Original Research

Intraosseous Access: a simulation analysis

Citation: Antov M., Bergesio G., Rinaldi B., Vallana V., Roasio A. "Intraosseous Access: a simulation analysis" (2022) *infermieristica journal* 1(2): 91-97. DOI: 10.36253/if-1923

Received: October 19, 2022

Revised: December 01, 2022

Just accepted online: December 25, 2022

Published: December 28, 2022

Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Competing Interests: The Author(s) declare(s) no conflict of interest.

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Abstract

Introduction: The priority in critical patients is to find a vascular access. The most used access is the peripheral venous access, but when its placement goes wrong or is difficult, the literature recommends implementing intraosseous (IO) access as a valid alternative. The IO access is a rapid, reliable and a relatively safe method. Despite the recommendations, IO access is rarely used when indicated. The objective of this study was to evaluate the critical points of the IO procedure, positioning time, percentage of success at first attempt in simulation and, in according to obtained outcomes, checking of the procedure inclusion within university programs.

Material and methods: A sample of 84 people was recruited; among them 44 were students attending the third year of the Degree Course in Nursing of the University of Turin (site of Asti) and 40 nurses from intensive care unit and emergency ward of Cardinal Massaia Hospital of Asti. A short lesson about IO access took place, followed by a practical demonstration. Subsequently, the IO access insertion performance and difficulty perceived were evaluated. Statistical analysis was performed by means of inferential and descriptive bivariate analysis.

Results: The average value of the performance "IO access insertion" was 12.2±1.22 (average of the assigned points by the sample). The average difficulty perceived was 1.65±0.42, and mainly found in "selection of the correct point of insertion" with a value of 2.64±0.87, "needle placement" with a medium value of 2.35±1.02 and "medication" with a value of 2.0±0.94. Average execution time of IO access and needle placement were 73.3 and 36.1 seconds, respectively. Finally, the success rate at the first attempt was 72.6%.

Discussion: The IO access execution time, for the complete procedure and for the needle placement only, was below the 3 minutes. Among nurses and students, data of the success of the procedure show significant results, but the difference between subgroups is still lower than expected considering

the results of the statistical analysis about procedure success, execution time and error percentage. Most critical issues were found in the retrieval of area of insertion, whereas the most difficulty perceived was on reference point selection, correct needle placement and medication. The procedure may become subject of teaching in the University.
Conclusion: The study evaluates the possibility of the IO access use, by underlining how is necessary a training about it. The principal reason of 'non-use' of this device is the disinformation of healthcare professionals. The results seem to underline the importance of a possible integration of IO access technique in the programs of Degree Nursing Course and post-base course. This may improve nursing in emergency situations and therefore, patient outcomes. When healthcare staff training is possible, periodical refresh is particularly recommended in order to maintain the acquired skills.

Keywords: IO Access, Simulation, Teaching, Nursing student.

Introduction

Intraosseous (IO) access is a technique that uses blood vessels inside the epiphyseal medullary space of long bones, with the aim of handling an emergency situation when the retrieval of a venous access, is necessary to support vital functions, is not possible in any other way[1]. Drugs, crystalloids, colloids, blood products, contrast media administration and collection of blood samples are also possible via IO access.

Notably, IO access in critical patients with severe hypotension seems to have a higher success rate compared to a traditional venous access; hence, IO access should be considered an alternative priority[2,3]. However, despite the literature underlines that IO access may be easily learnt by the healthcare staff, this procedure is still scarcely used[2,4,5].

In a randomized study, a sample of 182 patients in cardiac arrest with a venous access was investigated. In 91% of cases, IO access was inserted at first attempt, compared to an unsuccess rate of 43% for the venous access. In another study, IO access was significantly fast to insert (49 seconds) compared to the venous access (194.6 seconds). Therefore, there is evidence that IO access can be obtained rapidly and with lower attempts in critical situations, compared to the venous access[6,7]. In another study, Clemency et al., (2017) 19 compared the IO and venous access during the return of spontaneous circulation (ROSC) after cardiac arrest. The findings demonstrated that the IO access approach wasn't lower than the venous access; moreover, IO access had a 100% success rate for the first insertion attempt, and therefore greater than the venous access (70-74%)[8].

The Consortium for the IO access in healthcare practice recommends that this insertion techniques and its relative management should be always embedded in University programs for the healthcare students. In 2009, the Infusion Nurses Society declared that the nurses needed specific training to maintain certified skills about the optimal use of IO access and recognition of the complications related to its use[9].

The main anatomical sites of insertion in adults are tibia, and humeral or femoral head, whereas proximal or distal tibia should be used in pediatric patients[2]. The literature underlines how an IO access should be used in emergency situations in case of double failure in venous access placement, after 90 seconds if Glasgow Coma Scale is below 3, cardiac arrest, severe respiratory failure, shock, epilepsy, and intoxications during which an immediate antidote administration is needed[1]. Generally, IO access should not be used in patients with bone diseases such as osteogenesis imperfecta, osteomyelitis, fractures, previous failed attempt of IO access insertion in the same bone, and recent orthopedic surgery[10,11].

The objective of this study was to evaluate the critical points of the IO access procedure, placement time, difficulty perceived, and success rate at first attempt in a sample of Nursing Degree students and emergency nurses. Information about procedure time and success rate of IO placement access would promote evidence on its utility in critical situations and emphasize the possibility

to introduce the IO access procedure as a teaching subject in Degree Course programs.

Materials and methods

Sample

A non-probabilistic sample of 84 people was recruited as part of an observational prospective monocentric study from November to December 2021; among them, 44 participants were students attending the third year of Degree Course in Nursing of the University of Turin (site of Asti) and further 40 participants were nurses from intensive care unit and emergency ward of Cardinal Massaia Hospital of Asti (Table 1). All the participants voluntarily joined the study, after giving verbal and written consent. Students attending the first and the second years of the University and non-critical area nurses were excluded.

Study procedure

The sample was stratified in students and nurse's groups, then further divided in groups of variable size (7-10 learners), by splitting them into "students" and "nurses". The last few were analyzed in term of who had "work experience" and "already having experience of IO access placement". All the groups received a frontal lesson about IO access which lasted about 30 minutes, followed by a practical demonstration.

Peyton method[12], composed by four phases, was implemented. In the first phase, name demonstration, participants observed at normal speed the performance of the procedure carried out by an expert. In the second phase, named deconstruction, the technique was shown at a slower pace and broken down in parts. In the third phase, named formulation, learners could ask questions about the procedure. In the fourth and the last one, performance, participants independently performed the IO access and received appropriate feedback.

The outcomes evaluation consisted of two parts. The first one was the completion of a 13-item check list, derived from infusional solutions and drugs administration via IO access elaborated by the Helicopter Emergency Medical Servuce (HEMS) (Table 2). The final score of this checklist ranges from 0 to 13 points. In the second part of the evaluation, participants had to refer the perceived difficulty experienced during the IO access placement with a 5-point Likert scale (1= no difficulty; 2 = a little; 3 = enough; 4 = a lot; 5= max difficult) for all the 13 HEMS items. Medium time for the whole procedure and only for needle placement were detected.

A pork femur coated by a synthetic leather was used for the anatomical model. Technique simulation was done by a EZ-I0G3® drill and two Teleflex® needle sets of different size (AD needle set 25mm – LD needle set 45mm).

Data collection and analysis

Data were registered on Microsoft EXCEL® and then analyzed with Jamovi®. Descriptive and inferential statistical analysis were carried out. An explorative analysis of quantitative variables was performed, through the computation of main summary indices (media, standard deviation, and range). Absolute frequencies and percentages were used for qualitative variables. Then, bivariate analysis was carried out in order to evaluate the possible association between quantitative variables. A correlation matrix was constructed to evaluate the relationship among quantitative variables. An inferential parametric and non-parametric analysis was also performed to evaluate significant statistical differences between the two groups (students and nurses).

After normality and homogeneity of the data was verified with Shapiro-Wilk and Levene's test, respectively, we carried out reliability testing by confronting parametric (Welch's t) and non-parametric (Mann-Whitney's U) data.

Ethical committee consultation was not deemed necessary because the study was performed by means of an anatomical model and with the consent of the participants. Data were collected anonymously and in accordance with the Italian legislation.

Results

The overall average value of the *"IO access placement"* performance was 12.2 (SD±1.22, range 8-13). Students' average value of *"IO access placement"* was 11.9 (SD±1.42, range 8-13), whereas the average value for the nurses' was 12.6 (SD±0.69, range 11-13). Crossed performance data between the two groups showed a statistically significant correlation ($p < 0.003$). In the portion of the sample which already experienced IO access insertion, average result was 12.3 (SD±0.91, range 11-13), whereas the average value obtained by their counterpart was 12.2 (SD±1.26, range 8-13). Correlation between these two groups was not statistically significant.

An average value of 12.6 (SD±0.74, range 11-13) in performance was foundamong those who already had an experience of IO access insertion, whereas

for those who never had the experience was 12.1 (SD±1.25, range 8-13). This difference was not statistically significant.

Pearson's index between the *"years of work experience"* and insertion performance was 0.92 and not statistically significant ($p < 0.001$). The relationship across *"years of work experience"*, *"work experience in critical area"* and insertion performance was also no statistically significant.

About *"IO access insertion"*, related to the difficulty perceived, an average value of 1,65 in the Likert scale was obtained (SD±0.42, range 1-3,15); a higher difficulty was found in: (I) *"selection of the correct insertion/reference point (E1)"* with a medium value of 2.64 (SD±0.87, range 1-4); (II) *"needle insertion (E7)"*, with 2.35 points (SD±1.02, range 1-5), and (III) *"medication (E10)"* with a value of 2.0 (DS±0.94, range 1-4).

The average difficulty perceived by the students was 1.72 (SD±0.40, range 1-2.62) and was not found in E1 (2.79 SD±0.87, range 1-4), E7 (2.40 SD±0.98, range 1-4) and E10 (2.06 SD±0.91, range 1-4). In the "nurse" group, the average difficulty perceived was 1.56 (SD± 0.45, range 1-3.15), as evidenced in E1 (2.44 SD±0.84, range 1-4), E7 (2.28 SD± 1.09, range 1-5) and in E10 (1.92 SD ±0.99, range 1-4).

The average time for IO access placement was 73.3 seconds (SD±18.6, range 46-160); 72.2 seconds were obtained for the students' group (SD±15.3, range 47-114), whereas 75.7 seconds were obtainedfor the nurses' group (SD±22.2, range 46-160). Data about "time" crossed with groups did not show a statistically significant relationship.

The average time of needle placement (ΔT) was 36.1 seconds (SD±9.29, range 18-67), of which 36 seconds were obtained for nurses (SD±12.4, range 17-79). ΔT data crossed with both groups did not show a statistically significant correlation.

The nurse group carried out the technique with lower mistakes; for some items the average value exhibited the same results as in E2 (100%) and in E13 (100%), compared to E4 (100% vs 90%) and in E10 (98% vs 93%); instead, lower mistakes occurred in the students group.

The phase of IO access in which there were more difficulties was E7 (64-80%), particularly, the group student exhibited difficulties in E7 (64%), E8 (89%) and E10 (89%) whereas the nurse group exhibited them in E7 (80%). Success rate at first attempt in the whole sample was of 72.6% (n=84), 72.7% in the student group (n=44) and 72.5% in the nurse group (n=40).

Table 1. Sample characteristics.

	Total (n)	**Students**	**Nurses**
Male (%)	60	12	16
Female (%)	24	32	24
Età	28,4 (±8,38)	24,4 (±5,25)	34,3 (±8,51)

Legend. *M, mean; SD, standard deviation.*

Chart 2. IO access procedure of the Helicopter Emergency Medical Service (HEMS)

E1 – Insertion point selection – correct reference
E2 – Disinfection and skin preparation
E3 – To prepare the drill with the appropriate needle
E4 – To handle the drill
E5 – Needle pre-insertion
E6 – Drill activation
E7 – Needle insertion
E8 – To remove the drill and the spindle
E9 – Reflux test
E10 - Medication
E11 – Lidocaine flush
E12 – Physiological solution flush
E13 – Start infusion

Table 3. Results of the evaluation of passages of the HEMS, difficulty perceived and insertion time.
Legend: SD: standard deviation; IQR: interquartile range.

	Age	Difficulty tot	Difficulty media	E tot	T Tot	ΔT	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13
Mean	28.6	21.5	1.65	12.2	73.7	36.1	2.64	1.13	1.54	1.56	1.73	1.46	2.35	1.61	1.42	2.00	1.38	1.37	1.32
Median	27.0	21.0	1.62	13.0	72.0	36.0	3.00	1.00	1.00	1.00	2.00	1.00	2.00	1.00	1.00	2.00	1.00	1.00	1.00
SD	8.38	5.50	0.42	1.22	18.6	10.2	0.87	0.43	0.63	0.68	0.70	0.70	1.02	0.73	0.63	0.94	0.60	0.60	0.56
IQR	10.0	7.00	0.54	1.00	24.3	13.0	1.00	0.00	1.00	1.00	1.00	1.00	1.25	1.00	1.00	2.00	1.00	1.00	1.00
Minimum	20	13	1.00	8	46	17	1	1	1	1	1	1	1	1	1	1	1	1	1
Maximum	59	41	3.15	13	160	79	4	3	3	4	4	4	5	4	3	4	4	4	3

Discussion

In Italy, the formative programs of the Degree Course in Nursing are regulated by the Ministerial Decree n.270 of 20/04/21[13] which includes the hours of tuition in class and laboratory to acquire gestural skills, in addition to training.

In the first two years, acquisition of technical expertise is planned for oral, subcutaneous, intravenous and aerosol administration.

Within the medical and critical areas of nursing teaching modules, particular attention is paid by teachers about the retrieval of peripheral venous access. In emergency, endovenous ways assures rapidity of the effect, especially when the patient conditions are deteriorating[8,9]. However, the peripheral access technique largely depends on the patients' vascular heritage and their clinical conditions[14]. This difficulty increases during a cardiac arrest. It is evidenced that the chance of finding a venous access in a pediatric patient with cardiac arrest after 3 minutes is 17% for peripheral access, 77% for central venous access, and 83% for IO access[15,16]. This confirms the difficulty of ensuring an endovenous access in emergency situations and shows that IO access may be an optimal solution. Also, another study confirms that the spped of needle placement in adult patients ranges from 32 to 50 seconds, with a success rate from 79,5% to 97,8%, according to the infusion technique (manual or semiautomatic)[17].

Even if a difference among different retrieval techniques was not found in this study, the average IO access insertion time was less than 3 minutes; therefore, the obtained results are reasonably in line with the literature[8,9,17]. Considering the average time of complete procedure (i.e., until the beginning of the infusion), the time spent was less than 3 minutes. Considering the different levels of expertise, the literature evidences that the skills significantly affected the IO access insertion time[15,18]. As with regard to the success rate of the performances considered in the study, the data show statistically significant results between students and nurses, but the observed difference on success rate and error placement is lower than the expected[7,8,9]. This result may be due to the facility of the technique execution and the ease of use of the EZ-IO device used in this study, as supported by the literature[2,19,20]. Even if the sample had lower success rates than other authors, average insertion times seem to be shorter[15,21,22].

The difference in the setting may also have affected the success rate; in fact, many authors have used simulation corpses that certainly made the scenarios more realistic. In this study, several difficulty during insertio were found due to the use of a portion of the anatomical model. Therefore, use of a complete human model to promote the correct view of anatomical references is recommended.

According to the literature, a significant number of participants have limited experience and knowledge about IO access and this surely affects its frequency and use, even in the context of appropriate performance[19]. The perceived difficulty about the selection of the reference point, the correct needle placement and the subsequent medication is comparable with the literature; thus more attention on these factors during the training is advisable[15]. We did not find a significant correlation between "years of work experience" and IO access outcome; this can be due to the characteristics of the sample, where in fact, most of the interviewed nurses had less than 5 years of work experience.

Considering that we obtained data that are fairly similar to those coming from the literature, IO access training may be feasible in less than 5 hours. In this study, the theory lesson were limited to 30 minutes, so that the remaining time could be used for practical exercise[15,19,23,24]. Another reflection that arises is that this training can possibly be integrated within Degree and post-based Degree courses.

Conclusion

The study allows to confirm how the IO access can be rapid, safe, and reproducible by Degree Course students and nurses, after adequate lessons and trainings. It will be useful to understand what kind and how many professionals have to be trained about placement, management and removal of and IO access. Moreover, the certification of the teaching and skills maintenance should be necessary, as well the creation of guidelines and protocols to secure the IO access use. Future studies in the future are needed to verify the use of this technique at work and the knowledge and skills of the professionals. Given the emergency situation during which the IO access is used and the advantage that the nurses of critical patients would obtain, the introduction of this technique in university and post-base programs are necessary.

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