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Original article

Training pediatric residents in point-of-care ultrasound: An assessment of the needs and barriers to acquire the skill

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A B S T R A C T

Introduction: The use of point-of-care ultrasound (POCU) is increasing globally. However, owing to the epidemiology of diseases and local management strategies, POCU may not be universally applicable. Before developing a POCU training program, because of limited resources for medical education, it was pivotal to conduct a needs assessment and identify the training barriers.
Methods: This study used a validated paper questionnaire. The survey instrument was distributed to 120 pediatric residents (male 60, female 60) training at our institution to assess their self-reported level of skill in POCU, and their perceptions with regard to the applicability of POCU, measured with a 5-point Likert scale. The skills deficit was measured by subtracting the self-reported level of skills in lung, cardiac, and abdominal POCU from the perceived applicability of POCU.
Results: Fifty-nine residents participated, resulting in a response rate of 50 and 48% (n = 29) for the male group, and 50% (n = 30) for the female group. The level of knowledge and proficiency was low. Scanning for free abdominal fluid was deemed the most applicable (mean 4.2 ± SD 1.1); however, the use of POCU to detect consolidation was considered least applicable (mean 2.7 ± SD 1.3). The skills deficit was highest for an abdominal POCU (mean 2.4 ± SD 1.6) and lowest for lung ultrasound (mean 1.4 ± SD 1.6). Although the majority (n = 48) agreed that this skill was essential, 3 (5%) had no interest, and 39% (n = 23) indicated a lack of time to acquire the skill.
Conclusions: Though pediatric residents in Saudi Arabia agree that POCU is an essential skill, large skill deficits exist, supporting the necessity to provide POCU training. However, there are several barriers to overcome to achieve this.

1. Introduction

Pediatricians proficient in the use of point-of-care ultrasound (POCU) can manage clinical concerns in unwell children when and where it is required [1–8]. The accuracy of POCU for the diagnosis of pneumonia, hepatomegaly, splenomegaly, dehydration, abscesses, and many other pathologies is excellent [1–11].

A substantial body of evidence supports the routine application of POCU in pediatric practice [1–11]. However, as it is a relatively new concept, few general pediatricians have no experience in POCU. To ensure the safe and efficient use of POCU, formal training is required [12,13]. However, evidence confirms that minimal training is required to obtain adequate proficiency [14,15].

The curriculum for pediatric residency training in Saudi Arabia does not include POCU. However, organizations in several countries have developed POCU guidelines and curricula that are specialty-specific [1,16–21], as multiple disciplines can use POCU effectively. However, substantial investment is required to integrate

Abbreviations: COVID-19, Corona Virus Disease 2019; AKI, Acute Kidney Injury; POCU, Point–of–Care Ultrasound; RR, Response Rate; SD, Standard Deviation.

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POCU in routine clinical practice, and owing to the limited resources available for medical education, the development of any new training program must be verified. A needs assessment is essential to determine whether the training of pediatric residents in POCU is appropriate and required [12,22].

The primary objective of the present study was to identify the pediatric residents' perceptions on the usefulness of POCU in their practice (i.e., applicability), and to quantify their self-reported level of skill in POCU (i.e., ability) to identify the skills deficit in the training of pediatricians. The deficit defines the requirements for instructions in POCU. Exploring the POCU training barriers of this cohort was the secondary objective of this study.

2. Methods

2.1. Study and survey design

This cross-sectional survey assessing the usefulness and the self-reported level of skill in POCU was performed with pediatric residents at a large tertiary referral center in Saudi Arabia. To design the survey, literature reporting evidence on its relevance to pediatrics and competencies required for the practice of POCU were reviewed [1–13,23–25]. From this background, two experts in survey design, medical education, POCU, and pediatrics (SFJ and RR) designed and validated a questionnaire with six subsections.

The first subsection included demographic information (i.e. postgraduate year of training (PGY), age, gender). The second subsection explored the participants' use of POCU, their training, and accreditation. The third focused on the needs assessment by investigating the applicability of POCU in terms of 15 distinct uses of POCU. For each indication, participants were asked regarding how relevant (useful) it was to their clinical practice. The fourth subsection explored the samples' skills (i.e., proficiency) in each use of POCU in subsection three. The fifth subsection assessed the level of knowledge related to the 16 principles of ultrasound, and the sixth, the pediatric residents' attitude toward POCU training and possible barriers.

After obtaining approval from the institutional review board, a pilot study was performed to obtain feedback related to the content, clarity, and length of the questionnaire. Five internal medicine residents agreed that the content was appropriate and the questions were clear, but recommended that the survey should be shortened. Sections one, two, and three were not changed. However, section four was shortened by exploring proficiency in three domains (lung ultrasound, focused cardiac ultrasound, and abdominal ultrasound) rather than in each application of POCU listed in section three. Four questions related to the knowledge of lung, abdominal, cardiac, and vascular ultrasound findings were removed from section five, as these overlapped with section four.

The revised survey instrument (Appendix 1) was reviewed by the same participants involved in the pre test, who agreed that the revised questionnaire was acceptable.

2.2. Participants

The study was conducted in the pediatric residency program of our institution. During the academic year from October 1, 2019, to October 31, 2020, there were 95 pediatric residents (male: 48, female: 47) enrolled in this program. This academic year was extended until October 31, 2020, by the Saudi Commission for Health Specialties, because of the disruption to training caused by the COVID-19 pandemic. This resulted in a unique situation as novice PGY-1 residents (25, male: 12, female 13) started their training on October 1, 2020, as scheduled. As our survey was conducted during this transitional period, there were technically two cohorts of PGY-1 residents. However, the novice PGY-1 residents were within the first month of their residency, and their views essentially represented those of interns who had chosen to undertake pediatric residency and the group was designated PGY-0 to differentiate them from the senior PGY-1 residents.

Finally, there were 120 pediatric residents at our institution when the study was conducted. To obtain a 10% error margin at a confidence level of 95%, it was estimated that the responses of at least 54 pediatric residents would be needed. All pediatric residents training at our institution were invited to participate and were allowed to respond with refusal. The paper-based questionnaire was distributed to the pediatric residents during various departmental activities in October 2020. No incentives were given, and informed consent was obtained before they participated in the survey.

2.3. Study outcomes

Closed questions (i.e., Y/N) were used to determine the participants' training and accreditation in POCU. The quantification of the participants' POCU practice used an incremental scale (more than once a day, daily, once a week, once a month, never). Pediatric residents were asked to use a Likert scale (1: very poor, 2: poor, 3: fair, 4: good, 5: very good) to describe their perception of the relevance of POCU (i.e., applicability) and their self-reported level of skills and knowledge with regard to POCU (i.e., proficiency).

The skills deficit for lung, cardiac, and abdominal ultrasound for each participant was calculated. The self-reported level of skills in the assessment of the three systems was subtracted from the average of the applicability of each indication for the use of POCU. For example, the proficiency in lung ultrasound was compared to the average applicability of lung ultrasound to detect pneumothorax, interstitial syndrome, consolidation, and pleural effusion. Similar methods for calculating skill deficits have been described [12,26]. Training barriers were chosen from a prepopulated list, which allowed the selection of more than one option. Free text comments were also encouraged.

2.4. Ethical approval

The institutional review board provided ethical approval for this study. All participants signed an informed consent form before the completion of the survey.

2.5. Statistical analysis

Standard descriptive statistics were used to analyze the data. Cronbach's alpha was calculated independently for each section of the questionnaire to determine the internal consistency. The sections measuring attitudes, applicability, proficiency, knowledge, and skills were assessed separately. All responses were included in the final analysis. Responses were grouped by sex and the year of postgraduate training. The categorical data are presented as frequency and percentage. The interval data, based on the 5-point Likert scale, are presented as frequency and mean ± SD, as described previously [12,26]. The categorical data were compared using Chi-squared or McNemar tests, and Student's t-test or analysis of variance (ANOVA) was used for the comparison of the interval data, as appropriate. Excel (version 2016, Microsoft, USA) was used to perform all statistical analyses.

3. Results

3.1. Demographic information and response rates

The samples' demographic information with the response rates are given in Table 1. The response rate (RR) was high (49%) and sufficient to achieve the desired error margin and level of confidence. Of the 120 pediatric residents (male 60, female 60), 59 participated (male 29, female 30). The female participants' RR (50%) was similar to that of the males (48%). Some participants did not answer all the questions, but all answers were included in the analyses.

3.2. The pediatric residents' attitude toward POCU training

The samples' attitude toward POCU training are given in Table 2. Most of the samples agreed or strongly agreed with the following statements: lack of access to ultrasound out-of-hours compromises patient care (45, 78%; male 19), each department should have its own ultrasound machine (51, 88%; male 24), and POCU is an essential skill (48, 83%; male 24). In total, 37 pediatric residents (63%; male 17) strongly agreed or disagreed with the statements. The internal consistency of the questions in this subsection was moderate (Cronbach's alpha 0.63).

3.3. The applicability of POCU to the practice of pediatric residents in Saudi Arabia

The relevance (i.e., applicability) of the 15 POCU indications in pediatric residents' practice in Saudi Arabia are shown in Fig. 1. The internal consistency of the responses was very high (Cronbach's alpha 0.95). One-way ANOVA identified statistically significant differences between the means of the groups ($F(14,772) = 7.2$, $P < .00001$). The mean applicability of all uses for POCU combined was fair to good (3.6 ± SD 1.4) and 472 responses (60%) were very good or good.

The applicability of POCU to detect abdominal free fluid (4.2 ± SD 1.1) was the highest. Scanning for pleural effusion was considered useful (mean applicability 3.6 ± SD 1.4). However, other indications for lung ultrasound were deemed less useful. Of the POCU indications investigated, bedside ultrasound imaging for consolidation (2.7 ± SD 1.3) and interstitial syndrome (2.8 ± SD 1.3) were perceived to be the least applicable.

Saudi interns and Canadian residents in internal medicine also perceived that the best use of POCU was for detecting abdominal free fluid [12,26]. Thus, this indication for POCU is applicable globally.

3.4. The pediatric resident use of POCU, training, and accreditation

Of the sample, none had accreditation in POCU or focused cardiac ultrasound. Only 3 participants (8%; female 3, intern 1, PGY1 2) received some undergraduate training in POCU. Although none received any postgraduate training in POCU, 6 pediatric residents (10%, Male 3) reported using it regularly (i.e., at least once a month). Two of the 3 residents who received POCU training as undergraduates reported that they used it regularly. A few pediatric residents, who used POCU regularly, taught themselves, and their level of POCU knowledge is likely to be immature.

3.5. The level of POCU knowledge

The pediatric residents had the highest level of knowledge with regard to the basic principles of ultrasound (mean 2.1 ± SD 1.2). However, the overall self-reported POCU knowledge was low (Fig. 2). The lowest levels of knowledge were reported for B-mode imaging (mean 1.4 ± SD 0.8), Doppler imaging (spectral Doppler mean 1.4 ± SD 0.7), power Doppler (mean 1.4 ± SD 0.7), and archiving (mean 1.4 ± SD 0.8). The questions in this subsection had a very high internal consistency (Cronbach's alpha 0.96). This low level of knowledge reduces the pediatric residents' skills in POCU.

3.6. Barriers related to POCU training

Fig. 3 displays the barriers related to POCU training. Seven participants did not respond to this question. On an average, 2.2 (SD 1.4) barriers were cited per resident (Fig. 4). Lack of interest was rarely cited (3, 5%; female 1). The most frequent barriers listed were lack of trainers (38, 64.4%; female 20) and lack of time (30, 50.8%; female 18). It is noteworthy that 39% (23, female 12) reported that the residents lacked the time for POCU training. Attention to the samples' proficiency can provide insight into the significance of these barriers in clinical practice.

3.7. Pediatric residents' POCU proficiency and skills deficiency

Fig. 5 displays the samples' self-reported level of skills (i.e., proficiency) in lung ultrasound, FoCUS, and abdominal POCU. The

Table 1
Sample demographic information and response rates.

Variables	Totals	N (RR % Gender) N (RR % PGY)	Gender N (RR % Gender)		Age range (years) N (% PGY)		
			Male	Female	21–25	26–30	31–35
Gender							
Female	60	29 (48)	–	–	15 (50)	13 (47)	1 (3)
Male	60	30 (50)	–	–	15 (52)	14 (48)	(0)
Postgraduate year of training							
PGY 0	25	19 (76)	9 (75)	10 (77)	17 (90)	2 (11)	0 (0)
PGY 1	25	19 (76)	9 (69)	10 (83)	13 (68)	5 (26)	1 (5)
PGY 2	25	9 (32)	5 (27.3)	4 (36)	0 (0)	8 (100)	0 (0)
PGY 3	23	8 (39)	3 (55.6)	5 (29)	0 (0)	9 (100)	0 (0)
PGY 4	22	4 (18)	3 (20)	1 (14)	0 (0)	4 (100)	0 (0)
Total	120	59 (49)	29 (48)	30 (50)	30 (51)	28 (48)	1 (2)

The table presents the sample's demographic information and response rates. Age ranges, and response rates are stratified by postgraduate year (PGY) of training and gender. The changes in training owing to the loss of training time during the COVID-19 pandemic resulted in a unique situation. The novice PGY 1 residents started training on October 1, 2020, as scheduled. However, the academic year for the existing residents was extended until October 31, 2020. As our survey was conducted during this transitional period, there were technically two cohorts of PGY 1 residents. However, the novice PGY 1 residents' views were considered to be those of interns who had chosen to undertake pediatric residency and so were designated PGY 0 to differentiate them from the more senior PGY 1 residents who had completed one year of training. Data are presented as frequency and percentage of strata totals. N, number of responses; PGY, postgraduate year of training; RR Response Rate.

Table 2
Pediatric residents' attitudes toward POCU.

Statement about POCU	Likert scale response (N %)				
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
POCU is an essential skill	0 (0)	1 (1.7)	9 (15.5)	25 (43.1)	23 (39.7)
Lack of US out-of-hours compromises care	0 (0)	1 (1.7)	12 (20.7)	33 (56.9)	12 (20.7)
Need US machine in every department	0 (0)	0 (0)	7 (12.1)	32 (55.2)	19 (32.8)

Data are presented as frequency and percentage. Abbreviations. POCU, point-of-care ultrasound; US, ultrasound.

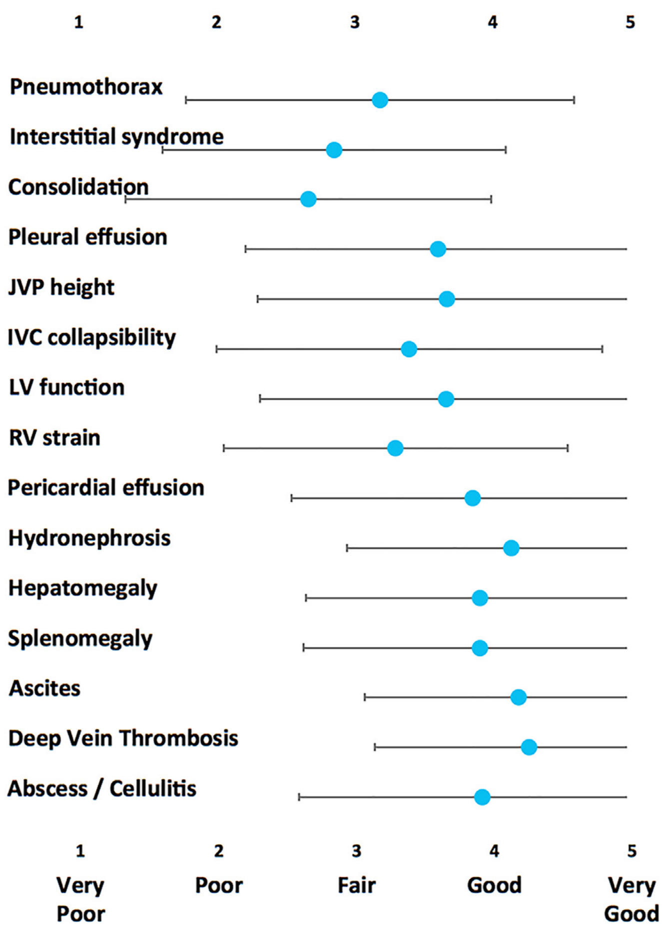

Fig. 1. Pediatric residents' perceptions of the applicability of POCU.
This figure illustrates pediatric residents' perceptions of the applicability of POCU. Applicability is rated on a 5-point Likert scale (1, Very Poor; 2, Poor; 3, Fair; 4, Good and 5, Very Good). Data are presented as mean ± standard deviation. Abbreviations. DVT, deep vein thrombosis; JVP, jugular venous pressure; IVC, inferior vena cava; LV, left ventricle; RV, right ventricle.

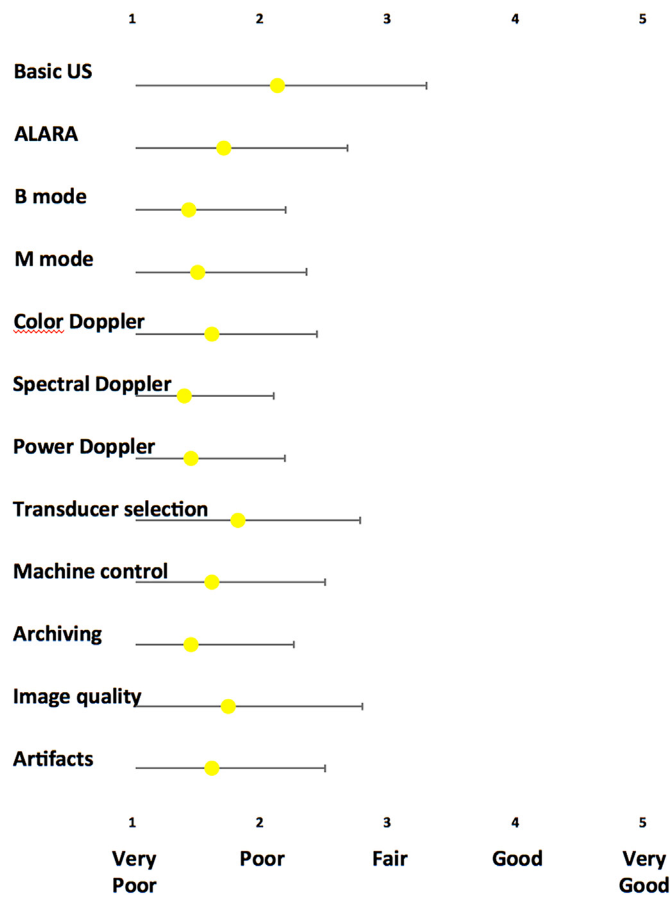

Fig. 2. Pediatric residents' knowledge of the principles of ultrasound required to use POCU.
This figure illustrates pediatric residents' knowledge of the principles of ultrasound. Knowledge was self-reported on a 5-point Likert scale (1, Very Poor; 2, Poor; 3, Fair; 4, Good and 5, Very Good). Data are presented as mean ± standard deviation. Abbreviations. ALARA, as low as reasonably achievable; B mode, M mode, motion mode; US, ultrasound.

internal consistency in this subsection was high (Cronbach's alpha 0.91). The pediatric residents' POCU proficiency was low. The self-reported proficiency in abdominal POCU (mean 1.7 ± SD 1.0) was the lowest. The self-reported mean proficiency in lung ultrasound (mean 1.8 ± SD 1.1) and FoCUS (mean 1.8 ± SD 1.0) were also low. However, the self-reported skills were significantly lower ($P < .00001$) than the perceived usefulness of POCU in pediatric practice. Fig. 5 shows the skill deficits identified. The deficit was highest in terms of abdominal POCU (mean 2.4 ± SD 1.6) and lowest for lung ultrasound (mean 1.3 ± SD 1.6). The skills deficit for FoCUS was also significant (mean 1.9 ± SD 1.6). Consideration of participants' comments may provide important insights into this topic.

3.8. Comments

Comments were written by five residents. Two residents stated that they would like to be trained, and another that it should be officially included in the pediatric residency training. One resident stated that they never used POCU, and another indicated that being at a tertiary care center with adequate radiological support made it less likely for pediatric residents to have opportunities to use POCU. They also highlighted that there was no dedicated time for POCU training.

4. Discussion

Point-of-care ultrasound is useful for examining children at the

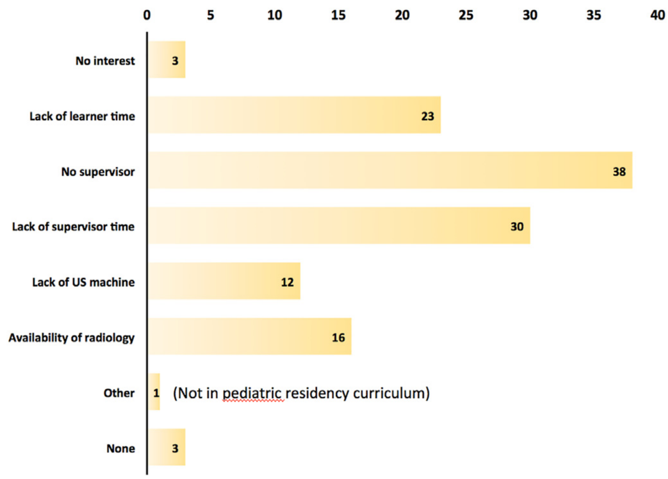

Fig. 3. Barriers to learning POCU during pediatric residency training.
This figure illustrates the training barriers in POCU reported by a sample of pediatric residents. Data are presented as frequency. Abbreviations. POCU, point-of-care ultrasound; US ultrasound.

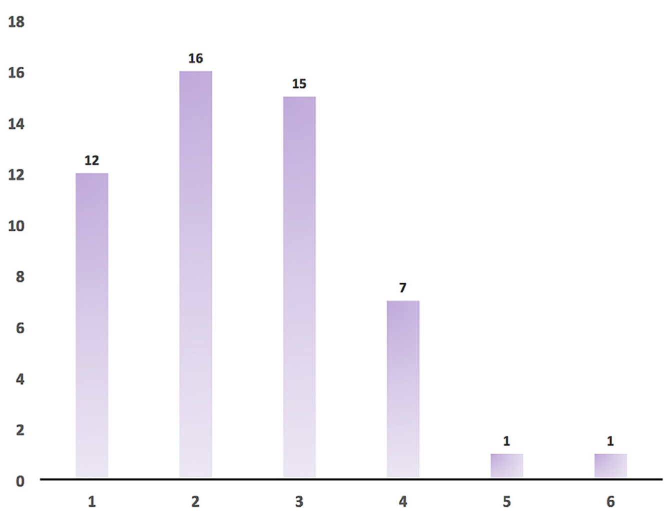

Fig. 4. Number of barriers to learning POCU reported by each resident.
This figure illustrates the number of training barriers in POCU reported by each pediatric resident. Data are presented as frequency. Abbreviations. POCU, point-of-care ultrasound.

bedside [1–11]. POCU is a relatively recent development, not yet included in the general pediatric residency curriculum in Saudi Arabia, underpinning the fact that none of the residents received any postgraduate training in POCU. However, the majority of the samples (80%) indicated that POCU training is essential. A formal needs assessment was required as the cost of implementing a pediatric POCU curriculum is high.

4.1. Pediatric residents' attitude towards the usefulness, training, and use of POCU

The use of POCU was perceived to be applicable to pediatric practice in Saudi Arabia (Fig. 1). In pediatric practice, the most used application of POCU was the detection of abdominal free fluids. A Canadian study with internal medicine residents reported similar findings, which supports the adoption of pre-existing internal medicine training programs as feasible and desirable. In addition, the international standardization of POCU curricula may also be considered.

Though the present study was conducted towards the end of the first wave of the COVID-19 pandemic, the samples did not consider the ability to detect consolidation and interstitial syndrome with POCU to be useful in pediatric practice. It should be noted that the samples' knowledge of ultrasound and their ability to perform POCU were low (Figs. 2 and 5). The study highlighted a lack of awareness of recent literature highlighting the usefulness of lung ultrasound in the assessment of COVID-19 in children [27]. This observation supports the importance of involving subject experts in curriculum development.

4.2. Pediatric residents' self-reported level of skills in POCU

The samples' POCU level of skills were low. The disparity between the perceived usefulness and the ability to perform the skills define specific skills deficit [12,26]. These deficiencies can be resolved with educational interventions [12–15]. In this context, measurement of the deficits would guide the appropriate deployment of limited resources for medical education.

4.3. Measurement of skills deficiencies

The applicability of POCU in pediatric practice was rated higher than the level of skills (i.e. proficiency; Fig. 5). This observation highlights significant POCU skill deficiencies in the pediatric residency program (Fig. 5). These deficiencies can only be resolved by developing and implementing a specialty-specific POCU training program.

4.4. Overcoming the barriers of POCU training

The barriers cited most frequently were lack of trainers and time (Fig. 3). These barriers can be overcome by increased trainer availability [26]. Access to ultrasound machines should also be facilitated. Ultrasound machines can cost as much as SAR 350,000, depending on brand, size, and quality. Low-cost ultraportable devices are now readily available [28]. Regardless, the financial investment required to overcome these barriers will be substantial.

It is noteworthy that nearly 40% of the samples perceived a lack of time to learn as the reason why they could not obtain skills in POCU. This will be a substantial barrier to surmount. The prospect of acquiring a new skill can seem challenging. However, with minimal training, residents interested in developing skills in POCU can rapidly become proficient [14,15]. Pediatric residents do have multiple competing demands on their time that they must prioritize for their immediate career progression. For example, annually, pediatric residents must pass the specialty board examinations set by the Saudi Commission for Health Specialties. However, they must also make time to acquire the clinical acumen and skills (e.g., POCU) they require to provide quality care for children. Though initiating training during medical school would be ideal, literature indicate that training must be delivered in residency programs and fellowships until this can be realized [26].

4.5. Limitations and strengths

The survey was performed toward the end of the scholastic year. The pediatric PGY-4 residents had almost completed their training, making the findings and suggestions applicable to pediatric fellows, at least at the start of their fellowships.

Although the response rate achieved the desired accuracy, the study does have some limitations. There are many potential sources of bias in data derived from self-reported knowledge [29]. The pediatric residents' self-reported level of POCU skills and

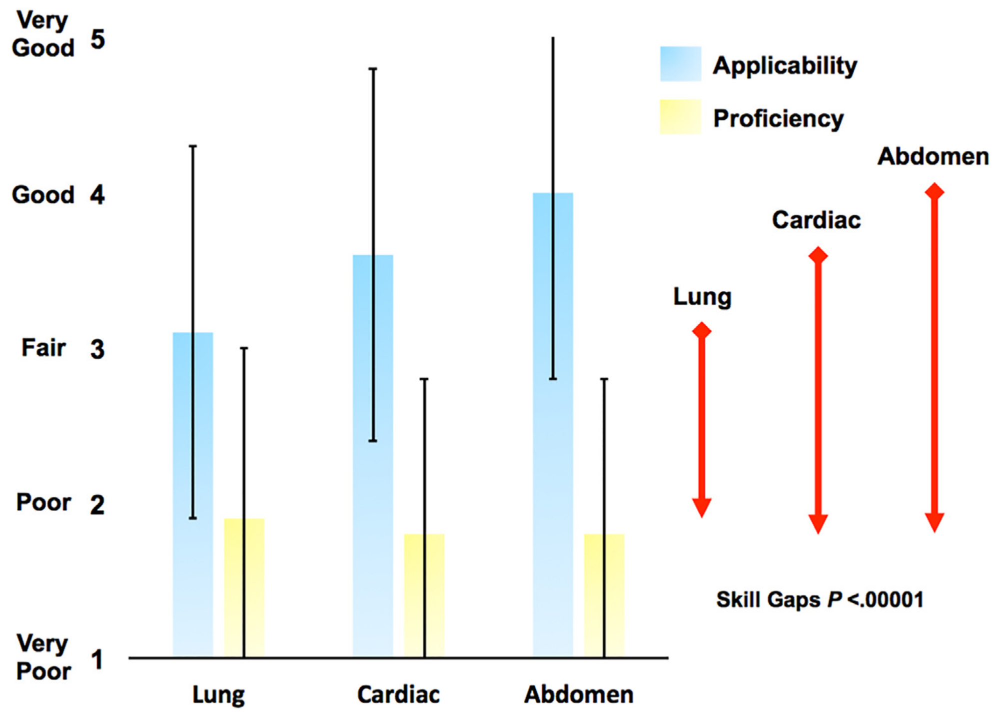

Fig. 5. Pediatric residents' skill deficits in POCU.
This figure illustrates pediatric residents' skill deficits in 3 organ systems for POCU. The skill deficit for each system for POCU was calculated by subtracting individual pediatric residents' self-reported proficiency in it from their mean perception of the indications for POCU of that system. All skill deficits were significant ($P < .00001$). Data are presented as mean ± standard deviation. Abbreviations. POCU, point-of-care ultrasound.

knowledge were low. Our personal experience corroborates these findings.

The generalizability of the findings may be limited. It was performed with residents in one pediatric residency training program in Riyadh, Saudi Arabia. However, the pediatric residency program at our institution is large and accepts interns trained at medical schools throughout Saudi Arabia. The residency program also includes elective rotations. Residents can choose to undertake these elective placements in any hospital in Saudi Arabia. Residents, who trained at other centers within Saudi Arabia, also transfer to our institution. The probability that the samples represent pediatric residents trained elsewhere in Saudi Arabia is high. It may provide insight for countries where the training programs also have an annual specialty board examination. The findings of our study are relevant to institutions that aim to advance general pediatrician training in POCU; safely and effectively.

4.6. Addition to literature

The present study provides evidence that pediatric residents' training in Saudi Arabia perceives POCU skills applicable in their present practice. However, there is no POCU training available during pediatric residency training. As a result, the samples' level of POCU knowledge and skills were low. This finding is likely to reflect in the training of residents in pediatrics throughout Saudi Arabia, indicating a substantial POCU skills deficit. A minority was not interested in being taught about POCU, and many pediatric residents felt that they lacked the time required for POCU training.

The observation that a few pediatric residents, who used POCU were self-taught, raises clinical governance issues. These must be resolved by introducing curricula with formal processes for supervision, governance, and accreditation in POCU. However, until POCU is integrated into medical school training, pediatricians must achieve these skill deficits during their residency or fellowships. Pediatric residency program directors must be aware of the skill deficits and take the necessary steps.

5. Conclusions

In Saudi Arabia, although pediatric residents perceive that POCU is a useful skill, they do not receive any training in this domain. Their proficiency is low, and a significant skills deficit was identified. However, few trainers are available, and almost half of the residents indicated that they lacked the time required for POCU training. There are several barriers to overcome to integrate POCU into the pediatric residency training.

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Sources of funding

None to declare.

Ethics approval and consent to participate

The institutional review board of King Abdulaziz Medical City (KAMC) at the King Abdullah International Medical Research Center, Riyadh, Saudi Arabia approved this study. Informed consent was obtained from all participants.

CRediT authorship contribution statement

Syed Furrukh Jamil: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Validation, Roles/. **Rajkumar Rajendram:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Roles/.

Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.ijpam.2021.06.001.

Visual abstract

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijpam.2021.06.001.

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