DOI: 10.4274/jbuch.galenos.2024.93798
J Dr Behcet Uz Child Hosp 2024;14(3):175-180

Original Article

Use of Intraosseous Access in the Pediatric Emergency Department: A Single Center Experience

Pediatrik Acil Serviste İntraosseöz Erişim Kullanımı: Tek Merkez Deneyimi

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ABSTRACT

Objective: We aimed to compare the efficacy of a battery-powered drill [EZ-intraosseous (IO)] with that of 18-gauge intravenous cannula (18GIVC) needle used for IO access in infants.

Method: This prospective observational study was conducted in the pediatric emergency department between April 1, 2019, and November 3, 2020. Since limited number of EZ-IO needles were available, the first IO accesses were made with 18GIVC needles in all infants. In cases where IO access with 18GIVC failed at the first attempt, the second attempt was made with EZ-IO drill. The cases were divided into two groups: Group 1 (patients with IO access with 18GIVC at first successful attempt) and Group 2 (patients with IO access with EZ-IO drill at the second successful attempt). The Mann-Whitney U test and Fisher's exact or chi-square tests were used for statistical analysis, with level of statistical significance set at $p<0.05$.

Results: Forty six infants were included in the study. In 34 (79.9%) patients the first access with 18GIVC needles was successful. Second attempt with EZ-IO drill was successful in the remaining 12 (26.1%) patients. The cases in Group 1 were younger than in Group 2 ($p<0.001$). All cases aged six months or younger were included in Group 1 ($p<0.001$). The time required for IO access with the EZ-IO drills was statistically significantly shorter compared to the that required for 18GIVC ($p<0.001$). Extravasation was observed in 8 cases (22.2%) within Group 1.

Conclusions: Use of EZ-IO drills provides a quick, efficient, and dependable method for IO access in critically ill infants. If resources are limited, the experienced user can use the 18GIVC hypodermic needle as a last resort for IO access in critically ill infants younger than 6 months.

Keywords: Intraosseous access, EZ-IO, 18-gauge needle, critically ill infant, resource limited situations

ÖZ

Amaç: Süt çocuklarında intraosseöz (IO) erişim için kullanılan pille çalışan matkap (EZ-IO) ile 18-gauge intravenöz kanül (18GIVC) iğnenin etkinliğini karşılaştırmayı amaçladık.

Yöntem: Bu prospektif gözlemsel çalışma, 1 Nisan 2019 ile 3 Kasım 2020 tarihleri arasında çocuk acil servisinde gerçekleştirildi. EZ-IO iğne sayısı sınırlı olduğundan tüm bebeklerde ilk IO girişimi 18GIVC ile yapıldı. İlk denemede 18GIVC'nin başarısız olduğu durumlarda ikinci deneme EZ-IO ile yapıldı. Olgular iki gruba ayrıldı: Grup 1 (ilk başarılı denemede 18GIVC ile IO erişimi olan hastalar) ve Grup 2 (ikinci başarılı denemede EZ-IO ile IO erişimi olan hastalar). İstatistiksel analizlerde Mann-Whitney U testi ile Fisher's exact veya ki-kare testleri kullanılmış olup, $p<0,05$ değeri istatistiksel anlamlılık sınırı olarak kabul edilmiştir.

Bulgular: Çalışmaya 46 çocuk dahil edildi. Bunlardan 34'ünde (%79,9) 18GIVC ile ilk erişim başarılı oldu. Kalan 12 hastada (%26,1) EZ-IO ile ikinci deneme başarılı oldu. Grup 1'deki olgular Grup 2'ye göre daha küçüktü ($p<0,001$). Yaşları ≤6 aylık küçük olguların tamamı Grup 1'deydi ($p<0,001$). EZ-IO ile IO erişim süresi 18GIVC'ye kıyasla istatistiksel olarak daha kısaydı ($p<0,001$). Grup 1'de 8 olguda (%22,2) ekstravazasyon görüldü.

Sonuç: EZ-IO, kritik hasta bebeklerde IO erişimi için hızlı, etkili ve güvenilir bir cihazdır. Kaynaklar sınırlıysa deneyimli kullanıcı, 6 aydan küçük kritik hasta bebeklerde IO erişimi için son çare olarak 18GIVC hipodermik iğneyi kullanabilir.

Anahtar kelimeler: İntraosseous erişim, EZ-IO, 18-gauge iğne, kritik hasta çocuğu, kaynakların sınırlı olduğu durumlar

Received: 26.10.2024
Accepted: 03.11.2024

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Cite as: Yalçın G, Özdemir Balcı Ö, Başer A, Anıl M. Use of Intraosseous Access in the Pediatric Emergency Department: A Single Center Experience. J Behcet Uz Child Hosp. 2024;14(3):175-180

INTRODUCTION

Achievement of vascular access and administering necessary fluids and drugs in critically ill children convey vital importance. Intraosseous (IO) access is recommended in critically ill patients in whom vascular access is not possible or presumably cannot be performed quickly[1]. In the bone marrow of long bones, the medullar sinuses connect to the veins. Through the IO, all fluids and drugs can be delivered into the bloodstream by inserting the needle through the cortex of a bone into the medullar space. Since these veins are supported by bone matrix, they do not collapse in case of hypoperfusion and shock. Proximal and distal tibia, humerus, and femur are the most preferred regions, and tuberosities around the tibia, proximal to the tibia, are the most frequently used regions for IO access in children[2,3].

There are three types of IO needles: manual IO needles (e.g., Jamshidi needle), spring-loaded devices (e.g., Bone Injection Gun: BIG, WaisMed, Yokneam, Israel), and battery-operated drills (e.g., Arrow® EZ-IO® System, Teleflex, USA). All these devices have certain costs. The most expensive one is the EZ-IO drill. In routine use, hypodermic needles are not recommended as they can be easily clogged[2,4]. Especially in some emergency departments with limited financial resources, the appropriate device for IO intervention may not always be at hand. According to our observations, those who cannot afford to purchase standard IO devices, those who are not trained in the use of devices such as EZ-IO drills, or those who think that hypodermic needles are also an effective option, use the non-recommended over-the-counter devices for IO access. As far as we know, no studies in the literature have compared the effectiveness of hypodermic needles with the EZ-IO device to be used for IO access The aim of this study is to compare the efficacy of the 18-gauge intravenous cannula (18GIVC) and the EZ-IO device for IO access in critically ill infants aged 1-12 months hospitalised in pediatric emergency departments, focusing on IO access time, success rates, and relevant complications, to determine the most efficient and reliable method for clinical use when peripheral venous access cannot be established.

MATERIALS and METHODS

Study Design, Setting and Participants

This prospective observational study was conducted in the pediatric emergency department of a tertiary care teaching and research hospital between 04.01.2019 and 11.30.2020. Children who presented between 08.00 and 17.00 on weekdays were included in the study. All procedures were performed by the same pediatric emergency specialist in order to achieve standardization in the measurements and to minimize the limitations of the study. A total of 3 physicians and 5 nurses were working in each shift in the pediatric emergency department where the study was conducted. Approximately 120,000 patients applied to the pediatric emergency department during the study period.

In cases where peripheral vascular access could not be established within 90 seconds or in 3 consecutive attempts due to hemodynamic instability of the patient, or in cases where the attending physician predicts that the peripheral vascular access cannot be established, IO intervention was performed in the pediatric emergency department. Critically ill infants that required IO access and aged between 1-12 months were included in the study. Patients with extremity trauma, history of IO intervention, and/or chronic bone disease were excluded from the study (Figure 1).

IO Access and Definitions

IO access was achieved using two different methods: manual IO access with a hypodermic needle (an 18GIVC) and IO access with the standard EZ-IO needle (EZ-IO PD15 GA 15 mm) recommended for children weighing between 3 and 39 kg was performed on the left proximal tibia, located 1 cm below and medial to the tibial tuberosity. If the first attempt was IO PD 15 GA 15 mm), recommended for children weighing between 3 and 39 kg. In all cases, the initial attempt was made with the 18GIVC. Due to the limited supply of EZ-IO needles, the EZ-IO was used as a secondary option when attempts with 18GIVC needles were unsuccessful. All IO interventions were performed by the same pediatric emergency specialist. In all patients, IO access was performed on the proximal part of the left tibia located 1 cm inferomedial to the tibial tuberosity. If the first attempt was unsuccessful, the second attempt was made in the corresponding area on the right proximal tibia. Local analgesia was not applied to any patient before the procedure. A nurse recorded the IO access time with a stopwatch in patients in whom IO attempts were successfully achieved. IO access time was not recorded on failed attempts. Once all necessary materials were prepared and the intervention site was sterilized, a chronometer was started as soon as the pediatric emergency specialist pricked the skin with the needle tip. The procedure followed standard

protocols. The doctor indicated the completion of the procedure by saying "OK" upon sensing the entry of the needle tip into the bone marrow, noted by a sudden reduction in resistance after passing through the bone cortex, then the stopwatch was stopped. The duration of this procedure was recorded as the IO access time in seconds. Successful IO access was defined by stable needle fixation and absence of extravasation following bone marrow aspiration and/or fluid administration. Emergency treatment and patient monitoring proceeded according to standard procedures, and the IO access time was noted in minutes. Age, gender, etiology of hemodynamic instability, Glasgow Coma Scale (GCS) score on admission, type of IO access (first successful attempt with 18GIVC or second successful attempt with EZ-IO), IO access time (in seconds), duration of IO access (in minutes), complications, first venous blood gas analysis results obtained in pediatric emergency department, and patient's outcomes (death or discharged alive) were recorded.

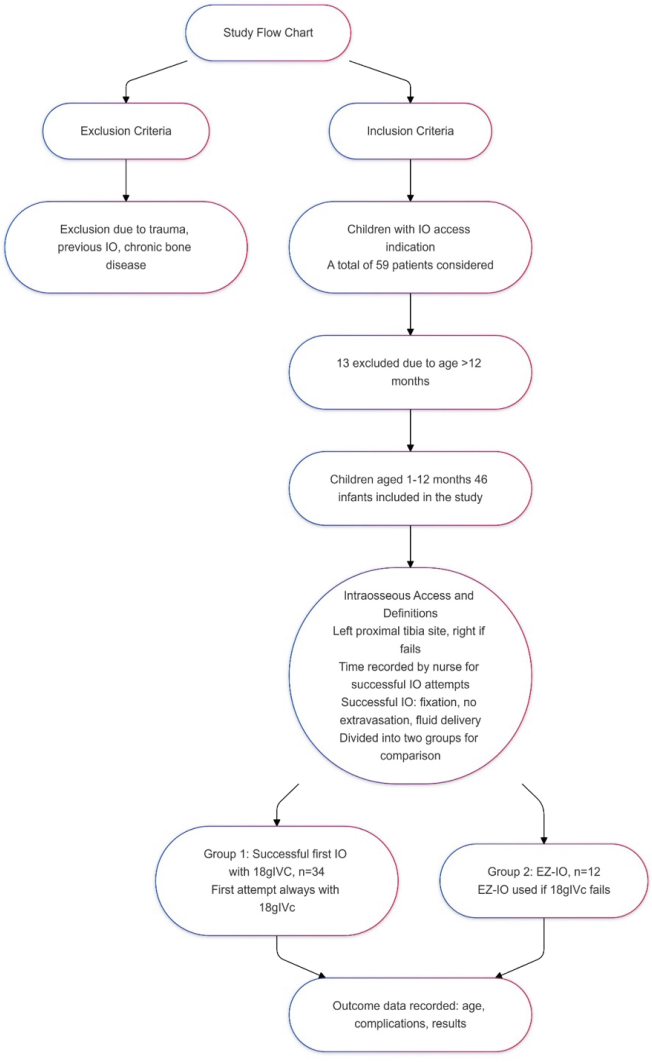

Figure 1. Study flow chart

IO: Intraosseous, 18GIVC: 18-Gauge intravenous cannula, EZ-IO: Battery-powered drill

The cases were divided into two groups and compared: Group 1 (patients with IO access using 18GIVC at first successful attempt) and Group 2 (patients with IO access using EZ-IO device at the second successful attempt).

Statistical Analysis

The data were analyzed with the SPSS 21.00 statistical package program (SPSS Inc©, Chicago, USA). Numerical variables were expressed as medians with interquartile ranges (IQRs), and categorical variables were presented as frequencies and percentages. Comparisons between Group 1 (successful first attempt using 18GIVC) and Group 2 (successful second attempt with EZ-IO) were made. Mann-Whitney U test was applied for numerical data that did not follow a normal distribution. Categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate. Statistical significance was determined at a p-value of less than 0.05.

Ethical Considerations

The study was conducted in accordance with World Medical Association Declaration of Helsinki. Ethical principles for medical research involving human subjects, and approved by the Health Sciences University Turkey, Gazi Yaşargil Training and Research Hospital Clinical Research Ethics Committee (approval number: 633, date: 15.01.2021).

RESULTS

IO access was performed in a total of 59 patients during the study period. Thirteen cases were excluded from the study because they were older than 12 months. Sixteen male and 30 female infants (median age: 6 months; IQR: 3-8; minimum: 1; maximum; 12;) were included in the study. When Group 1 (n=34) and Group 2 (n=12) were compared, patients in Group 1 were younger than in Group 2 (5 months vs. 9 months; p<0.001). All of the cases aged ≤6 months were in Group 1 (p<0.001) There was no significant intergroup difference in terms of the distribution of male and female infants (32.4% male in Group 1 vs. 41.7% in Group 2, p=0.726). The median GCS scores were similar between the two groups [10 (IQR 8-11) in Group 1 vs. 11 (IQR 4-12) in Group 2, p=0.758].

Considering the etiologies of hemodynamic pathologies in patients, hypovolemic shock (n=31; 67.4%), cardiac arrest (n=6 ;13%), respiratory failure (n=6 :13%) and septic shock (n=3; 6.5%) were detected in indicate number (%) of patients. In 34 (79.9%) infants, the first access with 18GIVC was successful. Second attempt with EZ-IO was successful in the remaining 12 (26.1%) patients. No patient required a third attempt (Table 1).

The IO access time with EZ-IO was statistically shorter compared to 18GIVC (7.9 seconds vs. 16.8 seconds) (p<0.001). Extravasation developed in a total of 8 (23.5%) cases. All cases with extravasation were in Group 1. All extravasations developed after the first hour of IO treatment. No other complication was observed except extravasation. Regarding patient outcomes, the mortality rate was slightly higher in Group 2, with 3 patients (25%) compared to 2 patients (5.9%) in Group 1 without any statistically significant intergroup difference (p=0.103). Five (10.8%) cases died (4 in the emergency department and one in the intensive care unit 36 hours after the interventions) (Table 2).

When both groups were compared in terms of the first venous blood gas results obtained in the pediatric emergency department, no statistically significant differences were observed in parameters such as pH, pCO_2, HCO_2, and lactate levels (p>0.05) (Table 3).

At the time of analysis of the study results, while the total costs of 18GIVC needle, and EZ-IO drill used in the study to the hospital were approximately 5, and nearly 26 400 Turkish Liras, respectively.

DISCUSSION

In this study, we found that hypodermic needles, although not routinely recommended, can be used as a last resort for IO access in critically ill infants in a resource-limited pediatric emergency department. IO access was achieved at the first attempt with a hypodermic needle in three-quarters of the cases. As expected, getting IO access with the battery-powered drill is much faster and more efficient. IO access was quickly achieved with EZ-IO drills without wasting time in infants whose IO access could not be achieved in the first attempt with the

Table 1. Comparison of the patients in Group 1 (patients in whom first attempt with 18GIVC was successful) and Group 2 (patients in whom second attempt using instead EZ-IO drill instead of 18GIVC was successful) in terms of age, gender, GCS scores and etiologies of hemodynamic disorder

	Group 1, n=34, n (%)	Group 2, n=12, n (%)	p-value
Age: month median (IQR)	5 (3-6)	9 (8-11)	**<0.001**[1]
≤6 months	28 (82.4)	0	**<0.00**[2]
Male gender	11 (32.4))	5 (41.7)	0.726[2]
GCS, n (IQR)	10 (8-11)	11 (4-12)	0.758[1]
Etiology of hemodynamic disorder			
Hypovolemic shock	24 (70)	7 (58.3)	
Cardiac arrest	4 (11.8)	2 (16.7)	
Respiratory failure	4 (11.8)	2 (16.7)	0.895[3]
Septic shock	2 (5.9)	1 (8.3)	

[1]: Mann-Whitney U test, [2]: Fisher's exact test, [3]: Chi-square test, EZ-IO: Battery-powered drill, 18GIVC: 18-Gauge intravenous cannula, IQR: Interquartile range, GCS: Glasgow Coma Scale

Table 2. Comparison of the patients in Group 1 (patients in whom first attempt with 18GIVC was successful) and Group 2 (patients in whom second attempt using instead EZ-IO drill 18GIVC was successful) in terms of IO access time, duration of IO route, IO access-related complication and patient outcome

	Group 1, n=34	Group 2, n=12	p-value
IO access time, median second (IQR)	16.8 (12.5-19.9)	7.9 (7.1-8.4)	**<0.001**[1]
Duration of IO route, median minute (IQR)	150 (120-180)	125 (96-198)	0.754[1]
Complication, n (%)			
Extravasation	8 (23.5)	0	0.090[2]
Exitus, n (%)	2 (5.9)	3 (25)	0.103[2]

[1]: Mann-Whitney U test, [2]: Fisher's exact test, EZ-IO: Battery-powered drill, 18GIVC: 18-Gauge intravenous cannula, IQR: Interquartile range, GCS: Glasgow Coma Scale, IO: Intraosseous

Table 3. Comparison of the patients in Group 1 (patients in whom first attempt with 18GIVC was successful) and Group 2 (patients in whom second attempt using instead EZ-IO drill 18GIVC was successful) in terms of initial venous blood gas results obtained in the pediatric emergency department

	Group 1, n=34	Group 2, n=12	p-value
pH, median (IQR)	7.12 (6.91-7.20)	7.10 (6.98-7.21)	0.784[1]
pCO_2, median, mmHg (IQR)	56.1 (33.2-79.7)	65.9 (33.4-85.7)	0.762[1]
HCO_3, median, mEq/L (IQR)	11.5 (8.4-17.4)	11.5 (7.3-14.4)	0.599[1]
Lactate, median, mmol/L (IQR)	5.7 (4.2-12)	5.3 (2.3-14.1)	0.634[1]

[1]: Mann-Whitney U test, EZ-IO: Battery-powered drill, 18GIVC: 18-Gauge intravenous cannula, IQR: Interquartile range

hypodermic needle. Extravasations developed in one-fourth of infants who had IO access with a hypodermic needle; however, this complication did not result in termination of IO access in any infant. Studies examining the outcomes of IO accesses using hypodermic needles are very rarely encountered in the current literature and their use for IO access is not routinely recommended. However, we think that this research contributes to the literature in terms of showing that it can be used as a last resort in infants when resources are limited.

The preferred anatomic location for pediatric IO access is the proximal tibia. Various tools can be used to reach the bone marrow from this region. Although inexpensive and easily accessible hypodermic/butterfly needles are user friendly, they are not recommended for routine use as they can be easily clogged with bone fragments. For this reason, they are not used in similar studies especially after the 2000s[5]. In studies conducted before the 2000s; butterfly needles could be used successfully for IO access in infants. The authors stated that since the bone cortex in infants is very thin, the hypodermic needle easily reaches the bone marrow without clogging. In addition, the authors stated that the very few fat cells in the bone marrow of infants increased the chances of being successful when hypodermic needles without a stylet are used for IO access. It was reported that hypodermic needles could be an effective and inexpensive option if financial resources are limited[6]. Based on their experiences, some authors have stated that hypodermic needles can be used when available resources are insufficient; and in case of clogged needles, they suggest practical solutions such as removing the clogged needle and inserting a second needle through the needle tract[7]. IO access options were compared in cadavers of stillborn babies. Post-procedural spectral computed tomography of the cases was taken to confirm the location of the needle. Studies have shown that IO access with a manually inserted hypodermic needle is much more effective than the use of EZ-IO device. The very narrow intramedullary cavity in newborn infants facilitates manual IO access with a hypodermic needle in this age group[8]. Since our study group consisted of infants, IO access with hypodermic needle was successfully achieved in three out of four cases in experienced hands. In our patient group, the age of the cases in which hypodermic needles were successfully inserted was lower than that of the unsuccessful group. In other words, IO access with a hypodermic needle was successful in infants younger than six months of age. This result suggests that hypodermic needles even without stylets may be a successful option for IO access in infants younger than 6 months.

The battery-powered drill has been shown to be effective in IO access in over 90% of children[9,10]. In experienced hands, when the standards are followed, the success rate rises to 100%[2,4,6]. However, in some studies, authors reported that use of manual IO needles had a higher success rate, especially in patients younger than three years old[4,11]. When comparing manual needles and EZ-IO devices, manually inserted IO needles were found to be more successful than EZ-IO devices in infants weighing less than 8 kg. In cases weighing less than 8 kg, IO access was achieved in 5 seconds with manual needle and 13 seconds using EZ-IO drill. In cases weighing more than 8 kg, IO access was achieved in 9 seconds with a manual needle and in 10 seconds with EZ-IO device. As can be seen, manual insertion of an IO needle can be performed faster when compared to EZ-IO in small infants[12]. In general, it is not desirable for the IO access time to exceed 30 seconds[11]. In our study, battery-powered drill was successful in all cases. IO access was achieved in approximately 17 seconds with hypodermic needles and in approximately 8 seconds with an EZ-IO drill. When evaluating these results, it is necessary to consider that the age of the patients who were treated successfully with the hypodermic needle was younger than 6 months, and that those who were treated with EZ-IO drill were infants aged 6-12 months. More importantly, and as a strength of our study, all IO interventions were performed by the same experienced pediatric emergency medicine specialist. Our study results have shown that, in experienced hands, EZ-IO

drills can be successfully and fastly applied for IO access in infants between 6-12 months of age.

IO access is generally a safe practice, and the complication risk is less than 1%. The most common complication is extravasation. It occurs as a result of needle displacement. In terms of compartment syndrome, the extremity where the intervention is made should be evaluated[5,12]. In our study, only extravasation was seen as a complication and all of the extravasations occurred in the hypodermic needle group. Extravasation was observed in approximately one out of every four cases. However, it was not necessary to terminate the procedure of IO access in cases with extravasation. Compartment syndrome did not develop in any of our patients. There were no complications in those with IO access performed using EZ-IO drills. These results have shown once again that IO access is a safe undertaking in experienced hands and when standards are followed.

Study Limitations

The main limitation of the study is the inability to compare the efficacy of other standard IO devices. However, if we had other IO access options in the resource-limited conditions, the hypodermic needle should not be used. Another limitation of the study is the limited number of study participants. The strength of the study is that both hypodermic needles and EZ-IO device were used by the same experienced pediatric emergency medicine specialist. Another feature of the study is that efficacy of IO access was only studied in infants. Thus, the study was carried out with IO devices applied by the same experienced user on infants with similar anatomical features.

CONCLUSION

In experienced hands, EZ-IO drill is a fast, effective, and reliable device for providing IO access in critically ill infants. But, where resources are limited, IO access with an 18-gauge hypodermic needle can be attempted, especially in infants younger than six months. Infants whose IO access was performed using a hypodermic needle, should be carefully monitored for postprocedural complication of extravasation.

Ethics

Ethics Committee Approval: Ethical principles for medical research involving human subjects, and approved by the Health Sciences University Turkey, Gazi Yaşargil Training and Research Hospital Clinical Research Ethics Committee (approval number: 633, date: 15.01.2021).

Informed Consent: Retrospective study.

Author Contributions

Concept: G.Y., Design: G.Y., Data Collection or Processing: G.Y., Ö.Ö.B., A.B., M.A., Analysis or Interpretation: A.B., M.A., Literature Search: Ö.Ö.B., Writing: G.Y.

Conflict of Interest: The authors have no conflict of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

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