ORIGINAL RESEARCH

Learning Success and Influencing Factors in Out-of-Hospital Placement of Intravenous Catheters

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Abbreviation:
IV: intravenous

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Abstract

Introduction: Placing peripheral intravenous catheters ("IV lines") is a standard procedure for health care professionals in acute and emergency medicine. The study aimed to determine the learning curve and success rates in applying IV lines during a three-year paramedic training and the factors influencing successful placement.

Methods: This was a prospective and noninterventional observational study to determine the influencing factors, learning outcomes, and performance in the placement of IV lines by trainees and experienced paramedics. Trial registration: German Clinical Trials Register, ID DRKS00024631.

Results: From February 1, 2016 through December 31, 2021, a total of 3,547 peripheral venous accesses attempts were performed: 76.5% (n = 2,712) by trainees and 23.5% (n = 835) by experienced practitioners. The trainee group had one-to-three years of training and the experienced group had 11 (SD = 11) years of work experience after training (one-to-35 years). The learning or success curve in the successful placement of peripheral venous accesses was 85.2% in the first year of training, 88.5% in the second year of training, and 92.5% in the third year (and the end of training). It was then 94.3% in the fourth year (first year of being experienced). Successful insertion of peripheral venous accesses in the experienced group was up to 97.0%. The first-attempt success rate was 90.4% across the entire trainee group versus 95.9% in the experienced group (P <.0001).

Significant factors influencing successful placement of IV lines were puncture site (P = .022), catheter size (OR = 0.600; P = .002), and number of attempts (OR = 0.370; P <.001). The time of day (or night) was not influential. Work experience, patient age, or blood pressure were also not significant.

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Introduction

Placing peripheral intravenous catheters ("IV lines") is a standard procedure for health care professionals in emergency medicine. Whether it is used for volume therapy, medication application, or laboratory blood sampling, this procedure takes precedence over all other application procedures and should therefore be performed safely.

The existing literature shows that success rates in peripheral venous access depend on the setting and the profession. For example, the success rate for paramedics was higher than 90%.[1,2] Nurses achieved success rates from 86% to 99%.[3–5] Medical students ranged from 47% for the first attempt to 86% for the fifth attempt.[6] If medical students had prior (paramedic) training, then there was a higher success rate in placing peripheral venous cannulas (81% versus 47% without prior experience; P = .038).[6]

In Germany, training for Emergency Medical Services changed from a two-year to a three-year training. Although the insertion of IV lines is an essential standard procedure in emergency medicine, it is unclear how many venous accesses are inserted during this time and how the success rate in this skill develops. Thus, the aim of the study is a longitudinal analysis of the learning success regarding the placement of peripheral venous accesses in Emergency Medical Services.

Methods

This was a prospective and non-interventional, single-arm observational study. A prospective simulation study was carried out at the training site of the German Red Cross

Category	Skills
Airway Management	Bag-valve-mask ventilation, i-gel (supraglottic airway device), NIV-therapy, oxygen therapy.
Pharmacotherapy (Independently, or for some indications only when an emergency physician has been requested.)	Crystalloid infusion, acetylsalicylic acid, epinephrine, amiodarone, atropine, butylscopolamine, dimethindene maleate, flumazenil, furosemide, glucose, ipratropium bromide, heparin, ketamine, morphine, naloxone, midazolam, nitroglycerin, prednisolone, salbutamol, tranexamic acid, urapidil.
Electrotherapy (Mostly used if emergency physician was requested—or is en route—to emergency site)	Defibrillation, cardioversion, transcutaneous pacing.
Trauma	Pelvic sling, tourniquet, hemostatic gauze, needle decompression, spinal immobilization, bandages.
Routes of Administration	Intravenous, intramuscular, intraosseous, inhalation.

Table 1. Local Approved Procedures of Trained and Certified Paramedics

Emergency Medical Service in Reutlingen, Germany as a part of a curricular training course. Beyond paramedics, emergency physicians are also deployed in Emergency Medical Services in Germany. The physicians are dispatched in the event of life-threatening illnesses, injuries, or other indications that exceed the competence of paramedics. Dispatch is coordinated by the dispatch center following an emergency call or upon request by paramedics.

The participants were: (1) paramedic students enrolled in a three-year training program; (2) paramedics who completed their training and were followed up (a control group); and (3) paramedics who participated regardless of their training and with different lengths of professional experience. Training took place at the school (1920h), hospital (720h), and rescue station (1960h). Participation was voluntary. The basic sample size for the study is limited and based on the available number of trainees. The approved competencies of paramedics are remarkably heterogeneous in Germany despite state-specific training. The local competencies at the site of the study are shown in Table 1. An emergency physician must be requested to the site for all measures surpassing the competencies in Table 1.

The study participants received a documentation form that was completed and returned to the Quality Management Department as a part of the training evaluation. The documentation sheet was used in all sections of practical training (hospital/Emergency Medical Services) or operational service. Patient data were only collected anonymously. The following parameters were collected on the sheet: patient age, systolic blood pressure, puncture site, venous catheter size, number of puncture attempts, placement of IV lines successful (yes/no), prehospital suspected diagnosis, shift time, and vein status. With regard to the trainees, the age, previous experience, and current year of training were determined as part of the training evaluation.

The primary endpoint was the successful placement of a peripheral IV catheter. The placement of an indwelling peripheral venous cannula was considered successful if it was possible to draw blood or administer drugs or fluids through the cannula into a peripheral vein. Failure was considered to be an indwelling venous cannula with a paravenous position or an unproductive venous cannula from which it was not possible to draw blood or administer medication or fluids.

For the Emergency Medical Services, the indication for the insertion of IV line was the IV use of medication/infusions or as a precautionary measure in the event of a feared deterioration in the patient's condition (ie, deterioration that would make peripheral vascular access more difficult and delay the administration of medication).

This research project was reviewed by the Ethics Committee at the Medical Faculty of the Eberhard Karls University (Tübingen, Germany) and the University Hospital Tübingen (Tübingen, Germany; number 125/2020BO2) and was classified as unobjectionable. The study was registered in the German Clinical Trials Register (ID DRKS00024631).

Descriptive statistics were reported on a metric scale with a mean (standard deviation). Frequencies are indicated with absolute and relative numbers. Two-tailed P values of <.05 were considered statistically significant. The χ^2-test and, for independent samples with normally distributed data, the t-test or a binary logistic regression analysis were used to calculate differences or predictors. Statistical analyses were performed with SPSS Statistics 28 (IBM; Armonk, New York USA).

Results

From February 1, 2016 through December 21, 2021, there were 3,547 peripheral venous accesses attempts performed by paramedics: 76.5% (n = 2,712) were performed by trainees and 23.5% (n = 835) by experienced personnel. Patients treated by the two types, trainees and experienced, differed significantly with respect to age (62 [SD = 21] years versus 63 [SD = 22] years; P = .048) as well as systolic blood pressure (135 [SD = 31]mmHg versus 126 [SD = 37]mmHg; P <.001).

The trainees placed an average of 58.5 (SD = 24.6) IV lines in the first year of training, 69.8 (SD = 29.6) in the second year, and 58.7 (SD = 25.2) IV lines in the third year of training.

Learning or puncture success among trainees was 85.2% in the first year, 88.5% in the second year, 92.5% in the third year, 94.3% in the fourth year, and 100.0% in the fifth year (two years after training [P <.001]). Overall, the success rate was 88.4% for trainees and was up to 97.0% for experienced personnel (P <.001). Figure 1 shows that the success rate over time reached 97.0%. The favorite puncture site in the trainees was the back of the hand (41.4%); it was the antecubital veins (34.2%) in the experienced group (Table 2).

Clinical assessment of vein status (visibility/possibility to sense the vein) was considered poor (23.6%), moderate (40.1%), or good (36.3%). Clinical assessment of vein status correlated strongly with

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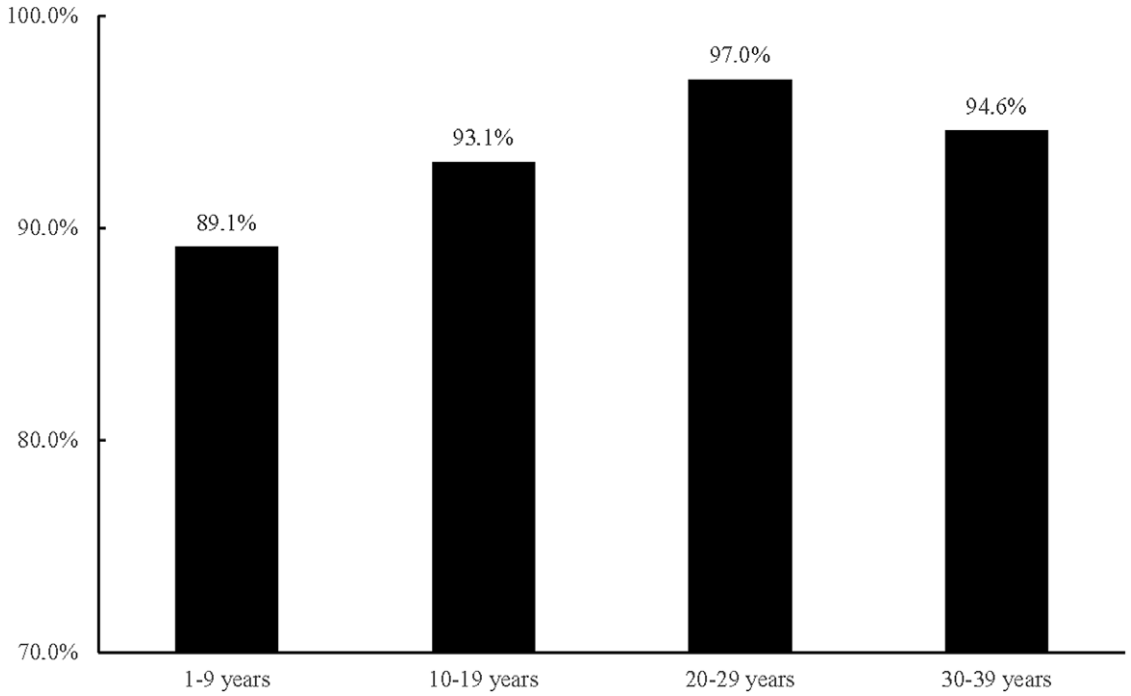

Figure 1. Success Rate in Placing an IV Line in 10-Year Periods.
Note: The result suggests a learning success that persists over the years, but this can decrease slightly with older age or more work experience; success rates start at 89.1% and peak at 97.0% (P <.001).
Abbreviation: IV, intravenous.

success in access placement (ie, success was 84.5% with poor vein conditions, 95.8% with moderate conditions, and 99.7% with good vein conditions).

Only 9.4% of venipunctures were performed prehospital in the context of trauma. Very few were performed trauma indications; 55.9% of the accesses were placed during night services with 44.1% during the day. Among the trainees, 36.7% of the IV lines were placed in the hospital and 53.9% of venipunctures were performed prehospital.

Regression analysis showed no significant influence of experience on success in establishing the IV line (OR = 1.018; 95% CI, 0.986-1.051). Only the puncture site (P = .022), catheter size (OR = 0.600; 95% CI, 0.434-0.828), and number of attempts (OR = 0.370; 95% CI, 0.222-0.616) were significant (Table 3). The Nagelkerkes R-squared was 0.157.

Discussion

Placing a safe IV line is one of the most important skills in emergency medicine. This observational study shows the learning success of trainees in Emergency Medical Services in establishing IV lines; it also shows the general influences underlying successful puncture. The available data show respectable learning success, especially versus experienced users. The rather small group of experienced users should not be seen as a control group in the sense of a controlled study. Rather, they serve as a perspective comparison group. The data are partially statistically significant, but there are few clinically relevant differences with regards to puncture site, catheter size, number of puncture attempts, and success rate per puncture attempt.

Here, the learning success or puncture success is quite remarkable and thus also comparable with existing literature.[1–5] Of interest in this context is what the teaching and learning methods were like.

As stated, "the only way to learn how to place an infusion needle is to place an infusion needle."[7] The question is whether this can only be on the patient or also on training equipment. Lund, et al attempted to answer that question of where and how venipuncture can be better learned: in a randomized-controlled study, they showed that the IV cannulation-related skills acquired in a skills lab are superior to bedside teaching.[8] In the present case, the paramedics followed a skills-based training with the four-step approach. This was then embedded in a competence system for Emergency Medical Services.[9,10]

Here, 36.7% of the performed IV lines were placed in the hospital and 53.9% of vein punctures were performed prehospital. This is interesting, because the hospital was traditionally seen as the most important component in practical-clinical training.[11] However, these results underscore the importance of recognizing the Emergency Medical Service as a clinical-practical training site as well—albeit one in a challenging setting.

The results show an increase in success in the aggregated chart with a maximum between 20 years and 29 years of professional experience. Interestingly, the success rate decreases again thereafter. In fact, studies show that age-specific changes are also registered in medical professionals: skills, cognitive abilities, as well as physiological factors such as eyesight can play a role.[12–14] In fact, some data suggest that older, or rather longer-tenured, personnel are not performing as well in patient care.[15] Thus, there seems to be at least some indicator that age has an impact on performance.

The question of the correct indication is interesting. Here, the coded diagnoses or indications were recorded, but other factors

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	Trainee		Experienced		P Value
	n	%	n	%	
Puncture Site					<.001
Antecubital	914	34.2%	281	34.2%	
Back of Hand	1106	41.4%	275	33.5%	
Forearm	648	24.3%	261	31.8%	
Other	3	0.1%	4	0.5%	
Catheter Size					<.001
16 Gauge	37	1.4%	31	3.7%	
18 Gauge	837	31.0%	313	37.5%	
20 Gauge	1774	65.6%	450	54.0%	
22 Gauge	55	2.0%	40	4.8%	
Number of Puncture Attempts					.025
1 Attempt	2313	85.4%	725	86.9%	
2 Attempts	375	13.8%	96	11.5%	
3 Attempts	19	0.7%	9	1.1%	
4 Attempts	3	0.1%	2	0.2%	
5 Attempts	0	0.0%	2	0.2%	
Success Rate per Puncture Attempt					<.001
1 Attempt	2087	87.1%	695	88.1%	
2 Attempts	291	12.1%	86	10.9%	
3 Attempts	18	0.8%	6	0.8%	
4 Attempts	1	0.0%	2	0.3%	
5 Attempts	0	0.0%	0	0.0%	

Table 2. Puncture Site, Catheter Size, Number of Puncture Attempts, and Success Rate per Puncture Attempt

such as pain and hypotension are also indications for IV therapy; thus, no attempt was made to question the SOP-driven indication. Other studies support the high appropriateness of infusion lines by paramedics, but even experts have different ideas about the correct indication.[16] Further studies show that the placed IV access lines were often not used at all, and the authors concluded that this may also have meant that there was no indication.[1,17] Regardless, patient satisfaction in relation to infusion lines in a London, UK study showed high levels of satisfaction and agreement, particularly when the indication was explained to patients.[18]

The indications of IV lines also certainly depend on the system and the region. In these data, only approximately 10% of access events were for trauma-related diagnoses, similar to other studies.[19] The first-time insertion success incidence of 87.1% is in line with the literature.[5]

The factors impacting the successful creation of IV access sites are quite interesting. The quality of the regression model was not particularly ideal with a Nagelkerkes R-squared of 0.157. However, most other publications do not comment on the quality of their regressions. Other regressions often show that patient age is a relevant predictor, but not in this case.[5,20,21] This may ultimately be due to the distribution within the age range. Of note, work experience had no effect on IV success in the regression (OR = 1.018; 95% CI, 0.986-1.051; P = .282), although there was an increase in the longitudinal analysis. This is consistent with other studies.[21]

"Vein visibility and palpability" is often considered a significant predictor of successful venipuncture.[5,20,22] In this descriptive analysis, vein status also correlated highly with puncture success and was highly significant in the differently calculated regression model. However, the documentation of the IV lines was collected independently and was not validated externally; thus, there could have been inconsistencies in assessment. Thus, this variable was not used in the regression.

Overall, the results mean that paramedics have a significant increase in success rates in the placement of IV access sites. Factors influencing successful puncture are heterogeneously described in the literature. For example, the predictor "size of the needle" will depend on the underlying vessel: a larger vessel should thus be easier to puncture because it would require a larger needle. Ultimately, patients with IV access sites are satisfied, provided that they have been adequately informed.

Limitations

There are no explicit details on the forms of learning, and thus everything was presumably practiced on real patients. The documentation of the attempts was carried out by the participants themselves and only checked by the instructors in a note format. This could also have an influence, particularly if the documentation sheet was forgotten and had to be filled in later. Thus, it is also not entirely clear how many assignments were not documented. Also, some of the years of training overlapped, and the number of cases is not sufficient to show the impact of the number of accesses on success.

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Predictor	Coefficient	SE	Odds Ratio	95% CI		P Value
Professional Experience	0.018	0.016	1.018	0.986	1.051	.282
Indication (Trauma)	−0.282	0.462	0.755	0.305	1.868	.543
Puncture Site (Reference: Back of Hand)						.022
Puncture Site (Forearm)	0.791	0.525	2.205	0.788	6.170	.132
Puncture Site (Antecubital)	−0.639	0.411	0.528	0.528	0.236	.120
Catheter Size	−0.511	0.165	0.600	0.434	0.828	.002
Number of Attempts	−0.995	0.260	0.370	0.222	0.616	<.001
Service Time (Night)	−0.995	0.260	0.717	−0.995	0.260	.361
Patient Age	−0.001	0.008	0.999	0.983	1.015	.883
Systolic Blood Pressure	0.000	0.005	1.000	0.942	0.991	1.009

Table 3. Binary Logistic Regression Analysis, Dependent Variable "Success in Establishing the IV Line"
Abbreviations: IV, intravenous; SE, standard error; 95% CI, 95% confidence interval.

Conclusion

Placing IV access lines is a life-saving and necessary ability for all paramedics. Many therapies can only be performed with safe and fast IV lines. Therefore, this procedure must be an important part of the training. Different methods can lead to differential success. Training under real-life circumstances is very important and has no alternative. Nevertheless, the health and rights of the patients are important and should be treated with respect. If a peripheral IV line cannot be established quickly, then an alternative approach should be considered (eg, intraosseous access or alternative medication application like nasal or intramuscular). These alternative approaches should be part of the training as well and must be learned in a similar theoretical and practical way.

Quality venous puncture is a fast and safe process that guarantees therapy. Therefore, an adequate choice of IV line size and optimization of the conditions (ie, puncture site, brightness, position of the patent) are simple methods to improve the success of the measure. Patient safety and comfort are always a key priority.

Author Contributions

David Häske: conceptualization, methodology, validation, formal analysis, writing - original draft, project administration, funding acquisition.
Wolfgang Dorau: conceptualization, resources, data curation.
Fabian Eppler: conceptualization, resources, data, writing - review & editing.
Niklas Heinemann: conceptualization, resources, visualization, writing - review & editing.
Bernd Hochgreve: resources, data curation.
Benjamin Schempf: supervision, writing - review & editing.

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