The use of alternative vascular access in emergency care

Huszár, Máté Huba

UNIVERSITY OF ZAGREB
SCHOOL OF MEDICINE

Máté Huba Huszár

The Use of Alternative Vascular Access in Emergency Care

GRADUATE THESIS

Zagreb, 2023

This graduation paper was made at the Department of Internal Medicine, Division of Intensive Care Medicine at University Hospital Centre Sisters of Charity, Zagreb, under the supervision of Professor Vesna Degoricija, MD, PhD, and it was submitted for evaluation in the academic year 2022/2023.

The graduation paper was made at the Chair of Internal Medicine, University of Zagreb, School of Medicine.

Mentor: Professor Vesna Degoricija, MD, PhD

Abbreviations:

- BIG Bone Injection Gun (by PerSys Medical)
- CIEM Croatian Institute of Emergency Medicine
- CPD Continuing Professional Development
- CPR Cardiopulmonary Resuscitation
- CVC Central Venous Catheter
- DIVA Difficult Intravenous Access
- EBM Evidence-based medicine
- ED Emergency Department
- EM Emergency Medicine
- EMS Emergency Medical Services (pre-hospital)
- ERC European Resuscitation Council
- EZ-IO Arrow® EZ-IO® System (by Teleflex)
- ICP Intracranial Pressure
- IO Intraosseous route
- IV Intravenous
- MET Medical Emergency Team
- NIO Next-Generation IO™ (by PerSys Medical)
- PIV Peripheral IV
- PVC Peripheral Venous Catheter (cannula)
- TBI Traumatic Brain Injury (TBI)
- UHC University Hospital Centre (Klinički bolnički centar)

Contents:

Summary

TITLE: **The Use of Alternative Vascular Access in Emergency Care**

AUTHOR: **Máté Huba Huszár**

A variety of alternative emergency vascular access solutions have been tested and described in the literature. In cases of difficult intravenous access (DIVA) in emergency settings, intraosseous access (IO) has consistently been suggested by professional organisations as the most suitable alternative to peripheral venous catheters (PVC) due to its proven superiority. IO is the quickest and safest option when immediate intravenous access cannot be established.

This thesis, as a descriptive cross-sectional study, presents structured survey data about IO utilisation in the city- and county of Zagreb. The participants were licensed healthcare professionals of emergency departments and pre-hospital emergency medical services (EMS). Findings indicate that IO access is not being used to its full potential due to a lack of sufficient awareness, equipment, training, and fear of use. Most of the respondents (85%) experienced at least a few DIVAs in emergency situations during the recall period, and over 82% believed that at least some of their patients would have benefited from earlier vascular access. However, more than half of the participating practitioners have never thought of placing an IO, and only 9% have inserted one during the prior six months. Those who considered an IO but did not place one (37%) indicated lack of availability (42%), fear of use (17%) and lack of training (12%) as the most common reasons.

Various measures could be implemented to encourage the use of IO access in emergencies, such as improving training programmes, ensuring continuous availability, and introducing monitoring and quality assurance mechanisms.

KEYWORDS: Intraosseous access; infusions, intraosseous; IO; Vascular access; Emergency medicine

Sažetak

NASLOV: **Upotreba alternativnog vaskularnog pristupa u hitnoj pomoći**

AUTOR: **Máté Huba Huszár**

U literaturi su testirani i opisani različiti alternativni hitni vaskularni pristupi. U slučajevima otežanog intravenskog pristupa u hitnim situacijama, profesionalne organizacije predlažu intraosealni (IO) pristup kao najprikladniju alternativu perifernim venskim kateterima zbog njegove dokazane superiornosti. IO pristup je najbrža i najsigurnija opcija kada se u kritičnom trenutku ne može uspostaviti trenutni intravenski pristup.

Ovaj diplomski rad, kao deskriptivna presječna studija, predstavlja strukturirane anketne podatke o korištenju IO pristupa u gradu Zagrebu i Zagrebačkoj županiji. Sudionici su bili licencirani zdravstveni djelatnici hitne službe i predbolničke hitne medicinske pomoći. Rezultati pokazuju da se IO pristup ne koristi u punom potencijalu zbog nedostatka svjesnosti, opreme, obuke i straha od korištenja. Većina ispitanika (85%) doživjela je barem nekoliko hitnih situacija u kojima je postavljanje intravenskog katetera bilo otežano, a preko 82% vjeruje da bi barem neki od njihovih bolesnika imali koristi od ranije uspostavljenog vaskularnog pristupa. Međutim, više od polovice ispitanika nikada nije razmišljalo o postavljanju IO pristupa, a samo 9% ga je koristilo tijekom prethodnih šest mjeseci. Oni koji su razmatrali IO pristup, ali ga nisu postavili (37%) naveli su nedostatak dostupnosti opreme (42%), strah od korištenja (17%) i nedostatak obuke (12%) kao najčešće razloge.

Različite mjere mogle bi se provesti kako bi se potaklo korištenje IO pristupa u hitnim slučajevima, poput poboljšanja programa obuke, osiguravanja stalne dostupnosti opreme te uvođenja mehanizama praćenja i osiguranja kvalitete provedbe.

KLJUČNE RIJEČI: Intraosealni pristup; infuzije, intraosealne; IO; vaskularni pristup; hitna medicina

Preface / Background

Since the dawn of the first successful parenteral fluid therapies in the 19th century, healthcare professionals have frequently faced difficulties securing access to intravascular spaces. As cited by Barsoum and Kleeman (1):

> *"…in certain cases of vascular collapse ... one would throw the injection into the cavity of the peritoneum." – Hayem, 1885*

Difficult intravenous access (DIVA) situations are commonly encountered in emergency settings. There are several reasons for this, most notably: dehydration, haemorrhage and other forms of hypovolemia leading to the collapse of the peripheral veins, as described by Eren (2), and the growing number of complex patients with multiple chronic conditions, as this population often presents with vulnerable peripheral veins prone to rupturing during PVC insertion.

As pointed out by Davis et al. (3), there is no universally accepted understanding of what exactly DIVA is. A clear and comprehensive definition has been suggested as a result of a high-strength systematic review by Bahl et al. (4) – according to this, Difficult Intravenous Access (DIVA) is:

- *"when a clinician has two or more failed attempts at PIV access using traditional techniques,"*
- *"physical examination findings are suggestive of DIVA (e.g. no visible or palpable veins), or"*
- *"the patient has a stated or documented history of DIVA."*

Prompt drug or fluid therapy initiation can be lifesaving in specific emergencies, such as anaphylactic shock, massive haemorrhage, sepsis, burns, or cardiac arrest. At the same time, delayed access often leads to worse outcomes (5–7).

When repeated PVC insertion attempts fail, the next step in management is often to insert, or request the insertion of a central venous catheter (CVC). As summarised by Key and Duffy (8), in this procedure, a longer single- or multi-lumen flexible catheter is inserted into a large vein, usually with the help of a guidewire (Seldinger technique). Commonly chosen vessels are the internal jugular, the subclavian, and the femoral veins. However, it is worth noting that this is a more complicated procedure that requires a sterile field, more complex equipment, trained assistance, and commonly ultrasound guidance too (with a sterile cover and sterile ultrasound gel). The procedure demands extensive training and experience from the executing practitioner, and even when successful at the first attempt, it often results in a significant delay. Liu et al. (9) demonstrated that securing a CVC takes more than 15 times longer than establishing an Intraosseous (IO) access. Furthermore, it is impractical and riskier during Cardiopulmonary Resuscitation (CPR), as chest compressions and ventilation efforts can obstruct or disturb the practitioner trying to establish access to a central vein. Central venous catheterisation also has some specific complications, which may render its utilisation in some emergency situations inadvisable. For example, as this procedure may lead to pneumothorax or haemothorax, its use would carry additional risk when either of these conditions pre-exists on the contralateral side from the planned location of insertion (e.g., trauma patients). It may also be reasonable to delay this procedure or choose an alternative anatomical site or route in arrhythmias, cardiac tamponade, and brachial plexus injury. CVC insertion into the jugular veins should generally be avoided in case of increased intracranial pressure (ICP) or recent traumatic brain injury (TBI), as explained by Ziai et al. (10).

The **ideal alternative to a PVC** would have the following properties: requires minimum training, is easy to establish at multiple possible sites, is ready to use as quickly as possible, relatively painless, cost-effective, reliable, safe and widely available. This panacea of medical devices does not exist; however, a range of alternatives are available, some of which I will discuss below.

AVAILABLE ALTERNATIVES TO PERIPHERAL VENOUS CATHETER (PVC):

Several options have been suggested (11,12) and tested, which could be used to secure vascular access when the traditional method of peripheral venous catheterisation is no longer possible. In this section, I will list a few viable alternatives other than the IO route, which will be detailed later; and the CVC, which has already been discussed above.

- External Jugular Lines:

In certain circumstances, it may still be possible to insert a large-bore standard PVC device, such as Vasofix® or Braunüle®, into the left or right external jugular vein, as these vessels sometimes remain relatively well filled, even in hypovolemic patients. In theory, this site also offers rapid drug distribution due to its vicinity to the heart. However, Lahtinen et al. (13) demonstrated that failure at this site is more common, and it is also slower compared to cannulating the antecubital vein. There is a theoretical risk for iatrogenic pneumothorax, hydrothorax – according to Franzini et al. (14), and damage to the great vessels of the neck. Similarly to CVC insertion, it is also impractical during CPR.

- PVC under ultrasound guidance:

Emergency medicine practitioners can be trained relatively quickly to use ultrasound (or other illumination devices) to visualise a larger peripheral vein and insert a cannula, even when it is not possible to use the traditional technique, as demonstrated by Brannam et al. (15). However, ultrasound equipment is not always readily available, they are expensive, and finding a suitable peripheral vein can take time. During CPR, passive movements of the limbs may render it difficult to visualise a vessel.

- Saphenous Vein Cutdown:

Venous cutdowns were once the first alternative, requiring minimal additional training for physicians. In this procedure, the skin is incised above the expected position of a larger peripheral vein using a scalpel. Once in the subcutaneous space, blunt dissection is utilised until the vessel is visualised and elevated with a haemostat. One or two sutures are commonly passed underneath the vessel before a partial incision is made to allow the passing of a cut IV giving set or the

catheter of a CVC set. Although not commonly utilised anymore, this technique may still be lifesaving in resource-scarce settings or, when performed in parallel with other techniques, as a backup. According to Rhee et al. (16), vascular access can be achieved in under 5 minutes. There are also several alternative sites available for venous cutdowns, as detailed by Chappell et al. (17). However, this technique is nowadays rarely employed due to the availability of less invasive and quicker techniques. Venous cutdowns also carry the risk of haemorrhage, air embolism, peripheral nerve damage, and infection, as listed by Lee et al. (18), and commonly result in scarring.

- Intralingual / Sublingual Injection:

Some drugs have been successfully injected into or under the tongue. A limited number of studies (19–21) evaluated the efficacy of this route and described successful cases of utilisation. However, fluid resuscitation via this route would not be possible due to potential airway obstruction. There is also an obvious risk of introducing pathogens into the bloodstream from the oral cavity, and failure carries the risk of aspiration.

- Intrapenile route - Corpus Cavernosum (CC) vascular access:

Direct injection and fluid infusion into one of the corpora cavernosa of the penis (also called intracavernous infusion – ICI) has been tested and described in the scientific literature (22–25). Interestingly, besides rapid and safe access with minimal complications, fast flow rates have also been demonstrated – which suggests a promising alternative route in the fluid resuscitation of males. Possible publication bias and resistance to utilising this route in clinical practice make it difficult to collect further evidence. Nevertheless, it is yet another alternative to consider in the case of male patients in DIVA emergencies when no other route is immediately available.

INTRAOSSEOUS ACCESS (IO):

The currently available best option in case of DIVA in emergency settings is IO. A number of high-strength studies (26–29) support its use in both hospital and pre-hospital settings; it is proven safe, effective, quick, easy to use, and requires minimal training.

There are two common mechanisms of action employed by a range of different devices (of different manufacturers). The 'power driver' technology uses an active rotation of the IO needle to penetrate the bone medulla – an example of such a device is EZ-IO® by Teleflex. 'Spring-loaded' versions shoot or punch a needle rapidly into the bone marrow with one rapid movement – an example is NIO™ by PerSys Medical. Intraosseous vascular access devices have been going through remarkable improvements during the last few decades, and several models are now licensed by the relevant regulatory bodies for human use, both in Europe and worldwide.

The use of IO access devices can be taught to healthcare professionals quickly, and it does not require much experience before one can use it safely. The first attempt success rate in out-of-hospital cardiac arrests (OHCA) was shown to be superior to peripheral venous cannulation (PVC) by Reades et al. (30).

IO access can be established at multiple anatomical sites, including the head of the humerus, proximal tibia, distal femur or distal tibia. Beaumont et al. (31) demonstrated that drugs reach the highest maximum circulating concentration when injected at the humeral site, which may be advantageous during CPR. First-attempt success was slightly higher at the proximal tibial insertion site in another study conducted by Reades et al. (32). This location may also be easier to access in obese patients, and it could be more convenient when multiple interventions take place at the patient's head, such as securing the airway.

Virtually all kinds of pharmacotherapy can be administered safely through the IO route, including all resuscitative drugs, fluids, and blood components. Injected substances reach the central circulation rapidly, according to Cameron et al. (33). Based on the research of Tyler et al. (28), IO access is also suitable for blood

transfusion. There is some evidence provided by Elliott et al. (34) for IO administration of antidotes, and Krähling et al. (35) described a CT contrast administration via this route – in which case they attained good-quality images.

Blood sampling is also possible through IO access, both for traditional laboratory tests and point-of-care devices, as has been demonstrated by multiple studies (36,37). It is generally considered reasonable to evaluate results as if they were venous samples. However, it is important to note that laboratories do not yet have their reference ranges validated for IO samples.

Summary of the most recent comprehensive resuscitation guidelines regarding IO use:

- European Resuscitation Council Guidelines 2021 by Perkins et al. (38):
    - "Peripheral IV lines are the first choice for vascular access. Competent providers might use ultrasound to guide cannulation. In case of an emergency, **limit the time for placement to 5 min (2 attempts) at most**. Use rescue alternatives earlier when the chances of success are considered minimal."
    - "**Consider intraosseous (IO) access if attempts at IV access are unsuccessful or IV access is not feasible.**"
    - "**For infants and children, the primary rescue alternative is intraosseous (IO) access**. All paediatric advanced life support (ALS) providers should be competent in IO placement and have regular retraining in the different devices (and puncture sites) used in their setting."
- 2020 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care by Panchal et al. (39)
    - "…establishing a peripheral IV remains a reasonable initial approach, but **IO access may be considered when an IV is not successful or feasible**."

There are only a few contraindications to IO use. These are fracture of the targeted bone, infection of the overlying skin, severe bone diseases, compartment syndrome of the extremity, and a recent attempt of IO insertion in the same bone. Different manufacturers may list additional contraindications for the use of their devices; therefore, the instructions of the used licensed product should be followed.

According to research conducted by Petitpas et al. (29), complications related to IO access are infrequent, occurring in less than 1% of cases. However, when complications do arise, the most common one is compartment syndrome of the limb where the IO needle was inserted. Other complications, such as extravasation resulting from undiscovered fractures, IO needle displacement or 'drill-through' or 'punch-through' may also occur. As the risk of complications increases with time, it is recommended to avoid using IO access for longer than 24 hours. In most cases, it is safe to establish a central line during this time period.

The insertion of an IO access is not significantly more painful than that of a CVC, as demonstrated by Liu et al. (9). However, IO injections and infusions cause considerable pain, and therefore, if time allows, a local anaesthetic should be injected before high-pressure IO drug or fluid administration. Philbeck et al. (40) showed that minimal discomfort can be achieved by administering 40mg 2% lidocaine into the IO port after insertion, followed by a 10 ml rapid flush of 0.9% NaCl solution. One should always keep this in mind, especially in the case of conscious patients.

Hypothesis

It has been hypothesised that IO access devices are underutilised in hospital and pre-hospital Emergency care in the city- and county of Zagreb. – Recommendations[1] of early conversion to IO access in emergencies when peripheral IV placement fails, are not followed to a sufficient degree.

[1] Recommendations summarised briefly:

- failure to place IV access (max. 5 minutes or two failed attempts)
- when PVC placement is considered too difficult
- consider IO as a first choice in cardiac arrest or decompensated shock when IV cannulation is unlikely to be successful.

Objectives

The aims of this graduate thesis are the following:

- To examine whether healthcare professionals in the target area utilise IO to a sufficient degree when they judge the situation as a DIVA in an emergency. (description)
- To identify possible barriers to timely conversion to IO in emergency care in the target area. (possible causal associations)
- To explore and recommend potential quality improvement methods and identify possible measures to approximate the current guidelines and the observed practice. (possible solutions)

Material and Methods

This thesis incorporates a descriptive cross-sectional study on the utilisation of IO access in DIVAs encountered in emergency situations in the city- and county of Zagreb. It also provides a brief review of the available scientific literature on alternatives to PVC in emergency settings, with a focus on the intraosseous route.

Sampling method and Data collection:

A structured survey was constructed with extensive consultation with experts in medical statistics and with the involvement of my mentor. A total of 14 questions enquired about the frequency of use of PVCs in DIVA situations, DIVA in case of cardiac arrest, practitioners' clinical judgement on their patients' need for early vascular access, the frequency and circumstances of IO access utilisation, specific training on IO devices, and demographic data.

Convenience sampling method was employed at two different University Teaching Hospitals' emergency departments in Zagreb, as well as at pre-hospital EMS (Ambulance services) serving the same area and patient population, namely the City of Zagreb EMS service (*Nastavni zavod za hitnu medicinu grada Zagreba*), and the County of Zagreb EMS service (*Zavod za hitnu medicinu Zagrebačke županije*). At the hospitals and the City of Zagreb EMS service, doctors and nurses on duty were asked to complete the surveys on two consecutive shifts to minimise the overlap of staff. At the County of Zagreb EMS service, the heads of participating branches distributed the surveys amongst their staff. Data collection was concluded between January 11 and March 3. 2023.

Participation was voluntary, and in line with the current code of research ethics of the faculty and institutions involved. My mentor and I were available for questions, which was clearly communicated to all participants; however, we did not receive any enquiries from the participants.

Only two physicians refused to participate, while some others could not take time due to continuous clinical obligations.

Participants had the option to complete the surveys either in Croatian or in the English language.

Sample Size and Generalisability:

Overall, 147 responses were collected, of which 17 were excluded according to the following criteria: work in EM must be equal to or longer than the six-month recall period applied in the questions; responses with missing answers shall be excluded to minimise response bias.

Of the 130 included responses, 41 (31.54%) are from hospital settings, and 89 (68.46%) are from pre-hospital EMS. Table 1. summarises the responses collected by setting and sites.

Table 1 - Responses by site and setting

Site	*Number of valid responses*	*Setting*
UHC 'Rebro'	26 (20%)	Hospital ED
UHC Sestre Milosrdnice	15 (11.54%)	Hospital ED
City of Zagreb EMS	32 (24.62%)	Pre-hospital EMS
Dugo Selo (County of Zagreb EMS)	17 (13.08%)	Pre-hospital EMS
Ivanic Grad (County of Zagreb EMS)	7 (5.38%)	Pre-hospital EMS
Jastrebarsko (County of Zagreb EMS)	15 (11.54%)	Pre-hospital EMS
Sv. I. Zelina (County of Zagreb EMS)	10 (7.69%)	Pre-hospital EMS
Velika Gorica (County of Zagreb EMS)	8 (6.15%)	Pre-hospital EMS

The total population of registered healthcare professionals employed in the surveyed settings is 553. A breakdown of this is summarised in Table 2, for which data was provided by officials of the respective organisations.

Table 2 - study population by employers and function

Site	*Doctors*	*Nurses*	*Overall*
UHC 'Rebro'	34	95	129
UHC Sestre Milosrdnice	19	50	69
City of Zagreb EMS	66	97	163
County of Zagreb EMS	55	137	192
Sum:	174	379	553

Using the standard formula for calculating the minimum required sample size (see below), It has been demonstrated that the number of included responses allows generalisation within the population (registered nurses and doctors) of the examined institutions.

$$n_{min.\ required} = \frac{\frac{z^2 \times p(1-p)}{e^2}}{1+\left(\frac{z^2 \times p(1-p)}{e^2 N}\right)} = 119$$

Where,

N is the population size x
z is the z-score 1.96
e is the margin of error 0.08
p is the standard of deviation..... 0.5

Data Analysis:

Responses were registered in Microsoft Excel, where I performed exclusions according to the aforementioned criteria, sample size calculations, and extracted descriptive statistical data. I used DATAtab software to perform chi-squared tests for hypothesis testing to determine whether statistically significant differences exist between selected groups.

Limitations:

Precautions were taken to minimise errors and bias in this study; however, some weaknesses are inherent to the study design due to convenience sampling, the lack of available validated questionnaires, and the manual transfer of data from the surveys into Microsoft Excel.

At the beginning of the survey, emergencies were clearly defined in the questionnaire as “when the patient is at imminent risk of permanent disability or death if fluid or drug therapy is not administered early. (E.g., Cardiac arrest, sepsis, decompensated shock, rapidly deteriorating patient, massive haemorrhage, polytrauma, traumatic brain injury, severe burns, loss of consciousness, etc.).”

Results

Demographic data:

From the 130 included respondents, 68 (52.31%) were female and 62 (47.69%) were male; 75 (57.69%) were registered nurses and 55 (42.31%) were medical doctors; 111 (85.38%) were full-time- and 19 (14.62%) were part-time employees; the age distributions are summarised in Table 3 below.

Table 3 - Age distribution of respondents

Age group (years of age)	Frequency	%
Under 25	13	10%
25-34	71	54.62%
35-44	24	18.46%
45-54	11	8.46%
55-64	11	8.46%

The average work experience in emergency settings expressed in months was 98.54 (Median 72, Std. Deviation 95.63, Minimum 7, Maximum 456).

Core results: – All the data reported in the section below pertains to a 6-month recall period unless specified otherwise.

Out of 130 practitioners, 117 (90%) inserted a PVC in emergency situations at least a few times, while 13 (10%) indicated that they had never placed one. Further data is represented in Figure 1 below.

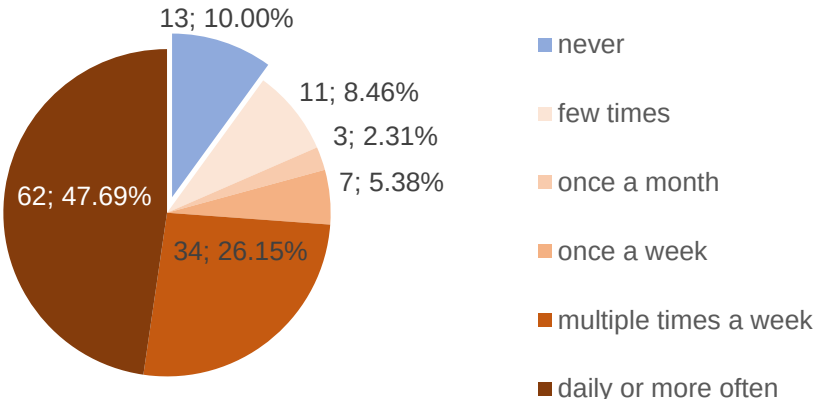

Figure 1 - Frequency of PVC use in Emergencies

Difficult Intravenous Access (DIVA) in emergencies were reported by 111 (85.38%) respondents, and 19 (14.62%) of them said they had not experienced one. A breakdown of the responses is illustrated in Figure 2.

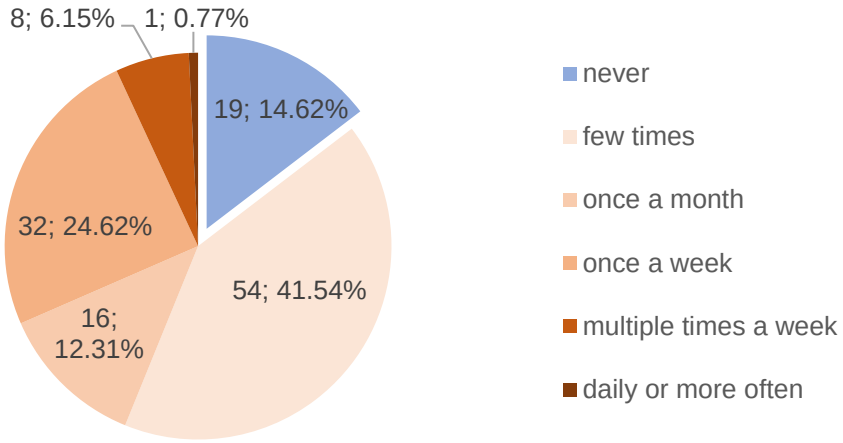

Figure 2 - Frequency of DIVAs in emergencies

In this aspect, statistically significant differences can be demonstrated between different functions (medical doctors and registered nurses) and between different settings (hospital and pre-hospital). Demonstrated with Chi-squared tests, more nurses experienced DIVA in emergencies ($\chi^2(5)=16.59$, $p=.005$, Cramér's $V=0.36$), and it occurred more commonly in hospital settings ($\chi^2(5)=13.61$, $p=.018$, Cramér's $V=0.32$), as illustrated in Figure 3 and detailed in Table 4 and Table 5 respectively.

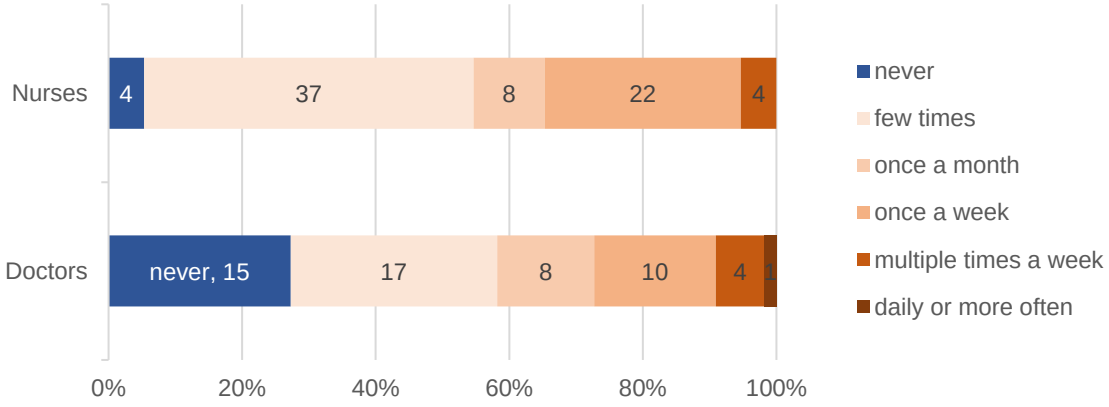

Figure 3 - DIVAs encountered by different groups - Registered Nurses and Medical Doctors

Table 4 - DIVAs encountered by different groups - Registered Nurses and Medical Doctors

	Medical Doctors		Registered Nurses		Total
	Observed frequencies	Expected frequencies	Observed frequencies	Expected frequencies	
never	15	8.04	4	10.96	19
few times	17	22.85	37	31.15	54
once a month	8	6.77	8	9.23	16
once a week	10	13.54	22	18.46	32
multiple times a week	4	3.38	4	4.62	8
daily or more often	1	0.42	0	0.58	1
Total	55	55	75	75	130
Chi^2=16.59; df=5; p=.005					

Table 5 - DIVAs encountered by different groups - hospital and pre-hospital settings

	hospital		pre-hospital		Total
	Observed frequencies	Expected frequencies	Observed frequencies	Expected frequencies	
never	8	5.99	11	13.01	19
few times	9	17.03	45	36.97	54
once a month	4	5.05	12	10.95	16
once a week	16	10.09	16	21.91	32
multiple times a week	4	2.52	4	5.48	8
daily or more often	0	0.32	1	0.68	1
Total	41	41	89	89	130
Chi^2=13.61; df=5; p=.018					

DIVA in cardiac arrest situations was reported by 54 (41.54%) participants, 56 (43.08%) negated, and 20 (15.38%) were unsure.

Hundred and seven (82.31%) participants were of the opinion that at least a few of their patients (in emergencies) would have benefited from an earlier vascular access, 12 (9.23%) believed that none of their patients would have, and 11 (8.46%) were undecided. The findings for this question are depicted in Figure 4.

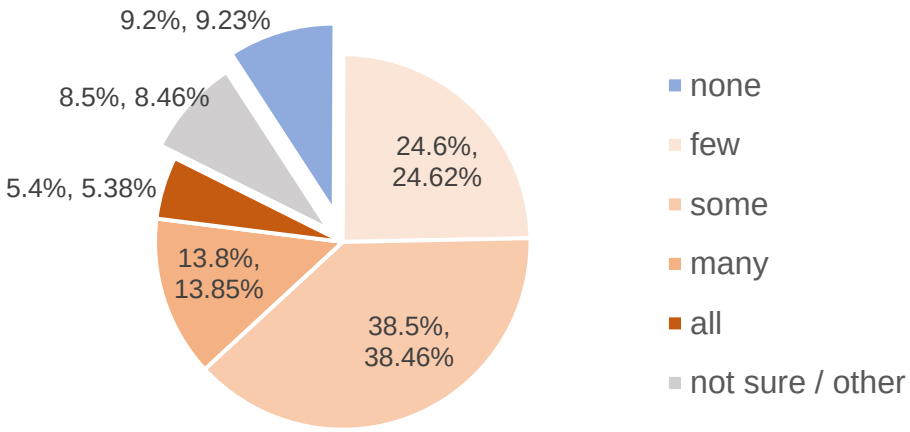

Figure 4 - "Do you think any of your patients would have benefited from faster vascular access?"

In this case, too, there was a statistically significant difference between the responses provided by hospital and pre-hospital staff. – EMS professionals were more likely to say that their patients would have benefited from faster vascular access ($\chi^2(5)=15.22$, p=.009, Cramér's V=0.34). These findings are detailed in Table 6.

Table 6 - "Do you think any of your patients would have benefited from faster vascular access?" - response difference by groups - hospital and pre-hospital

	hospital		pre-hospital		Total
	Observed frequencies	Expected frequencies	Observed frequencies	Expected frequencies	
None	7	3.78	5	8.22	12
Few	14	10.09	18	27.91	32
Some	10	15.77	40	34.23	50
Many	7	5.68	11	12.32	18
All	3	2.21	4	4.79	7
Not sure	0	3.47	11	7.53	11
Total	41	41	89	89	130
Chi^2=15.22; df=5; p=.009					

All 130 (100.00%) respondents stated they knew what IO access was.

To the question, "*Have you ever thought that your patient would benefit from an early placement of Intraosseous access (IO)?*", 66 (50.77%) answered "*No, I never thought that.*", 16 (12.31%) answered yes and an IO was placed, while 48 (36.92%) said they thought about it, but they did not or could not place one for some reason.

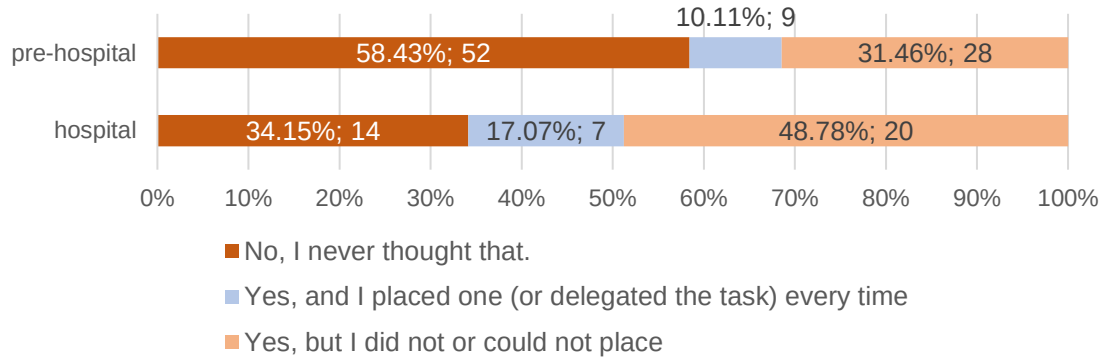

Figure 5 - "Have you ever thought that your patient would benefit from an early placement of Intraosseous access (IO)?" - answers illustrated by groups - hospital and pre-hospital.

Here too, a statistically significant difference can be demonstrated between the hospital and pre-hospital groups by Chi-squared test ($\chi^2(2)=6.64$, p=.036, Cramér's V=0.23). The results with further details are illustrated in Figure 5 and are summarised in Table 7.

Table 7 - "Have you ever thought that your patient would benefit from an early placement of Intraosseous access (IO)?" - group difference summarised - hospital and pre-hospital

	hospital		pre-hospital		Total
	Observed frequencies	Expected frequencies	Observed frequencies	Expected frequencies	
No, I never thought that	14	20.82	52	45.18	66
Yes, and I placed one every time	7	5.05	9	10.95	16
Yes, but I did not or could not place one	20	15.14	28	32.86	48
Total	41	41	89	89	130
$Chi^2=6.64$; df=2; p=.036					

Those who answered with *"Yes, but I did not or could not place one"* (48; 36.92%) were asked to indicate the reason for this. Frequencies for specific answers are given in Figure 6. Out of the 22 participants who indicated that no IO access device was available, 11 were from the City of Zagreb EMS service, 9 were from UHC Sestre milosrdnice hospital, and 2 were from UHC 'Rebro' hospital. Among the "*other*" answers, which respondents could elaborate on, some examples were: "*boss says it's too expensive*", "*There was no time to do it since fast transport was more convenient.*", and a few contraindications were referenced.

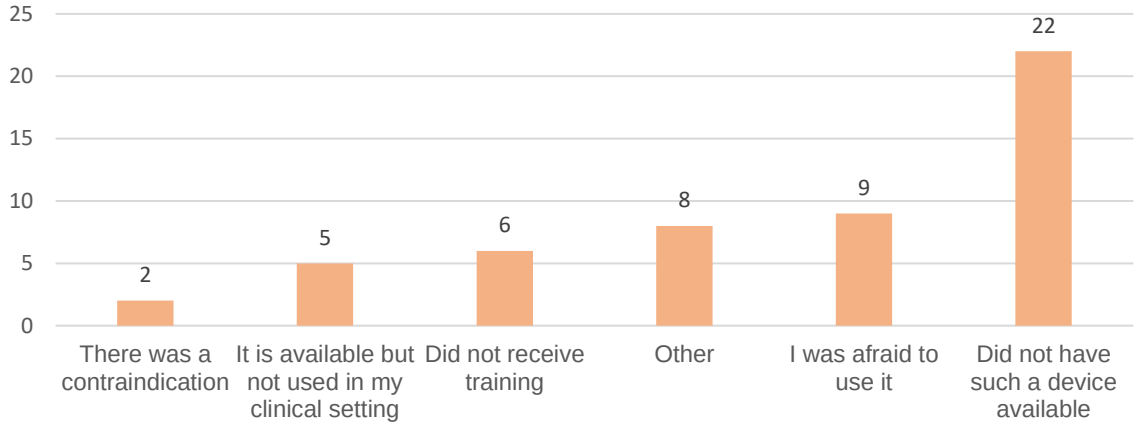

Figure 6 - Reason for not using IO when believed needed

Out of the 130 respondents, 119 (91.54%) never utilised IO access in emergency situations, 9 (6.92%) used it a few times, and 2 (1.54%) indicated that they utilise it approximately once a month, as depicted in Figure 7. Of note, from the 55 responding ED medical doctors, only 2 have reported IO use.

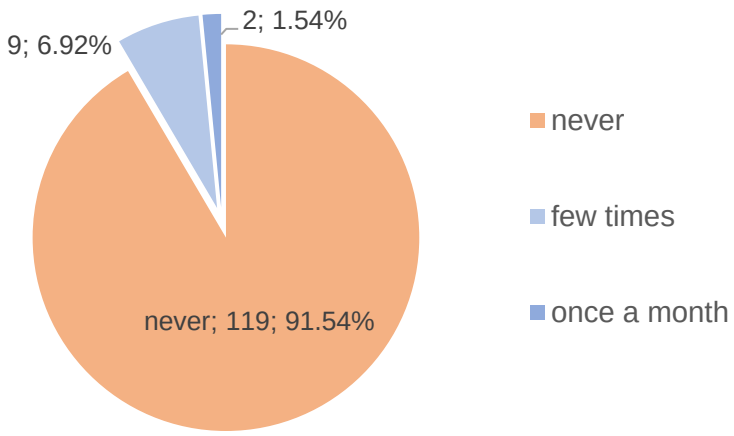

Figure 7 - Frequency of IO access utilisation

Of all the 130 participating EM practitioners, 42 (32.31%) have never received any training about the use of IO access devices, while the rest of them (88; 67.69%) participated in some form of formal training about the use of at least one type. – These data are to be understood for the practitioners' lifetime, not the 6-month recall period. Data about the IO training background of registered nurses and medical doctors is illustrated in Figure 8.

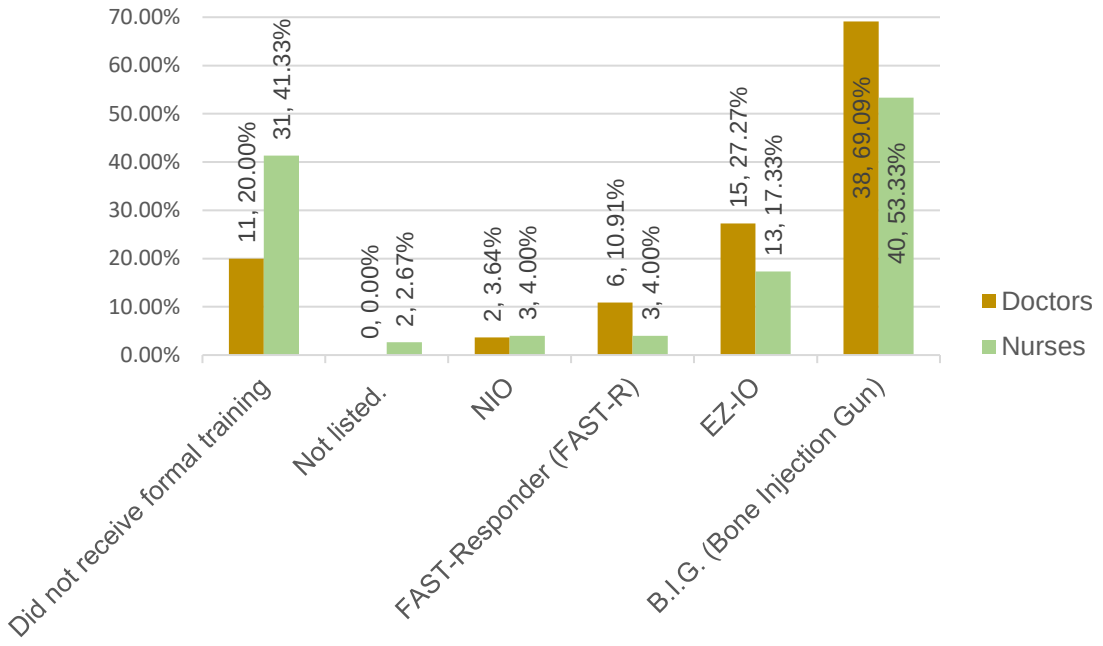

Figure 8 - Formal training received on specific IO access devices by groups - medical doctors and registered nurses.

Overall, nurses reported lower rates of training for almost all types of devices, with the exemption of NIO™ by PerSys Medical.

The average frequencies for each investigated type are reported in Table 8.

Table 8 - Overall training reported by specific types of IO access devices

Age group (years of age)	Frequency	%
Did not receive formal training	42	32.31%
Not listed	2	1.54%
NIO	5	3.85%
FAST-Responder (FAST-R)	9	6.92%
EZ-IO	28	21.54%
B.I.G. (Bone Injection Gun)	78	60.00%

Discussion

IO access in EM is generally underutilised (9,29,41,42), which was observed in this study too. The majority (85.38%) of the EM practitioners identified the occurrence of DIVAs in critically ill patients, yet most of them did not place an IO; and more than half of them did not even consider it. Based on the findings, it appears that while ED and EMS personnel do have some knowledge about IO access, it may not be their primary consideration when facing DIVA scenarios. As one respondent put it, "*I didn't even think about this option.*" – the same participant had received formal IO training and had recalled DIVA situations.

The fact that at least 41.54% recalled DIVA in cardiac arrest but less than 9% placed an IO suggests that most practitioners do not actively consider IO access as the first choice in cardiac arrest.

Hospital EM personnel face difficulties in placing a PVC more often than their pre-hospital peers (EMS), which is possibly due to the "scoop and run" strategy employed by the ambulance crew, when their clinical judgement suggests that. Their patients, transferred to the EDs, will become the DIVA case of hospital staff who no longer have the option of delaying this task. As one participant wrote: "*There was no time to do it since fast transport was more convenient.*" Nevertheless, we should keep in mind that IO access can be secured in less than a minute, as it has been demonstrated by Liu et al. (9).

However, pre-hospital EMS professionals were more likely to express a belief that at least some of their patients would've benefited from earlier vascular access. This is possibly due to their relatively limited options; while in hospitals, there are several available backups, such as ultrasound guidance and Intensive Care specialists with extensive experience in central venous cannulation.

The lack of availability of IO access devices is likely an issue at certain locations; however, results should be interpreted with some caution, as practitioners might not have been aware of where to find these, and availability was not investigated at the examined sites. Furthermore, IO access devices are listed among the standard minimum required equipment of both the ambulance

vehicles[2] and the triage rooms of hospital Emergency Departments[3] in Croatia. Despite these, temporary unavailability may still occur at some sites due to reasons not explored by this study, such as supply shortages, financial considerations, possible non-compliance, etc. Healthcare professionals should familiarise themselves with the type of IO equipment at their disposal and ought to address their line managers in case of any issues with availability. Systematic quality assurance mechanisms should also address availability and compliance. Internal audits could help ensure that EM personnel has uninterrupted access to the equipment they need to be able to practice in accordance with professional guidelines and recommendations. External reviews and national monitoring of the use of medical devices may also improve overall quality. Unfortunately, purchase and turnover data is not yet routinely monitored by public health authorities in Croatia. Once its market surveillance aspect is fully implemented, the EUDAMED database[4], as part of the framework of the new EU rules on medical devices (Regulation (EU) 2017/745), could also aid cross-border monitoring of IO use under the code "*A03040102: Intraosseous infusion kits, single-use*".

Figure 9 - Photo by Dr. Dominik Raos, MD. – Specialist in Emergency Medicine (MSc), head of IHMS Sv. I. Zelina - Institute for Emergency Medicine of the County of Zagreb

[2] Standard medicinske opreme, medicinskih uređaja i pribora za obavljanje djelatnosti izvanbolničke hitne medicine - Nn 80/2016 [Internet]. Narodne novine; Available from: ELI: /eli/sluzbeni/2016/80/1813
[3] Standard medicinske opreme medicinskih uređaja i pribora za obavljanje bolničke hitne medicine - Nn 80/2016 [Internet]. Narodne novine; Available from: ELI: /eli/sluzbeni/2016/80/1816
[4] Medical Devices - EUDAMED [Internet]. 2023 [cited 2023 Jun 3].
Available from: https://health.ec.europa.eu/medical-devices-eudamed_en

Lack of appropriate training seems to be the most important factor contributing to the underuse of IO access in some countries, as it is described by Hallas et al. (41,43). My study population demonstrated a remarkable general theoretical knowledge of the IO route, as 100% of the respondents passed the relevant qualifying question. However, 32.31% of the participants have never received formal training about the use of a specific IO access device. This suggests that besides the amount, focus should also be directed to the quality of IO-related educational activities. Another study conducted in Slovenia by Žunkovič et al. (44) found that EM nursing staff sought more and better quality training about IO use. In Croatia, in accordance with national legislation[5] Continuing Professional Development (CPD) is required for all EM practitioners to renew their licenses in three-yearly cycles. The Croatian Institute of Emergency Medicine (CIEM) has published high-quality manuals (45–47) to support the CPD of EM professionals, all of which cover DIVA and IO access to a sufficient degree. Yet, awareness about IO use is still not universal. As the second most commonly indicated barrier was 'fear of use' in this study – perhaps we should focus less on what practitioners know, and more on how they would behave in real-life situations. We need them to advance from the *'knows'* level of Miller's pyramid (48) to the *'does'* - Figure 10. The educators of micro-credentials shall incorporate this into their didactic concepts and enable their trainees to practice in high-fidelity simulation environments. IO access should also be incorporated efficiently into the basic curricula of medical and nursing schools as part of the expected Learning Outcomes (LO) or, ideally, as part of the Entrustable Professional Activities (EPAs) of the graduates. Higher education institutions should mainly focus on their nursing programmes in this aspect, as results of this study indicate that registered nurses place more IOs than medical doctors, even though they receive less formal training.

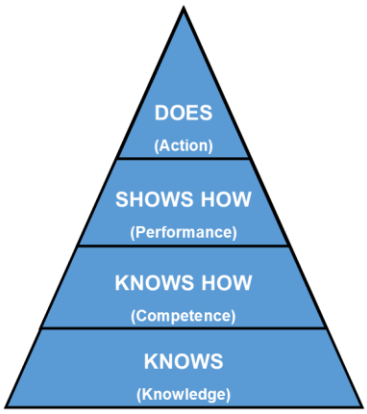

Figure 10 - Miller's Pyramid of clinical competence

[5] 1. Edukacijski programi u izvanbolničkoj hitnoj medicini - Izdanje: NN 80/2016 [Internet]. Narodne novine; 2016 [cited 2023 Jun 4]. Available from: ELI: /eli/sluzbeni/2016/80/1817

Five participants who deterred from IO use indicated "*It is available, but not used in my clinical setting."* as the reason*,* one wrote "*I was not in decision-making position.*", one said "*I was not allowed.*", and another one wrote "*boss says it's too expensive*". This cluster of responses likely represents a type of barrier originating from **local practices (traditions)**, which can be rather inflexible at times. It should be remembered that expert opinions (e.g., "*This is how we usually do it here*") are the weakest form of scientific evidence. As Masic et al. (49) put it:

"The key difference between evidence-based medicine and traditional medicine is not that EBM considers the evidence while the latter does not. Both take evidence into account; however, EBM demands better evidence than has traditionally been used."

Therefore, practitioners should be encouraged to regularly reflect on their own practice, review the available evidence, and raise concern (50) if they identify some local traditions that could be improved in order to achieve safer practice and better outcomes. Additionally, clinical leaders, mentors and supervisors shall empower their colleagues by endorsing IO placements and by reassuring their teams about the justified application of this technique.

This study indicates that EM practitioners are most familiar with the use of the Bone Injection Gun (BIG) device produced by PerSys Medical. As this company has a newer version, the NIO – Next-Generation IO™, decision-makers ought to be aware of the risk of possible gradual discontinuation of the BIG. Since NIO was also shown to be superior to BIG in terms of first-attempt success rates, as demonstrated by Bielski et al. (51), decision-makers should consider adding NIO as a demonstration device during their specific IO access training sessions. The use of NIO and EZ-IO (by Teleflex) appear to be equally easy to learn, as demonstrated by Shina et al. (52); however, as each of them may have their specific advantages in different situations due to their different mechanism of action (see Preface), it may be reasonable to have these two **types of devices** available in clinical settings and at specific training sessions.

To my best knowledge, as of the publication of this graduate thesis, no other studies have been released about the utilisation of IO access devices in Croatia.

Hence, this descriptive study warrants further research in the field of IO access use in Croatian emergency care to vet the reasons postulated above. Broader analytical studies involving other regions of the country could serve as evidence to be used by professionals, public authorities and healthcare institutions during their decision-making processes and could ultimately contribute to the enhancement of the quality of emergency care and health outcomes. Furthermore, the use of IO access should also be investigated in other healthcare settings, such as intensive care and reanimatology, and the work of other medical emergency teams (MET) – like those on sports events, military operations, etc.

I hereby declare that I do not have any conflict of interest to disclose. – I have no personal or professional affiliation with any of the producers or distributors of any of the products mentioned in my thesis.

Conclusions

Intraosseous access is rarely used in the City and County of Zagreb relative to the frequency of reported difficult intravenous access situations. EM professionals know about IO access but seldom identify and act on its indications in practice. While the lack of availability of IO access devices may play a role in certain circumstances, the quality of training and intrapersonal factors such as ‘fear of use’ seem to be the most important barriers.

Universal awareness about the IO route amongst EM practitioners has not yet been achieved, and some are lacking specific training. To ensure optimal outcomes, it may be advisable to consider adjusting IO-related education and training programs to align with a competence-based approach and address the barriers identified. Local practices should be aligned with evidence-based guidelines, and all stakeholders shall take an active role in this process.

Due to possible issues with availability, the management of emergency services ought to consider looking at the supply of IO access devices at their institutions and empowering their teams to utilise this technique. It could be advantageous to implement both domestic and EU-wide market surveillance.

To enhance our comprehension of IO access utilisation in Croatia and to evaluate the suggested solutions and possible associations, more research is necessary.

Acknowledgements

I am grateful to my mentor, Professor Vesna Degoricija, for her support and patience. Your knowledge, professionalism, and work ethic inspired me from the early years of my medical studies. Thank you for accepting my topic, for your help with contacting the participating institutions, gaining ethical committee approval, and for the background information you kindly provided.

I would like to thank Professor Vladimir Trkulja and Dr Pero Hrabač for their kind help and advice during the planning phase of my study, and Professor Ivan Gornik for the population data he kindly provided. I am especially grateful to Dr Mario Šekerija for generously devoting his time to multiple consultations on the statistical aspects.

Dr. Dominik Raos, *MD. – Specialist in Emergency Medicine (MSc), head of IHMS Sv. I. Zelina - Institute for Emergency Medicine of the County of Zagreb* deserves special thanks for his enthusiastic engagement with my study. Dr Raos provided me with valuable information, encouraged other participating branches, and even sent me photos without being asked to do so. I believe that without his contribution, I wouldn't have been able to gather sufficient responses. Thank you!

I want to thank all the participants for taking the time to answer my questions even in such busy settings. I hugely appreciate the assistance of the lead nurses who helped with logistics, Marino Čanađija, *mag.med.techn.spec., univ.mag.admin.sanit*. for his personal efforts to accommodate my research at the City of Zagreb EMS service and for providing further information for my research, Lucija Braje, *mag.oec* and all the heads of the participating branches of the County of Zagreb EMS service.

I express my heartfelt gratitude to my family for their unwavering support throughout my medical studies. I am particularly indebted to my mother for motivating me to apply and for providing financial stability throughout. I am also grateful to Matija, whose support has been invaluable in enabling me to concentrate on my studies with ease. I am truly thankful to them both.

Finally, I have two dear friends, Matthias and Marina, who have always been a reliable source of joy, encouragement, but also constructive feedback. I am grateful for their valuable contributions and the countless adventures we have shared together. I especially want to thank Marina for her assistance in translating the survey and the summary of this thesis.

References

1. Barsoum N, Kleeman C. Now and Then, the History of Parenteral Fluid Administration. Am J Nephrol. 2002;22(2–3):284–9.

2. Eren H. Difficult Intravenous Access and Its Management. In: Ultimate Guide to Outpatient Care [Internet]. IntechOpen; 2021 [cited 2023 May 25]. Available from: https://www.intechopen.com/chapters/75477

3. Davis EM, Feinsmith S, Amick AE, Sell J, McDonald V, Trinquero P, et al. Difficult intravenous access in the emergency department: Performance and impact of ultrasound-guided IV insertion performed by nurses. Am J Emerg Med. 2021 Aug;46:539–44.

4. Bahl A, Johnson S, Alsbrooks K, Mares A, Gala S, Hoerauf K. Defining difficult intravenous access (DIVA): A systematic review. J Vasc Access. 2021 Nov 17;11297298211059648.

5. Im Y, Kang D, Ko RE, Lee YJ, Lim SY, Park S, et al. Time-to-antibiotics and clinical outcomes in patients with sepsis and septic shock: a prospective nationwide multicenter cohort study. Crit Care. 2022 Jan 13;26(1):19.

6. Lupton JR, Neth MR, Sahni R, Jui J, Wittwer L, Newgard CD, et al. Survival by time-to-administration of amiodarone, lidocaine, or placebo in shock-refractory out-of-hospital cardiac arrest. Acad Emerg Med Off J Soc Acad Emerg Med. 2023 Mar 4;

7. Barrow RE, Jeschke MG, Herndon DN. Early fluid resuscitation improves outcomes in severely burned children. Resuscitation. 2000 Jul;45(2):91–6.

8. Key W, Duffy M. Central Venous Cannulation. Anaesth Tutor Week. 2009 Jun 15;(138):13.

9. Liu Y yan, Wang Y peng, Zu L yun, Zheng K, Ma Q bian, Zheng Y an, et al. Comparison of intraosseous access and central venous catheterization in Chinese adult emergency patients: A prospective, multicenter, and randomized study. World J Emerg Med. 2021;12(2):105–10.

10. Ziai WC, Chandolu S, Geocadin RG. Cerebral herniation associated with central venous catheter insertion: risk assessment. J Crit Care. 2013 Apr;28(2):189–95.

11. Orlowski JP. Emergency Alternatives to Intravenous Access: Intraosseous Intratracheal, Sublingual and Other-Site Drug Administration. Pediatr Clin North Am. 1994 Dec 1;41(6):1183–99.

12. Alternative Methods to Vascular Access in the Emergency Department. Ann Emerg Med. 2017 Jul;70(1):116.

13. Lahtinen P, Musialowicz T, Hyppölä H, Kiviniemi V, Kurola J. Is external jugular vein cannulation feasible in emergency care? A randomised study in open heart surgery patients. Resuscitation. 2009 Dec;80(12):1361–4.

14. Franzini S, Paradiso E, Casiraghi C, Scalia Catenacci S, Sofi G, Leva E. Massive Hydrothorax Following External Jugular Vein Cannulation in an Infant. J Case Rep. 2019 Aug 8;9(2):103–5.

15. Brannam L, Blaivas M, Lyon M, Flake M. Emergency nurses' utilization of ultrasound guidance for placement of peripheral intravenous lines in difficult-access patients.
Acad Emerg Med Off J Soc Acad Emerg Med. 2004 Dec;11(12):1361–3.

16. Rhee KJ, Derlet RW, Beal SL. Rapid venous access using saphenous vein cutdown at the ankle. Am J Emerg Med. 1989 May 1;7(3):263–6.

17. Chappell S, Vilke GM, Chan TC, Harrigan RA, Ufberg JW. Peripheral venous cutdown. J Emerg Med. 2006 Nov;31(4):411–6.

18. Lee MM, Anand S, Loyd JW. Saphenous Vein Cutdown. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 [cited 2023 May 27]. Available from: http://www.ncbi.nlm.nih.gov/books/NBK532880/

19. Nichols WA, Cutright DE. Intralingual injection site for emergency stimulant drugs. Oral Surg Oral Med Oral Pathol. 1971 Oct 1;32(4):677–84.

20. Rothrock SG, Green SM, Schafermeyer RW, Colucciello SA. Successful resuscitation from cardiac arrest using sublingual injection for medication delivery. Ann Emerg Med. 1993 Apr;22(4):751–3.

21. Wisely NA, Mayall R. Intralingual succinylcholine injection provides a rapid onset of muscle relaxation in an emergency.
Anaesthesia. 2001;56(12):1203–16.

22. Bradley M. Brief Report: Systemic Vascular Access and Resuscitation via Corpus Cavernosum. Mil Med. 2016 Nov;181(11):e1491–4.

23. Godec CJ, Cass AS. The penis — A possible alternative emergency venous access for males? Ann Emerg Med. 1982 May;11(5):266–8.

24. Pertek JP, Coissard A, Meistelman C, Cormier L, Hubert J. Intracavernous infusion: an alternative route to intravenous access during resuscitation? Ann Emerg Med. 1998 Dec;32(6):753–4.

25. Osbun N, Rogers MJ, Walsh TJ, Yang C. Peripheral rapid infusion via the corpus cavernosum: An investigation of penile vascular access flow rates. J Trauma Acute Care Surg. 2017 Nov;83(5):975–7.

26. Voigt J, Waltzman M, Lottenberg L. Intraosseous Vascular Access for In-Hospital Emergency Use: A Systematic Clinical Review of the Literature and Analysis. Pediatr Emerg Care. 2012 Feb;28(2):185–99.

27. Wang D, Deng L, Zhang R, Zhou Y, Zeng J, Jiang H. Efficacy of intraosseous access for trauma resuscitation: a systematic review and meta-analysis. World J Emerg Surg WJES. 2023 Mar 14;18(1):17.

28. Tyler JA, Perkins Z, De'Ath HD. Intraosseous access in the resuscitation of trauma patients: a literature review. Eur J Trauma Emerg Surg Off Publ Eur Trauma Soc. 2021 Feb;47(1):47–55.

29. Petitpas F, Guenezan J, Vendeuvre T, Scepi M, Oriot D, Mimoz O. Use of intra-osseous access in adults: a systematic review. Crit Care Lond Engl. 2016 Apr 14;20:102.

30. 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 Dec;58(6):509–16.

31. Beaumont LD, Baragchizadeh A, Johnson C, Johnson D. Effects of tibial and humerus intraosseous administration of epinephrine in a cardiac arrest swine model. Am J Disaster Med. 2016;11(4):243–51.

32. Reades R, Studnek JR, Garrett JS, Vandeventer S, Blackwell T. Comparison of first-attempt success between tibial and humeral intraosseous insertions during out-of-hospital cardiac arrest. Prehosp Emerg Care. 2011;15(2):278–81.

33. Cameron JL, Fontanarosa PB, Passalaqua AM. A comparative study of peripheral to central circulation delivery times between intraosseous and intravenous injection using a radionuclide technique in normovolemic and hypovolemic canines. J Emerg Med. 1989;7(2):123–7.

34. Elliott A, Dubé PA, Cossette-Côté A, Patakfalvi L, Villeneuve E, Morris M, et al. Intraosseous administration of antidotes - a systematic review. Clin Toxicol Phila Pa. 2017 Dec;55(10):1025–54.

35. Krähling H, Masthoff M, Schwindt W, Stracke CP, Schindler P. Intraosseous contrast administration for emergency stroke CT. Neuroradiology. 2021;63(6):967–70.

36. Jousi M, Laukkanen-Nevala P, Nurmi J. Analysing blood from intraosseous access: a systematic review. Eur J Emerg Med Off J Eur Soc Emerg Med. 2019 Apr;26(2):77–85.

37. Strandberg G, Larsson A, Lipcsey M, Eriksson M. Comparison of Intraosseous, Arterial, and Venous Blood Sampling for Laboratory Analysis in Hemorrhagic Shock. Clin Lab. 2019 Jul 1;65(7).

38. Perkins GD, Graesner JT, Semeraro F, Olasveengen T, Soar J, Lott C, et al. European Resuscitation Council Guidelines 2021: Executive summary. Resuscitation. 2021 Apr;161:1–60.

39. Panchal AR, Bartos JA, Cabañas JG, Donnino MW, Drennan IR, Hirsch KG, et al. Part 3: Adult Basic and Advanced Life Support: 2020 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care.
Circulation. 2020 Oct 20;142(16_suppl_2):S366–468.

40. Philbeck T, Miller L, Montez D. Pain Management During Intraosseous Infusion Through the Proximal Humerus.
Ann Emerg Med. 2009 Sep 1;54(3):S128.

41. Hallas P, Brabrand M, Folkestad L. Reasons for not using intraosseous access in critical illness. Emerg Med J EMJ. 2012 Jun;29(6):506–7.

42. Bradburn S, Gill S, Doane M. Understanding And Establishing Intraosseous Access. Anaesth Tutor Week [Internet]. 2015 Jun 25 [cited 2023 Jun 3]; (317). Available from: https://resources.wfsahq.org/atotw/understanding-and-establishing-intraosseous-access/

43. Hallas P, Brabrand M, Folkestad L. Complication with Intraosseous Access: Inquiry of Scandinavian Users' Experiences. West J Emerg Med Integrating Emerg Care Popul Health [Internet]. 2013 [cited 2023 Jun 8];14(5). Available from: https://escholarship.org/uc/item/6js6w38r

44. Žunkovič M, Markota A, Lešnik A. Attitudes towards the Utilization of Intraosseous Access in Prehospital and Emergency Medicine Nursing Personnel. Medicina (Mex). 2022 Aug 12;58(8):1086.

45. Antić G, Čanađija M, Čoralić S, Kudrna K, Majhen R, Simić A. Izvanbolnička Hitna Medicinska Služba - Priručnik za doktore medicine [Internet]. Tomljanović B, editor. Zagreb: Hrvatski zavod za hitnu medicinu; 2018 [cited 2023 Jun 4]. 502 p. Available from: https://www.hzhm.hr/source/projekti/kontinuirano/02_HZHM-Prirucnik_IHMS-doktori-medicine.pdf

46. Antić G, Čanađija M, Čoralić S, Kudrna K, Majhen R, Simić A. Izvanbolnička Hitna Medicinska Služba - Priručnik za medicinske sestre - medicinske tehničare [Internet]. Tomljanović B, editor. Zagreb: Hrvatski zavod za hitnu medicinu; 2018 [cited 2023 Jun 4]. 478 p. Available from: https://www.hzhm.hr/source/projekti/kontinuirano/03_HZHM-Prirucnik_IHMS-MS-MT.pdf

47. Ivanišević K, Miklić Vitez L, Mikšaj M, Nesek – Adam V, Pavletić M. Objedinjeni Hitni Bolnički Prijam - Priručnik za medicinske sestre - medicinske tehničare [Internet]. Kudrna Prašek K, Lovrić N, Važanić D, editors. Zagreb: Hrvatski zavod za hitnu medicinu; 2018 [cited 2023 Jun 4]. 218 p. Available from: https://www.hzhm.hr/source/projekti/kontinuirano/06_HZHM-Prirucnik_OHBP-MS-MT.pdf

48. Miller GE. The assessment of clinical skills/competence/performance. Acad Med J Assoc Am Med Coll. 1990 Sep;65(9 Suppl):S63-67.

49. Masic I, Miokovic M, Muhamedagic B. Evidence Based Medicine – New Approaches and Challenges. Acta Inform Medica. 2008;16(4):219–25.

50. GMC copyright. Raising and acting on concerns about patient safety [Internet]. Manchester: General Medical Council; 2012 [cited 2023 Jun 5]. 24 p. Available from: https://www.gmc-uk.org/-/media/documents/raising-and-acting-on-concerns-about-patient-safety---english-0617_pdf-48902813.pdf

51. Bielski K, Szarpak L, Smereka J, Ladny JR, Leung S, Ruetzler K. Comparison of four different intraosseous access devices during simulated pediatric resuscitation. A randomized crossover manikin trial. Eur J Pediatr. 2017 Jul;176(7):865–71.

52. Shina A, Baruch EN, Shlaifer A, Shovali A, Levi M, Yosefy O, et al. Comparison of Two Intraosseous Devices: The NIO Versus the EZ-IO by Novice Users-A Randomized Cross Over Trial. Prehosp Emerg Care. 2017;21(3):315–21.

Biography

Máté H. Huszár is a final year medical student at the University of Zagreb, School of Medicine – Medical Studies in English programme, as well as a registered nurse with an active licence to practice in Hungary. He is also one of the elected student representatives of his class, a student member of the School's 'Quality Promotion Committee', and a member of the European Students' Union's (ESU) 'Quality Assurance Student Experts' Pool'.

Máté was awarded the Dean's Commendation for academic excellence in 2022.

His interest in emergency and critical care medicine and his performance at an EPALS course of the European Resuscitation Council (ERC) gained him an Instructor Potential rating in 2022. After completing his Generic Instructor Course, he is currently an ALS and EPALS Instructor Candidate of the ERC.

Quality Assurance (QA) of health education in the European Higher Education Area is an extracurricular passion of Máté. He presented at relevant international training events and conferences, and participated in international external QA reviews as the student member of expert panels.

In his spare time, Máté also enjoys spending time with his family, sailing, skydiving, and skiing.