Combat Vascular Access

A Scoping Review

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ABSTRACT

Medical leadership must decide how to obtain vascular access in a combat environment. Adequate combat trauma resuscitation requires efficient vascular access. A search of the Medline and EMBASE databases was conducted to find articles on combat vascular access. The primary dataset of interest was the type of vascular access obtained. Other data reviewed included who performed the intervention and the success rate of the intervention. The search strategy produced 1,339 results, of which 24 were included in the final analysis. Intravenous (IV), intraosseous (IO), and central venous access have all been used in the prehospital combat environment. This review summarizes the available combat literature to help commanders make an evidence-based decision about their prehospital vascular access strategy.

KEYWORDS: *intravenous access; vascular access; interosseus access; central venous catheters*

Introduction

The prehospital combat environment poses unique challenges and deserves specific study. Whereas in a civilian environment, there is a growing body of evidence that quick evacuation to surgical care is paramount, the military prehospital provider may not be afforded that option. Tactical environment, enemy threats, and limits on available transportation may necessitate prolonged field care (PFC).[1] Interventions such as tranexamic acid (TXA), freeze-dried plasma, and blood products may need to be administered by the combat prehospital provider near the point of injury. To administer these agents, IV or IO access must be acquired in the prehospital combat environment. The purpose of this scoping review is to evaluate the available literature describing prehospital access techniques that have been used in combat, the provider level of training, and their success rate. This review will inform military medical leadership's mission planning.

Methods

We conducted a search in Medline and EMBASE databases. The search terms included the following combinations of subject headings and keywords: infusions, intraarterial, intraosseous, intravenous, subcutaneous, catheterization, central venous, blood transfusion, intravascular drug administration, intraosseous drug administration, blood vessel catheterization, fluid resuscitation, combat, military medicine, military personnel, warfare, armed conflict, and battlefield. Searches were restricted to humans and adults. No language restrictions were applied. Studies of vascular and IO access performed in the prehospital combat environment were included. Studies were excluded if the patients were less than 18 years old, if it was an animal study, or if it was a case report or review article. The type of access obtained, type of provider performing the intervention, and success and complication rates were recorded. We did not limit the dates of our review. All studies were uploaded into Cochrane's Covidence.org reference management system. This review was registered with PROSPERO (CRD42021207114).

All studies were subject to a title and abstract review by two independent examiners (JW, TM). In this step, obviously irrelevant studies were excluded. A third party was used to resolve conflicts (SS). Remaining studies were subject to full text screening. Data were extracted from study text, tables, and figures, when necessary.

Results

The search resulted in 1,339 studies, 10 of which were duplicate studies and were removed. Abstract screening removed 1,229 studies, leaving 100 studies for full text review. Full text review excluded 76 more, leaving 24 studies for inclusion (Figure 1-Prisma Diagram). Sixteen papers reported on IV access in combat (Table 1). Six papers reported on tibial IO access (Table 2), two papers reported on humeral access (Table 3), and four papers reported on sternal access (Table 4). Twelve papers reported on IO access but did not specify the location of the catheter (Table 5). Two papers described pre-hospital central line placement (Table 6).

Intravenous Access

From the 16 papers included in this review, there were a total of 5,898 patients with attempted IV access. Three papers reported on the success rate (1,842 patients).

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TABLE 1 *Peripheral IV*

Study	Design	Patients	Success Rate	Provider Type	Complications
Bebarta et al., 2013[5]	Case Series	2	2/2 (100%)	—	—
DuBose et al., 2017[4]	Retrospective Descriptive Review	24	—	• Surgeon • EM physician • RN anesthetist • Physician Assistant	—
Lairet et al., 2012[14]	Retrospective Descriptive Review	21	—	—	Longer transport times in patients receiving IVF
Lairet et al., 2019[15]	Prospective Descriptive Review	1,413	—	—	—
Maddry et al., 2015[16]	Retrospective Descriptive Review	—	—	• Medic • Paramedic • RN • MD	—
Maddry et al., 2015[17]	Retrospective Descriptive Review	500	—	• Medic • Paramedic • RN • MD	—
Maddry et al., 2016[18]	Retrospective Descriptive Review	758	706/758 (93%)	—	—
Maddry et al., 2016[19]	Retrospective Descriptive Review	—	—	• Medic • Paramedic • Physician Assistant • Nurse • Physician	—
Manley et al., 2017[20]	Case Series	4	—	• General surgeon • EM physician • RN anesthetist • Surgical Technician • Respiratory Therapist	—
Nadler et al., 2014[7]	Retrospective Descriptive Review	18	—	—	—
Nadler et al., 2015[2]	Retrospective Descriptive Review	1,082	887/1,082 (82%)	• Physician • Medic • Paramedic	"No complications found"
Reeves et al., 2020[21]	Prospective Descriptive Review	1,305	—	—	—
Schauer et al., 2019[10]	Retrospective Descriptive Review	432	—	• Medical Officer • Medic • First Responder	—
Schauer et al., 2019[22]	Retrospective Descriptive Review	205	—	—	—
Shlaifer et al., 2019[23]	Retrospective Matched Case Cohort	96	—	—	—
Travers et al., 2019[24]	Retrospective Descriptive Review	38	—	Physician	—

EM = emergency medicine, IV = intravenous, IVF = intravenous fluids, MD = medical doctor, RN = registered nurse

Nadler et al. used prehospital patient care records to identify 1,082 Israeli combat trauma casualties, in whom one or more peripheral IV attempts had been documented.[2] They reported an overall 82% success rate after one or more attempts at peripheral venous access. The number of IV attempts was reported in 742 (69%) patients, with some patients having up to eight attempts. A total of 96% of successful procedures were performed in the first two attempts. Provider type was reported in 605 patients (physician 303; medics 219; paramedics 83). Physicians had an 85% (257/303) success rate. Combat medics and paramedics had 79% (174/219) and 77% (64/83) success rates, respectively. This is the only paper that described IV access complications, and they reported no complications.

Maddry et al. reviewed IV and IO access attempts during air evacuation from point of injury.[3] A total of 832 patients were identified as having had one or more IV or IO access attempts. Peripheral IV access was the initial method in 758 patients, and 706 of these were successful (93%). The level of training of the provider was not reported.

DuBose et al. reviewed 173 patients treated by a forward surgical team with advanced providers.[4] Fourteen percent of patients (24/173) had IV access obtained by tactical combat care providers prior to transport to the forward surgical team. The forward surgical team performed an IV insertion in an additional 88 patients. Overall, 65% of patients received an IV with most being placed by the forward surgical team.

Bebarta et al. examined hospital records from 15 patients who presented to a combat medical treatment facility in traumatic cardiac arrest.[5] They reported on lifesaving interventions,

TABLE 2 *IO Unspecified*

Study	Design	Patients	Success Rate	Providers	Complications
DuBose et al., 2017[4]	Retrospective descriptive review	3	—	• Surgeon • EM physician • RN anesthetist • PA	—
Lairet et al., 2012[14]	Retrospective descriptive review	3	—	—	Longer transport times in patients who received IVF
Lairet et al., 2019[15]	Prospective descriptive review	285	—	—	—
Lewis & Wright 2015[25]	Retrospective descriptive review	830	1,000/1,014 (98.3%)	—	Retained sternal needles Removal of retained sternal needle in OR
Maddry et al., 2015[17]	Retrospective descriptive review	59	—	• Medic • Paramedic • RN • MD	—
Maddry et al., 2015[16]	Retrospective descriptive review	63	—	• Medic • Paramedic • RN • MD	—
Maddry et al., 2016[18]	Retrospective descriptive review	86	73/86 (85%)	—	—
Maddry et al., 2016[19]	Retrospective Descriptive Review	—	—	• Medic • Paramedic • PA • Nurse • Physician	—
Manley et al., 2017[20]	Case series	1	—	• General surgeon • EM physician • RN anesthetist • Critical care RN • Surgical Technician • Respiratory Therapist	—
Suay et al., 2011[26]	Prospective descriptive review	25	19/25 (76%)	• Medical Officer • Nursing Officer • Paramedic	• Pain
Reeves et al., 2020[21]	Prospective descriptive review	259	—	—	—
Travers et al., 2019[24]	Retrospective descriptive review	3	—	• Physician	—
# of studies	**12**	**11**	**3**	**7**	**3**

EM = emergency medicine, IO = intraosseous, IVF = intravenous fluids, MD = medical doctor, RN = registered nurse

TABLE 3 *Tibial IO*

Study	Design	Patients	Success Rate	Providers	Complications
Cooper et al., 2007[9]	Case series	26	31/32 (97%)	• Physician • Paramedic • ER RN	• No infection • Pain • Bent needle • Fracture/retained needle • Needleless insertion
Harcke et al., 2011[6]	Post—mortem descriptive review	52	58/61 (95%)	—	—
Nadler et al., 2014[7]	Retrospective descriptive review	30	18/36 (50%)	• Physician • Paramedic	—
Nadler et al., 2015[2]	Retrospective descriptive review	30	15/30 (50%)	—	—
Schauer et al., 2019[10]	Retrospective descriptive review	18	—	• Medical Officer • Medic • First-responder	—
Vassallo et al., 2014[8]	Prospective descriptive review	21	20/21 (95%)	—	Reported, but none observed for tibial IO
# of studies	**6**	**6**	**5**	**3**	**2**

ER = emergency room, IO = intraosseous, RN = registered nurse

TABLE 4 *Sternal IO*

Study	Design	Patients	Success Rate	Providers	Complications
Harcke et al., 2011[27]	Postmortem examination series	98	78/98 (79.6%)	—	High placement, at level of the clavicle
Hodgetts et al., 2017[13]	Case series	2	—	—	• Retained sternal needle tips
Schauer et al., 2019[10]	Retrospective descriptive review	5	—	• Medical officer • Medic • First-responder	—
Vassallo et al., 2014[8]	Prospective descriptive review	24	19/24 (79.2%)	—	• Breakage on removal
# of studies	**4**	**4**	**2**	**1**	**3**

IO = intraosseous

TABLE 5 *Humeral IO*

Study	Design	Patients	Success Rate	Providers	Complications
Schauer et al., 2019[10]	Retrospective descriptive review	5	—	• Medical Officer • Medic • First-responder	—
Vassallo et al., 2014[8]	Prospective descriptive review	66	55/66 (83.3%)	—	• Intra-articular insertion • Breakage on removal
# of studies	**2**	**2**	**1**	**1**	**1**

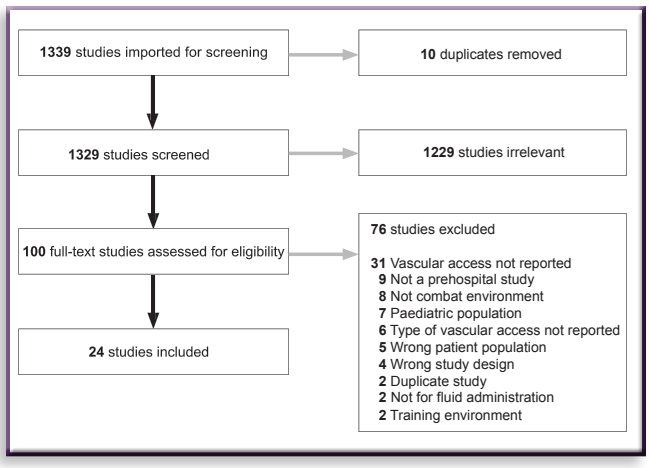
IO = intraosseous

TABLE 6 *Central Lines*

Study	Design	Patients	Success Rate	Providers	Complications
DuBose et al., 2017[4]	Retrospective descriptive review	15	—	Surgical resuscitation team: • Surgeon • ER physician • RN anesthetist • PA	—
Tobin et al., 2015[11]	Retrospective descriptive review	3	—	—	—
# of studies	**2**	**2**	**0**	**1**	**0**

ER = emergency room, RN = registered nurse, PA = physician assistant

FIGURE 1 *Prisma Diagram.*



including vascular access. The method of access was not specified. They reported that two patients (13%) received vascular access in the prehospital environment and both were successful. The level of training of the prehospital provider was not described.

Eight papers reported on the type of provider that obtained prehospital IV access. These included physicians, registered nurses, physician assistants, medics, paramedics, respiratory therapists, and tactical combat casualty care providers. The rationale for combat IV access was for TXA administration, analgesia, antibiotics, antiemetics, crystalloid, blood products, and sedation.

Tibial Intraosseous

Six papers reported on prehospital tibial IO access on a total of 177 patients with 198 attempts. Five of the six papers included the success rate.

Harcke et al. published a descriptive autopsy case review of 52 traumatic battlefield deaths who received a tibial IO.[6] A total of 61 tibial IOs were inserted. They utilized post-mortem CT imaging to identify whether placement was successful. All right tibial IO insertions were successful (24/24), and 92% of left insertions were successful (34/37). The three unsuccessful insertions describe the needle tip in the soft tissue with the needle not perpendicular to the cortex.

Nadler et al. performed a retrospective review of prehospital combat patients who received a tibial IO placed by the Israeli Defense Force Medical Corps.[7] A total of 36 attempts on 30 patients were described. Sixteen of the first attempts at tibial IO were successful (53%). A second attempt was made in five cases with successful access achieved in two. A third

attempt was made on one patient but was unsuccessful. The overall success rate of patients receiving a tibial IO was 60%. In a subsequent manuscript, Nadler et al. described 30 patients who underwent IO insertion following unsuccessful attempts at IV access.[2] A 50% success rate for tibial IO was reported. Vassallo et al. (Camp Bastion, Afghanistan) reported on 21 tibial IO insertions.[8] They reported an overall success rate of 95%. Cooper et al. reported success rates of tibial IO insertion by the UK Defense Medical Service in Afghanistan.[9] Three patients had a tibial IO attempted in the prehospital setting.

Complications were reported in the Cooper and Vassallo papers. These were identified in one study and included pain, needle fracture with fragment retention, "needleless insertion," and a bent needle.[8,9] Indications for IO were reported in two papers (Cooper et al. and Schauer et al.), which included blood products, crystalloid, induction agents for intubation, analgesia, antibiotics, sedation, antiemetics, TXA, and vasopressors.[9,10] The provider type was reported in three papers (Cooper et al., Nadler et al., and Schauer et al.) and included physicians, registered nurses, paramedics, medics, and first responders.[7,9,10]

Sternal Intraosseous

Four papers report on sternal IO insertion, on a total of 129 patients.

Harcke et al. published a descriptive autopsy case review on 98 sternal IO insertions.[27] They utilized post-mortem CT imaging to identify whether placement was successful. Eighty-one cases had sternal IOs in place, and in three of these cases, the tip of the needle was outside of the sternum. In 18 cases, there was evidence of needle holes, but no device in place; these were likely unsuccessful attempts. This would yield a success rate of 78 out of a total 98 cases (80%).

Vassallo et al. (Camp Bastion, Afghanistan) recorded 24 sternal IO insertion attempts.[8] Nineteen of these (79%) were successful. There was one case of device fracture upon removal that did not affect ability to function prior to removal. The providers that performed the sternal IO insertions included medical officers, medics, and first responders. The indications for sternal IO placement were administration of crystalloid, blood products, antibiotics, paralytics, sedatives, vasopressors, antiemetics, and TXA. Complications that have been reported include retained needle tip, and needle tip outside the body of the sternum.

Humeral Intraosseous

Two papers report on humeral IO insertion (Schaeur et al. and Vassalo et al.) on a total of 71 humeral IO insertions.

Vassallo et al. (Camp Bastion, Afghanistan) recorded 66 insertion attempts of humeral IOs. Fifty-five of these were successful (83%).[8] Reported complications included intra-articular insertion and breaking of the device upon removal, resulting in a retained needle.

Schauer et al. (Operation Inherent Resolve) reported on 5 patients with humeral IO insertion.[10] No success rate was reported. Providers who inserted the IOs were physicians, paramedics, and medics. Indications for access were administration of crystalloids, blood products, antibiotics, paralytics, sedatives, vasopressors, antiemetics, and TXA.

Central Venous Catheter

Two papers report on central line placement. DuBose et al. described a forward surgical team placing 15 central lines in a total of 173 patients (8.7%).[4] The forward surgical team included a surgeon, an emergency medicine physician, a registered nurse anesthetist, and a physician assistant. These central lines were used for blood products, TXA, analgesia, sedation, antibiotics, and antiemetics. Tobin et al. (Afghanistan) reported on three central line placements during inflight air evacuations from point of injury.[11] Neither paper reported on any complications.

Discussion

Trauma patients benefit from urgent evacuation to surgical care. Unfortunately, the combat environment may require prolonged field care or delayed evacuation. Prehospital combat providers may be required to obtain intravascular or intraosseous access for resuscitation, sedation, or other therapies.

This literature shows that IV access has a high success rate in the combat prehospital environment. In the two largest series, the identified the success rates were 82% (Nadler et al., 2015) and 93% (Maddry et al., 2016).[2,3] Nadler discovered that the majority of success was obtained in the first two attempts.

Tibial and sternal IO access has been used extensively in combat, with humeral access being less common. For the two papers reporting exclusively on patients from the prehospital combat environment, the tibial IO could be established in 50% (15/30) and 60% (18/30) of patients, with some requiring multiple attempts.[2,7]The single paper that described prehospital sternal insertion reported a success of 79%. Cadaveric studies demonstrated appropriate placement of sternal IOs in 80% of cases with three needles outside of the sternal cortex; this is concerning for potential mediastinal or cardiac injury. Humeral IO insertion success was reported in one paper as 83%.

Based on these data, we recommend the following algorithm for prehospital vascular access. The most reliable and successful means to achieve access is peripheral IV cannulation. We recommend two attempts at IV cannulation should be conducted. If these are not successful, then IO access should be obtained. Combat literature does not report on dislodgement of IO during transport. However, civilian data suggest tibial IOs are less likely to be dislodged than humeral (5.8% vs. 33%).[12] This is in keeping with the authors' experience. We would suggest attempting tibial IO insertion after failed IV cannulation. If there is suspected thoracic or intra-abdominal injury, or significant lower extremity injury, humeral IOs are preferred. Due to the potential for mediastinal injury from sternal IOs extremity IOs should be first line (Figure 2).[13]

Central venous catheters have been used successfully by physicians in the forward environment. In the special case of providers with advanced training and central line experience, they can be considered.

Conclusion

This scoping review suggests that IV cannulation is the preferred method of prehospital vascular access in the combat environment. IO techniques should be used as rescue interventions.

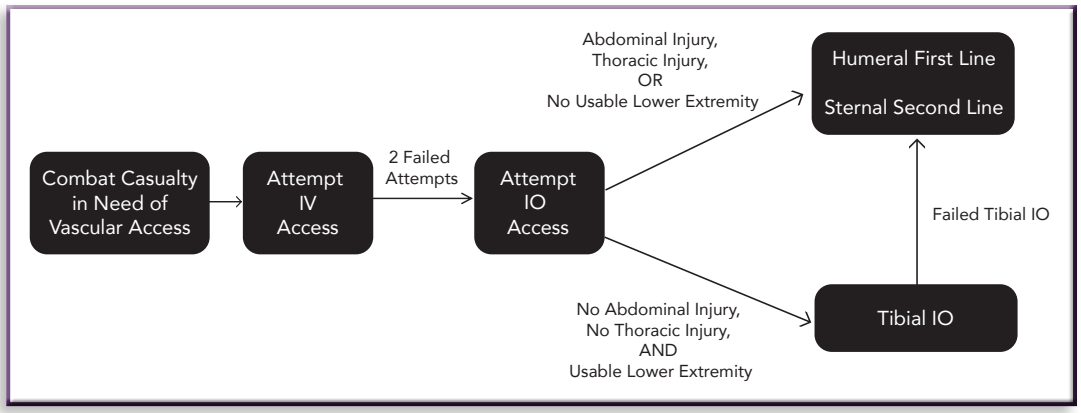


FIGURE 2 *Algorithm.*

IO = intraosseous

Future research should attempt to capture success rates to guide and refine military medical prehospital resuscitation.

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