

Ultrasound cardiac output monitor inter-rater agreement in Pediatric Intensive Care Unit

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Abstract

Objective: Although Ultrasound Cardiac Output Measurement (USCOM) is relatively simple to operate, its reliability for novice user needs to be assessed. This study aims to determine inter-rater agreement of USCOM between pediatric residents as novices and pediatric intensivist as experienced operator.

Design: An observational study.

Setting: A single-center study in Pediatric Intensive Care Unit.

Patients and participants: Pediatric residents underwent in-house training and 20 practice scans, followed by blinded trans-aortic USCOM cardiac index (CI) measurements made by one

of two randomly selected pediatric residents paired with one pediatric intensivist. CI, its categorization and image quality, were noted.

Measurements and results: Paired measurements were performed on 48 subjects. Median of subjects age were 2 years (1 month to less than 18-year-old). Spearman's rank showed strong positive correlation of CI ($r_s=0.77$; 95% CI=0.62-0.86). Inter-rater agreement by Cohen's kappa showed substantial agreement on CI ($\kappa=0.78$).

Conclusion: Following training, pediatric residents were able to measure CI using USCOM with substantial inter-rater agreement.

Key words: Ultrasound machine, hemodynamic monitoring, cardiac output, Intensive Care Units, pediatric.

Introduction

Hemodynamic monitoring plays an important role in identifying cardiovascular impairment and therapeutic response in the critically ill patient. (1) Basic parameter such as heart rate, blood pressure, central venous pressure, and urine output are commonly utilized to assess hemodynamic status.

Cardiac index (CI) measurement plays important part in pediatric hemodynamic monitoring. Clinician's estimation of the CI on the pediatric patient based on clinical data was inaccurate. (2)

Pediatricians were reluctant to measure CI, which could be due to several factors, such as complications with traditional methods that were not uncommon, difficulties of obtaining access, and the inadequacy of comparable standards which make validation for newer techniques challenging. (2) CI were calculated by dividing cardiac output with body surface area (BSA). Cardiac output monitor ideally should be able to provide efficient, continuous, reliable hemodynamic data, with minimum response time, operator-independent, and non-invasiveness. (3) Ultrasound Cardiac Output Monitor (USCOM) can provide a non-invasive cardiac output measurement with the relatively short learning curve for the operator. (4) Its reliability in the pediatric patient with normal cardiac anatomy was comparable to pulmonary artery catheter thermodilution. (5)

Cardiac output measured by the function of stroke volume (SV) and heart rate (HR). In the trans-aor-

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tic measurement, USCOM measures cardiac output by using Doppler ultrasound to continuously track blood flow out of aorta to produce flow profile of velocity time integral (VTI). Stroke volume measured by multiplying the VTI and cross-sectional area (CSA) of the aortic valve that approximated using a proprietary algorithm based on patient's gender and height or by manual input of previously known size. (6,7)

Hemodynamic monitoring by Doppler ultrasound can be affected by operator's skill. (8) USCOM is reliable and has a relatively short learning curve and can be operated by the various health professionals. (9) Inter-rater agreement on the pediatric patients were varied. Trained operator examination on healthy school children showed high intraclass correlation $r=0.94$ (95% CI 0.93-0.94). (10) Lin concordance coefficient for examination for anesthetized children undergoing elective surgery or imaging procedure using magnetic resonance imaging was 0.87 (95% CI 0.72-0.92). (11) Urgent ultrasound guided hemodynamic measurement by Pediatric Medical Emergency Team in the ward showed moderate agreement ($\kappa=0.44$ [95% CI 0.27-0.61]). (12)

Study of the reliability of USCOM examination in pediatric intensive care is limited. In our PICU setting, USCOM examinations were also performed by the pediatric residents. The objective of this study was to measure the inter-rater agreement of USCOM for pediatric residents as novice operators against a pediatric intensivist as the more experienced operator on pediatric intensive care unit patients.

Methods

This observational single-center study was conducted at Pediatric Intensive Care Unit Dr. Sardjito Hospital, Yogyakarta, Indonesia. Approval was received from the Faculty of Medicine, Nursing and Public Health Universitas Gadjah Mada Ethics Committee (No.KE/FK/1169/EC/2017). Written informed consent was obtained from all participants.

Patients

This study was conducted between February-April 2018. Consecutive in-patients at PICU aged 1 month to less than 18-year-old that need hemodynamic monitoring were eligible. Patients with suspected or known congenital heart disease, valvular cardiac defect, pericardial effusion, pericardial tamponade, arrhythmia and/or pulmonary hypertension were excluded. Patients that were agitated, obese and/or have any condition in suprasternal

notch that would hinder probe attachment such as tracheostomy were also excluded. No changes in sedation were done for sedated patients.

Study protocol

Prior to patient recruitment, two randomly selected pediatric residents who had no prior ultrasound training underwent in-house training developed based on technical information available about the device which obtained from the manufacturer. It consisted of 120 minutes of audiovisual training about the basic of USCOM, technique to perform trans-aortic examination, how to acquire acceptable image quality, and to interpret the result. Training scans were performed 20 times on PICU patients for each pediatric resident, guided by pediatric intensivist, focused on obtaining the maximal possible image quality based on Freemantle acoustic image score criteria (**Table 1**). Score ≥ 3 out of 6 is considered adequate.

Pediatric intensivist and trained pediatric resident then performed the paired USCOM scans. USCOM 1A[®] (USCOM Ltd, Australia) device was used in this research. Patients' data consisted of patients' gender, body weight, length, and blood pressure were input by the researcher, body surface area were automatically calculated by the device. Eligible patient was put in supine position. Pediatric intensivist performed the trans-aortic USCOM examination by placing probe that already coated with ultrasound gel (Aquasonic[®] 100) on suprasternal notch. All scans were performed using 2.2 Mhz transducer. Trans-aortic were chosen due to its simplicity on probe placement and relatively quicker to acquire image. (4) Operator manipulated position of the probe until satisfactory signal was obtained. Operator then froze the screen, selected minimum of three acceptable cardiac profile tracings and saved the results. Measured CI were noted and image quality were scored using Freemantle criteria by the researcher. CI were used instead of cardiac output in this study because it also takes into account the BSA. CI were categorized into normal or abnormal by operator based on the normal limit constructed by measurement on healthy Chinese children. (13) One of the two pediatric residents then performed the examination on the same patient, within 15 minutes of each other. If more than 15 minutes has passed and no satisfactory image was acquired, the examination was stopped and considered as failed. Operators were blinded of another operator's result by clearing the monitor of the result and forbidding the other paired operator to be present in the same room when performing scans. Study flow chart is pre-

sented in **Figure 1**.

Statistics

A sample size of 48 paired scans were used for Cohen's kappa (κ) of 2x2 category based on power at 80% and alpha of 0.05. (14) Pediatric intensivist was considered as representation of more experienced operator, while pediatric residents were considered as novice operators. Mean percentage differences of CI were measured by dividing the difference of CI between pediatric intensivist and residents with mean of CI for that scan. Independent sample t-test of mean percentage difference between two pediatric residents was done to compare the two novice operators. Correlations of CI between novice and more experienced operator were measured by Spearman's rank and Cohen's kappa measurements were used to determine inter-rater agreement for CI. SPSS version 20.0 (IBM, Armonk, NY, USA) was used for statistical analysis.

Results

Inter-rater agreement was assessed based on 48 paired USCOM scans. There were no failed scans. Baseline characteristic of the study participant is presented in **Table 2**. The mean percentage difference of CI between pediatric intensivist and residents was 10.8%. There was no significant difference between two pediatric residents ($p=0.09$). Median of CI were 4.05 (2.2-6.0) l/min/m² for pediatric intensivist and 4.3 (2.3-6.2) l/min/m² for pediatric residents. There was no significant difference of CI among pediatric intensivist and residents ($p=0.54$). Image quality was $\geq 4/6$ on Freemantle criteria for all 48 patients. There was no significant difference in image quality between operators ($p=0.65$). Spearman's rank (r_s) for correlation of CI between novice operators and experienced operator was 0.77 (95% CI 0.62-0.86). Scatterplot of this correlation is showed in **Figure 2**. Percent agreement of novice compared to more experienced operators was 95.83% and κ for inter-rater agreement was 0.78.

Discussion

Subsequent to in-house audiovisual training and 20 training scans pediatric residents as novice users can utilize USCOM to measure CI with substantial inter-rater reliability ($\kappa=0.78$) compared to pediatric intensivist as the more experienced user. These findings add to the current literature on inter-rater agreement study of the USCOM. This is the first inter-rater agreement this device performed for pediatric residents compared to a pediatric intensivist in PICU.

Although novice operators in our research had no previous experience in using an ultrasound device to measure hemodynamics, these results showed that with minimal training, novice operators can provide reliable hemodynamic measurement by using USCOM in the PICU. Similar results were also found for USCOM scans in healthy children, anesthetized children, and neonates. (10,11,15) All of our scans quality were of good quality, this might contribute to the better result that performed by Pediatric Emergency Medical Team, (12) in which only 75.9% were of good quality. Previous study showed that during training, mean percentage difference of SV decrease from 19% at the beginning to 5.9% at the end of training. (9) Mean percentage differences of CI in this study were only assessed in paired measurement, after training of 20 scans were completed.

Our research was performed in a critical care setting, and its CI correlations were similar to the results obtained in an emergency department ($r=0.79$). (16) USCOM performed under a more controlled environment such as magnetic resonance imaging (MRI) and elective surgery showed better correlation. (11) Although all scans performed on sedated patient were acceptable, CI correlation was better in anesthetized children, (11) where only 10.4% of our subject were sedated.

Limitations

Our study had several limitations. This study only measured the reliability of USCOM in various operator. Considering this study were performed in critically ill children, it could be suggested that stability of hemodynamic during CI measurement were difficult to achieve. We limited the duration of paired scans for both operators to be under 15 minutes to assume the stability of hemodynamic. To ensure the validity of CI value, the results need to be compared to other hemodynamic monitoring tools such as thermodilution or echocardiography. Both of those hemodynamic monitoring methods were not feasible to be performed in our setting. Due to device unavailability, all of the scans were performed using 2.2 Mhz probe, more appropriate probes need to be utilized for infant patient. Considering that all operators used the same probe for all USCOM examination, this did not contribute to the inter-rater reliability.

Operator's skill to obtain optimal Doppler signal was vital for CI estimation using USCOM. Improper ultrasound beam alignment with the outflow tract of the aorta can produce poor VTI measurement, undervaluation of SV, and lead to inaccurate CI estimation. The learning curve of operators was

not assessed in this study. Although twenty training scans were considered sufficient for skill attainment in pediatric patient, (11,16) based on our experience, more training is needed for the novice user to reliably obtain appropriate image quality. Based on the study of the learning curve of USCOM, 25 training scans can provide better skill acquisition. (9)

Conclusions

Following training, pediatric residents were able to measure CI using USCOM with substantial interrater reliability in comparison to pediatric intensivist. Application of such procedures could potential-

ly enhance monitoring of non-invasive hemodynamic in our critical care patients. Future researches are needed to assess the utility of using USCOM, especially for unstable pediatric patients.

Conflicts of interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Table 1. Freemantle criteria to determine ultrasound/acoustic image quality for USCOM from Dey & Sprivilis (4)

1.	Well-defined image base
2.	Well-defined image peak
3.	Well-defined commencement of flow or heart sound
4.	Well-defined cessation of flow or heart sound
5.	Appropriate scale used in screen
6.	Minimal acoustic interference

Legend: USCOM=Ultrasound Cardiac Output Monitor.

Table 2. Baseline characteristic of study participants

Characteristics	
Age	2 years (1 month to less than 18-year-old)
Body surface area (m ²), median (range)	0.54 (0.25-1.60)
Male, n (%)	22 (45.8%)
Sedation, n (%)	5 (10.4%)

Figure 1. Study flow chart

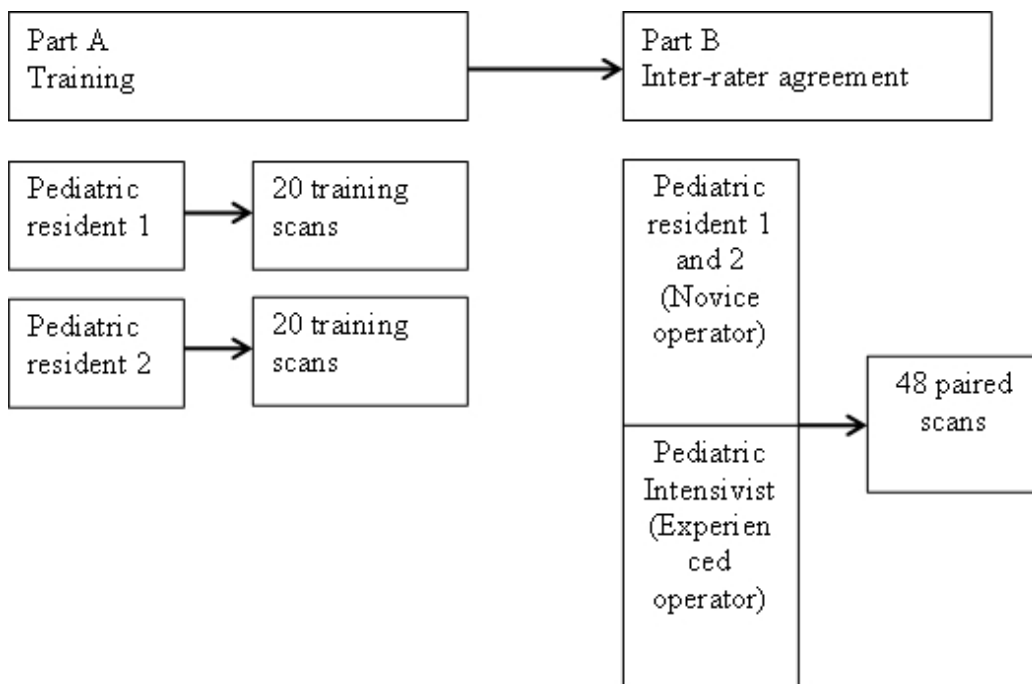
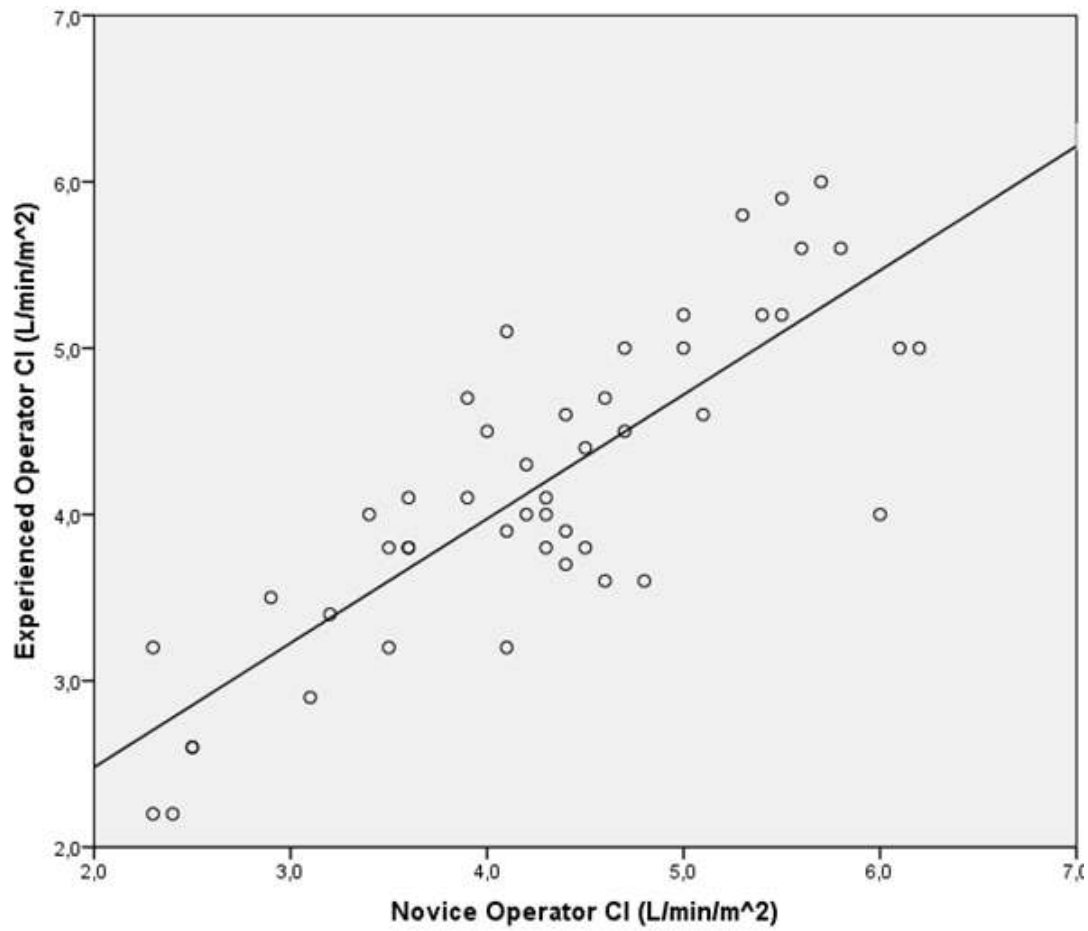


Figure 2. Scattered plot of the correlation between novice operator and experienced operator



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