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Evaluation and Improvement of Knowledge of Medical Staff on Pulse Oximetry in Educational Hospitals

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Abstract

Background: Pulse Oximeter monitoring has become so common over previous decades that in some health care units, blood oxygen level is now considered as the fifth vital sign. However, it seems there is still some lack of knowledge and/or experience among medical staff operating pulse oximeter and interpreting its results. The aim of this study was to investigate and compare the knowledge on Pulse Oximetry among medical staffs working with these devices.

Methods: A standardized questionnaire on the performance of pulse oximetry and influencing factors was provided to a group consisting of nurses, pediatric residents, respiratory therapists and anesthetic technicians before and after an educational program on pulse oximetry. Responses to the questionnaires before and after the course were analyzed and compared.

Results: A total number of 101 participants completed the questionnaires which constituted 31 pediatric residents (31%), 51 nurses (50%), 7 respiratory therapists (7%) and 12 anesthetic technicians (12%). Pre course and post course mean knowledge score on pulse oximetry in participants were 10.93 ± 4.55 and 14.07 ± 1.98, respectively ($p< 0.001$). Implementing educational program on pulse oximetry, increased the percentage of mean knowledge score on pulse oximetry significantly from 74% to 93% ($p<0.001$).

Conclusion: Educational course for pulse oximetry, significantly improved the knowledge scores among participants in our study. Continuing medical education (CME) and adequate training programs to improve the lack of knowledge on pulse oximetry is highly recommended.

Keywords: Pulse oximetry, Medical staff, Nurse, Pediatric resident, Physical therapist, Anesthetic technician, Medical knowledge

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Background

Pulse oximetry is considered an important and frequently used device for non-invasive monitoring and assessment of arterial blood oxygenation (1). It is imperative for medical staff, especially those who work in emergency rooms, ICUs and CCUs, to know the functions of the pulse oximetry device and more importantly how to accurately explain and interpret the obtained data to better evaluate and take care of critically ill patients (2, 3).

Most of the initial assessment and treatment of acutely ill patients is provided by trainee doctors and nurses working at hospitals. Previous studies have shown that there is a lack of knowledge on pulse oximetry in trainees and other medical staff who are usually measuring vital signs in patients (2-8); and this lack of knowledge has the potential to influence patients' outcome and contribute to the high level of clinical errors. It may result in the failure to detect clinical deterioration, to perform timely intervention, and to commence simple supportive care leading to cardiac arrest, intensive care unit admission, or death. Frequently, there is poor management of the patient's airway, breathing, circulation, oxygen therapy, fluid balance, and monitoring. Although the cause of such insufficient care is inevitably multi-factorial, basic education in acute care and the preparation of staff for clinical practice seems to be important determinants (9). During the departments' meetings and grand rounds, we received significant amounts of reports from our colleagues and attending physicians about misinterpretation and misunderstanding of pulse oximetry among medical staff working in neonatal and pediatric wards. In order to address this issue, we decided to evaluate the knowledge of our staff who are actively interacting with the patients' vital signs in pediatric hospitals; and also provide an opportunity for the medical staff to participate in educational courses for learning and updating their knowledge on critical care issues such as pulse oximetry.

Methods and Materials

In this cross-sectional study, we evaluated the knowledge of our medical staff consisted of nurses, pediatric residents, anesthetic technicians and respiratory physiotherapist who worked in intensive care units in pediatric Centers in 3 training hospitals of Iran University of medical sciences (Tehran, Iran). To obtain a high response rate and decrease missing data, we tried to use a short-in-length questionnaire, which could be easily and rapidly answered. We preferred to choose a standardized questionnaire which includes only closed format and true/false questions. A standardized questionnaire which was developed by Attin et.al. (4) was used for data collection that consisted of 3 sections: (1) demographic data (occupational status, record of service in pediatric unit, experience of using Pulse Oximetry, basic knowledge about Pulse Oximetry, and its educational program type); (2) fifteen short answer questions to determine the knowledge of participant about Pulse Oximetry (Table 1). (As our study was conducted for neonatal intensive care units, 2 questions were omitted from original questionnaire due to irrelevancy to neonatal care and (3) evaluating knowledge of participant after a session about pulse oximetry in clinical cases. The questionnaire was translated into Farsi language and then the translation was evaluated by 3 bilingual (English-Farsi) experts for evaluating and proofreading it. The reconciled Farsi version was then back-translated by a bilingual English-Farsi (native English) speaker, not familiar with the original questionnaire. Then a pilot study was performed on 10 subjects and finally the questionnaire was validated by 3 clinicians familiar with questionnaire and pulse oximetry.

From January to December 2014, the questionnaire was distributed to a convenience sample of health care professionals who were involved in pediatric care. Residents and nurses were enrolled in the study when they had completed their first year of training or practice. The participants were from 3 tertiary care teaching hospitals (Rasoul Akram, Akbar Abadi and Ali-Asghar). The questionnaires were distributed unexpectedly among participants; and they completed the forms voluntarily on site within 20 minutes from the distribution. One of the investigators or a physician who did not participate in the study proctored the entire process at all locations. After filling out the questionnaire, the subjects were asked to participate in an educational course for pulse oximetry. Most of them agreed to participate in the course and completed the course. The time of the course was flexible and included 5 hours of education which was executed mostly at the weekends. Post-course evaluation was performed 3 to 6 weeks after educational course by giving the same questionnaires to the subjects. Correctly answered questions were summed to measure the knowledge score of each participant. Unanswered items were considered as false. Chi-square test was used for categorical variables between groups. We found that all continuous variables were normally distributed using Kolmogorov - Smirnov test. Thereafter, one-way analysis of variance (ANOVA) was used to compare the mean scores between groups with unequal sample size and student t-test used for comparison between pre- and post-course scores in each group. Because multiple comparisons were made on the same data for the comparison of the knowledge scores, the Bonferroni correction was applied to reduce the occurrence of type I errors. Therefore, a p-value less than 0.02 was considered statistically significance. Statistical analysis was performed using Statistical Package for Social Sciences v.18 (SPSS Inc., Chicago, IL, USA).

The study was approved by the ethics committee of the Iran University of Medical Sciences (Tehran, Iran).

Table 1. Demographics of subjects participated in the study

	ED	N-ICU	P-ICU	P-Ward	Total	P-value
Age						
≥ 40	9	3	8	28	51	0.15
< 40	16	13	15	25	71	
Gender						
Male	15	9	11	27	62	0.86
Female	10	12	12	26	60	
Educational Lev-el	12	8	11	34	65	0.04
Nurse	8	6	5	16	35	
PR	5	5	4	0	14	
AT	0	2	3	3	8	
RT						
Professional ex-perience (years)						
< 5						0.01
≥5 & < 10	14	7	7	15	43	
≥ 10	6	8	8	11	33	
	5	6	8	27	46	

ED: Emergency department; P-ICU: Pediatric Intensive Care Unit; N-ICU: Neonatal Intensive Care unit; P-Ward: Pediatric Ward; PR: Pediatric Residents; AT: Anesthetic Technician; RT: Respiratory Therapist

Results

A total number of 122 questionnaires were distributed initially and all of them were answered by medical staff. One hundred and one subjects completed the educational course and responded post course questionnaire. The final responders were evaluated including 26 pediatric residents (42.6%), 35 nurses (57.4%). Demographic data is depicted in Table -1. There was a statistically significant difference in educational level (p= 0.01) and professional experience (p= 0.01) of participants in different departments. After educational program on pulse oximetry, the mean score increased significantly from 74% to 93% (p <0.001) (Table -3).

Based on the educational level, 27 nurses (54%), 14 residents (28%), 7 anesthetic technicians (14%) and 2 respiratory therapists (4%) answered to all 15 pre-course questions completely.

Also, comparison of pulse oximetry mean knowledge score (POMKS) among participants who completed the educational course showed statistically significant difference in some of the parameters which is depicted in Table - 4.

Table 5 depicts the comparison of our study to other previous studies which evaluated the knowledge of medical staff on pulse oximetry. Figure 1, illustrates the mean pre-course scores based on the clinical experience of respondents.

Table 2. Demographics of subjects completed the study

	ED	N-ICU	P-ICU	P-Ward	Total	P-value
Age						
≥ 40	6	3	6	22	37	0.04
< 40	14	13	14	23	64	
Gender						
Male	13	7	10	23	53	0.95
Female	7	9	10	22	48	
Educational Level						0.008
Nurse	9	5	8	29	51	
PR	7	5	5	14	31	
AT	4	4	4	0	12	
RT	0	2	3	2	7	
Professional experience (years)						0.008
< 5	13	7	7	15	42	
≥5 & < 10	5	7	7	10	29	
≥ 10	2	2	6	20	30	

ED: Emergency department; P-ICU: Pediatric Intensive Care Unit; N-ICU: Neonatal Intensive Care unit; P-Ward: Pediatric Ward

Table 3. Percentage of correct answers for questions addressing understanding of Pulse Oximetry questionnaire given before and after the educational program on pulse oximetry

	Before program (%)					After Program (%)				
	Nrs (n=65)	Res (n=35)	RT (n=8)	AT (n=14)	Total (n= 122)	Nrs (n=51)	Res (n=31)	RT (n=7)	AT (n=12)	Total (n=101)
1. Pulse oximetry is a method for continuous noninvasive measurement of arterial Oxygenation and ventilation.	58 (89)	32 (94)	7 (88)	12 (86)	115 (94)	50 (98)	31 (100)	7 (100)	12 (100)	100 (99)
2. For oxygen saturations from 70% to 100%, pulse oximeter technology has been found to be accurate	43 (66)	25 (71)	6 (73)	10 (72)	89 (73)	47 (92)	29 (93)	7 (100)	11 (92)	94 (93)
3. Clinical observation alone has been shown to be as effective as pulse oximetry monitoring in the rapid detection of hypoxemia.	41 (63)	27 (77)	5 (63)	10 (72)	83 (68)	43 (84)	27 (87)	6 (87)	11 (92)	86 (86)
4. Significant hypoxemia is unlikely during transport of patients.	52 (80)	25 (71)	5 (63)	9 (64)	91 (75)	48 (95)	30 (98)	7 (100)	12 (100)	97 (96)
5. Pulse oximetry may be unreliable in severely anemic patients.	51 (78)	24 (68)	5 (63)	9 (64)	89 (73)	46 (91)	29 (94)	7 (100)	11 (92)	93 (92)
6. During vasoconstriction and hypotension, the overall performance of finger sensors is generally better than performance of sensors at other sites (ie, ear, forehead, nose).	48 (74)	29 (83)	6 (73)	11 (79)	94 (77)	44 (86)	29 (94)	6 (87)	12 (100)	91 (90)
7. Pulse oximetry can be used safely and effectively in place of frequent analysis of arterial blood gases when decreasing FIO2 to wean patients from mechanical ventilation.	46 (71)	27 (77)	6 (73)	9 (64)	88 (72)	47 (92)	30 (98)	6 (87)	11 (92)	94 (93)
8. Pulse oximetry sensors should be applied at the level of the patient's heart because pulse Oximetry readings may be lower in dependent extremities.	44 (67)	26 (74)	5 (63)	9 (64)	84 (69)	46 (91)	29 (94)	7 (100)	11 (92)	93 (92)
9. Use of the less-pigmented nail bed rather than the skin as a sensor site is preferred in darkly pigmented patients	47 (72)	28 (80)	7 (88)	10 (72)	92 (75)	49 (96)	30 (98)	7 (100)	12 (100)	98 (97)
10. Vasoconstriction combined with low pulse pressure can limit the ability to detect hypoxemia	40 (61)	25 (71)	5 (63)	10 (72)	80 (65)	47 (92)	28 (91)	6 (87)	11 (92)	92 (91)
11. Pulse oximetry readings are usually not affected by body position or ambient light.	44 (68)	23 (65)	5 (63)	9 (64)	81 (66)	48 (95)	29 (94)	7 (100)	12 (100)	96 (95)
12. Spot checks of pulse oximetry readings are as helpful in assessing a patient's oxygenation status as the evaluation of continuous monitoring over time	41 (63)	24 (69)	6 (75)	11 (79)	82 (67)	47 (92)	28 (91)	6 (87)	12 (100)	93 (92)
13. Patients are at increased risk for desaturation during invasive procedures.	56 (86)	31 (86)	8 (100)	12 (86)	107 (88)	50 (98)	30 (97)	7 (100	12 (100)	99 (98)
14. Pulse oximetry is not an indicator of adequacy of ventilation.	51 (78)	29 (83)	7 (88)	12 (86)	99 (81)	49 (96)	31 (100)	7 (100)	12 (100)	99 (98)
15. Pulse oximetry is adequate for monitoring hyperoxemia in premature neonates.	52 (80)	28 (80)	6 (75)	11 (79)	97 (79)	48 (95)	30 (98)	6 (87)	11 (92)	95 (94)
Total score (average of individuals answered correctly)	47 (73)	27 (77)	6 (76)	10 (73)	90 (74)	47 (93)	29 (94)	7 (96)	11 (92)	94 (93)

Nrs = Nurses, Res = Pediatric Residents, RT = Respiratory Therapist, AT = Anesthetic Technician

Discussion

In this study, due to enrollment of different groups with significant differences in education and professional levels, comparisons among study findings was difficult. To reduce these differences, we decided to use a questionnaire that does not include clinical scenarios; so it was easier for those who had less professional experience to answer the questions. The mean knowledge score in our study before educational course was 10.93 ± 4.55, corresponding to a mean percentage of correct responses of 73%. Comparing the response rate in our study to other previous studies, we noticed that it was higher than the reported responses by other authors such as Kruger and Longden on 203 hospital staff members with 68.5% correct answers (11) or the results by Attin et. al. (4) and Harper (5), which were 62% among their participants. Even though their participants were only nurses, in comparison to their results, nurses in our study had better performance prior participating in educational course (72% correct response).

Younger individuals with lower clinical experience had the lowest scores. Also, senior individuals with more clinical experience responded much better (Figure 1 and Table 1, p = 0.01). Those who had clinical experience more than 10 years had better pre -course scores. This can be explained by the experience of the seniors, previous training classes for seniors and more encounter to pulse oximeter devices during the years. Educational level of participants was another parameter that seemed to show a significant difference, however using ANOVA test and using a weighted mean, we noticed that there was not any statistically significant difference in pre-score knowledge among participants based on their educational level (Table 1, p = 0.04). The better response rate among Anesthetic technicians and respiratory therapists was due to the special classes that they

Table 4. Comparison of pulse oximetry mean knowledge score (POMKS) among participants who completed the course based on the knowledge, experiment, department, education, age and gender

Variable	Pre-course POMKS (Mean ± SD)	Post-course POMKS (Mean ± SD)	P-value
Age			
≥ 40 (n= 37)	13.46 ± 3.2	14.92 ± 0.27	0.03[a]
< 40 (n= 64)	9.47 ± 4.59	13.58 ± 2.35	< 0.001[b]
			0.01[c]
Gender			
Male (n=53)	10.66 ± 4.58	13.89 ± 2.19	< 0.001[d]
Female (n=48)	11.23 ± 4.55	14.27 ± 1.74	< 0.001[e]
Educational Level			
			< 0.001[f]
Nrs (n=51)	10.84 ± 4.53	13.90 ± 2.26	0.002[g]
PR (n=31)	11.39 ± 4.47	14.19 ± 1.80	0.01[h]
AT (n=12)	10.33 ± 5.33	14.42 ± 1.51	< 0.001[i]
RT (n=7)	10.57 ± 4.50	14.14 ± 1.57	
Professional experience (years)			
< 5 (n=42)	7.07 ± 4.09	12.76 ± 2.57	< 0.001[j]
≥5 & < 10 (n= 29)	12.79 ± 2.82	15.00	< 0.001 [k]
≥ 10 (n = 30)	14.53 ± 1.25	15.00	< 0.001 [l]
			< 0.001 [m]
Department			
N-ICU (n=16)	10.00 ± 4.97	13.94 ± 2.05	0.002[n]
ED (n= 20)	9.60 ± 4.59	14.20 ± 1.70	< 0.001[o]
P-ICU (n=20)	10.90 ± 4.24	14.70 ± 0.97	< 0.001[p]
P-Ward (n= 45)	11.87 ± 4.37	13.78 ± 2.36	< 0.001[q]

ED: Emergency department; P-ICU: Pediatric Intensive Care Unit; N-ICU: Neonatal Intensive Care unit; P-Ward: Pediatric ward; Nrs = Nurses, Res = Pediatric Residents, RT = Respiratory Therapist, AT = Anesthetic Technician; POMKS: Pulse Oximetry Mean Knowledge Score

[a] $p = 0.03$ *among participants with age ≥ 40 comparing pre and post course POMKS*
[b] $p < 0.001$ *among participants with age < 40 comparing pre and post course POMKS*
[c] $p = 0.01$ *participants with age ≥ 40 vs. those with age <40 comparing pre course POMKS*
[d] $p < 0.001$ *among male participants comparing pre and post POMKS*
[e] $p < 0.001$ *among female participants comparing pre and post POMKS*
[f] $p < 0.001$ *among nurses comparing pre and post course POMKS*
[g] $p = 0.02$ *among pediatric residents comparing pre and post course POMKS*
[h] $p = 0.01$ *among anesthetic technicians comparing pre and post course POMKS*
[i] $p < 0.001$ *among respiratory therapists comparing pre and post course POMKS*
[j] $p < 0.001$ *among participants with professional experience < 5 years comparing pre and post course POMKS*
[k] $p < 0.001$ *among participants with professional experience ≥ 5& < 10 years comparing pre & post course POMKS*
[l] $p < 0.001$ *among participants with professional experience > 10 years comparing pre and post course POMKS*
[m] $p < 0.001$ *participants with professional experience < 5 years vs. those with > 10 years comparing pre course POMKS*
[n] $p = 0.002$ *among participants working at N-ICU comparing pre and post course POMKS*
[o] $p < 0.001$ *among participants working at ED comparing pre and post course POMKS*
[p] $p < 0.001$ *among participants working at P- ICU comparing pre and post course POMKS*
[q] $p < 0.001$ *among participants working at P-ward comparing pre and post course POMKS*

must take on vital signs monitoring including pulse oximetry.

Although results prior to educational course seemed satisfactory, but significant knowledge deficits were observed among participants in responding to some questions. We noticed that most of participants were unaware of the factors that might affect the interpretation of pulse oximetry. Questions 10,11, 12, 3, 2 and 8 with respectively 42, 41 and 40, 39, 38 and 38 incorrect responses showed the lowest percentage of correct responses. Questions 10 and 11 were related to the factors affecting pulse oximetry interpretation.

Comparison of pre-and post-course POMKS among participants who completed the educational course for pulse oximetry showed a significant improvement in their results (Table 4). This implies that educational course was an effective way to increase the knowledge of medical staff regarding pulse oximetry. Although most of studies on the knowledge of medical staff on pulse oximetry indicate that there is a lack of knowledge among their study group, but they did not evaluate the effect of education and training courses on their subjects (6 -18). The surveys or questionnaires used in these studies are variable and there is not a consolidated method for evaluation of knowledge on pulse oximetry. Also, these studies were performed on different groups of medical staff. We decided to choose our

Table 5. Summary and comparison of several previous studies evaluating knowledge on pulse oximetry in medical staff

Researcher/year	Sample size	Type of Survey/questionnaire	Main findings
Stoneham/1994 [2]	30 nurses, 30 junior doctors	12 items questionnaire	3% understood how a pulse oximeter works and 97% of doctors and nurses did not understand how a pulse oximeter worked
Rodriguez/1994 [10]	134 junior doctors	16 items questionnaire	67% knew what is the use of pulse oximeter
Kruger/1997 [11]	33 doctors, 164 nurses, 6 AT*	14 items questionnaire	Only 68.5% correctly stated that what pulse oximeter measures
Bilgin/2000 [12]	44 nurses & 12 junior doctors	17 items questionnaire	75% of participants knew what a pulse oximetry measures
Attin/2002 [4] [α]	331 registered nurses, 82 doctors & 29 RT*	17 items true/false questionnaire	66% responded correctly prior to educational course
Howell/2002 [13]	8 medical staff, 30 trained nurses, 12 untrained nurses	7 items questionnaire	Only 57% trained nurses, 33% untrained nurses and 63% of medical staff were aware of how pulse oximeter works
Teoh/2003 [14]	74 senior doctors, 47 junior doctors	16 items questionnaire	Only 36% correctly answered 3 questions about the accuracy and limitations of pulse oximetry
Davies/2003 [15]	34 doctors, 29 nurses	12 items questionnaire	71% knew how a pulse oximetry works
Harper/2004 [5]	19 nurses	32 items questionnaire	Only 32% knew how pulse oximetry works
Popovich/2004 [16]	42 nurses, 15 doctors, 9 RT	19 items questionnaire	84% knew what pulse oximetry measures
Giuliano/2006 [3]	551 experienced critical care nurses	7 items questionnaire	86% knew poor perfusion affects the accuracy of readings
Fouzas/2010 [17]	187 pediatricians, 143 family practitioners,175 nurses	14 items questionnaire	Pediatric health care professional has marked deficiency in their knowledge on pulse oximetry
Huijgen/2011 [18]	42 GPs, 4 GP# registrars	?	50% knew what pulse oximetry measures
Kiekkas/2013 [8]	207 nurses	21 items questionnaire	61.8% knew how pulse oximetry works
Seeley/2015 [7]	307 graduate nurses	21 items questionnaire	80.5% knew how pulse oximetry works
Current study [α]	65 nurses, 35 doctors, 8 RT*, 14 AT*	15 items questionnaire	94% knew what pulse oximetry measures

**AT: Anesthetic technician, RT: Respiratory therapist; # PCP: Primary care pediatrician, GP: General practitioners*
[α] Studies that implemented an educational course

subjects based on their frequency of encounter to the pulse oximetry device and we noticed that these is a high probability that our target group encounter more often with pulse oximetry devices. There are scarce studies in which the educational course has been used to evaluate the pre- and post-course knowledge of the participants (4). The results of these studies also indicate that the training programs are effective in improvement and updating the knowledge of medical staff on pulse oximetry (4). In a similar study by Attin et. al., they designed a questionnaire and gave it to staff members before an educational course on pulse oximetry. A total of 442 staff members including 331 registered nurses, 82 physicians and 29 respiratory therapists completed the questionnaires. The same survey/questionnaire were given to participants within several months after implementing the educational program on pulse oximetry. A total number of 252 individuals responded to the questionnaires (212 registered nurses, 22 physicians and 18 respiratory therapists). The overall mean percentage of correct responses increased from 66% to 82% (p< 0.01) (4). In comparison to their study, our participants responded much better and the overall mean percentage of correct responses increased significantly from 74% to 93% (Table 3).

The educational programs are meant to encourage individuals to learn more and update their knowledge and the environment should be prepared appropriately for participants in a way that they do not feel embarrassed because of their lack of knowledge on a particular subject or issue. They should be motivated and feel comfortable to participate and they should be notified that these courses are for their own benefit and their

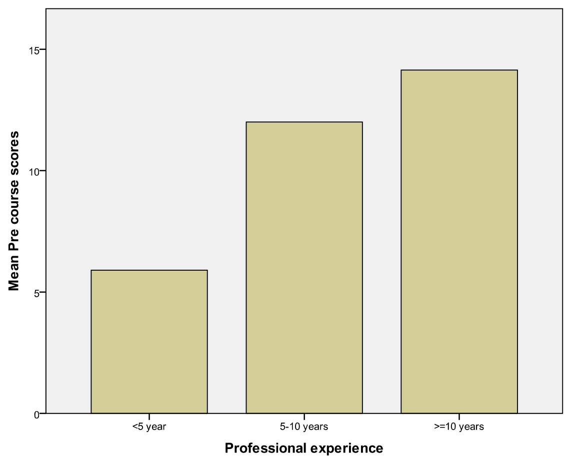

Figure 1. Mean pre course scores based on the clinical experience of respondents

patients.

Our study had some limitations. To encourage responding to the questionnaires as honestly as possible, we told subjects that data collection would be completely anonymous, and no subject identifiers were used. Some subjects who completed the questionnaire given before the start of the educational program did not participate in educational course or complete the questionnaire given after the program.

Also, we found out that most of medical staff complained about the timing of the programs and interference with their schedules. In order to solve this problem, we planned to make a training website on important and mandatory educational subjects and items that are related to emergency medicine such as interpretation of pulse oximetry, EKG, Spirometry, blood test analysis, etc. These training programs will be provided to our medical staff working in educational hospitals and they will receive access codes (username & passwords) to log in and credits will be considered completing the courses. Continued Medical Education keep medical staff up to date and therefore will reduce the chance of making medical errors due to lack of knowledge.

Conclusion

Educational course for pulse oximetry significantly improved the knowledge scores among participants in our study. Continuing medical education and adequate training programs are mandatory to improve the lack of knowledge on pulse oximetry.

Conflicts of interest: Authors declared none.

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