CASE REPORT

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Utility of point-of-care ultrasound in the pediatric intensive care unit

Reagan Lyman, BA[1], Yoshikazu Yamaguchi, MD[2, 3], Alok Moharir, MD[2,3], Joseph D. Tobias, MD[2,3]

[1]Ohio University Heritage College of Osteopathic Medicine, Dublin, Ohio
[2]Department of Anesthesiology & Pain Medicine, Nationwide Children's Hospital, Columbus, Ohio (USA)
[3]Department of Anesthesiology & Pain Medicine, The Ohio State University College of Medicine, Columbus, Ohio (USA)

Correspondence:
Reagan Lyman Nationwide Children's Hospital
700 Children's Drive
Columbus, Ohio 43205 (USA).
Phone: (937) 479-3236
E-mail: rl476718@ohio.edu
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ABSTRACT

For critically ill patients, point-of-care ultrasound (POCUS) has been rapidly adopted for use in emergency departments and critical care units for diagnostic purposes and to guide decision making. We present two unique clinical scenarios in the Pediatric Intensive Care Unit (PICU), one in which ultrasound was used as a diagnostic tool to identify pulmonary edema, and the other in which ultrasound was used to facilitate placement of a naso-duodenal tube for enteral feeding. The potential role of POCUS in the PICU is presented and its utility in these two unique clinical scenarios discussed.

Key words: Ultrasound; PICU; Enteral feeding; Pulmonary edema

Although, many cases will still require further radiological tests, The success of POCUS lies in immediate diagnosis allowing at the spot therapeutic interventions without wasting precious time.

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INTRODUCTION

Ultrasound can serve as an effective diagnostic tool in patient care to quickly make a diagnosis without exposing the patients to the potential harm from ionizing radiation during x-rays or CT scans. This technology uses sound waves that are transmitted through tissues and differentially reflected back to the transducer as a function of tissue and structure density. Although the limited spatial and temporal resolution of ultrasound initially restricted its use to static imaging with limited diagnostic utility, advancements in technology have resulted in real-time scanning, portability, and increased sensitivity.[1] For adult patients, point-of-care ultrasound (POCUS) has rapidly been adopted for use in emergency departments and critical care units to guide decision making and avoid more expensive and more time-consuming imaging methodologies.[1] POCUS also has the potential to improve care in the Pediatric Intensive Care Unit (PICU), but data supporting its efficacy are limited.[2] We present two unique clinical scenarios, one in which ultrasound was used as a diagnostic tool to identify pulmonary edema, and the other in which ultrasound was used to facilitate placement of a naso-duodenal tube for enteral feeds. The potential role of POCUS in the PICU is presented and its utility in these two unique clinical scenarios discussed.

Institutional Review Board approval is not required at Nationwide Children's Hospital for presentation of case reports involving one or two patients.

CASE REPORT 1

The patient was a 21-month-old, 19.1 kg male child with no significant past medical history who presented for epigastric hernia repair and lysis of penile adhesions. During the preoperative evaluation on the day of surgery, the mother reported that the child had cough for a few days and rhinorrhea prior to arrival; however, physical exam and vital signs were unremarkable and the patient was cleared for surgery. After the induction of general anesthesia, the patient's

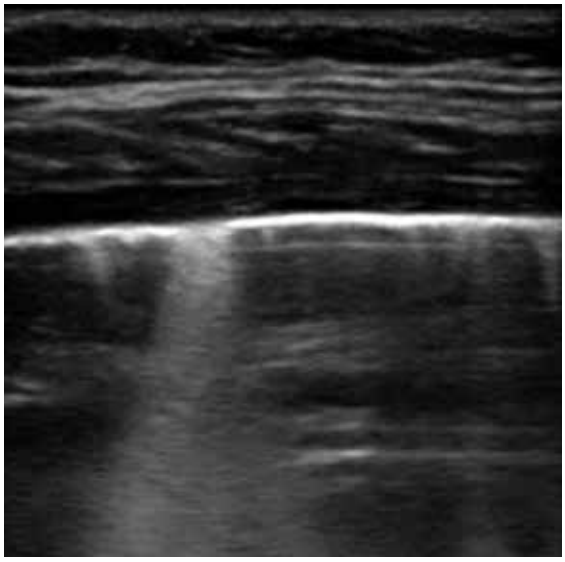

Figure 1: POCUS of lungs showing B-lines

trachea was easily intubated and the procedure completed without incident. While emerging from anesthesia following tracheal extubation, the patient developed severe bronchospasm/laryngospasm with decreased air exchange. This progressed to severe hypoxemia, bradycardia, and cardiac arrest. Resuscitation followed standard Pediatric Advanced Life Support algorithms with the administration of chest compressions, tracheal intubation, and the administration of epinephrine. After 4-5 min, there was return of spontaneous circulation and the child was transported to the PICU. Following admission to the PICU, there were several episodes of difficulties with ventilation, presumed to be due to bronchospasm. POCUS of the lungs was performed at the bedside which demonstrated multiple B lines without degeneration of pleural membrane, suggestive of pulmonary edema and not pneumonia (Figure 1). A chest radiograph confirmed the diagnosis of pulmonary edema, while an echocardiogram revealed normal function leading to the diagnosis of negative pressure pulmonary edema. Blood pressure support was provided by an epinephrine infusion at 0.03-0.05 μg/kg/min and diuresis started by the intermittent administration of furosemide. Mechanical ventilation was gradually weaned and the patient's trachea was extubated the next day. Rapid viral antigen testing was positive for rhinovirus/enterovirus. The remainder of the patient's hospital course was unremarkable and he was discharged home on 4th postoperative day.

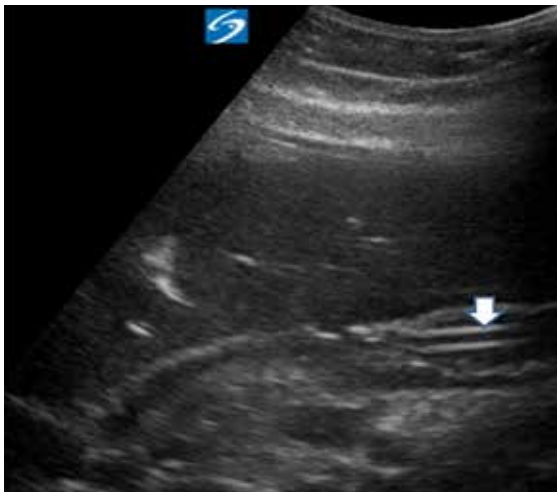

Figure 2: Naso-duodenal tube in the proximal duodenum

CASE REPORT 2

Our second patient was a 17-year-old, 73.8 kg female, with no significant past medical history, who initially presented to the Emergency Department with abdominal pain and diarrhea. She was admitted to the Infectious Disease service after a diagnosis of *C. difficile* colitis was made. The patient was subsequently transferred to the PICU after developing symptoms of sepsis and profound dehydration. Following admission to the PICU, the patient had multiple complications resulting in respiratory failure and requiring endotracheal intubation. Feeding intolerance with nasogastric (NG) feeds necessitated placement of a naso-duodenal feeding tube. Using ultrasound guidance, the feeding tube was advanced into the stomach toward the antrum of the stomach and visualized as it passed through the pylorus (Figure 2). An abdominal radiograph confirmed the correct placement and the feeding tube was secured.

DISCUSSION

Since its introduction, POCUS has played a big role for both diagnostic assessment and procedural guidance in the PICU. In 2015, the American Academy of Pediatrics published a policy statement endorsing the use of POCUS by pediatric emergency medicine physicians referencing the utility of the modality in both patientcare outcomes as well as patient satisfaction.[3] Additionally, in a survey of pediatric critical care fellowship program directors, 87% believed that POCUS should be used by ICU physicians as a rapid diagnostic tool and 97% believed that ICU physicians should utilize POCUS to improve procedural success.[4] Due to its portability, low cost, and ability to obtain rapid results in diverse situations, bedside ultrasound can serve as a valuable tool in the PICU. This is further demonstrated by two of our cases presented here.

Our first case demonstrates the potential utility of rapid bedside ultrasound of the chest in identifying

the etiology of hypoxemia in a critically ill child requiring endotracheal intubation and mechanical ventilation following an intraoperative event. Although there is limited data supporting the use of ultrasound in the PICU, previous studies in the adult population have demonstrated the utility of POCUS examination of the chest in the diagnosis of pneumothorax, pleural effusion, pneumonia, and pulmonary edema.[5,6] Lichtenstein et al. described the 'Bedside Lung Ultrasound in Emergency' protocol (BLUE protocol), which takes into account a number of imaging findings including lung sliding, B lines, and A lines in order to differentiate the causes of acute respiratory failure.[5] For example, the diagnosis of pulmonary edema is indicated by the presence of diffuse B lines moving synchronously with lung sliding. The BLUE protocol diagnoses pulmonary edema with a sensitivity of 97% and a specificity of 95%.[5] The first step in the BLUE protocol is to determine the presence or absence of lung sliding. Lung sliding is the normal process of the visceral pleura gliding over the parietal pleura during respiration. It has been described as having a shimmering or "ants marching on a string" appearance on ultrasound.[5,6] The presence of lung sliding rules out pneumothorax.[5,6]

B lines [an example of the comet-tail artifact (a grey-scale or color ultrasound finding seen when small calcific / crystalline / highly reflective objects are interrogated and is believed to be a special form of reverberation artifact)], as noted in our first patient, are also outlined in the BLUE protocol and indicate a diagnosis of either pulmonary edema or pneumonia.[5] B lines appear as hyperechoic (white), well-defined vertical lines that extend from the pleural line. This represents a reverberation artifact that occurs when there is a mismatch in acoustic impedance.[5] In the case of pulmonary edema, the marked difference in density between the fluid-filled alveoli and the surrounding air within the lung 'traps' the ultrasound beam resulting in the reverberant echo pattern, or comet-tail artifact.[6] Other studies have demonstrated a high degree of sensitivity and specificity when comparing lung ultrasound to chest radiograph and computed tomography scanning for the diagnosis of pneumonia, pleural effusions, pneumothorax, and other lung pathology.[6] These studies further highlight the role of POCUS in the differential diagnosis of acute respiratory failure.

Our second case demonstrates the potential utility of POCUS in ultrasound guidance of feeding tube placement in the PICU patient. Early enteral feeding in the ICU setting has been shown to have several beneficial physiological effects.[7] Despite ongoing clinical investigations, the optimal route of feeding (gastric versus duodenal) remains controversial and is likely influenced by various patient and clinical factors. Although NG feeds are frequently used, there may be a higher incidence of aspiration or intolerance. Therefore, in many patients, post-pyloric feedings (nasoduodenal) may be preferred despite the fact that placement of a nasoduodenal feeding tube may be more challenging. Various techniques have been evaluated for placement of nasoduodenal feeding tubes including blind, fluoroscopic-guided, and endoscopic guided techniques.[8] Given cost constraints and other concerns, blind placement at the bedside is frequently chosen for the initial technique and other options reserved when blind placement fails or is not feasible.[8] When blind techniques fail, it may be necessary to transport the patient to the radiology suite for placement which entails time, patient transport concerns, exposure to ionizing radiation, and staffing issues. We found that POCUS may offer a simple, cost effective, bedside technique to facilitate placement of a nasoduodenal tube at the bedside while avoiding patient transport issues and exposure to ionizing radiation. As demonstrated in our patient, POCUS was used to visualize the feeding tube as it passed into the stomach and was advanced towards the antrum (Figure 2). Although the feeding tube cannot be seen in the duodenum as this structure is retroperitoneum, the tube can be visualized in the gastric antrum as it passes through the pylorus.

The technique may also be beneficial and useful for placement of a standard NG tube for enteral feedings.[9] Historically, placement of an NG tube has been a blind procedure with depth of placement determined by age-related, height-based formulae or measured distances such as nose-ear-xiphoid (NEX) and nose-ear-mid-umbilicus (NEMU).[9] Placement was then generally verified by auscultation.[10] However, given a number of complications related to misplacement of such tubes, recommendations for clinical practice have changed. In 2012, the Children's Hospital Association issued a patient safety alert identifying the risks associated with blind placement of NG tubes. Misplacement can result in serious complications including aspiration, esophageal or gastric perforation, placement into the respiratory tract, or even the cranium and brain.[9,10] While radiography is the gold standard in determining accurate placement, repeated exposure to radiation, cost, and time must be considered. Additionally, due to the portability of ultrasound, it may be easier to utilize POCUS in the PICU than to transport the patient to radiology to confirm NG placement, suggesting that ultrasound may provide the needed safety assurance in confirming correct NG placement while limiting the inconveniences associated with radiographic confirmation.

CONCLUSION

In summary, our cases demonstrate the potential utility of POCUS in the PICU. Bedside ultrasound

can be used in a variety of settings, providing rapid results without an exposure to the hazards of ionizing radiation. As the techniques of POCUS are user-dependent, additional studies

addressing POCUS training requirements would be beneficial.

Conflict of interest: None declared by the authors

Authors' contribution:

RL, YY, AM: conduction of study work and manuscript editing

JDT: concept, conduction of study work, and manuscript editing

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