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Four years of EZ-IO® system in the pre- and in-hospital emergency setting

Research Article

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Abstract: Objective: In emergency medicine, the intraosseous access (IOA) is the alternative to the intravenous access. Our aim was to evaluate the use of a semiautomatic IOA device (EZ-IO®) in ground and air based physician staffed emergency medical systems and at a university hospital. Methods: Since January 2008, the EZ-IO® system was evaluated prospectively for four years and analysed statistically. Results: 83 IOA were performed in prehospital and 5 in in-hospital setting. 78% of the patients were adults; 22% were children between 7 days and 6 years. 98% of all patients were in potentially life-threatening situations (NACA IV-VII). IOA was established during CPR in 55%. The primary insertion site was the proximal tibia (98%). In children, IOA was used significantly more often as primary access to the vascular system than in adults (86.2% vs. 38.9%, $p < 0.001$). First attempt/ overall success rates were 94% / 99%. Unsuccessful attempts occurred in 7.8% (n=7). In the prehospital ground based physician staffed EMS, IOA was established in 69 of 20.175 missions (0.34%). Conclusions: The semiautomatic EZ-IO® system is an effective method for achieving vascular access. In critically ill children, it was used more often as first approach to the vascular system compared with adults. .

Keywords: *Intraosseous access • Emergency medicine • Success rate • Complications • Paediatric emergencies*

1. Introduction

In pre- and in-hospital emergency medicine, the intraosseous access (IOA) is a recommended and frequently used procedure. It is reported to be a safe, simple and effective alternative to the intravenous access (IVA) and is described to be associated with a low rate of complications. The semiautomatic EZ-IO® system is a fast and efficient method to establish an IOA [1-5]. The current published guidelines of the European Resuscitation Council (ERC) on cardiopulmonary resuscitation (CPR) recommend the intraosseous route when intravenous access cannot be achieved within the first two minutes of resuscitation [6]. Two strategies can be found: (1) Primary strategy is used when there is an assumed delay in achieving vascular access by intravenous attempts and thus the intraosseous access is chosen as first approach to the vascular system. (2) Secondary strategy describes intraosseous usage after failed intravenous attempts.

The aim of the present study was to evaluate the use of a semiautomatic intraosseous device (EZ-IO®) in the pre- and in-hospital emergency setting after its introduction in two ground and one air based physician staffed emergency medical systems (EMS) and at a German surgical university hospital. Patient characteristics, frequency of intraosseous puncture, indication for IOA, insertion sites, self-estimated insertion times, users' characteristics, success rates and complications were the parameters to be analysed.

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2. Materials and methods

The EZ-IO® system (9050 Power Driver, Vidacare, San Antonio, USA) used in this study is a semiautomatic, rechargeable battery powered device for multiple use with integrated two bevelled, hollow drill-tipped needles of different length. For adult patients >39 kg of weight, the needle is 25 mm long. For children (3-39 kg), it is 15 mm long. The needle for large tissue over insertion site or humeral insertion is 45 mm long. The diameter (1.8 mm) and flow rate (15 gauge) is the same for all of them.

Before 2008, the EZ-IO® system had not been used in our two physician staffed ground based emergency medical services (EMS), our one physician staffed air rescue service and in our surgical university hospital. After its introduction to these settings in January 2008, its use was evaluated prospectively from 1st January 2008 to 31st December 2011. The frequency of IOA was calculated for the two ground based EMS systems for the period of four years.

Therefore, a special documentation protocol (Figure 1) was developed which had to be filled out by EMS physicians, paramedics (under supervision of an EMS physician) or in-hospital working anaesthesiologists after the use of the EZ-IO® system. It contained questions about patients´ characteristics (age, gender, weight), severity of illness using the National Advisory Committee for Aeronautics (NACA)-Score, estimated diagnosis, indication for IOA, number of IVA-attempts before and after IOA, IOA location, self-estimated insertion times, success rate and complications of intraosseous puncture.

The patients were divided in 'Total', 'Adults' and 'Children <7 years' groups. The resulting study data were entered into an electronic database (Microsoft® Excel 2010, Microsoft Corporation, Redmond, USA) and evaluated using SPSS software (Version 19.0, SPSS Inc., Chicago, USA). Categorical data were summarized by means of relative and absolute frequencies. Quantitative data were summarized using median with quartiles (Q1 and Q3). The Kolmogorov-Smirnov test was applied to check for normal distribution. Due to non-normally distributed data, non-parametric methods for evaluation were used (chi-square test for categorical data, Mann-Whitney test for continuous data). A p-value <0.05 was considered statistically significant.

3. Results

3.1 Setting and patient characteristics

In the study period of four years, the EZ-IO® system was used for 88 IOA in 87 patients (one patient was punctured with two needles). 83 of 88 IOA (94.3%) were done in prehospital circumstances (ground and air based), whereas 5 of 88 IOA (5.7%) were performed in the in-hospital setting.

48 of 88 IOA (54.5%) were performed during cardiac arrest (NACA VI+VII). 38 of 88 IOA (43.2%) were done in other potentially life threatening emergency situations (NACA IV+V). These were due to cardiovascular (n=8), respiratory (n=8), traumatic (n=8), neurological (n=7), toxic (n=4) and other (n=3) events. In two cases (2.3%), IOA was performed without potential danger of life (NACA Score < IV). The first case was an IOA for prehospital analgesia in a patient with limb fracture. The second case was in-hospital in a child after inhalative induction of anaesthesia, where no other vascular access could be established.

The total patients group (n=87, age: median 54 years, quartile1-quartile3: 22-69 years, minimum-maximum: 7 days-91 years) was divided in the adult group (68 of 87 patients = 78.2%; age: median 61 years, quartile1-quartile3: 48-71 years, minimum-maximum: 17-91 years) and the children group (19 of 87 patients = 21.8%; age: median 7 months, quartile1-quartile3: 2-23 months, minimum-maximum: 7 days-6 years).

3.2 Frequency of IOA

IOA rates were calculated for the two prehospital ground based physician staffed EMS missions. In the study period of four years, 69 IOA were performed in 20.175 emergency missions (0.34%). Out of all ground based paediatric emergency missions, the IOA rate was 2.4% (15 IOA in 624 missions). There were no significant differences concerning annual IOA rates in the two ground based EMS within the observation period (2008: 21 IOA in 3509 missions = 0.60%; 2009: 20 IOA in 5235 missions = 0.38%; 2010: 6 IOA in 5223 missions 9 = 0.11%; 2011: 22 IOA in 6208 missions = 0.35%).

3.3 Indication for IOA

The indications for IOA can be seen in Table 1.

Table 1. Indication for IOA.

	Primary strategy (EZ-IO® as 1st device to achieve vascular access)		**Secondary strategy** (EZ-IO® as 2nd device to achieve vascular access)		**Number of IVA attempts**
	n	**(%)**	n	**(%)**	n (median, Q1 - Q3)
Total	20	**24.1**	63	**75.9**	3.0, 2.0 - 4.0
Adults	9	**13.8**	56	**86.2**	3.0, 2.0 – 4.0
Children < 7 years	11	**61.1**	7	**38.9**	3.0, 0.75 – 4.0

IOA= intraosseous access; IVA= intravenous access; n= number; Q1= Quartile 1; Q 3= Quartile 3

Intraosseous access documentation protocol

O EMS-mission O in-hospital mission

Patient

gender: O male O female mission number: _____

age: _____ O months O years mission date: _____

weight: __ kg NACA (I - VII): ____

Kind of emergency

O cardiac arrest O cardiovascular O respiratory
O trauma O neurological O other

diagnosis: _____

indication for intraosseous access:

O impossible placement of intravenous access → reason: _____
O assumed delay of vascular access by i.v. attempts → reason: _____
O other, please name: _____

Did you try to place or did you place successfully an i.v. access <u>before</u> establishing the intraosseous access?

O yes O no
O if yes : → number of attempts: _____
→ number of successfully placed i.v. needles: _____
→ estimated time from arrival to the beginning of i.o. puncture: _____ O sec O min

Did you try to place or did you place successfully an i.v. access <u>after</u> establishing the intraosseous access?

O yes O no
O if yes : → number of attempts: _____
→ number of successfully placed i.v. needles: _____

Intraosseous insertion site

O proximal tibia O distal tibia O other: _____

Who placed the intraosseous access?

O paramedic O resident physician 3rd-5th year O specialized physician > 5th year

Which discipline did the i.o. access placing physician belong to?

O anaesthesiology O surgery O internal medicine O paediatrics O other:_____

How many intraosseous needles did you placed before the actual intraosseous access?

O prehospital _____ (number) O in-hopital _____ (number)

Was the attempt to establish the intraosseous access successful?

O yes → if yes: - number of attempts: _____
- time needed _____ sec
- drugs applicated? O yes O no
- if yes, which drugs? _____

O no → if no: - name reasons in category 'complcations and problems' (see below)

Complications and problems

O not successful because of failed puncture O extravasation
O bone fracture O technical failure:_____
O other: _____

How do you evaluate the i.o. flow rate?
O only application of fluid boli possible
O freely running fluid
O volume therapy possible

Bitte füllen Sie diesen Qualitätssicherungsbogen direkt im Anschluss an die Patientenversorgung aus
und senden ihn an Dr. E. Popp oder Dr. L. Reinhardt,
Klinik für Anaesthesiologie, Sektion Notfallmedizin, Universitätsklinikum Heidelberg.

Figure 1. Intraosseous access documentation protocol.

In the total and adult group, secondary strategy (EZ-IO® as second device to achieve vascular access after failed IVA attempts) was more frequent than primary strategy (EZ-IO® as first device because of assumed delay to achieve vascular access by IVA attempts). In contrast, primary strategy was more frequent in children than in adults. Thus, IOA was more often the first approach to the vascular system in children compared with adults (38.9% vs. 86.2%, p <0.001). The number of IVA attempts in the different groups in case of second strategy was not different. In the documentation protocol, users were asked for their subjective reason to use the EZ-IO® device.

In children, users stated significantly more often than in adults that they had chosen the IOA because of the assumption that vascular access would be achieved by IVA attempts only with delay (12 of 18 children (66.7%) vs. 20 of 64 adults (30.8%), p=0.007).

3.4 Insertion sites and self-estimated times

In 97.7% (n=84) the proximal tibia was the primary location of IOA. In one case, the distal tibia was chosen after a failed attempt in the proximal tibia due to obesity. In a case with a trapped trauma patient in a car with only one arm reachable, the proximal humerus was punctured.

The self-estimated time that passed between the arrival on scene and insertion of an IOA was 3 minutes (Quartile1: 2 minutes, Quartile3: 5 minutes). The self-estimated insertion time, defined as period from taking the EZ-IO® needle out of the package to its successful insertion, was 15.0 seconds (Quartile1: 10 seconds, Quartile3: 30 seconds).

3.5 Users' characteristics

The intraosseous puncture was done by physicians (72.9%) or by supervised paramedics (27.1%). 71.8% of the users had already performed an IOA prior to the actual puncture. The physicians' clinical specializations were anaesthesiology (74.6%), internal medicine (19.0%) or surgery (6.3%). 46.8% of the physicians were residents with working experience from three to five years; 53.2% were specialists in their discipline and had been working for more than five years.

3.6 Success rates and complications

The first attempt and overall success rates by the EZ-IO® device are descripted in Table 2. Only in one case out of 88 (1.1%), the IOA was finally not successful, but however, after the first missed intraosseous puncture no further attempts were performed.

In the total group, failed punctures occurred in 7.8% (n=7) of all performed attempts (2nd and 3rd attempts included). Two events with wrong needle length due to obesity and large tissue over the injection site were documented. In children, failed punctures were seen in 13.6% (n=3) of all attempts.

Table 2. Success rates and complications of intraosseous puncture.

	First attempt success		Overall success		Attempts to successful insertion		Failed puncture		
					> 1	> 2		Missed / Extravasation	Wrong needle
	n	(%)	n	(%)	n	n	(%)	n	n
Total	79	**94.0**	83	**98.8**	2	2	**7.8**	5	2
Adults	62	**95.4**	64	**98.5**	0	2	**5.9**	2	2
Children < 7 years	17	**89.5**	19	**100.0**	2	0	**13.6**	3	0

n=number

In all conscious patients, first step was a subcutaneous infiltration with scandicaine 1%. After the insertion of the intraosseous needle, pain during the injection of sodium chloride 5-10 ml occurred in 5 out of 40 (12.5%) patients staged NACA III-V even though lidocaine 10-40 mg had been administered through the intraosseous route before.

4. Discussion

Within the present four-year case series, a semiautomatic IOA device (EZ-IO®) was demonstrated to be a quick and safe method for achieving vascular access with high success rates in critically ill adult and paediatric patients.

In this prospective study, we evaluated the IOA in two physician staffed ground and one air based EMS as well as in a surgical university hospital. In line with the results of a French ground based EMS study with 39 IOA in 9876 patients (0.39%) [7] and a German air based EMS study with an increase from 0.1% to 0.4 % over four years [8], the IOA rate in our ground based EMS was 0.34%. A recently published report from Berlin, Germany, with a generous indication position for IOA showed an unexpectedly high overall IOA rate of 1.49% [9]. Although the demographic settings are different in all investigations, they demonstrate that IOA plays an important role in emergency medicine. In line with the literature in children younger than seven years, our prehospital ground based IOA rate was 2.4% ([10]: 2.5%).

Several authors have shown that the EZ-IO® system is an efficient tool for achieving IOA [1-5]. The overall success rate of IOA procedures in our analysis was 98.8%. These results are comparable with several other previously published investigations ([4]: 87%, [2]: 96%, [7]: 97%). Moreover, the 1st attempt success rate in our investigation with 94% is in line with other data concern-

ing this device ([7]: 84%, [4] 85%, [1] 90%, [11] 97%), as well as the success rates in children (1st attempt success rate [12]: 83.9%). We could also point out that the EZ-IO® is a fast tool for achieving vascular access, as shown by the self-estimated insertion times. Other data showed short insertion times ([13]: 2 minutes compared with central venous access; [1]: 1.8 minutes compared with Bone Injection Gun; [5]: 32 seconds compared with manual Cook needles).

According to the current guidelines, an IOA is indicated when an IVA cannot be established within the first two minutes of resuscitation and in life threatening situations [6,14]. In our study, cardiac arrest was seen in 54.5% of all established IOA. In almost all of the remaining cases, the emergency team treated critically ill patients with NACA Scores of IV or V. Following secondary strategy, one or more IVA attempts had been performed before placing the IOA in the total group. By contrast, primary strategy was used significantly more often in children. Obviously, in children, the operators' readiness of using the EZ-IO® system was higher. Considering the reasons for intraosseous puncture, an explanation can be found: In children, the assumption of delayed vascular access by IVA attempts was stated significantly more often than in adults. Thus, in critically ill children, EMS physicians use the EZ-IO® system particularly because they expect that vascular access can be achieved better and faster compared with puncturing a peripheral vein.

Another study with 182 adult patients compared the times spent to successful vascular access by tibial IOA, humeral IOA and peripheral IVA during CPR. The tibial access was faster and had a higher first attempt success rate than the peripheral IVA and the humeral IOA [15]. The times to tibial insertion are comparable with those of our study (4.6 vs. 3.0 minutes). A reason for the high rate of IVA attempts before IOA in the total and adult group of our examination may also be that EMS staff tended to do things they are used to do often and well. Inserting an IVA is a very common procedure that is performed daily by all physicians of our study. Furthermore, the IOA is a more invasive tool, since there is the potential risk for severe complications after intraosseous insertions, such as extravasation with following compartment syndrome [16,17], bone fracture [18,19], cerebral air embolism [20] or osteomyelitis [21]. The infection risk can be minimized if the intraosseous needle is removed within 24 hours. This information was submitted regularly to the admitting wards in our study. In our study, only a small rate of complications at the time of establishing the IOA was seen.

However, it seems clear that IOA must be established quickly when vascular access is needed and other possibilities cannot be realized in a timely manner. It is important to point out that the IOA procedure may only be performed within the limits of its correct indications. In the present investigation, in two out of 87 patients, an intraosseous puncture was performed in patients without potential danger of life. It should be avoided in non-life threatening cases as described in a subgroup by Helm et al. [8], as there is the risk of complications that is not in accordance with the benefit for the patient. Despite all advantages, the IOA is an invasive method that must follow the current national [10] and international [6] guidelines. For this purpose, an adequate workshop-based teaching has to be recommended [5].

5. Limitations

This analysis was performed in a small area with a low number of intraosseous punctures. The ground based subgroup for calculating IOA rates was even smaller. In-hospital IOA rates were not calculated due to heterogeneity of the in-hospital study population. In air based EMS, due to incomplete denominator, a frequency analysis was not possible. Nevertheless, in our opinion, our examination provides representative data concerning the pre- and in-hospital use of a semiautomatic IOA device.

Moreover, we must mention that insertion times and the time that passed until the beginning of insertion of IOA were self-estimated times. Nevertheless, a comparison with other previously published data revealed similar results. However, further multicenter studies have to be recommended in order to achieve more knowledge about intraosseous insertions and especially about its complications. In this regard, the development of an international intraosseous access database could be useful.

6. Conclusions

The semiautomatic EZ-IO® system is an effective method for achieving vascular access with high success rates. In critically ill children, it was used more often as primary strategy to establish vascular access compared with adults.

Conflicts of interest

The authors declare that they have no competing interests.

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References

[1] Leidel BA, Kirchhoff C, Braunstein V, Bogner V, Biberthaler P, Kanz KG. Comparison of two intraosseous access devices in adult patients under resuscitation in the emergency department: A prospective, randomized study. Resuscitation. 2010;81(8):994-999

[2] Sunde GA, Heradstveit BE, Vikenes BH, Heltne JK. Emergency intraosseous access in a helicopter emergency medical service: a retrospective study. Scand J Trauma Resusc Emerg Med. 2010;18:52.

[3] Levitan RM, Bortle CD, Snyder TA, Nitsch DA, Pisaturo JT, Butler KH. Use of a battery-operated needle driver for intraosseous access by novice users: skill acquisition with cadavers. Ann Emerg Med. 2009;54(5):692-694

[4] Frascone RJ, Jensen JP, Kaye K, Salzman JG. Consecutive field trials using two different intraosseous devices. Prehosp Emerg Care. 2007;11(2):164-171

[5] Brenner T, Bernhard M, Helm M, Doll S, Volkl A, Ganion N, et al. Comparison of two intraosseous infusion systems for adult emergency medical use. Resuscitation. 2008;78(3):314-319

[6] Deakin CD, Morrison LJ, Morley PT, Callaway CW, Kerber RE, Kronick SL, et al. Part 8: Advanced life support: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations. Resuscitation. 2010; 81Suppl 1: e93-e174

[7] Gazin N, Auger H, Jabre P, Jaulin C, Lecarpentier E, Bertrand C, et al. Efficacy and safety of the EZ-IO intraosseous device: Out-of-hospital implementation of a management algorithm for difficult vascular access. Resuscitation. 2011;82(1):126-129

[8] Helm M, Hossfeld B, Schlechtriemen T, Braun J, Lampl L, Bernhard M. [Use of intraosseus infusion in the German air rescue service : nationwide analysis in the time period 2005 to 2009]. Anaesthesist. 2011;60(12):1119-1125

[9] Kellner P, Eggers M, Rachut B. Der Einsatz des intraossären Zugangs im präklinischen Notarztdienst. Notfall Rettungsmed. 2011;14:379-388

[10] Helm M, Biehn G, Lampl L, Bernhard M. [Pediatric emergency patients in the air rescue service. Mission reality with special consideration to "invasive" measures]. Anaesthesist. 2010;59(10): 896-903

[11] Schalk R, Schweigkofler U, Lotz G, Zacharowski K, Latasch L, Byhahn C. Efficacy of the EZ-IO needle driver for out-of-hospital intraosseous access--a preliminary, observational, multicenter study. Scand J Trauma Resusc Emerg Med. 2011;19:65

[12] Myers LA, Russi CS, Arteaga GM. Semiautomatic intraosseous devices in pediatric prehospital care. Prehosp Emerg Care. 2011;15(4):473-476

[13] Leidel BA, Kirchhoff C, Bogner V, Braunstein V, Biberthaler P, Kanz KG. Comparison of intraosseous versus central venous vascular access in adults under resuscitation in the emergency department with inaccessible peripheral veins. Resuscitation. 2012;83(1):40-45

[14] Bernhard M, Gräsner J, Gries A, Fischer M, Böttiger BW, Helm M. Die intraossäre Infusion in der Notfallmedizin. Anästh Intensivmed. 2010;51: S615-S620

[15] Reades R, Studnek JR, Vandeventer S, Garrett J. Intraosseous versus intravenous vascular access during out-of-hospital cardiac arrest: a randomized controlled trial. Ann Emerg Med. 2011;58(6):509-516

[16] Moen TC, Sarwark JF. Compartment syndrome following intraosseous infusion. Orthopedics. 2008;31(8):815

[17] Simmons CM, Johnson NE, Perkin RM, van Stralen D. Intraosseous extravasation complication reports. Ann Emerg Med. 1994;23(2):363-366

[18] Bowley DM, Loveland J, Pitcher GJ. Tibial fracture as a complication of intraosseous infusion during pediatric resuscitation. J Trauma. 2003;55(4):786-787

[19] Melker RJ, Miller G, Gearen P, Molliter L. Complications of intraosseous infusion. Ann Emerg Med. 1990;19(6):731-732

[20] van Rijn RR, Knoester H, Maes A, van der Wal AC, Kubat B. Cerebral arterial air embolism in a child after intraosseous infusion. Emerg Radiol. 2008;15(4): 259-6252

[21] Rosetti VA, Thompson BM, Miller J, Mateer JR, Aprahamian C. Intraosseous infusion: an alternative route of pediatric intravascular access. Ann Emerg Med. 1985;14(9):885-888