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Research Article

A Prospective Area-Based Analysis of the use of Intraosseous Access in Children

Czesniewicz-Majcher A[1], Ghazali A[2,3]*, Lardeur JY[4] and Oriot D[3,5]

[1]Department of Emergency, Hospital of Niort, France
[2]Department of Emergency, Pitié-Salpêtrière University Hospital, Paris, France
[3]Simulation Laboratory, Faculty of Medicine, Poitiers, France
[4]Department of Emergency, Poitiers University Hospital, Poitiers, France
[5]Pediatric Emergency Department, University Hospital, Poitiers, France

***Corresponding author:** Aiham Ghazali, Department of Emergency, University Hospital of Pitié-Salpêtrière, 47-83, boulevard de l'Hôpital, 75013 Paris, France

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Abstract

Introduction: Intraosseous (IO) access is recommended in children in cardiopulmonary arrest and in decompensated shock. There is no data on the actual use of IO access in children under such circumstance sat an area-based level. The aim of this study was to evaluate the use of IO access in children in a 1.8 million inhabitant-region of France (Poitou-Charentes) and the components influencing it.

Methods: A 1-year prospective study was carried out in 5 pediatric wards and 5 emergency units with their related EMS. Primary objective was analysis of success rate. Secondary objectives were analyses of the incidence of IO insertion, and the variables that may influence success rate (age, type of IO device, and training of the physician).

Results: 20 attempts of IO access were recorded in 13 children (2m.o.-10y.o.) A large majority of them (10/13, 77%) were <2y.o. Success rates were 60% per trial and 85% per child. The incidence of IO access use was very low (<2/10,000 children). In this small cohort, neither age nor type of device was factors that affected success rate. 12 out of the 13 physicians who attempted IO access had received specific training.

Conclusion: Use of IO access in children was a very rare event with a moderate success rate. 77% of children were <2y.o. No factor influencing success rate was identified. 12/13 physicians were properly trained which questions on the repetition of such training. Larger studies (national registry) are necessary to explore compliance with guidelines and analyze factors influencing success.

Keywords: Intraosseous access; Child; Emergency medicine; CPR; Area-based research

Abbreviations

CPR: Cardiopulmonary Resuscitation; IO: Intraosseous; IV: Intravenous

Introduction

Obtaining vascular access in children in vital distress is often a challenge due to the collapse of the peripheral venous system [1,2]. For an infant under CPR (cardiopulmonary resuscitation) conditions, obtaining an intravenous line (IV) requires more than 10 minutes in 24% of cases and is impossible in 6% of cases [3]. This is the reason why an Intraosseous (IO) access is recommended as a first attempt in children under CPR conditions and in decompensated shock; it is also recommended as a second try when a peripheral vein is not found after 60 seconds in a patient in shock, or when peripheral IV is insufficient [4,5]. Despite these indications, the use of IO access is rare [6]. Yet learning the procedure is fairly easy on a mannequin [7], which allows repetitions to achieve a high rate of success [8].

The exact incidence and success rate of IO access use in children is not known in a prospective study at an area-based level. We hypothesized that use of IO access in children was very rare and associated with a poor success rate. The aim of our study was to investigate use of IO devices in children at an area-based level in a French region.

Methods

Type of study

This study took place in the Poitou-Charentes region of France (1.8 million inhabitants), having 5 majors hospitals with the only pediatric admissions of the region (lately named 5 hospitals). Institutional Research Board approval was obtained, as well as approval from administrative department of each hospital. All physicians participating were informed of the research and gave their consent. All results were kept confidential. This prospective study was conducted on the basis of inclusion of every child having an attempt of IO access in the 5 hospitals.

Objectives

The primary objective was to measure success rate of IO access in children in the Poitou-Charentes region.

The secondary objectives were: 1) to determine incidence of use of IO access; 2) To study the factors that may affect success rate of IO access placement: age, type of device, and training of physicians.

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Table 1: Summary of the 1-year prospective study on the use of IO access in children in the Poitou-Charentes region, France.

Patient	Location	Age	Diagnosis	Number of trials	Success rate per trial	Device
1	EMS	36 m.o.	CA	1	1/1 (100%)	Cook®
2	PED	2 m.o.	Shock – CHF*	2	2/2 (100%)	Cook®
3	PED	3 m.o.	Shock - Purpura fulminans	1	1/1 (100%)	Cook®
4	AED	7 y.o.	CA	3	1/3 (33%)	Cook®
5	EMS	6 y.o.	CA	1	1/1 (100%)	Cook®
6	PED	12 m.o.	Shock - Dehydration	1	0/1 (0%)	Cook®
7	AED	2 m.o.	SUDI	2	1/2 (50%)	LP/EZ-IO®
8	EMS	8 m.o.	Shock - Dehydration	1	0/1 (0%)	EZ-IO®
9	AED	12 m.o.	Shock - Burns	3	1/3 (33%)	EZ-IO®
10	AED	10 y.o.	Septicshock	1	1/1 (100%)	EZ-IO®
11	EMS	3 m.o.	SUDI	1	1/1 (100%)	Cook®
12	EMS	13 m.o.	Shock – Dog bites	1	1/1 (100%)	EZ-IO®
13	EMS	18 m.o.	CA - Drowning	2	1/2 (50%)	Cook®
13				**20**	**12/20 (60%)**	

Legend: AED: Adult Emergency Department; CA: Cardiac Arrest; CHF: Congestive Heart Failure; EMS: Emergency Medical Service; LP: Lombar Puncture needle 22G 38 mm; PED: Pediatric Emergency Department; SUDI: Sudden Infant Death of Infancy; *: Received 2 IO accesses.

Study population

The French Poitou-Charentes region includes four departments: Vienne, Deux-Sèvres, Charente-Maritime, and Charentes. This study was conducted from2010/11/01 to 2011/10/31 with inclusions of every child (<18 y.o.) from the 5 major hospitals of the region where an attempt of IO access was tried in the 5 hospitals (emergency and pediatric departments). In-hospital and out-of-hospital use of IO access in children were recorded. In France, Emergency Medical Service (EMS) is a medical service where each emergency team (1 emergency physician, 1 resident, 1 nurse, and 1 ambulance driver) is involved in medical, trauma, and pediatric emergencies requiring medical support. Emergency physicians and residents of these teams have very often working rotations in places, EMS and emergency department. The head physicians of emergency and pediatric departments of the Poitou-Charentes region were contacted and their consent was obtained. Information were extracted by the physician on charge from the patient's file: place of work, age of the child, diagnosis, existence of a peripheral IV prior to IO, site of insertion, device, number of attempts, success or clinical findings if failure, and previous training of the physician.

Outcome

The primary endpoint was success rate of IO access. The secondary endpoints were the incidence of the procedure, the influence of the type of device on success rate, the child's age (<or > 24 months), and any training received.

Statistical analysis

The software used was Microsoft Excel. Descriptive data were expressed as mean ± standard deviation or percentage. The effect of age, type of IO device on the success rate was evaluated by Fisher tests and chi 2 (univariate analysis) and an exact logistic regression (multivariate analysis). A value of $p<0.05$ was considered significant.

Results

Population

Results are summarized on Table 1. Over the one-year period, a total of 20 trials were performed to insert an IO access in 13 children (2 months to 10 years old). A large majority of them (10/13, 77%) were less than two years old. Seven children were in shock and 6underwent CPR. For 10 of the 13 children included, a peripheral IV was attempted prior to IO access. In 6 cases out of 13, IO access insertion was performed during pre hospital care, 4 times in a General Emergency department, and 3 times in a Pediatric Emergency department.

Primary objective

The IO access was inserted in proximal tibia in all cases. Its placement was successful in 11 out of 13 children (85%), in whom 12 of the 20 attempts were successful (60%), which defines the success rate per trial. The failure of IO access was always associated with local swelling at the insertion site.

Secondary objectives

Incidence: During the study period, 67,668 children under 18 years of age were admitted to the Emergency or Pediatric departments of the region. The incidence of placement of an IO access was 0.19/1000 (<2/10,000 children), with a confidence interval of 95% from 0.10 to 0.33%.

Factors that may affect success rate: The 2 failures occurred in infants8 and 12-month old. The IO access in the 3 children over 2-y.o. (6, 7, and 10 y.o.) was always successful. Success rate per trial was similarly low regardless of the age of the child: 53% in children <2y.o. vs. 60% in children >2y.o.

The most commonly used devices were Cook® needles (12/20 attempts) and EZ-IO® (7/20). The other attempt involved a spinal

needle device. There was no difference in success rates between hand-held devices (Cook® needle + LP needle) and mechanical devices (EZ-IO®), respectively 8/13 (61%) vs. 4/6 (57%). Fourteen of the 20 attempts were performed in children <2y.o. (70%), 7 with a Cook® needle, 6 with an EZ-IO® device, and 1 with a spinal needle. In this population of children less than 2 y.o., success rate was 71% with Cook® needle and 50% with EZ-IO® device (p=0.59). Success rate of the first attempt, regardless of the device, was not significantly different in children over 2y.o. (66.7%) than in children less than 2 y.o. (57%) (p=0.83).

Ten of the 11 physicians who successfully inserted an IO access had received specific training in pediatric emergency procedures. The two who failed were similarly trained.

Discussion

Main results

This 1-year prospective regional study showed that success rate per trial of IO access insertion was poor (60%), while the success rate per child reached 85%. IO access insertion use was recorded on an area-based analysis as a very rare event (<2/10,000 admissions). In 75% of cases it involved children less than two years old. In this very small cohort, we did not find any factor that may influence success rate. To our knowledge this is the first prospective area-based study of the use of IO access in children.

Limitations

We are aware of the limitations of this study. First of all, the number of children included was very small, and we could not obtain significance on some issues due to lack of power of statistical tests. It might be possible that there was an underestimation of the use of IO access since there are seven other small hospitals in the Poitou-Charentes region. But this possibility would be improbable since these hospitals do not have any pediatric capacities and usually transfer children to one of the five other hospitals included in the study.

Primary objectives

Success rate per child was 85% in this prospective study, similar to the 76 % reported in adults and children over 5 years [9], and to the 86% reported in a retrospective study of 6 years [6], but lower than the 94 % reported in children [7]. In contrast, success rate per trial was poor (60%).

Secondary objectives

The present study recorded a very rare incidence of IO access use (1.9/10,000 patients), less than 4/10,000 found over a 2-year study in a Turkish pediatric emergency department [10], but more than 0.6/10,000 found in a 3-year pediatric study among 450 Californian hospitals [11] (not including pre hospital care).

Children less than 2 y.o. represented 77% of pediatric patients in whom an IO access was performed, which was similar to the reported 85% [12]. But in an all-ages helicopter study over 7 years, children less than 2 y.o. represented 25% of the population receiving an IO access [13].

Success rate was moderate and not influenced by the age of the child, similar to those reported - 72-77 % - in this age group [9]. In the present study, the 2 children in whom IO access failed were less than 2 y.o. It is likely that failure was due to a transfixion of the second cortical layer which resulted in extra vasation and subcutaneous swelling. This may be related to incorrect procedure [8,14]. The difficulty of IO insertion at this age is due to the fact there is a narrow margin of safety for correct positioning of the needle into the tibial medullary, since the diameter is less than 10 mm wide in infants' proximal tibia site [15].

In the present study, the type of device used did not influence the success rate. In mixed population – adults and children – the use of EZ-IO® was found to provide better and faster intraosseous access compared with the use of manual devices, and also were associated with fewer complications [16]. A pediatric study found a 94% success rate for EZ-IO® among 95 children (mean age 5.5 years) [17]. A recent literature review of the 10 studies comparing the use of semi-automatic IO infusion devices to manual needles suggested a superiority of the battery-powered IO driver over manual needles [18]. But this review did not study success rate according to age group. To date, no study addressed the success rate in small children according to the type of device. Anderson reported a 87% success in children less than 2 y.o. with manual technique [19], whereas others reported a 50% success rate on a mixed population [13]. Although easy to use [1] and with a 95%-100% success rate in adults (17,20,21), EZ -IO®(as BIG®) exposes to the risk of not noticing sufficiently in time a sudden lack of resistance while perforating the first cortical layer and accidentally transfixing the second, which is even more probable in small children [8,14,17]. Success rates in children as well as adults of the first trial with EZ-IO® vs. Cook® needles were respectively 97.8% and 79.5% [20]. In a pediatric population, success rate of the first trial with EZ-IO® was 80% [10]. Furthermore, simulation studies showed a shorter time of insertion of the IO device for EZ-IO® compared to Cook® needle [21,22], and a higher success rate on the first trial compared to BIG® [23].

In 10 of the 13 children of the present study, placement of a peripheral IV was attempted prior to IO access. This may have been different from the recommendations [4,5] and have delayed placement of IO access [7], since peripheral IV placement success rate is as low as 65% in compromised infants [24]. But without a recording of the exact timing of the resuscitation events it was impossible to state there was non-compliance with guidelines, as it has been previously reported [25]. Late insertion of IO access (after several failures of peripheral IV) might not be able to impact prognosis [26]. The more serious the child's condition, the more difficult is venous access [3,26] and getting an administration route is all the more urgent [2]. This is why the recommendations emphasize vascular access in less than 5 minutes [4].

All but one physician who attempted an insertion of IO access received an appropriate initial training. Then, the question is, facing such a rare event, the repetition of simulation-based training and its frequency.

External validity

The present1-year prospective study analyzed the use of IO access in children in our region and the factors that influence it. Results showed a very small population that questions the actual compliance with recommendations. This fact needs to be addressed by a study with a broader population, like a national registry. Such cohort

studies would also be able to answer the question of the influence of device type and age on success rate.

Finally, emphasis should be put on training – preferentially simulation-based – in insertion of IO access, since it is a very rarely utilized procedure occurring in high-stakes situations, with a possible detrimental effect of its failure. Furthermore, education should focus on skill maintenance over time.

Conclusion

The present study prospectively analyzed the use of IO access in children in a 1.8 million region over one year. Insertion of an IO access remained a very rare event, with a moderate success rate. No particular factor influencing the success rate of IO insertion were identified, mainly due to the small number of children included. This is of importance, given the life-threatening situations in which it is used. Repeated simulation-based training of emergency physicians might be necessary to increase success rate. Finally, the analysis of factors influencing success rate remains to be explored in larger studies, likely a national registry.

Contributors' Statement

Aleksandra Czesniewicz-Majcher: Dr. Czesniewicz-Majcher designed the data collection instruments, collected the data, made the analysis, and drafted the initial manuscript.

Aiham Ghazali: Dr. Ghazali supervised data collection, reviewed and revised the manuscript.

Jean-Yves Lardeur: Dr. Lardeur reviewed and revised the manuscript.

Denis Oriot: Pr. Oriot conceptualized and designed the study, coordinated the data collection, supervised and critically reviewed the manuscript.

All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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