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Literature review

Prehospital use of peripheral intravenous catheters and intraosseous devices: An integrative literature review of current practices and issues

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ABSTRACT

Introduction: Peripheral intravenous catheters and intraosseous devices have been widely used in the prehospital setting for a considerable period. Changes in technology and guidelines have led to an increase in situations where use of these devices in a prehospital setting is recommended. Despite being commonplace they are not without risk of harm to the patient.
Study objective: To examine critically the research-based literature related to incidence of insertion of peripheral intravenous catheters and intraosseous devices, the use of these vascular access devices and to determine which health professionals insert them, most commonly, in the prehospital setting.
Methods: An integrative review was undertaken using material retrieved following a systematic search of research literature databases, grey literature and secondary sources written in English. No date limit was applied to the search and the searching was undertaken until September 2019. Articles specifically addressing peripheral intravenous catheter and intraosseous device use in the prehospital setting were selected.
Results: The search resulted in 20 articles being included in the review, 17 related to peripheral intravenous catheters and three for intraosseous devices. All articles related to observational studies across a variety of services and settings.
Conclusion: The role of vascular access in the prehospital setting continues to be significant, particularly for patients who are critically unwell. This review identified that differences in service structure, geography and the patient's condition all impact on the insertion and use of these vascular access devices. Despite this there are limited data reported that can allow prehospital clinicians and services to benchmark their practice.

1. Introduction

Vascular access is integral to modern health care for the provision of medication and fluids through peripheral intravenous catheters (PIVCs) and intraosseous devices (IOs). Obtaining vascular access in the prehospital setting is vital at times and a delay or failure to do so can negatively impact on patient outcomes [1,2]. However, these devices are not without risk with studies reporting a range of issues and complications related to their insertion, use, care and removal [3–5]. For the purposes of this article the term prehospital will be used to denote the practice setting being considered. This includes paramedic led care, however, globally there are differences in how Emergency Medical Services (EMS) or Ambulance Services staff their programs, with a range of health care providers undertaking this role [6,7]. It is acknowledged that this practice setting is changing, and that emergency care is not the sole purpose of these services, and increasingly the hospital is not the destination for patients in the care of these services [8].

Use of PIVCs in health care is common with one large international study indicating that 59% of hospital inpatients have at least one PIVC in situ at any one time [9]. Over 330 million PIVCs are inserted annually, in North America, and over a billion PIVCs are used globally within inpatient hospital settings [3,4,9–11]. The use of PIVCs has been well studied in the inpatient hospital setting with researchers examining factors such the use, misuse, complications

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and risks involved with these devices, as well as who inserts them and how to care for the device once it is inserted [4,12–16].

Intraosseous devices, once the mainstay of vascular access especially during the 1930's and the First and Second World Wars due to the ease of use, are not as prevalent currently because of improvements in PIVC technologies [17,18]. IO devices infuse medication or fluid directly into the bone marrow. Recently there has been an increase in IO insertion, particularly in the adult prehospital and hospital resuscitation settings, due to automatic devices improving the ease and speed of use [5,19–22]. Adding to the drive to increase use of the IO route, major treatment guidelines have recently re-introduced recommendations relating to the use of IO devices in the prehospital setting that call for earlier consideration of this route for vascular access [20,21]. Despite this, research exploring the use of and risks to patients in either the prehospital or hospital setting, is limited compared to PIVCs.

Inherent to the use PIVCs and IO devices for vascular access, in the prehospital setting, are risks to patient safety. Both PIVCs and IO devices are at a risk of failure, can injure patients and be portals of infection with subsequent negative patient outcomes [3,5,10,23,24]. Low utilization of PIVCs post placement indicates a need to better understand what drives clinicians to insert a device, particularly as guidelines have changed to move away from prophylactic insertion of PIVCs to insertions being made due to the clinical judgement and decision making of the clinician [2,25–27]. Given the changing nature of prehospital care in general and in guidelines that impact when these devices are used it is worthwhile examining current practices relating to PIVCs and IO devices through literature currently available [20,21,28].

2. Aims

This integrative literature review will critically examine the research-based literature related to incidence of insertion of PIVCs and IOs, the use of these devices and which health professional inserts them in the prehospital setting.

3. Methods

An integrative review was undertaken using a pre-planned, systematic search strategy due to the eclectic nature of some literature related to the topic and generally limited experimental research in this setting. Integrative reviews allow for the inclusion of differing methodologies while maintaining rigor and accuracy but limiting bias [29]. Further studies on integrative reviews have shown that this method has strengths in reviewing dynamic topics where emerging research and established knowledge coincide and may highlight differences which have previously not been addressed [30,31].

4. Search strategy

Previous studies have highlighted the difficulty in searching for public health literature as required for this study as journals may not be indexed in the same database, such as MEDLINE, or indexed at all [32]. To mediate this the following databases were searched: Medline, CINAHL, EMBASE, SCOPUS, PUBMED, Web of Science and EBSCO. The following search terms were used to access literature about PIVC and IO device use in the prehospital setting: Peripheral cath*, Peripheral cann*, Intravenous cath* NOT central, Intraosseous* Catheter, intravenous NOT central, Cannula, intravenous NOT central AND Emergency med* OR prehospital OR pre-hospital OR emergency nurs* OR paramed* OR ambulance.

Due to the relatively small number of peer reviewed journals related specifically to paramedicine/prehospital care the articles were not limited to peer reviewed journals. Grey literature related to the search topics was explored using Google Scholar, Google and duckduckgo.

5. Inclusion, exclusion and quality

The sources were limited to journal articles in English with no limits on publication dates to ensure location of all relevant literature. Articles were initially reviewed by the first author on title and abstract. Qualitative and quantitative research was included that related to the target population of prehospital emergency care where vascular access by PIVC or IO was being studied/reported. Literature was commonly excluded due to cross over of search terms between vascular access and other medical interventions. For instance, catheter can also be linked to urinary and nasal use rather than intravenous leading to exclusion of those articles.

The quality of studies to be included in the review was assessed using the Mixed Methods Appraisal Tool (MMAT) version 2018 as it allows for the assessment of quality across a range of methodological designs including qualitative, quantitative and mixed methods [33]. First published in 2009 the MMAT has been utilized extensively and updated to ensure reliability [34]. The MMAT uses five methodological categories (qualitative, quantitative randomized controlled trials, quantitative nonrandomized, quantitative descriptive, and mixed methods studies) each of which have five quality criteria related specifically to the study design type [33,34]. Scoring using the MMAT is not recommended, rather the criteria are considered met or not met [33]. In this review authors 1 and 2 independently undertook the appraisal with author 4 adjudicating any disagreement. While excluding studies with low methodological quality as assessed by the MMAT is usually discouraged, four studies were considered not suitable for inclusion following critical appraisal [33]. Of the studies included in the review a range of meeting between one and five of the associated quality criteria was found and is documented in Tables 1 and 2.

6. Results

Fig. 1 outlines the results of the search screening, eligibility and inclusion processes. Twenty articles are included in the review with seventeen focused on PIVCs and three relating to IO devices. Of these one is quantitative non-randomized trial while the rest are quantitative descriptive studies. Half of the studies are from the United States of America (n = 10) with other studies from the United Kingdom, Norway, France, Israel, Canada, Sweden and South Africa. Articles are published between 1989 and 2018 with three published in the last five years. Tables 1 and 2 summarize the included literature for PIVCs and IO devices respectively.

Three concepts relating to PIVCs and IO devices were identified within the literature: (i) incidence of insertion for differing prehospital patient populations; (ii) use of PIVCs/IO devices post insertion, and (iii) health professional inserting prehospital PIVCs/IO devices. Each of these will be discussed in turn.

Incidence of PIVC insertion for differing prehospital patient populations — The reported incidence of insertion of PIVCs has high variability. This variability is related to the study focus and the population being studied. Studies reporting on patient encounters that required medical control input or were defined as trauma cases showed incidences greater than 80% [35,36]. Broader populations and studies designed for evaluating larger service groups/areas showed lower incidences. Seven studies report an incidence between 30% and 80% [25,37–42] while a further six report an incidence of insertion for PIVCs as being less than 30% [26,43–46]. Of this last group the study by Myers reports the lowest incidence of insertion (1.6%) however the incidence is of pediatric

Table 1
Studies reporting incidence of PIVC insertion and/or use in the prehospital setting.

Reference/year	Study design	Population sample	Incidence of insertion	Incidence of device use	Inserted by	MMAT [33]
Bester [2] 2014	Retrospective Chart Audit	Successful PIVC attempts >8 yrs old N = 242	N/A	18.8% (39) set up for Fluid bolus used 9.2% (19) set up for med used 72% (149) prophylactic only 42.3% (156) considered not necessary	ILS & ALS providers	Criteria 4.3, 4.4, 4.5 for quantitative descriptive not met, criterion 4.2 can not tell
Engels [35] 2014	Retrospective Chart Audit	Trauma Pt received unmatched blood in trauma bay N = 208	81% (168)	N/A	N/A	All criteria for quantitative descriptive met
Gausche [36] 1998	Retrospective consecutive case series	Pt encounters requiring base hospital medical call N = 452	86% (461)	N/A	Paramedic	All criteria for quantitative descriptive met
Gonzalez [43] 2008	Retrospective Chart Audit	Pts treated following MVC N = 45763 Total N = 34341 Rural N = 11422 Urban	Rural: 18.3% (5693) Urban: 11.3% (1057)	N/A	N/A	All criteria for quantitative descriptive met
Göransson [37] 2011	Cross sectional study with Retrospective Chart Audit	Adult pts arriving at a Level 1 trauma Hospital by Ambulance N = 345	39% (135)	59% (79)	RN & Paramedic	Criterion 4.4 for quantitative descriptive not met
Graham [26] 2013	Prospective Observational Study	Pts treated by service N = 6600	Yr 1 25.1% Yr 2 21.5% Yr 3 18.9% Yr 4 13.5% Yr 5 13.5%	30% (874/1254)	Paramedic	Criterion 4.5 for quantitative descriptive not met
Henderson [38] 1998	Retrospective chart audit	Adult patients presenting to rural ED via EMS N = 278	30% (84)	16.6% (14)	Paramedic	All criteria for quantitative descriptive met
Jones [55] 1989	Prospective observational study with chart audit	IV line attempts (Not pts seen in the study time) N = 102	91% (93) (of those an IV was attempted. No denominator for overall pt prevalence.	N/A	Paramedics	Criterion 4.4 for quantitative descriptive can not tell
Kuzma [39] 2009	Retrospective Chart Audit	Pt treated by regional EMS' N = 34585	60% (20732)	29.7% (6157)	Paramedics	All criteria for quantitative descriptive met
Lapostolle [40] 2007	Prospective observational study	Pts treated by service N = 902	55% (495)	N/A	Nurse 63% (315) Dr 10% (51) St Nurse 7% (33) St Dr 12% (62) Other 7% (36)	Criterion 4.4 for quantitative descriptive not met
Minville [25] 2005	Prospective observational study	Pts treated by service during study N = 669	58% (388)	71% reported but not defined.	Nurse 63% Dr 29% Student 8%	All criteria for quantitative descriptive met
Myers [44] 2013	Retrospective Chart Audit	Pts <18 yrs treated by service during study N = 261008 (note this is all pts)	1.6% (4188) of all pts regardless of age but only PIVCs in those <18 yrs.	N/A	Paramedics	All criteria for quantitative descriptive met but 4.5 not all reported
Nadler [45] 2015	Retrospective chart audit	Pt treated by IDF Medical Corp during study N = 7476	14.5% (1082)	N/A	Defence combat medics, paramedics, physicians	Screening question 1, No. All criteria for quantitative descriptive met
Pace [41] 1999	Prospective Observational Cohort Study	Consecutive cohort of Pts treated by service during study N = 290	56.9% (165)	28% (81)	Paramedics/Student Paramedics	Criterion 4.4 for quantitative descriptive not met, criterion 4.5 can not tell
Seymour [42] 2012	Population based retrospective chart audit	Non-injured, non-cardiac arrest encounters N = 56332	50% (28078)	N/A	Paramedics	All criteria for quantitative descriptive met
Snooks [47] 2000	Case study review based on Chart Audit	Pts receiving PIVC during study period N = 24427	N/A	45.3% (11085)	Paramedics	All criteria for quantitative descriptive met
VanderKooy [46] 2018	Retrospective Chart Audit	Pediatric Pt Encounters during study period N = 545	27% (149)	38.7% (43)	Paramedics	All criteria for quantitative descriptive met

Table 2
Studies reporting incidence of IO device insertion and/or use in the prehospital setting.

Reference/year	Study design	Population sample	Incidence of insertion	Incidence of device use	Complications	Inserted by	MMAT [33]
Gazin [50] 2011	Prospective, observational study	Pts requiring vascular access in MICU N = 4666	0.8% (39)	97% (38)	Unable to use (1) Transient local inflammation (1)	Paramedics	Criterion 4.4 for quantitative descriptive not met
Sunde [49] 2010	Retrospective Chart Audit	Pt encounters during study period N = 6116	1.1% (70) 0-3 yrs old 3.97% (18/453) 3–6 yrs old 0% (0/198) 7–17 yrs old 1.03% (5/486) 18–78 yrs old 0.94% (47/4979)	50–96% various factors, mainly failures led to non-use.	N/A	Doctor	All criteria for quantitative descriptive met
Wolfson [48] 2017	Retrospective Chart Audit	Adult Pt encounters during study period N = 180742	0.3% (543)	N/A	N/A	Paramedics	All criteria for quantitative descriptive met

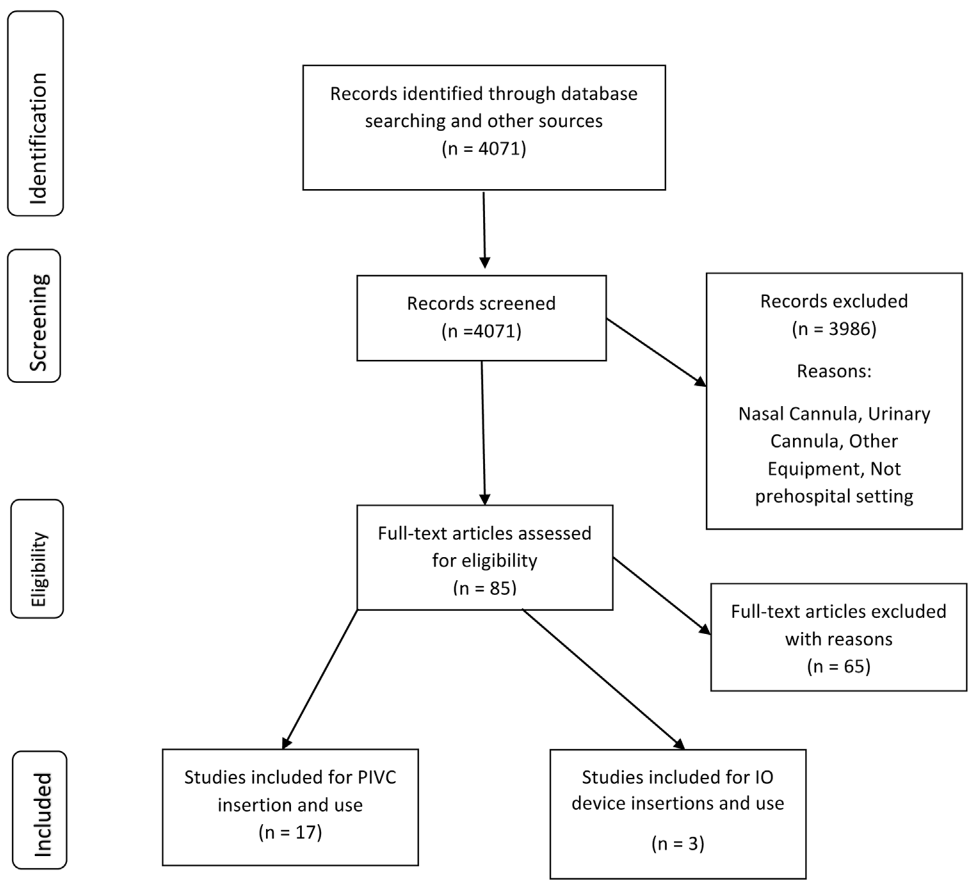

Fig. 1. PRISMA Flow Diagram of publications reporting prehospital PIVC and IO device insertion and use.

PIVC insertions with all EMS encounters regardless of age as the denominator [44]. As such it is difficult to use this result to compare with other studies that limited denominators to match the population used in the numerator.

PIVC use post insertion — Of the nine studies reporting how or if PIVCs inserted in this setting are used a range of results were found. One study reported the use of these devices at a rate higher than 80% [25]. The use of PIVCs was found to be between 30–80% in six studies [2,26,37,39,46,47]. Only two studies reported a usage rate less than 30% [38,41]. Most studies investigated a range of factors around PIVC use rather than identifying usage as a research goal. Appropriateness of PIVC insertion was reported in a study from the United Kingdom where it was found that 81.4% (n = 149) of PIVCs in the study were inserted appropriately. However, it was also found that those paramedics that inserted PIVCs more frequently also inserted them for inappropriate reasons [47]. Prehospital utilization of PIVCs was the focus of one study from a South African perspective that reports 72% (n = 149) of PIVCs inserted were not used and considered prophylactic only. Of those PIVCs used 9.2% (n = 19) had medication administered and 19% (n = 39) for fluid administration [2].

Health professional inserting prehospital PIVCs — A diverse skill mix exists globally, however, most studies (n = 14, 73%) reported paramedics inserting PIVCs. Within this group some reported on the different levels of paramedic, however, generic reporting as paramedic/ambulance officer, depending on the service nomenclature used, was most common [2,41]. The study by Nadler included paramedics as well as combat medics and physicians as the setting of the study was within the Israeli Defense Force [45]. Two studies from French prehospital services did not indicate insertion by paramedics [25,40]. In these studies, the services have Registered Nurses, Doctors and students of these professions providing clinical care, including insertion of PIVCs.

Interosseous device rates of insertion, use and who inserts them – Three studies were found that investigated IO device use in the prehospital setting. All are observational studies and relied on chart audits for some of their results. The incidence of insertion reported by these studies ranges from 0.3% to 1.1% although in Sunde's study 0–3 year olds had an incidence of 3.9% [48,49]. Two studies reported on utilization of the IO devices inserted [49,50]. Both studies reported that the intention to use the device was over 95%, which indicates that these devices are being used in situations where vascular access is required. Sunde provides an example of this reporting that 76% (n = 53) of patients in the study were in cardiac arrest, 10% (n = 7) were multi trauma, 7.1% (n = 5) had seizures/epilepsy and 4.3% (n = 3) were in respiratory failure [49]. Failure of the device does occur with Sunde reporting a range of use from 50% for manual IO insertions, 55% for Bone Injection Gun insertions to 96% for EZ-IO™ insertions [49]. Paramedics inserted the device in two of the studies and doctors in one, which was representative of the staffing profile of the prehospital service being studied [48–50].

7. Discussion

This review has found that prehospital research on the incidence or rate of PIVC insertion and the use of these devices is limited to small cohort studies or quality improvement projects [35,37,38,40]. Often these studies focus on questions not relating to PIVC insertion incidence and/or rate and can therefore lack generalizability outside of the specific study population [35]. Cohort studies of patients also limit the generalizability to the wider population. Several studies were undertaken in quite defined geographic areas which can limit the relevance of their results for services that have a different service model or have a divergent population socially or geographically [25,38,40,46,51,52].

The wide range of incidence of insertion and use reflects the variations in study aim, study sizes, study population and location. Studies reporting higher incidences of insertion tend to be focused on a patient population that would be expected to require a vascular access device due to their clinical need [35,36]. Similarly, the studies reporting higher usage of PIVCs are examining patient populations in which the patient is more likely to need intravenous fluids or medication. Service-related factors combine with patient need in Minville's study reporting 71% usage where the study is based in a doctor-staffed service attending high acuity patients [25].

Lower insertion incidence is evident in studies that look at broader population groups. One study reported a decrease in insertion rates from 25.1%–13.5% over a five-year period in patients treated by a particular service with the authors suggesting this decrease was possibly due to a reduction in unnecessary insertions [26]. While another, focused on pediatric patients, included all patient conditions in a particular geographic region and reported an insertion rate of 27% [46]. Interestingly these studies also report lower rates of use, 30% and 38.7% respectively [26,46]. Potential reasons for inserting but not using a PIVC are not discussed by the authors [26,46]. It has been suggested that PIVCs can be inserted for reasons other than patient need [53]. Pace reports the only predictor of unused PIVCs was the presence of a paramedic student indicating that the placement of the PIVC was for training rather than clinical need [41]. Barr supports this as a potential issue to appropriate PIVC practices and adds that some PIVCs are being placed to please the receiving hospital [53]. Many authors do suggest that services consider policy that avoids recommending routine placement of PIVCs, particularly if there is no intent for use at the time [26,46]. This recommendation is consistent with recommendations outside of the prehospital setting [54].

There are varying service profiles for prehospital care globally and the scope of practice for paramedics can differ greatly, however, the term paramedic is employed extensively to indicate the professional providing care in the prehospital setting in many studies [51]. The review does not show that the profession of the person inserting the PIVC has an impact; particularly on the prevalence of insertion or use. Those services primarily staffed by medical staff report insertion rates of 55% and 58% which while higher than some, as may be expected as these services would see higher acuity patients, is also lower than those studies reporting on high acuity patient groups [25,35,36,40]. This suggests two potential influences on device insertion by medical practitioners. Either the higher-level training of an emergency physician impacts their decision to insert a PIVC so they are less inclined to insert based on protocol and instead use clinical acumen leading to lower insertion rates despite acuity or, those patients being treated in services staffed by doctors are not uniformly higher acuity as those treated in studies specifically targeting high acuity patient populations [25].

The insertion prevalence of IO devices appears to be much more consistent than that of PIVCs. While limited literature was identified specifically examining IO insertion and use, in the prehospital setting, the prevalence of insertion was uniformly low with the incidence of use high and the intention to use the device potentially higher. A study evaluating the performance of various types of IO device described an overall prevalence of insertion of 1.1% with some variation across age groups from 0% in 3–6 yr old to 3.97% in 0–3 yr old patients [49]. This is the highest prevalence reported while the lowest was 0.3% in a large study (n = 180,742) comparing practices between two levels of paramedics undertaking adult IO insertions [48].

From the IO studies identified the intention to use the devices is considered to be 100% due to the nature of the device and the situations in which it is deployed [49,50]. Sunde reported that these devices are being used in situations where vascular access is required but intravenous access may be difficult or impossible [49]. This correlates with guidelines for IO use and supports the high intention to use [21]. Actual prevalence of use is reported as less than 100% in two studies [49,50]. All authors indicate that non use was uniformly due to device issues such as insertion related problems (wrong site), technical problems (device did not work/stylet and catheter bent) or extravasations (misplacement of catheter/catheter fell out). More technologically advanced devices appear to have less issues effecting use and are appropriate for various levels of prehospital health professional [48].

8. Limitations

There are potential limitations with this review. Despite a wide search incorporating a range of search terms combined with a low threshold for inclusion it is possible that relevant publications may have been missed. There were no large-scale, research-based studies reporting on statewide or national EMS use of PIVCS or IO devices found. Thus, this review relies on observational studies many of which are limited in focus to specific populations or services. The age of the reviewed articles is a concern. With 85% (n = 17) of the articles being older than five years it is unclear if contemporary practice is consistent with these reports. Publication bias may

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lead to studies that show practices incongruent to evidenced based practice not being published.

9. Conclusion

PIVC and IO device insertion and use varies significantly globally. Differences in EMS staffing, clinician scope of practice, geography and patient condition all impact on the insertion and use of these vascular access devices. Given the enduring nature of these treatment modalities further study is suggested to determine why patients are receiving these devices, what treatment patients are being administered through these devices and why these devices may not be used if inserted. This will allow services and individual clinicians to benchmark their practice in this important area.

Authorship

MM conceived the study. MM, MW, BL and NB designed the study. MM undertook data collection. MM undertook data analysis. MW, NB and BL supervised data collection and analysis. MM prepared the manuscript. MM, MW, NB and BL approved the manuscript

Conflict of interest

The authors have no conflicts of interest relevant to this manuscript. This paper was not commissioned.

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