Tittle Page POCUS versus chest X-ray in high frequency oscillatory ventilation

Ozlem Sahin[1], Derya Colak[1], Sevinc Kalin[1], Funda Yavanoglu Atay[1], Omer Guran[1], and Ilke Mungan Akin[1]

[1]Umraniye Egitim Ve Arastirma Hastanesi

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Abstract

Introduction: The most prevalent method for evaluating lung expansion in high-frequency oscillatory ventilation (HFOV) is chest X-ray (CXR). The purpose of this study was to compare the accuracy of chest radiography with point-of-care ultrasound (POCUS) in determining lung expansion. **Methods:** This prospective study included newborns who required HFOV and were being monitored in the Neonatal Intensive Care Unit. A single neonatologist assessed lung expansion with a chest x-ray and POCUS, to measure the costal level of the right hemidiaphragm and compare the results. **Results:** A neonatologist took 55 measurements on 28 newborns with a gestational age of 32 (23.2-39.4) weeks who were followed on HFOV. The rib counts obtained from anterior chest ultrasonography and posterior CXR showed a statistically high concordance ($p<0.05$). **Conclusions:** Lung ultrasonography is a reliable method in the evaluation of lung expansion in patients followed on HFOV.

Introduction

High-frequency oscillatory ventilation (HFOV) is a lung-sparing strategy that is frequently applied as a rescue therapy in neonates when conventional mechanical ventilation methods fail, and its use in neonatal units has increased over the past years. It prevents the traumatic 'inflation-deflation' cycle generated by conventional ventilation by maintaining a low tidal volume and constant mean airway pressure [1]. Although it works by reducing excessive tension in the alveoli with very small tidal volumes, providing optimal lung volume is important for effective HFOV[2]. The inability to reliably measure changes in lung volume at the point of care is one of the most significant barriers to optimize lung volume during HFOV in newborns[3]. Although numerous approaches for determining appropriate lung capacity in HFOV have been tried, they have not yet been widely used due to practical constraints[4-7]. Although the simpler method of CXR has limitations, lung expansion can be measured to a certain extent.

The purpose of this study was to compare the results of POCUS with CXR to limit radiation exposure while being fast and more practical in the neonatal intensive care unit (NICU).

Materials and Methods

This prospective observational study was conducted between January 2022 and December 2022 in a 61-bed NICU. The ethical approval was obtained from the ethics board of the hospital. The written informed consent was obtained from the parents of each participant before lung USG.

Newborns who were hospitalized in the NICU during the study period and treated with HFOV for any cause (as primary or rescue therapy) and for whom parental consent was obtained were included in the study. The study did not include those without parental consent and those with chest deformities, congenital lung malformation, or diaphragmatic pathology. Weeks of gestation, birth weights, and postnatal ages of the patients were recorded.

The patients were followed on HFOV using Leoni Plus devices (Courtesy of Löwenstein Medical Technology, Bad Ems, Germany). Generally CXR is obtained to assess lung aeration after mechanical ventilator adjustments in accordance with procedures.

Lung USG was performed right before CXR, using pre-warmed gel on the linear probe (13 MHz) of a portable ultrasonography device (Esaote, Mylab Seven, 201236) while the baby was in the supine position within the incubator. The linear probe was placed in the longitudinal plane on the right mid-clavicular line, and the ribs were counted by advancing in the craniocaudal axis without lifting the probe from the chest until the right hemidiaphragm was observed (Picture 1). In order to avoid alterations in lung mechanics due to positional changes, we evaluated the ribs on anterior aspect. Each patient had a single measurement. Throughout the examination, the optimal blood oxygenation and body temperature are maintained.

To minimize variability, all USG measurements were performed by a single neonatologist who had received two weeks of training from a radiologist on the use of the equipment and anatomical landmarks of the chest before the onset of the study.

CXR was performed in an anterior-posterior position immediately after lung USG using a portable X-ray device (Siemens, Mobilet Miramax, 3638, 1015544537) by the radiology technician. The CXR image, which had been digitized in the hospital system, was examined by another neonatologist who was blinded to the thorax USG findings. To assess lung aeration, the posterior costae in the right hemithorax were counted in the craniocaudal direction, until the level of the hemidiaphragm and recorded. The localization of the posterior part of the right diaphragm positioned at the level of the 9^{th} costa was considered as the landmark for optimal lung expansion during HFOV[8]. Following validation with CXR, which is still regarded as the gold standard, corrective steps for HFOV were performed.

Statistical Analysis

Statistical analyses were performed using the IBM Statistical Package for the Social Sciences (SPSS) for Windows 23.0 (IBM Corp., Armonk, NY). Continuous values are given as mean $\pm$ standard deviation (SD), or as median (range) according to the homogeneity of the distribution, which was evaluated using the Kolmogorov-Smirnov test. Categorical data are presented as numbers (n) and frequencies (%) and were analyzed by the $\chi 2$ test. The "Intraclass Correlation Test" was used to evaluate the concordance between rib counts measured by CXR and POCUS. A p-value of < 0.05 was considered statistically significant.

Results

Within the scope of the study, a total of 28 intubated patients, 11 of whom (39.3%) were female, were included in the evaluation. 55 measurements were made in 28 patients. The distribution of the demographics and clinical findings is shown in Table 1. Table 2 shows the measurements made using POCUS and CXR in patients on mechanical ventilator in HFOV mode, as well as the patients' adjusted age and weight at the time of measurement.

Table 3 displays the findings of the intraclass correlation analysis, which assessed the concordance between POCUS imaging of the anterior chest and CXR of the posterior chest in terms of costal distances until the diaphragm level. The concordance between the two assessments was significantly correlated (r:0.913, $p<0.001$). During the procedure, no adverse events were reported, and no patients required intervention.

Discussion

In this study, we compared the findings from CXR, which is typically conducted to evaluate lung expansion in preterm and term infants treated with HFOV, with that of POCUS, which we performed in our NICU The level of the right hemidiaphragm, which we assessed for lung expansion using both CXR and POCUS, was comparable in both methods.

Unlike conventional ventilation, HFOV has a lung protective effect by keeping hyperinflation at a minimum with low tidal volumes. However, optimal lung volume must be ensured for effective ventilation and oxygenation. Many experimental and clinical studies have been conducted to evaluate optimal lung volume during

HFOV. However, even though these sophisticated devices used in studies provided more exact information than SaO_2 and diaphragm level measurements, they could not be used in clinical practice due to practical difficulties[5-7,9-13].

Although measuring lung capacity during HFOV is challenging, CXR can be used for approximation. Chest radiography is one of the most commonly used imaging modalities in the NICU. CXR, which is mostly performed in the anteroposterior supine position, is sufficient for the evaluation of the chest wall, heart, lungs, diaphragm, catheter, and endotracheal tubes. Because optimizing lung expansion is an important aspect of the HFOV strategy, CXR should be performed frequently in the early phases of HFOV, and subsequently at least daily as the patients become more stable. Furthermore, if a small adjustment in mean airway pressure leads to a significant increase in the patient's oxygen requirement, CXR should be performed to assess lung volume [14]. If conditions do not improve or deteriorate despite performing lung opening maneuvers to restore sufficient end-expiratory volume, a CXR should be taken [15].

The position of the diaphragm and the relative flattening of the diaphragm are two criteria to consider lung expansion. The right hemidiaphragm should be located between the lower border of the 8^{th} to 10^{th} ribs for optimal lung expansion. Although more advanced technologies are needed for more precise lung volume estimation, CXR, which is routinely employed in all neonates who require mechanical ventilation, appears to be a more practical overall strategy [7,13,14]. However, substantial concerns have recently emerged regarding the harmful consequences of radiation exposure in diagnostic procedures (radiography, computed tomography, angiography, etc.) that entail a high risk of malignancy development. The risk of malignancy may increase later in life due to both the effect of radiation exposure on cells in the neonatal period and the fact that children who are growing are more radiosensitive. Newborns in critical condition are still regularly subjected to radiographic imaging during the management of pulmonary diseases. The desire to reduce exposure and various disadvantages of CXR have highlighted the POCUS in NICU. POCUS has become a more favorable technology than radiography due to its point-of-care applicability, diagnostic reliability, faster detection compared to CXR, lack of radiation damage, repeatability, ability to evaluate disease course and response to treatment, and low cost [16].

POCUS should become part of the clinical examination and should be performed by clinicians who can properly interpret the images to avoid time loss for newborns and should be regarded as an ethical choice rather than an alternative method to radiography. For the clinicians to perform POCUS, they should be trained for 6-8 weeks and have evaluated about 20-30 patients [17,18]. In our study, POCUS was performed by a neonatologist who had previously been trained and used ultrasonography in her daily practice.

In this study, we evaluated the extent of lung expansion using ultrasonography to reduce radiation damage in babies on HFOV in our unit. With CXR, the right hemidiaphragm was recorded at the median 9^{th} rib (8-11) while with POCUS it was recorded at the 7th (6-8.5) rib. We associated the difference of about two ribs with the anatomical structure of the chest wall and the rib level of the right hemidiaphragm being counted posteriorly with CXR and anteriorly with USG. Such a good correlation of these measurements with each other shows that lung aeration can be evaluated following adjustments in HFOV using USG instead of CXR. Furthermore, the measurements taken at different postnatal ages of patients in our study at different weeks of gestation and with varied lung pathologies, as well as their correlation with CXR findings, enhance the method's clinical applicability regardless of gestational age and pathology.

Our study is the first in this field as no other studies have been conducted on this subject so far. However, randomized controlled studies in larger patient groups are required to routinely employ ultrasonography in the evaluation of appropriate lung volume, to respond to patients more promptly, to reduce radiation exposure and time loss, and to improve this method further.

Consclusion

The best solution for critically ill patients is to use practical, reliable, and effective point-of-care tools[13]. In our study, we aimed to evaluate lung expansion using ultrasonography so that patients would be exposed to less radiation due to CXR. The concordance of the results obtained by POCUS with the results obtained by

CXR was promising. However, we believe that standardization of reference values and guidelines is required for the accurate application of this method.

Statement of Ethics

Approval for this study was obtained from the hospital's ethics committee on (16.12.2021) with the reference number (B.10.1.TKH.4.34.H.GP.0.01/348). Written informed consent was obtained from the parents of each participant before US. Infants who did not have parental consent were excluded from the study.

Conflict of interest statement

There are no conflicts of interest.

Funding sources

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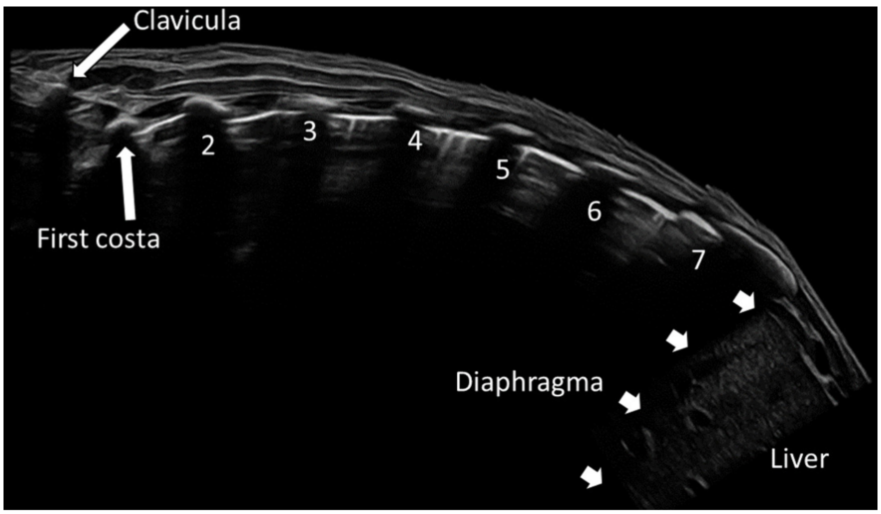

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