

Intraosseous Administration of Freeze-dried Plasma in the Prehospital Setting

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ABSTRACT **Background:** Freeze dried plasma (FDP) is a commonly used replacement fluid in the prehospital setting when blood products are unavailable. It is normally administered via a peripheral intravenous (PIV) line. However, in severe casualties, when establishing a PIV is difficult, administration via intraosseous vascular access is a practical alternative, particularly under field conditions.

Objectives: To evaluate the indications and success rate of intraosseous administration of FDP in casualties treated by the Israel Defense Forces (IDF).

Methods: A retrospective analysis of data from the IDF-Trauma Registry was conducted. It included all casualties treated with FDP via intraosseous from 2013 to 2019 with additional data on the technical aspects of deployment collected from the caregivers of each case.

Results: Of 7223 casualties treated during the study period, intravascular access was attempted in 1744; intraosseous in 87 of those. FDP via intraosseous was attempted in 15 (0.86% of all casualties requiring intravascular access). The complication rate was 73% (11/15 of casualties). Complications were more frequent when the event included multiple casualties or when the injury included multiple organs. Of the 11 failed attempts, 5 were reported as due to slow flow of the FDP through the intraosseous apparatus. Complications in the remaining six were associated with deployment of the intraosseous device.

Conclusions: Administration of FDP via intraosseous access in the field requires a high skill level.

IMAJ 2022; 24: 591-595

KEY WORDS: bone injection gun, freeze dried plasma (FDP), intraosseous vascular access, peripheral intravenous (PIV) line

Trauma is the primary cause of death among young people [1]. Hemorrhage and hypovolemic shock are the most common preventable causes of death among trauma casualties [2,3]. The critical elements in hemorrhagic shock treatment are bleeding control and fluid resuscitation, yet not all fluids are the same. Numerous protocols were used over the years, and the current understanding is that transfusion of blood products, in ratios similar to whole blood (1:1:1 of plasma, platelets, and packed red blood cells [pRBC]), is the preferable approach to significant blood loss [4,5].

Freeze dried plasma (FDP) is now a commonly used replacement fluid in the prehospital setting [6-10] particularly in remote military arenas where standard blood products are far from reach [11-13]. FDP is normally administered via a peripheral intravenous (PIV) line. However, in severe casualties, when establishing a PIV is delayed or difficult, the intraosseous approach may provide a relatively easy alternative for rapid access to a non-collapsible vascular compartment [14,15]. Studies have shown that infusion via intraosseous is a safe and effective means of delivering resuscitation fluids such as crystalloids, colloids, and blood products, to the intramedullary space and systemic circulation [16-18]. When an intraosseous needle is placed in the intramedullary space, it reaches a highly vascularized anatomical site. This space can serve as a direct channel to the systemic circulation even when the casualty presents with hypovolemic shock. The intraosseous approach is reported to have a shorter insertion time and higher success rate than PIV or central venous catheterization [19-23]. The main caveat of the intraosseous approach is that it requires specific expertise and experience [22].

FDP via intraosseous was reported previously in a single case report [23]. To determine the usefulness of this approach, we performed a retrospective analysis of all cases from the Israel Defense Force-Trauma Registry (IDF-TR) in which FDP via intraosseous was used. In this study we characterized the injuries in which FDP via intraosseous was required and determined the feasibility, complications, and success rate of this approach.

PATIENTS AND METHODS

ETHICS CONSIDERATIONS

The study was approved by the IDF-Medical Corps (IDF-MC) institutional review board (approval number: No. 2018–1948) and written according to the STROBE reporting guidelines.

STUDY DESIGN

This retrospective analysis of data from the IDF-TR [26] included all casualties treated with FDP and intraosseous at the point of injury (POI) by the IDF Advance Life support (ALS) providers between 2013 and 2019.

The IDF-TR is a prehospital military trauma registry containing data on all trauma casualties (civilian or military) cared for by military medical teams since 1997 as part of the Trauma and Combat Medicine Branch (TCMB) in the IDF-MC. Data were collected by medical providers at the POI using established casualty cards configured for recording data regarding location, mechanism, treatment, casualty status, and means and destination of evacuation. These data were subsequently entered into the IDF-TR within a few hours of injury by the treating physician or paramedic [24].

MATERIALS

Intraosseous access

Intraosseous access was attempted with two devices in these cases:

- BIG (WaisMed Ltd., Houston, TX, USA) is an automatic, spring-loaded, disposable injector that drives a 43.3 mm long cannulated, 15-gauge needle through the cortex of the bone enabling a direct passage for fluid transfusion with connectors for standard PIV tubing.
- EZ-IO (Teleflex Medical, Research Triangle Park, NC, USA) is an integrated drill with a 25 mm long stylet-tipped 15-gauge needle. In the latter, the bone marrow is accessed by drilling a hollow needle to a preset depth.

INTRAOSSEOUS ACCESS PROTOCOL

The IDF TCMB protocol guidelines regarding intraosseous access include any casualties who meet the criteria for venous access and previously had two failed attempts at peripheral line insertion by an ALS provider or three failed attempts overall. The preferable intraosseous placement site is the proximal tibia.

RESUSCITATION PROTOCOL

Clinical practice guidelines (CPG) of the IDF TCMB concerning remote damage-control resuscitation by ALS (physicians and paramedics) providers are shown in Figure 1. Any casualty with a penetrating injury of the trunk or of a transition zone

requires PIV access and immediate administration of 1 gram of tranexamic acid (TXA). In addition, regardless of the mechanism of injury, any patient assessed to be in severe hemorrhagic shock (heart rate more than 130 bpm or lack of radial pulse or systolic blood pressure less than 90 mmHg) receives TXA and one unit of FDP.

FREEZE-DRIED PLASMA

The fluid replacement used was the LyoPlas N-w (German Red Cross, DRK Blutspendedienst West, Zentralbereich Plasma, Hagen, Germany), according to the instructions of the manufacturer [7]. In brief, the lyophilized plasma product is reconstituted with 200 ml of pre-packed sterile water in a glass bottle and mixed manually for 2 to 3 minutes until the powder appears to be dissolved.

The FDP reconstituted solution is immediately infused IO to the trauma casualties in the field setting with gravity force being the only pressure gradient affecting the infusion rate.

DATA ANALYSIS

The data collected from the IDF-TR included demographics (age, sex, ethnicity), pulse, blood pressure, Glasgow Coma Scale score, injury type (location, mechanism), treatments administered at POI, details of the caregiver, mode of evacuation, and number of casualties in the event. In addition, all primary caregivers who administered FDP via intraosseous access were questioned individually, and the data were tabulated regarding the nature and source of any difficulties encountered.

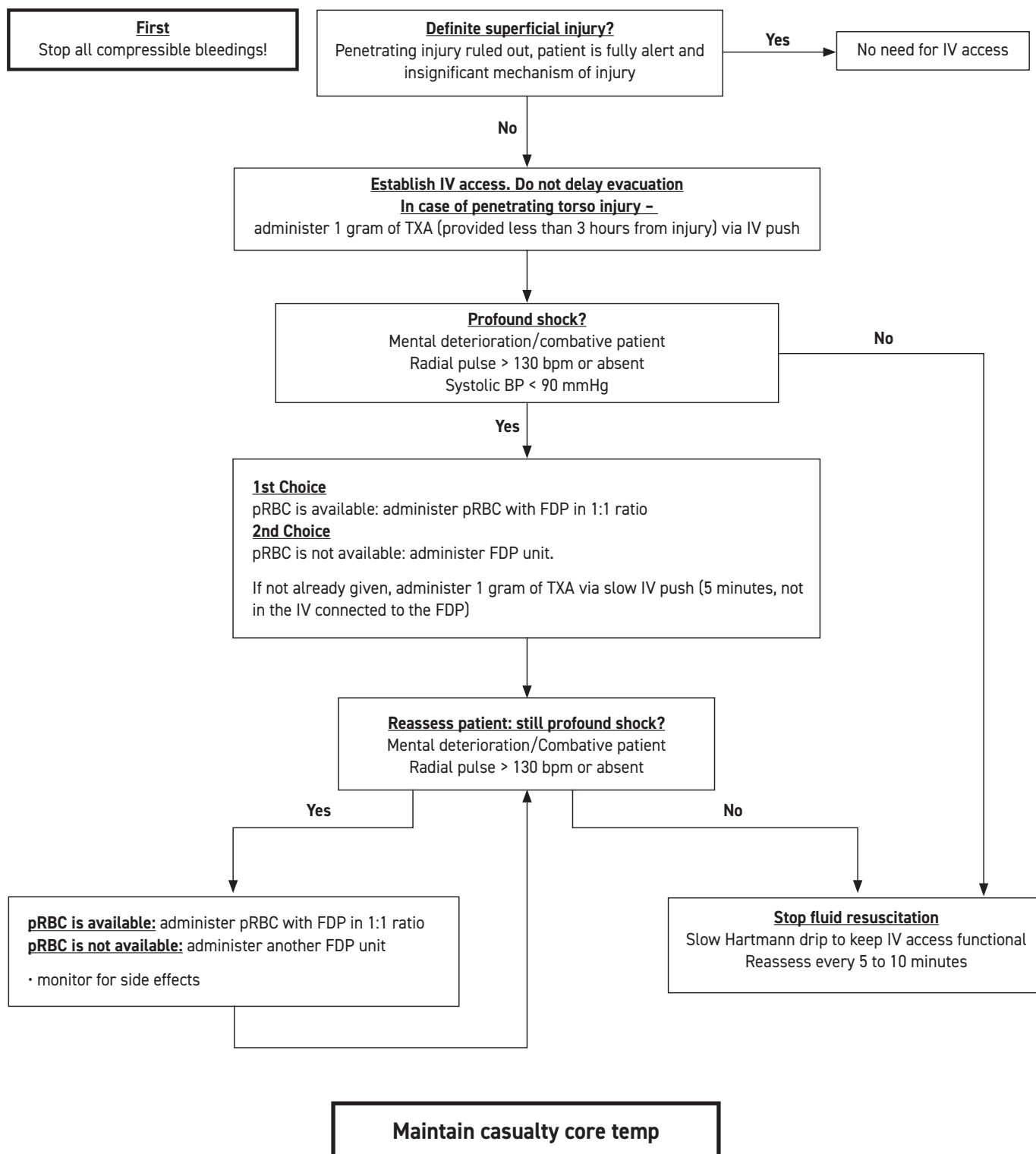
RESULTS

Between 2013 to 2019, 7223 casualties were treated by the IDF medical team. Intravascular access (PIV or intraosseous) was attempted in 1744. Of these, intraosseous access was attempted in 87, of which 67 (77%) succeeded. Of the 87 attempts at intraosseous access, FDP was the infused fluid in 15 representing less than one percent (0.86%) of the entire group of 1744 casualties requiring fluid replacement. Complications were encountered in 11 of the 15 cases (73%) where FDP was the fluid that was infused by intraosseous access.

All casualties were classified as urgent for evacuation due to their injuries, and the majority were subsequently evacuated by the aeromedical evacuation unit (9 of 15 [60%]). The casualties were young and predominantly male (age 28 ± 12 years of age, 73% male) [Table 1]. The mechanism of injury was a penetrating wound (gunshot or fragments) in most cases (12 of 15 [80%]), with the rest being blunt force trauma. In addition, the majority of these casualties (11 of 15 [73%]) presented with multi-system injury with multiple organs affected. The casualties were administered life saving procedures according to the indications and of the injury and surrounding circumstances including combat application tourniquet (CAT)

Figure 1. Israel Defense Force resuscitation protocol

bpm = beats per minute, FDP = freeze dried plasma, IV = intravenous, pRBC = packed red blood cells, TXA = tranexamic acid



(n=2), airway management (endotracheal intubation [n=7], cricothyroidotomy [n=1], or the insertion of laryngeal mask airway [n=1]), and chest decompression by needle and/or thoracostomy tube (needle as a bridge until thoracostomy) (n=5). All were treated with 1 gram of TXA (according to IDF TCMB CPG) [Table 2].

Of the 15 cases treated with FDP via intraosseous, 14 were administered the fluid using the BIG apparatus through the

proximal tibia, and one was infused using the EZ-IO through the proximal humerus. The complications encountered (11 of 15) were more frequent when the event included multiple casualties, and when the injury involved multiple organs [Table 2]. The caregivers who encountered difficulties reported that, in 5 of the 11 cases, the reason for the difficulty was insufficient flow of the FDP due to the consistency of the fluid which required applying active pressure with a syringe.

Table 1. Casualty characteristics

Variable	Total (n=15)- (%)
Gender	
Male	11 (73%)
Female	4 (27%)
Mechanisms of injury	
Gunshot	4 (27%)
Fragmental	6 (40%)
Penetrating	2 (13%)
Other (e.g., burn, internal, blast)	3 (20%)
Advance life support provider	
Physician	7 (47%)
Paramedic	8 (53%)

Table 2. Success/failure of interosseous administration of freeze-dried plasma according to characteristics of injury and first-line treatment

Variable	FDP via intraosseous administration		Total (n=15)
	Success (n=4)	Failure (n=11)	
Number of casualties per event			
Single	3	5	8
Multiple	1	6	7
FDP units per casualty			
1 unit	4	9	13
2 units	0	2	2
Live-saving treatment			
Airway manipulation	3	6	9
Chest drainage	0	2	2
CAT	0	2	2
Airway + CAT	1	2	3
None	0	2	2
Anatomical site of injury			
Multi-system	3	8	11
Chest	0	2	2
Torso	1	0	1
Limbs	0	1	1

CAT = combat application tourniquet, FDP = freeze dried plasma

DISCUSSION

The administration of FDP via the intraosseous approach is a relatively easy alternative for rapid access to a non-collapsible vascular compartment for cases of severe injuries in the pre-hospital emergency setting when standard blood products are unavailable and PIV infusion is difficult or unsuccessful. This approach is useful in situations of mass casualty events, including those involving pediatric casualties. The intraosseous approach was reported as a single case by Rottenstreich et al. [23]. Detailed information of such rare medical emergency events can be found mostly in military databases for which access is restricted. To the best of our knowledge, this retrospective analysis is the first multiple-casualty study to be published on this treatment approach.

Using the IDF-TR registry, we identified 15 cases of FDP infusion via the intraosseous approach and determined that success rate using this combination was only 27%. The reason for the high rate of technical complications appeared to be due partially to the consistency of the FDP solution and partially to the difficulties in establishing intraosseous access (23% failure rate). Another contributing factor was the fact that these cases mostly occurred during multiple casualty events with many cases with severe multi-organ involvement which poses another level of difficulty.

According to the manufacturer's specifications, the reconstituted lyophilized plasma product is delivered from a glass bottle with the rate of infusion determined primarily by gravity. This procedure precludes the care providers from applying external pressure to increase the plasma infusion rate. Therefore, the pressure gradient is determined primarily by gravity with respect to height of the bottle. We therefore suggest the reconstituted FDP be infused through a dedicated Y-tube similar to that used for packed RBCs according to CPG and IDF TCCMB guidelines [24,25].

LIMITATIONS

To the best of our knowledge this study is the first to evaluate the effects of FDP infusion via intraosseous access in multiple trauma victims. The issues raised in this study should be re-visited when additional subjects treated by this approach become available. As a retrospective analysis, recall bias of the caregivers regarding the procedure may have resulted in errors.

CONCLUSIONS

Administration of FDP via intraosseous access in the field requires a high skill level. Therefore, care providers must undergo periodic refreshers on the proper preparation of FDP for infusion and the optimal techniques of handling and application of the intraosseous devices.

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Capsule

Symptoms and risk factors for long COVID in non-hospitalized adults

Subramanian and co-authors undertook a retrospective matched cohort study using a UK-based primary care database, Clinical Practice Research Datalink Aurum, to determine symptoms that are associated with confirmed SARS-CoV-2 infection beyond 12 weeks in non-hospitalized adults and the risk factors associated with developing persistent symptoms. The authors selected 486,149 adults with confirmed SARS-CoV-2 infection and 1,944,580 propensity score-matched adults with no recorded evidence of SARS-CoV-2 infection. A total of 62 symptoms were significantly associated with SARS-CoV-2 infection after 12 weeks. The largest adjusted hazard ratios (aHRs) were for anosmia (aHR 6.49, 95% confidence interval [95%CI] 5.02–8.39), hair loss (aHR 3.99, 95%CI

3.63–4.39), sneezing (aHR 2.77, 95%CI 1.40–5.50), ejaculation difficulty (aHR 2.63, 95%CI 1.61–4.28), and reduced libido (aHR 2.36, 95%CI 1.61–3.47). Among the cohort of patients infected with SARS-CoV-2, risk factors for long COVID included female sex, belonging to an ethnic minority, socioeconomic deprivation, smoking, obesity, and a wide range of co-morbidities. The risk of developing long COVID was also found to be increased along a gradient of decreasing age. SARS-CoV-2 infection is associated with a plethora of symptoms that are associated with a range of sociodemographic and clinical risk factors.

Nature Med 2022; 28: 1706

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A Randomized, Controlled, Blinded Evaluation of Augmenting Point-of-Care Ultrasound and Remote Telementored Ultrasound in Inexperienced Operators

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ABSTRACT

Background: Handheld ultrasound devices present an opportunity for prehospital sonographic assessment of trauma, even in the hands of novice operators commonly found in military, maritime, or other austere environments. However, the reliability of such point-of-care ultrasound (POCUS) examinations by novices is rightly questioned. A common strategy being examined to mitigate this reliability gap is remote mentoring by an expert.

Objectives: To assess the feasibility of utilizing POCUS in the hands of novice military or civilian emergency medicine service (EMS) providers, with and without the use of telementoring. To assess the mitigating or exacerbating effect telementoring may have on operator stress.

Methods: Thirty-seven inexperienced physicians and EMTs serving as first responders in military or civilian EMS were random-

ized to receive or not receive telementoring during three POCUS trials: live model, Symbionix trainer, and jugular phantom. Salivary cortisol was obtained before and after the trial. Heart rate variability monitoring was performed throughout the trial.

Results: There were no significant differences in clinical performance between the two groups. Iatrogenic complications of jugular venous catheterization were reduced by 26% in the telementored group ($P < 0.001$). Salivary cortisol levels dropped by 39% ($P < 0.001$) in the telementored group. Heart rate variability data also suggested mitigation of stress.

Conclusions: Telementoring of POCUS tasks was not found to improve performance by novices, but findings suggest that it may mitigate caregiver stress.

IMAJ 2022; 24: 596–601

KEY WORDS: point-of-care ultrasound (POCUS), telemedicine, trauma, telementoring, ultrasound

*Rubrum Coelis is a joint Israel–Canadian group founded by Itamar Netzer, Elon Glassberg, and Andrew W. Kirkpatrick. Members who participated in this study are listed in alphabetical order.