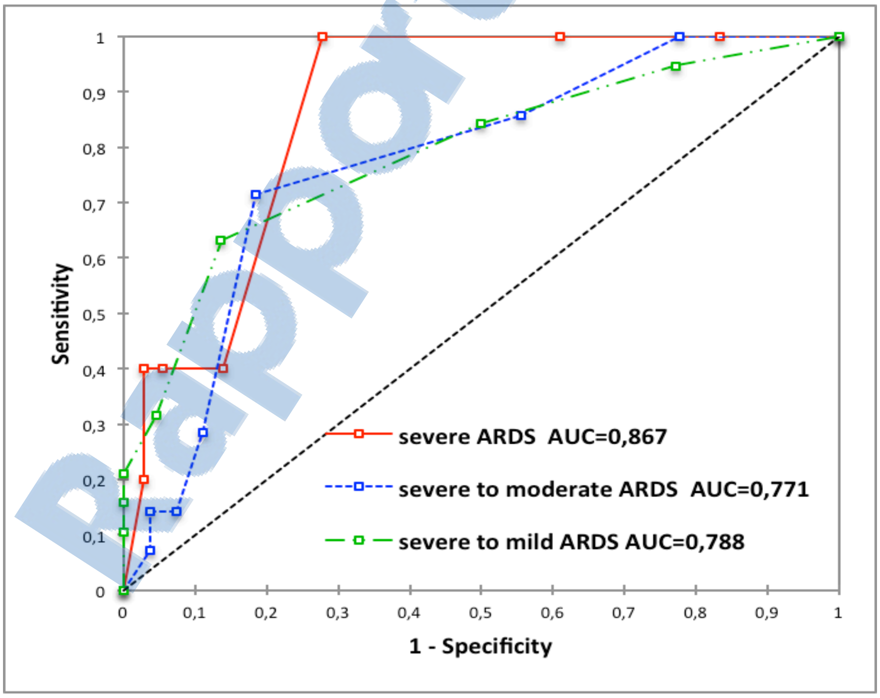


Table 3 – Patient Characteristics and Outcomes by ARDS Status

	ARDS (n=19)	No ARDS (n=22)	*p*
Demographics			
Age (mean ± SD)	36 ± 18	34 ± 14	0,58
Men, n (%)	13 (68)	16 (73)	0,97
Distribution of injuries			
Head trauma, n (%)	11 (58)	4 (18)	**0,01**
Chest trauma, n (%)	16 (84)	20 (91)	0,65
Abdominal trauma, n (%)	7 (39%)	13 (52%)	0,40
Spinal Fractures, n (%)	6 (32)	6 (27)	0,97
Long bone fractures, n (%)	6 (32)	5 (23)	0,78
Injury severity measures			
Glasgow come scale (mean ± SD)	10 ± 5	14 ± 2	**< 0,01**
ISS (median; IQR)	45; 35-54	25; 22-32	**< 0,01**
AIS, chest (median; IQR)	4; 3-5	3; 2-3	**< 0,01**
Catecholamine on admission, n (%)	9 (47)	0 (0)	**<0,01**
Total loading at H24, ml (mean ± SD)	5944 ± 2678	2961 ± 1509	**< 0,01**
Patients requiring blood transfusion at H24, n (%)	15 (79)	3 (14)	**< 0,01**
Physiologic parameters on admission			
SBP, mmHg (mean ± SD)	118 ± 36	130 ± 20	0,17
Heart rate, beats/min (mean ± SD)	103 ± 26	85 ± 18	**0,02**
Lactates, mmol/l (mean ± SD)	2,5 ± 1,5	1,9 ± 1,1	0,19
PaO_2/FiO_2, mmHg (mean ± SD)	261 ± 141	364 ± 110	0,34
$PaCO_2$, mmHg (mean ± SD)	49 ± 12	41 ± 6	**0,02**
Pulmonary status and outcomes			
Mechanical ventilation on admission, n (%)	16 (84)	2 (9)	**< 0,01**
Tidal Volume, ml/kg (mean ± SD)	7,5 ± 1,1	7,7 ± 0,1	0,82
Areas with contusion on LUS, n (median; IQR)	3 (2-4)	1,5 (1-2)	**< 0,01**
Mechanical ventilation in ICU, n (%)	19 (100)	6 (14)	**< 0,01**
Tidal Volume, ml/kg (mean ± SD)	7,0 ± 1,5	7,7 ± 1,4	0,37
Ventilator-free days by days 28, days (median; IQR)	15 (8-22)	28 (27-28)	**< 0,01**
Patient outcomes			
Length of total ICU stay, days (median; IQR)	13; 5-17	1; 1-2	**<0,01**
Mortality, n (%)	4 (21)	0 (0)	**0,04**

ISS, injury severity score; AIS, abbreviated injury scale; SBP, systolic blood pressure; LUS, lung ultrasonography; ICU intensive care unit.

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L'ECHOGRAPHIE PULMONAIRE PRECOCE PERMET LE DIAGNOSTIC DES LESIONS PULMONAIRES ET PREDIT LA SURVENUE DU SYNDROME DE DETRESSE RESPIRATOIRE AIGUE CHEZ LES PATIENTS POLYTRAUMATISES

RESUME

Introduction: L'échographie a montré son intérêt dans la prise en charge initiale des polytraumatisés instables. L'échographie pulmonaire (EPulm) se développe en réanimation, mais n'a pas été évaluée à l'accueil des polytraumatisés. Le volume de contusion pulmonaire initiale (au TDM) est prédictif de la survenue d'un SDRA. Le but de cette étude est d'évaluer la performance diagnostic de l'EPulm dans ce contexte, et sa capacité à prédire la survenue d'un SDRA.

Matériel et Méthodes: Etude prospective, observationnelle. Tous les polytraumatisés graves admis au déchoquage bénéficiaient d'une EPulm en aveugle des examens de radiologie. Les performances diagnostiques de l'EPulm étaient comparaient à l'examen clinique et la radiographie thoracique (EC+RT) pour chaque lésions (Hémothorax (HT), Pneumothorax (PTX) et Contusion Pulmonaire (CP), en prenant le résultat du TDM comme référence. La valeur prédictive de la présence de CP à l'EPulm pour la survenue d'un SDRA à 48h était recherchée.

Résultats: 45 patients ont été inclus. On retrouvait 25 HT, 30 PTX et 60 CP. L'EPulm avait une meilleure valeur diagnostic que la EC+RT pour chacune de ces lésions (aires sous la courbe : 0,84[0,59-1] vs 0,73[0.51-0,94] pour HT ; 0,81[IC95, 0,50-1] vs 0,74 [0,48-1] pour PTX et 0,88[0,75-1] vs 0,69[0,47-0,92] pour CP, p<0,05). La présence d'au moins 3 zones de CP (sur 8 examinées) était prédictive de la survenue de SDRA (sensibilité 63%; spécificité 86%, ASC=0,79), quelque soit la sévérité du SDRA.

Discussion: L'Epulm permet de prédire la survenue d'un SDRA précoce. Elle est plus performante que la EC+RT pour le diagnostic des lésions traumatiques du thorax de polytraumatisés sévères.

MOTS-CLES

Echographie pulmonaire	Polytraumatisme
Traumatisme thoracique	SDRA
Syndrome de détresse respiratoire aiguë	Contusion pulmonaire

FORMAT

☐ **Mémoire**
☒ **Article**[1] : ☒ à soumettre ☐ soumis ☐ accepté pour publication ☐ publié

suivi par : LASOCKI Sigismond

[1] statut au moment de la soutenance