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Nurses' knowledge and self-assessment of their clinical experiences of intraosseous access: A multicentre cross-sectional study

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ABSTRACT

Background: Intraosseous access is an effective and safe option when difficult vascular access occurs. The knowledge, competence, and clinical experience of nurses are collectively essential for the successful implementation of this approach in clinical practice. Education and clinical learning are the main pillars supporting this new practice to ensure patient safety. The aim of this study was to identify the nurses' knowledge and clinical experience of intraosseous access and the factors associated with the adoption of this procedure.

Methods: A cross-sectional study was carried out from October to December 2020. A convenience sample of 432 nurses from four Italian hospitals were involved. A structured questionnaire was used to assess the nurses' knowledge of the intraosseous access guidelines and their clinical experience.

Results: Most participants were female (71.5%) with more than 10 years of experience (63.7%) working in an emergency (38.9%) and medical (37.7%) setting. Most of the participants demonstrated their knowledge of the use of a device e.g., it is used if vascular access is not rapidly achieved in a child (83.1%) and the boluses of liquids required in the intraosseous procedure (72.7%). A few participants reported having placed intraosseous access (3.5%). A higher level of educational preparation and working in emergency and paediatric settings were associated with increased knowledge.

Conclusions: Our findings highlighted a sub-optimal level of knowledge of the IO procedure, little experience of this practice in clinical contexts, also associated with a lack of adequate protocols and devices available to nurses. Nurses need to develop their knowledge and practice the skill clinically to embed this practice. University and nurse educators should emphasise the relevance of this practice in nursing education and training, so as to improve the nursing care practice and level of patient safety.

1. Introduction

Intraosseous (IO) access relates to the placement of a specialised hollow bore needled through the cortex of the bone into the medullary space for the infusion of fluids and medication or for blood sampling [1]. This practice ensures a fast, safe, reliable, effective, and economic route to administer medications and perform laboratory tests in both hospital and pre-hospital settings [2,3] or in emergencies [4]. Moreover, it can be considered if attempts at IV access are unsuccessful or not feasible [5]. Also, the International Liaison Committee on Resuscitation (ILCOR) recently reported that IO access is a reasonable option for drug administration during a cardiac arrest when IV access is difficult [6].

IO access could be placed, maintained, and removed by physicians, nurses, and paramedics [7] so long as they are proven to have the appropriate knowledge and competency to ensure patient safety [8]. The Infusion Nurses Society [9] has indicated that specifically trained

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nurses are well placed to insert intraosseous devices, thereby facilitating timely, safe, and effective care. The research highlighted the higher success rates of IO insertion compared to vascular access [10] even in paediatric patients [10,11] and neonates [12]. However, the updated guidelines highlighted to consider intraosseous (IO) access if intravenous cannulation is unsuccessful or not feasible [13].

Despite IO access having gained considerable attention during the last decade and having been recommended as a safe and effective approach [3,14], it remains still underused in clinical practice [15].

Central venous catheterisation is the prevailing alternative to peripheral IV access, and IO insertion is only considered as the last option [15]. Insufficient knowledge of IO access by healthcare professionals [16], poor skills and limited experience in clinical practice [17], a lack of devices [18], or a lack of protocols to support clinical decision-making are the main reasons for not adopting this technique.

1.1. Background

The healthcare professionals' knowledge, skills and education related to IO access are crucial to fostering its more widespread use in clinical practice [17]. Educational interventions are the key facilitators associated with the healthcare professionals' use of IO access [19]. Theoretical knowledge provides the foundation for practice implementation, and at the same time, it is crucial to provide a clinical learning experience for competency development and the development of practitioner capability [20]. To increase the adoption of IO in clinical practice, healthcare professionals need to combine adequate theoretical training with practical experience of IO access [21]. Also, to maximise the knowledge and skills retention among healthcare professionals, it is essential to update the knowledge of practitioners in accordance with the latest guidelines [22] and to plan periodic clinical re-training [23]. The knowledge and competence implementation should be focused on evidence-based findings, on supporting self-directed learning [24], and on embedding them in clinical practice [25]. However, there are still gaps when it comes to translating the evidence into practice, such as a lack of knowledge and skills, healthcare policies, workforce shortage, and equipment availability. On the other hand, having the possibility to refer to experts, supportive leadership, clinical learning opportunities, and easy access to the protocols facilitates the implementation of a new procedure into practice [26]. Supporting the practitioners' confidence and self-efficacy alongside the knowledge and skills to perform intraosseous access will assist in the development of the practitioners' capability, thus enabling the nurses to take a key role in utilising IO in their clinical practice. Capability is defined as the combination of skills, knowledge, and self-efficacy which enables individuals to manage change, to be flexible, and to move beyond their current competency [27].

The guideline adoption requires constant monitoring, organisational support, and feedback regarding the healthcare professionals' clinical practice [28]. Therefore, to facilitate the adoption of IO practice, it is important to support the nurses' education, especially in the critical care departments where this practice could improve patient safety. For this purpose, the IO procedure should become a core element of nursing education and post-graduation training, especially in the intensive care, paediatric and emergency departments [8].

To date, there has been a dearth of evidence examining healthcare workers' knowledge and competence around IO access. Most studies involving medical staff have highlighted those major improvements are needed to implement this practice on a more widespread basis [29]. To our knowledge, no evidence exists about nurses' knowledge or clinical experience in reference to this practice [30].

This study aims to assess the sampled nurses' knowledge and clinical experiences of IO access and the background characteristics that support them in gaining the appropriate knowledge and clinical experience.

2. Methods

2.1. Design and setting

A multicentre cross-sectional study was conducted from October to December 2020 in four Italian hospitals [blinded for referee].

2.2. Study population

Using a convenience sample, all nurses employed in a medical, surgical, emergency, and paediatric setting who agreed to participate by signing the informed consent form were enrolled.

2.3. Study procedures and data collection

In each hospital, a trained researcher recruited the participants and delivered the questionnaire.

The participants were asked to complete the questionnaire and to submit it in a sealed envelope into the designated response box.

2.4. Instrument description

A questionnaire based on the European Resuscitation Council Guidelines [31] and the American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care [3,32] for the placement, management, and removal of IO access as designed and adopted. It included 35 multiple choice questions across the following sections:

i. *Sociodemographic information*: gender; age; level of education, years of experience; healthcare setting.
ii. *Knowledge assessment*: 10 multiple-choice items on IO access management selected from the Guidelines and exploring the following issues: (1) IO placement sites; (2) indications for use; (3) time required to reach different plasma concentrations; (4) time within which IO is used in a critically ill child; (5) administrable infusions; (6) indications for clinical use; (7) boluses of liquid required; (8) advantages versus central venous catheter (CVC) in cardiopulmonary resuscitation (CPR); (9) complications; and (10) contraindications. Each item provided four response alternatives: a correct answer (given one point), an incorrect answer, a distractor, and an "I don't know" option to prevent random responses from the respondents. The score range was 0–10 with a higher score indicating a higher level of knowledge.
iii. *Clinical experiences self-assessment*: 19 multiple-choice items were used to assess the nurses' perception of their own experience (4 items), skills (7 items), and training needs (8 items) regarding IO access.

A panel of 20 expert nurses evaluated the questionnaire's face and content validity. The expert panel were asked to score the clarity and relevance of each question using a 3-point Likert scale (1 = not relevant, 2 = relevant but not necessary, 3 = absolutely necessary). The panel expressed overall agreement with the questionnaire's clarity and relevance. The questionnaire was then pilot tested on a sample of 50 nurses. Item analysis was conducted to determine the difficulty level and the discriminating power of the items [33]. The item analysis was conducted using SITA v1.0 [34]. Overall, the difficulty index ranged from 0.5 to 0.8, showing satisfactory values (acceptability range was 0.0 to 1.0), except for item 3 (time to reach adequate plasma concentration in drug administration via IO access versus IV access) and for item 4 (in a critical child, the time within which IO is used if IV access cannot be found) (value = 0.24 and value = 0.30, respectively). Although these items were difficult for the responders, they were included in the final version of the instrument because they explored fundamental issues. Moreover,

they provide useful insights into core areas of the current guidelines. All items reported an excellent discrimination index with a value ≥0.4 (the acceptability range was −1.0 to +1.0). Item 5 (administrable infusions through IO access), item no. 6 (indications for clinical use of IO), and item 8 (advantages IO access versus CVC in CPR) reported a high capability to discriminate between groups of subjects (value = 0.9, value = 0.8, and value = 0.8, respectively).

2.5. Sample size

The sample size calculation was based on the data analyses performed (Mann–Whitney *U* test and Kruskal–Wallis tests) and on the expected effect size by considering the maximum number of categories involved, 4, after performing association analysis. Given a p-value of 0.05, a power of 0.80, and an effect size of 3, it was expected to involve at least 122 participants. When performing the multiple regression analysis model, we considered 4 predictors, a p-value of 0.05, and a power of 0.80. According to these parameters, the expected sample size was at least 84 participants.

2.6. Data analysis

The categorical variables were presented as frequencies and percentages. For the continuous variables, the mean, median, standard deviation (SD), and interquartile range (IQ) were calculated. The Mann–Whitney *U* test and Kruskal–Wallis tests were performed to assess the statistical differences. After the Kruskal–Wallis test, post hoc analysis was performed using the Mann–Whitney *U* test on each pair of categories by adjusting the p-value using the Bonferroni method. After testing that the distribution of the total score was not skewed, the relationship with the data collected through the questionnaire was assessed using multiple linear regression analysis, assuming that the dependent variable was knowledge's total score. The independent variables were level of education, years of experience, and the healthcare setting. All tests were considered statistically significant with a p-value <0.05.

Statistical analysis was conducted using RStudio v1.4 (RStudio Team, Boston, Massachusetts).

3. Results

3.1. Characteristics of the sample

The final sample consisted of 432 nurses (78.11% response rate), equally distributed among Region Marche (50.9%) and Region Puglia (49.1%). The mean age of the participants was 41.1 (SD = 10.8) years; most were female (71.5%). Table 1 summarises the sample's characteristics.

3.2. Nurses' knowledge of IO access management

There was a high rate of incorrect answers on the time to reach adequate plasma concentration versus IV access (82.9%), on the time within which IO is used if IV access is not available in a critical child (83.1%), on the boluses of liquids required in the procedure (72.7%), on the advantages of IO versus CVC in CPR (60.4%), and on main contraindications (62%). More than half of the respondents correctly answered the questions on the most used clinical situations of IO access (52.8%) and on the fluids that can be administered via IO (56.3%) (Table 2). There were no statistically significant differences for years of experience (p = 0.292) (Table 3). The median score increased with level of education: 3 for nurses with pre-academic education, 4.5 for those with a Bachelor's in Nursing, and 5 for those with a postgraduate education (p = 0.011). Regarding the healthcare setting, the nurses from emergency and paediatric areas scored significantly higher than nurses from other areas (p < 0.001) (Table 3).

Table 1
Overall characteristics of the sample.

Characteristics	N (%) / SD
Overall Sample	432 (100.0)
Mean age (SD)	41.1 (10.8)
Gender	
Male	123 (28.5)
Female	309 (71.5)
Region	
Marche	220 (50.9)
Puglia	212 (49.1)
Level of education	
Pre-academic education	141 (32.6)
Bachelor in Nursing	182 (42.1)
Post-graduate education	109 (25.3)
Years of experience	
<1	26 (6.0)
1–5	73 (16.9)
6–10	58 (13.4)
>10	275 (63.7)
Healthcare setting	
Surgical area	88 (20.4)
Emergency area	168 (38.9)
Medical area	163 (37.7)
Paediatric area	13 (3.0)

3.3. Factors related to the Nurses' knowledge

The multiple linear regression analysis revealed that 13.1% of the variance in the respondents' score was explained by the nurses' characteristics ($R^2 = 0.131$, $F_{5,426} = 12.85$, $p < 0.001$). Level of education is positively and significantly related to the nurses' knowledge ($\beta = 0.636$, $p < 0.001$), while working in a medical healthcare setting is negatively related to the dependent variable ($\beta = -0.830$, $p = 0.002$) (Table 4).

3.4. Clinical experience

Less than half of the participants reported a lack of knowledge of the IO guidelines (41.7%), did not attend a training course (63%), and did not have any re-training (60.6%). In total, 15 participants had placed an IO access previous (3.5%), of which, 11 were via the proximal tibia access point. Almost the entire sample had never removed an IO access (91%) and had never been in situations where they could have used IO access (83.1%). When they could have, they did not mainly due to an awareness of not having adequate enough knowledge (48%), a lack of devices (31.5%), and a lack of practice (16.4%). Specifically, 96.3% of the sample reported the need for simulation training to enhance their theoretical-practical knowledge (86.3%) and 68.6% reported the need for specific devices (68.6%) and protocols for IO access management (74%) (Table 5).

4. Discussion

This study aimed to assess the level of knowledge and clinical experience of the sampled Italian nurses on IO access and to investigate the factors associated with the nurses' capability to perform the procedure. Our results highlight the need for improvements in the nurses' knowledge of the guidelines and more practical experience of managing IO access. The participants indicated their willingness to further deepen their knowledge and clinical competence. IO access is the second line of approach if attempts at IV access are difficult or not successful and it is considered a valid option in emergency situations [6]. For this reason, this study provided useful insights to enhance nurse education and patient safety, by highlighting the gaps in implementing this procedure in clinical practice.

Table 2
Nurses' answers on 10 multiple-choice questions regarding knowledge on IO access management.

Item	N (%) of answers
1. **The sites used and recommended in the adult for intraosseous (IO) access placement are:**	
A. Distal femur, proximal tibia, distal tibia	58 (13.4)
B. I do not know	157 (36.3)
C. * Proximal humerus, distal femur, proximal tibia, distal tibia	208 (48.1)
D. Scapula, proximal humerus	9 (2.1)
2. **The most commonly used clinical situations of IO access are:**	
A. Emergency situations where rapid administration is required and where peripheral access is difficult to place due to oedema, obesity, burns in adults only	80 (18.5)
B. * Emergency situations where rapid administration is required and where peripheral access is difficult to place due to oedema, obesity, burns in adults and paediatric patients	228 (52.8)
C. I do not know	122 (28.2)
D. Only during cardiopulmonary resuscitation (CPR)	2 (0.5)
3. **IO drug administration achieves adequate plasma concentrations versus intravenous (IV) access**	
A. In twice the time	76 (17.6)
B. * In a comparable time	74 (17.1)
C. In half the time	42 (9.7)
D. I do not know	240 (55.6)
4. **In the critical child, how soon do you resort to IO if you cannot find IV access:**	
A. * Within 1 min	73 (16.9)
B. Within 2 min	73 (16.9)
C. I do not know	256 (59.3)
D. CVC is used	30 (6.9)
5. **The IO route allows the administration of:**	
A. * Liquids, drugs and blood products	243 (56.3)
B. I do not know	156 (36.1)
C. Only epinephrine and amiodarone	3 (0.7)
D. NaCl 0.9% and drugs only	30 (6.9)
6. **IO can be used:**	
A. * To administer and withdraw	174 (40.3)
B. I do not know	127 (29.4)
C. To administer	124 (28.7)
D. To withdraw	7 (1.6)
7. **The IO procedure requires:**	
A. * Abundant boluses of liquid by using manual pressure or pressure bag	118 (27.3)
B. 5 ml boluses of saline solution	41 (9.5)
C. Liquid boluses only in the infusion of blood products	36 (8.3)
D. I do not know	237 (54.9)
8. **During CPR, IO access versus central venous access provides**	
A. I do not know	191 (44.2)
B. Same advantages and safer for long-term use	45 (10.4)
C. * The same benefits, but less safe for long-term use	171 (39.6)
D. Fewer benefits and less safe for long-term use	25 (5.8)
9. **The main complications of IO, although rare, maybe**	
A. Pain and haemorrhage	65 (15.0)
B. Haemorrhage and compartment syndrome	29 (6.7)
C. * Infection and compartment syndrome	192 (44.4)
D. I do not know	146 (33.8)
10. **The main contraindications to the IO procedure are**	
A. Fracture and infection	112 (25.9)
B. * Fracture, infection, a previous attempt at the same site	164 (38.0)
C. I do not know	150 (34.7)
D. Obesity	6 (1.4)

* Correct answer according to 2015 ERC Guidelines.

Table 3
Median score (interquartile, IQ) on the overall score of the "knowledge" subscale, according to nurses' characteristics.

Characteristics	Median (IQ)	Effect size estimates	K-W p-value
Total cohort	4 (1–6)		—
Gender		0.037[b]	0.005[a]
Male	5 (2–7)		
Female	4 (0–6)		
Level of education		0.151[c]	0.011
Pre-academic education	3 (0–6)		
Bachelor in Nursing	4.5 (0–7)		
Post-graduate education	5 (2–6)*		
Years of experience		0.005[c]	0.292
< 1	5.5 (2–7.7)		
1–5	4 (0–6)		
6–10	5 (1.2–7)		
>10	4 (1–6)		
Healthcare setting		0.148[c]	<0.001
Surgical area	4.5 (1–6)		
Emergency area	5 (3–7)**		
Medical area	2 (0–5)		
Pediatric area	5 (3–6)		

* $p < 0.05$ test post-hoc vs. Pre-academic education, Bachelor in Nursing.
** $p < 0.05$ test post-hoc vs. surgical, medical, paediatric healthcare settings.
[a] Mann-Whitney's test.
[b] η^2 estimate of the effect size.
[c] ε^2 estimate of the effect size.

Table 4
Multiple linear regression analysis to assess the relationship between total score on ten multiple-choice questions and nurses' characteristics.

Characteristics†	***β* −(95% CI)**	**p-value**	**R^2 – F p-value Effect size (f^2)**
Level of education	0.217 (0.094; 0.339)	$p < 0.001$	$R^2 = 0.131$
Years of experience	−0.020 (-0.116; 0.075)	0.675	$F_{5,426} = 12.85$
Healthcare setting			$p < 0.001$
Surgical area	−0.428 (-0.980; 0.125)	0.129	$f^2 = 0.151$
Emergency area	−0.080 (-0.612; 0.453)	0.768	
Medical area	−0.830 (-1.364; −0.296)	0.002	
Pediatric area	NA*	NA*	

† Independent variables.
Dependent variable: Nurses' knowledge.
* Not Available.

4.1. Nurses' knowledge of the IO guidelines

The nurses' guidelines knowledge is a necessary, but not sufficient, condition to implement clinical practice [35]. However, the low levels of knowledge suggest that in everyday clinical practice, the lack of information could be translated into a partial adherence to guidelines, resulting in potential harm and lower level of patient safety [35,36]. Overall, the findings of this study revealed that the level of Italian nurses' knowledge of IO techniques is suboptimal. However, it is important to pointed out that the theoretical knowledge underpins the clinical practice, while the work environment represents the

Table 5
Nurses' answers to 19 multiple-choice questions related to self-assess the nurse's perception of own experience, skills and training needs regarding IO vascular access.

Item	N (%) of answers
1. **Do you know the latest guidelines on IO vascular access?**	
A. Yes	252 (58.3)
B. No	180 (41.7)
2. **Have you ever attended a training course where IO access was discussed?**	
A. No	272 (63.0)
B. Yes, during basic education (Undergraduate, Bachelor's Degree in nursing)	39 (9.0)
C. Yes, during postgraduate education (Master Degree in nursing science, advanced courses)	13 (3.0)
D. Yes, during a company training course	108 (25.0)
3. **If yes, do you consider the knowledge you have learned adequate to apply the IO procedure in practice?**	
A. Fairly	46 (28.8)
B. Very	13 (8.1)
C. Not at all	34 (21.3)
D. Little	67 (41.9)
4. **If yes, do you carry out re-training?**	
A. No	97 (60.6)
B. Yes, at least every 2 years	22 (13.8)
C. Yes, at least every year	29 (18.1)
D. Yes, every 3 years or more	12 (7.5)
5. **Have you ever placed an IO access?**	
A. No	417 (96.5)
B. Yes, more than once	8 (1.9)
C. Yes, only once	7 (1.6)
6. **If yes, you have placed the IO access in patients**	
A. Adults	10 (66.7)
B. Adults and paediatric	4 (26.7)
C. Paediatricians	1 (6.7)
7. **If yes, you have positioned IO access in case of**	
A. Cardiac arrest	1 (6.7)
B. Difficulties in finding IV access	9 (60.0)
C. Major trauma	5 (33.3)
8. **If yes, you have chosen to place the IO access**	
A. Distal femur	3 (20.0)
B. Distal tibia	1 (6.7)
C. Proximal tibia	11 (73.3)
9. **If yes, which presidium did you use?**	
A. BIG	5 (33.3)
B. EZ-IO	7 (46.7)
C. I do not remember	3 (20.0)
10. **Have you ever removed an IO access?**	
A. No	393 (91.0)
B. Yes, more than once	12 (2.8)
C. Yes, only once	27 (6.3)
11. **In your working context is the nurse autonomous in positioning the IO?**	
A. No, it is a medical prescription implemented by the nurse	68 (25.4)
B. No, it is a procedure decided and carried out by the doctor	163 (60.8)
C. Yes, the nurse is completely autonomous in the IO decision and procedure	37 (13.8)
12. **Have you ever been in a situation where you could have used IO access and didn't?**	
A. No	359 (83.1)
B. Yes, I waited for the anesthetist to place the CVC	34 (7.9)
C. Yes, I continued with the IV access attempts	39 (9.0)
13. **If yes, you did not use IO access for:**	
A. Awareness of not having adequate knowledge	35 (48.0)
B. Lack of devices	23 (31.5)
C. Lack of practice	12 (16.4)
D. Fear of making mistakes and insecurity	2 (2.7)
E. Belief that 'traditional' methods were more efficient and less risky	1 (1.4)
14. **Do you think a company training course is necessary to enhance your theoretical and practical knowledge?**	
A. No, I already feel formed	4 (0.9)
B. No, I am not interested	12 (2.8)
C. Yes, I consider a course and regular practical re-training to be necessary	218 (50.5)
D. Yes, I find a course useful	198 (45.8)
15. **Which mode of training course do you prefer?**	
A. Application exercise or simulation	373 (86.3)
B. Seminar	22 (5.1)
C. Video lessons	37 (8.6)
16. **Are there IO positioning devices in your operative units?**	
A. No	309 (71.5)
B. I do not know	62 (14.4)
C. Yes, but they are not used	25 (5.8)
D. Yes, they are used	36 (8.3)
17. **If not, do you think it is necessary to introduce IO devices?**	
A. No	97 (31.4)
B. Yes	212 (68.6)
18. **Are there company protocols on IO in your operative units?**	
A. No	269 (62.3)
B. I do not know	121 (28.0)
C. Yes	42 (9.7)
19. **If not, do you think it is necessary to introduce protocols on IO?**	
A. No	70 (26.0)
B. Yes	199 (74.0)

circumstances in which theoretical knowledge are applied. It is therefore necessary to reflect on this aspect, probably associated with the still current Italian debate on the development and recognition of advanced nursing knowledge and competences. In fact, at national level there is no formal recognition of nurses' advanced competences; although the contribution of the academic courses in increasing the theoretical knowledge is well established, continuing clinical education is poorly defined [37]. Therefore, the need to acquire advanced skills, such as those relating to the IO procedure, may seem unlikely for nurses, considering also that our findings showed the poor applicability of the technique in the clinical contexts and the few continuing education opportunities specifically designed to increase nurses' practical skills of the IO technique.

Regarding the specific knowledge of the IO procedure, our results revealed important gaps on the time required to reach plasma concentrations: only 17.1% knew that drug administration by the IO route reaches adequate plasma concentrations in a time comparable to that of the IV access. These findings echo what was found by Smereka and colleagues [38] who reported that 60.5% of the nurses find that the fluid infusion is much slower through the IO access than through the IV access. However, this item demonstrated critical values when testing the content validity and the difficulty index, and it should be considered with caution.

The nurses acknowledged IO as the most effective approach in emergencies. However, only 16.9% were aware that in a critical child, the IO route can be used within one minute if IV access cannot be found. Regarding the main complications of IO access, less than half of the nurses correctly indicated infection and compartment syndrome as the most important problems, while about one-third admitted that they did not know what they were. These results contrast with those of Smereka and colleagues [38] where 87.1% of the respondents correctly indicated

infection as a possible complication.

A small portion of the sample knew the main contraindications to the IO procedure being a bone fracture, infection, and a previous attempt at the same site. Probably, there is a lack of knowledge about the complications and contraindications associated with poor knowledge of the recommended sites for placing IO access. More detailed and practical training is necessary based on innovative teaching methods such as simulation technology-enhanced learning [39]. About half of the nurses did not know that during resuscitation, IO offers the same advantages. This result deserves attention considering that the insertion of a CVC requires a high level of expertise and can be time-consuming and difficult during resuscitation [23], whereas IO is a faster and safer way. Finally, higher levels of knowledge can be detected in two aspects: the IO route as a suitable option for the administration of fluids, drugs, and blood products, and the clinical situations in which IO access could be considered.

4.2. Nurses' perception of their experience, skills and training needs regarding IO access

Although the efficacy of IO access is well known, it is rarely adopted [40], as confirmed by our results. Only 3.5% of the sample had placed an IO, mainly in the emergency (53.3%) and surgical (26.7%) settings.

Academic-clinical partnerships are crucial for promoting the nurses' knowledge and clinical competencies [41]. The results show that approximately half of the sample had never participated in an IO training course and were not familiar with IO, similar to the findings of Smereka and colleagues [38]. Only a few respondents considered their knowledge as adequate.

In our sample, about half of those who have attended an IO training course did not carry out retraining. In contrast with this data, research shows that a training course should be consolidated by regular retraining [23].

Almost our entire sample stated that they had never placed an IO access (96.5%) in agreement with the work of Smereka and colleagues [38]. A possible explanation for this lack of experience could be due to the nurses' inadequate self-perceived knowledge, and their scarce awareness of the possibility of a nurse being independent when positioning an IO access. Moreover, more than half of the participants reported that in their clinical settings, IO access insertion is considered to be a medical prescription. Therefore, the position of IO access remains predominantly a medical intervention. This could be explained by considering the sociological theories on the professional boundaries in healthcare. In fact, it is recognised that healthcare professionals play a pivotal role in the development, negotiation, and maintenance of boundaries and in implementing various strategies for claiming specific knowledge and asserting their ownership over certain tasks [41].

However, the Infusion Nurses Society [9] clearly states that a qualified nurse, who is proficient in infusion therapy and who has been appropriately trained for the IO procedure, may insert, maintain, and remove these devices. In accordance with these statements, organisational policies should acknowledge the IO access as a nursing competence when properly documented.

The educational background of healthcare professionals should be characterised by the acquisition of knowledge and skills in IO positioning and management [8]. Continuing education provides the opportunity to learn and advance safe and effective nursing skills, especially those that are useful in life-threatening situations [9]. Given the importance of the IO technique for emergency, medical and surgical care, protocols should be implemented to ensure their effectiveness, appropriateness, and efficiency in nursing care practice [42]. Instead, our results show a lack of protocols and of adequate devices, while the nurses considered the introduction of protocols and devices to be necessary elements for safe and effective patient care [43].

4.3. Factors associated with the nurses' knowledge

Our results also highlighted some of the nurses' characteristics related to their level of knowledge of IO access. A higher level of education was predictive of a better total test score: nurses with postgraduate education scored significantly higher than those with a Bachelor's in Nursing and pre-academic education. Evidence suggests that nurses with a postgraduate education are more likely to perform critical thinking and have the right decision-making competencies, making it useful to implement advanced clinical competencies [44].

Furthermore, the nurses working in an emergency or paediatric clinical setting demonstrated a higher knowledge of the IO guidelines. Both areas are not significant predictors in the regression model. This could be due to IO access representing a faster and more effective infusion route in situations where peripheral IV access is difficult to find and therefore it is predominantly used in emergencies such as shock, severe dehydration, cardiac arrest, major trauma, or airway compromise [2], as well as in paediatric patients [10]. In this way, nurses working in those areas have a higher experiential knowledge of the procedure but not necessarily the associated knowledge of the guidelines.

5. Limitations

This study presents some limitations that need to be acknowledged. First, convenience sampling was utilised and therefore generalisation of our results should be considered with caution.

Secondly, we do not know whether the protocols adopted in the healthcare facilities were based on the updated guidelines and whether periodic retraining programmes were available. The results could therefore be affected by heterogeneous work and training contexts.

Also, the instrument is based on the participants' self-assessment, and due to this, the measures could be affected by a social desirability bias. Two items of the scale were rated as "difficult" by the participants, and this could also affect the outcome measures for those areas of assessment. It has not been possible to delete or reword those items because they covered two specific core areas of the guidelines. It is possible also that the items were scored as "difficult" due to the lack of exposure to IO insertion. There is little established correlation between self-assessment and independently rated competence [45,46,47]. However, self-assessment is widely used in assessing the need for further training [48].

Finally, our sample's characteristics and the cross-sectional design, while supporting reliable associations between the variables, suggests the need for caution when interpreting the regression model. Moreover, the regression model includes also non statistically significant parameters: while this could negatively affect the model's statistical fit, this approach better highlights the core areas to focus on for improving nurses' knowledge.

Paediatric nurses are less represented and further studies should focus more on this clinical setting and recruit a wider and more balanced sample. Furthermore, this study focused specifically on the nursing profession, as IO access is internationally recognised as a nursing competence. In different national settings, other healthcare profiles could be eligible for performing this procedure.

6. Relevance to clinical practice

This study contributes to strengthening the debate on the role of specialised nursing education and the importance of identifying strategies to expand advanced skills to increase the quality of care and patient safety outcomes [49,50].

The questionnaire used in the study could be periodically administered in clinical settings to assess the nurses' knowledge of IO access and to plan future educational and re-training programmes based on the target groups' characteristics and the nurses' working areas.

Nurse managers can find, in our findings, support for claiming the

importance of continuing education and training in the work environment to enhance patient safety. Managers need to convey the current evidence to nurses and inspire and support their adherence to the guidelines to improve the quality and safety of nursing care.

Therefore, within multidisciplinary teams, it is necessary to both enhance the nurses' role in this area and to introduce a specific knowledge and set of skills into clear and context-based nursing curricula. This nursing skill adoption is currently suboptimal in terms of clinical practice. Promoting opportunities for education, training, and simulation are crucial for a safe and effective advancement of clinical practice. Moreover, the implementation of an organisational policy for IO access would further promote the adoption of advanced nursing competencies and skills. The process of continuing professional development and skills acquisition is closely associated with practice development and defines the advancement of nursing practice.

Future research should focus on the implementation and evaluation of evidence-based educational interventions to determine their effect on increasing the appropriate and risk-aware use of IO access by nurses. Moreover, further studies might explore the IO access implementation amongst other healthcare workers and paramedics involved in emergency settings, if eligible for this procedure according to the specific healthcare and professional regulations in their own country.

7. Conclusions

Our study identified a low level of knowledge of the IO procedure, little experience of this practice among Italian nurses and a lack of protocols and of adequate devices in clinical settings. However, the participants showed a proactive approach by acknowledging the need to acquire advanced skills on IO access. A higher level of nurse's education is a predictor of an overall higher level of knowledge of the IO guidelines. Moreover, although we did not demonstrate evidence for working areas as predictors of better nurse's knowledge of IO guidelines, our results suggest that nurses working in paediatric and emergency settings showed higher level of knowledge. Further studies, with larger sample size, are required to better explore these preliminary findings.

However, the findings of this study are a starting point to further plan nursing education, advanced skills implementation, and continued training. The results, therefore, aim to highlight the relevance of academic, clinical, and organisational partnerships to invest in specialised academic courses and continuing nursing education to develop advanced nursing competencies, which positively affect nursing care quality and patient safety, by providing a wider set of competencies and clinical options in life-threatening situations.

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Ethical statement:

National and European laws (EU, 2016/679) have been adopted to ensure data confidentiality, in accordance with the Personal Data Act [Personal Data Act 523/1999. https://www.finlex.fi/en/laki/kaannokset/1999/en19990523.pdf (accessed October 3, 2020)]. The participation was voluntary to all participants and in compliance with the standards of informed consent, data confidentiality and anonymity (EU, 2016/679). Due to the type of data collected, and the descriptive design of the study, Research Ethics approval was not required. The administrative authorizations were requested and obtained from the Health Directors of the Local Health Providers [blinded for referee].

CRediT authorship contribution statement

Giancarlo Cicolini: Conceptualization, Methodology, Writing – review & editing, Supervision, Project administration. **Dania Comparcini:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Visualization. **Valentina Simonetti:** Conceptualization, Methodology, Resources, Writing – original draft, Writing – review & editing. **Cinzia Anna Maria Papappicco:** Software, Investigation. **John Unsworth:** Writing – review & editing. **Marco Tomietto:** Conceptualization, Methodology, Data curation, Writing – original draft, Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

[1] Dornhofer P, Kellar JZ. Intraosseous vascular access. StatPearls. Treasure Island (FL): StatPearls Publishing; 2022.
[2] Petitpas F, Guenezan J, Vendeuvre T, Scepi M, Oriot D, Mimoz O. Use of intraosseous access in adults: a systematic review. Crit Care 2016;20:102. https://doi.org/10.1186/s13054-016-1277-6.
[3] American Heart Association. 2005 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Part 7.2: Management of Cardiac Arrest. Circulation 2005;112:IV-58–IV-66.
[4] Schwartz D, Amir L, Dichter R, Figenberg Z. The use of a powered device for intraosseous drug and fluid administration in a national EMS: a 4-year experience. J Trauma 2008;64:650–5. https://doi.org/10.1097/TA.0b013e31814db2a6.
[5] Panchal AR, Bartos JA, Cabañas JG, et al. Part 3: Adult basic and advanced life support: 2020 American Heart association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation 2020;142:S366–468. 10.1161/CIR.0000000000000916.
[6] Granfeldt A, Avis SR, Lind PC, et al. Intravenous vs. intraosseous administration of drugs during cardiac arrest: a systematic review. Resuscitation. 2020;149:150–7. 10.1016/j.resuscitation.2020.02.025.
[7] Feldman O, Nasrallah N, Bitterman Y, et al. Pediatric intraosseous access performed by emergency department nurses using semiautomatic devices: a randomized crossover simulation study. Pediatr Emerg Care 2021;37:442–6. 10.1097/PEC.0000000000001621.
[8] Phillips L, Brown L, Campbell T, et al. Recommendations for the use of intraosseous vascular access for emergent and nonemergent situations in various healthcare settings: a consensus paper. J Emerg Nurs 2010;36:551–6. https://doi.org/10.1016/j.jen.2010.09.001.
[9] Infusion Nurses Society & Emergency Nurses Association. The role of the registered nurse in the use of intraosseous vascular access devices. J Infus Nurs 2020;43:117–20. https://doi.org/10.1097/NAN.0000000000000369.
[10] Bielski K, Szarpak L, Smereka J, Ladny J, Leung S, Ruetzler K. Comparison of four different intraosseous access devices during simulated pediatric resuscitation. A randomized crossover manikin trial. Eu J Pediatr 2017;176:865–71. https://doi.org/10.1007/s00431-017-2922-z.
[11] Mori T, Takei H, Sasaoka Y, Nomura O, Ihara T. Semi-automatic intraosseous device (EZ-IO) in a paediatric emergency department. J Paediatr Child Health 2020;56:1376–81. https://doi.org/10.1111/jpc.14940.
[12] Mileder LP, Urlesberger B, Schwaberger B. Use of intraosseous vascular access during neonatal resuscitation at a tertiary center. Front Pediatr 2020;8:571285. https://doi.org/10.3389/fped.2020.571285.
[13] Perkins GD, Graesner JT, Semeraro F, et al. European resuscitation council guidelines 2021: executive summary [published correction appears in Resuscitation. 2021 May 4;163:97-98]. Resuscitation 2021;161:1–60. 10.1016/j.resuscitation.2021.02.003.
[14] International Liaison Committee on Resuscitation. 2005 International consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. Part 4: advanced life support. Resuscitation 2005; 67:213–47. 10.1016/j.resuscitation.2005.09.018.
[15] Bloch S, Bloch A, Silva P. Adult intraosseous use in academic EDs and simulated comparison of emergent vascular access techniques. Am J Emerg Med 2013;31:622–4. https://doi.org/10.1016/j.ajem.2012.11.021.
[16] Szarpak L, Kurowski A, Adamczyk P, Czyzewski L, Truszewski Z, Zaśko P. Are junior doctors trained to use to use intraosseous access? Am J Emerg Med 2016;34:107. https://doi.org/10.1016/j.ajem.2015.10.020.
[17] Iskrzycki L, Smereka J, Szarpak L. Knowledge, skills, and attitudes concerning intraosseous access among hospital physicians. Crit Care Med 2017;45:e117.
[18] Hallas P. Challenges in the use of intraosseous access. Indian J Med Res 2016;143:261–3. https://doi.org/10.4103/0971-5916.182613.
[19] James Cheung W, Rosenberg H, Vaillancourt C. Barriers and facilitators to intraosseous access in adult resuscitations when peripheral intravenous access is not achievable. Acad Emerg Med 2014;21:250–6. https://doi.org/10.1111/acem.12329.

[20] Aiken LH, Sloane D, Griffiths P, et al. Nursing skill mix in European hospitals: cross-sectional study of the association with mortality, patient ratings, and quality of care. BMJ Qual Saf 2016;26:559–68. https://doi.org/10.1136/bmjqs-2016-005567.
[21] Engels PT, Erdogan M, Widder SL, et al. Use of intraosseous devices in trauma: a survey of trauma practitioners in Canada, Australia and New Zealand. Can J Surg 2016;59:374–82. 10.1503/cjs.011215.
[22] Johnson AM, Smith SM. Respiratory clinical guidelines inform ward-based nurses' clinical skills and knowledge required for evidence-based care. Breathe (Sheff) 2016;12:257–66. https://doi.org/10.1183/20734735.010816.
[23] Afzali M, Kvisselgaard AD, Lyngeraa TS, Viggers S. Intraosseous access can be taught to medical students using the four-step approach. BMC Med Educ 2017;17:50. https://doi.org/10.1186/s12909-017-0882-7.
[24] Silva MT, Galvao TF, Chapman E, da Silva EN, Barreto JOM. Dissemination interventions to improve healthcare workers' adherence with infection prevention and control guidelines: a systematic review and meta-analysis. Implement Sci 2021;16:92. https://doi.org/10.1186/s13012-021-01164-6.
[25] Graham ID, Tetroe JM. Getting evidence into policy and practice: perspective of a health research funder. J Can Acad Child Adolesc Psychiatry 2009;18:46–50.
[26] Häggman-Laitila A, Mattila LR, Melender HL. A systematic review of the outcomes of educational interventions relevant to nurses with simultaneous strategies for guideline implementation. J Clin Nurs 2017;26:320–40. 10.1111/jocn.13405.
[27] Bromley P. From competence to capability. Aust Nurs Midwifery J 2017;25:34.
[28] Matthew-Maich N, Ploeg J, Dobbins M, Jack S. Supporting the Uptake of Nursing Guidelines: what you really need to know to move nursing guidelines into practice. Worldviews Evid Based Nurs 2013;10:104–15. 10.1111/j.1741-6787.2012.00259.x.
[29] Szarpak L, Smereka J, Czyż R, et al. Knowledge and attitudes toward intraosseous access among emergency medical service practitioners in Poland. DEMJ 2017;2:112–5. https://doi.org/10.5603/DEMJ.2017.0024.
[30] Drozd A, Madziała M. Nurses' attitudes and beliefs concerning intraosseous access in pediatric patients. Am J Emerg Med 2016;34:1890. https://doi.org/10.1016/j.ajem.2016.06.064.
[31] Monsieurs KG, Nolan JP, Bossaert LL, et al. European resuscitation council guidelines for resuscitation 2015: section 1. Executive summary. Resuscitation 2015;95:1–80. https://doi.org/10.1016/j.resuscitation.2015.07.038.
[32] American Heart Association [AHA]. American Heart Association Guidelines for CPR and ECC; 2020. https://cpr.heart.org/-/media/cpr-files/cpr-guidelines-files/highlights/hghlghts_2020_ecc_guidelines_english.pdf [Accessed October 21, 2020].
[33] Haladyna TM. Developing and validating multiple-choice test items (3rd ed.). London, UK: Routledge; 2004.
[34] SITA: Valutazione dei processi formativi in sanità. Un sistema software per l'item analysis. Epicentro.iss.it.; 2022. https://www.epicentro.iss.it/igea/strumenti/sita [Accessed October 01, 2020].
[35] Simonetti V, Comparcini D, Miniscalco D, Tirabassi R, Di Giovanni P, Cicolini G. Assessing nursing students' knowledge of evidence-based guidelines on the management of peripheral venous catheters: a multicentre cross-sectional study. Nurse Educ Today 2019;73:77–82. https://doi.org/10.1016/j.nedt.2018.11.02.
[36] Simonetti V, Comparcini D, Flacco ME, Di Giovanni P, Cicolini G. Nursing students' knowledge and attitude on pressure ulcer prevention evidence-based guidelines: a multicenter cross-sectional study. Nurse Educ Today 2015;35:573–9. https://doi.org/10.1016/j.nedt.2014.12.020.
[37] Dimonte V, Palese A, Chiari P, Laquintana D, Tognoni G, Di Giulio P. Il dibattito sullo sviluppo di competenze specialistiche/avanzate degli infermieri[The debate on the development of advanced competences]. Assist Inferm Ric 2016;35:116–21.
[38] Smereka A, Stawicka I, Czyzewski L. Nurses' knowledge and attitudes toward intraosseous access: preliminary data. Am J Emerg Med 2016;34:1724. https://doi.org/10.1016/j.ajem.2016.06.031.
[39] Mulyadi M, Tonapa SI, Rompas SSJ, Wang RH, Lee BO. Effects of simulation technology-based learning on nursing students' learning outcomes: a systematic review and meta-analysis of experimental studies. Nurse Educ Today 2021;107:105127. https://doi.org/10.1016/j.nedt.2021.105127.
[40] Smereka J, Szarpak L, Filipiak KJ, Jaguszewski M, Ladny JR. Which intravascular access should we use in patients with suspected/confirmed COVID-19? Resuscitation 2020;151:8–9. https://doi.org/10.1016/j.resuscitation.2020.04.014.
[41] Liberati EG, Gorli M, Scaratti G. Invisible walls within multidisciplinary teams: Disciplinary boundaries and their effects on integrated care. Soc Sci Med 2016;(150):31–9. https://doi.org/10.1016/j.socscimed.2015.12.002.
[42] Minozzi S, Ruggiero F, Capobussi M, et al. EBM, guidelines, protocols: knowledge, attitudes and utilization in the era of law on professional responsibility and safety of health care. Recenti Prog Med 2018;109:294–306. https://doi.org/10.1701/2902.29247.
[43] Penketh J, McDonald M, Kelly FE. EZ-IO(®) intraosseous access teaching in the workplace using a mobile 'tea trolley' training method. Resuscitation 2016;99:e17–8. https://doi.org/10.1016/j.resuscitation.2015.11.016.
[44] Clark L, Casey D, Morris S. The value of Master's degrees for registered nurses. Br J Nurs. 2015; 24:328, 330, 332-4. 10.12968/bjon.2015.24.6.328.
[45] Scaffidi MA, Khan R, Grover SC, Gimpaya N, Walsh CM. Self-assessment of competence in endoscopy: challenges and insights. J Can Assoc Gastroenterol 2020;4(4):151–7. https://doi.org/10.1093/jcag/gwaa020.
[46] Forsman H, Jansson I, Leksell J, Lepp M, Sundin Andersson C, Engström M, et al. Clusters of competence: relationship between self-reported professional competence and achievement on a national examination among graduating nursing students. J Adv Nurs 2020;76(1):199–208. https://doi.org/10.1111/jan.14222.
[47] Lai NM, Teng CL. Self-perceived competence correlates poorly with objectively measured competence in Evidence Based Medicine among medical students. BMC Med Educ 2011;11:25. https://doi.org/10.1186/1472-6920-11-25.
[48] Taylor I, Bing-Jonsson P, Wangensteen S, Finnbakk E, Sandvik L, McCormach B, et al. The self-assessment of clinical competence and the need for further training: a cross-sectional survey of advanced practice nursing students. J Clin Nurs 2019;29(3):545–55. https://doi.org/10.1111/jocn.15095.
[49] Aiken LH, Sloane DM, Bruyneel L, et al. Nurse staffing and education and hospital mortality in nine European countries: a retrospective observational study. Lancet 2014;383:1824–30. https://doi.org/10.1016/S0140-6736(13)62631-8.
[50] Aiken LH, Sloane D, Griffiths P, et al. Nursing skill mix in European hospitals: cross-sectional study of the association with mortality, patient ratings, and quality of care. BMJ Qual Saf 2017;26:559–68. 10.1136/bmjqs-2016-005567.