



Sonographic patterns of lung consolidation in mechanically ventilated patients with and without ventilator-associated pneumonia: A prospective cohort study ☆,☆☆



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ABSTRACT

Purpose: Thoracic ultrasound (TUS) has been successfully used in the diagnosis of community-acquired pneumonia. Little is known about its diagnostic potential in ventilator-associated pneumonia (VAP). The purpose of this study was to systematically describe the morphology and temporal changes of sonographic patterns in mechanically ventilated patients and to evaluate the diagnostic performance characteristics of TUS-based VAP diagnoses. **Materials and methods:** Patients who were placed on invasive ventilation for reasons other than pneumonia and who were considered at risk for the development of VAP received daily TUS examinations while being closely monitored for the development of pneumonia.

Results: Fifty-seven patients were studied. The incidence of VAP was 21.1%. Sonographic patterns of reduced or absent lung aeration were found in 64.2% of examinations. The sonographic pattern of lung consolidation with either dynamic or static air bronchograms was 100% sensitive and 60% specific for VAP in those patients who developed clinical signs and symptoms compatible with pneumonia. The pretest and posttest probabilities were 0.38 and 0.6, respectively.

Conclusions: Sonographic patterns of abnormal aeration are frequently observed in mechanically ventilated patients. If sonographic lung consolidation with either static or dynamic air bronchograms is absent, VAP is highly unlikely. The presence of these sonographic patterns in patients with signs and symptoms suggestive of pneumonia significantly increases the probability of VAP.

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1. Introduction

Ventilator-associated pneumonia (VAP) is a frequent problem in intensive care medicine. It is estimated that approximately 10% to 20% of patients requiring mechanical ventilation acquire VAP [1]. Different definitions of VAP have been proposed: the American Thoracic Society defines VAP as a “pneumonia that arises more than 48–72 hours after endotracheal intubation” [2], whereas the Center for Disease Control

(CDC) definition includes patients who develop pneumonia within the 48-hour period of the placement of an artificial airway [3].

A set of criteria proposed by the CDC is widely used for the diagnosis of VAP. It incorporates the following features: signs and symptoms of inflammation and worsening pulmonary function and radiographic changes [3]. Shortcomings of the CDC criteria and indeed of any proposed alternative set of diagnostic criteria originate from the requirement to strike a balance between diagnostic sensitivity and specificity [4,5].

Any type of pneumonia causes lung consolidation; hence, radiographic changes are intrinsic to most diagnostic VAP algorithms [6]. Computed tomography (CT) offers the highest diagnostic accuracy for the detection of lung consolidation [7]. However, it cannot be routinely used in critically ill patients for reasons of logistics, economics, and radiation exposure [8]. The use of chest x-ray (CXR) has been extensively studied; it lacks both diagnostic accuracy and reliability, particularly if performed as a portable examination on a supine patient [9]. The introduction of supplemental imaging methods or the development of alternative imaging strategies for the diagnosis of pneumonia are eagerly awaited [7]. Thoracic ultrasound (TUS) has been successfully used in the diagnostic workup of patients with suspected community-acquired pneumonia. High sensitivities but variable specificities were

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☆☆ Author contributions: TB conceived and designed the study; contributed to the acquisition, analysis, and interpretation of the data and drafting of the manuscript; and takes responsibility for the integrity of the data and the accuracy of the data analysis. RE, TF, and DB contributed to the acquisition, analysis, and interpretation of the data; drafting of the manuscript; and critical revisions for important intellectual content. PS and TM contributed to the study conception; acquisition, analysis, and interpretation of the data; drafting of the manuscript; and critical revisions for important intellectual content. All authors read and approved the final manuscript.

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reported [10–13]. A small number of comparative studies were conducted in critically ill patients with confirmed consolidations by various aetiologies; these showed a high prevalence of sonographic features of lung consolidation and high agreement with the results of the CT [14–16]. As of yet, no reports on the use of TUS in the de novo diagnosis of VAP have been published [17].

If the favorable experience gained for the use of TUS in the diagnosis of community-acquired pneumonia could be replicated in the setting of VAP, an efficient diagnostic tool would become available to clinicians. However, TUS is much more challenging in mechanically ventilated patients than in other patient cohorts: supine position limits access, and the patients are often unable to cooperate. In addition, other conditions that reduce lung aeration, such as elevated diaphragms and atelectasis, may be present.

We, therefore, decided to prospectively evaluate sequential TUS in mechanically ventilated patients with the objectives to (a) systematically describe the morphology and temporal changes of sonographic

patterns in the course of critically ill patients without pneumonia, (b) study the sonographic features of VAP, and (c) evaluate the diagnostic performance of TUS-based VAP diagnoses.

2. Materials and methods

This was a prospective observational cohort study with convenience sampling, based on investigator availability in the multidisciplinary adult intensive care unit (ICU) of the Bern University Hospital (Inselspital). We included patients who were placed on invasive ventilation for reasons other than pneumonia. They were considered at risk for the development of VAP. Patient eligibility, recruitment, and inclusion and exclusion criteria are presented in Fig. 1. Patient management was not affected by inclusion in this study or modified by the results of the TUS examinations.

The study was performed from November 2012 to December 2013. It was approved by the responsible ethics committee (Kantonale

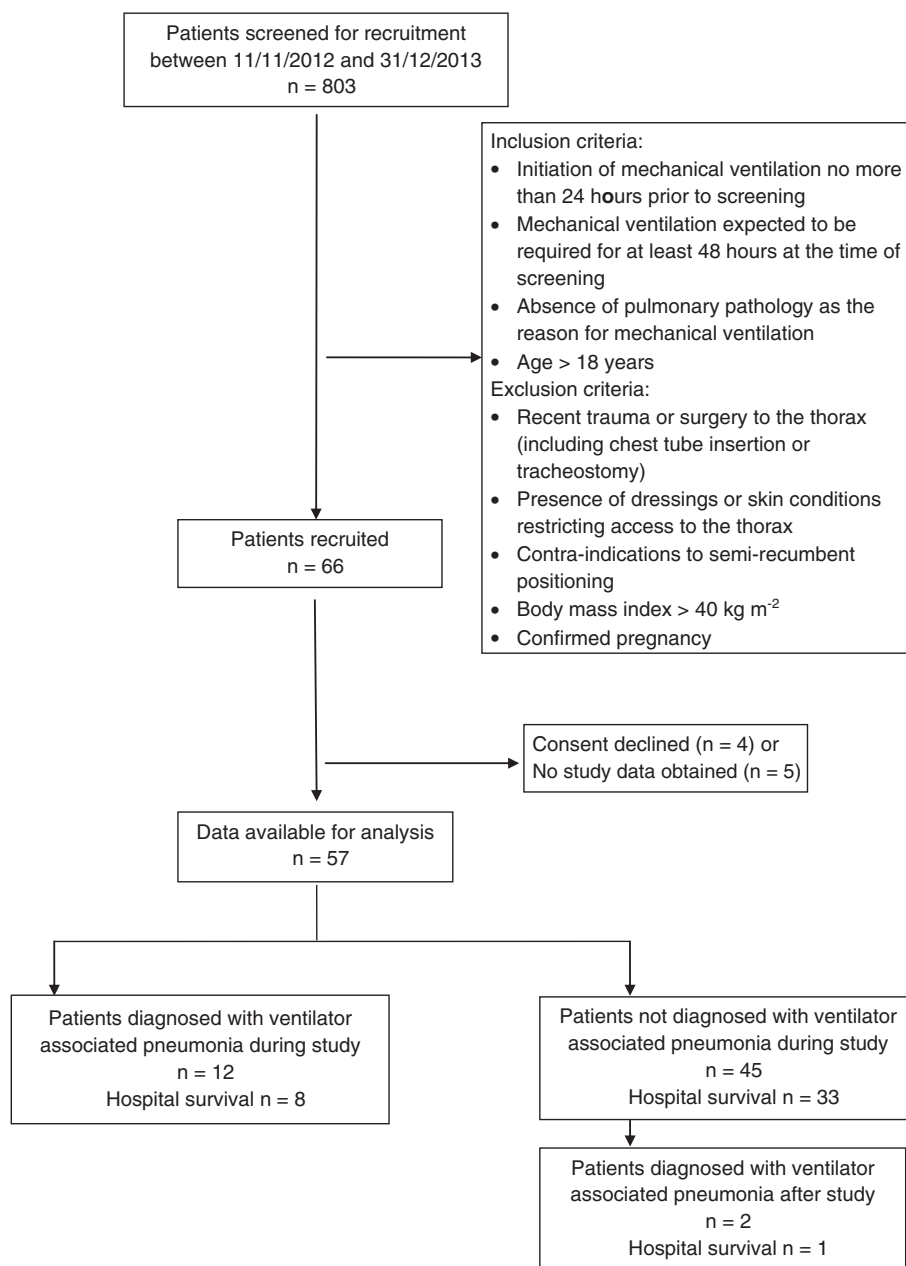


Fig. 1. Flow chart: patient screening, study inclusion, and outcomes.

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