Does it matter who places the intravenous? An inter-professional comparison of prehospital intravenous access difficulties between physicians and paramedics

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Objectives **Depending on the specific national emergency medical systems, venous cannulations may be performed by physicians, paramedics or both alike. Difficulties in the establishment of vascular access can lead to delayed treatment and transport. Our study investigates possible inter-professional differences in the difficulties of prehospital venous cannulation.**

Methods **Paramedics were interviewed for their personal attitudes towards and experiences in venous access. We analysed 47 candidate predictor variables in terms of cannulation failure and exceedance of a 2 min time threshold. Multivariable logistic regression models were fitted for variables of potential predictive value ($P < 0.25$) and evaluated by the area under the curve (AUC > 0.60) of their respective receiver operating characteristic curve. Results were compared with previously published data from emergency physicians.**

Results **A total of 552 cannulations were included in our study. All 146 participants voted that paramedics should be eligible to perform venous catheterizations. Despite ample experience in the task, almost half of them considered prehospital venous cannulations more difficult than those performed in hospital. However, the multivariable logistic regression found only patient-related and puncture site factors to be predictive of cannulation failure (patient age, vein palpability with tourniquet, insufficient ambient lighting: model AUC: 0.72) or cannulation delay (vein palpability with tourniquet: model AUC: 0.60).**

Conclusion **Our study shows that venous cannulation is well established among paramedics. It presents itself with similar difficulties across medical professions. Not the numerous specific circumstances of prehospital emergency care, but universal factors inherent to the task will influence the success at venous catheterization.** ***European Journal of Emergency Medicine*** **24:443–449**

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Introduction

Despite decades of clinical practice especially in European Emergency Medical Services (EMS), the issue of prehospital venous cannulation still remains disputed [1–4]. Advocates will point out the largely extended spectrum of treatment options only available with venous access and in some countries, this will also be the case for paramedics, not just physicians. Opponents will argue that the resulting delay in transport to hospital care stands against the procedure. It is beyond this controversy, however, that a difficult cannulation can lead to serious timely delay for both life-saving extended measures and immediate transport and should best be avoided in the first place. As a consequence, a recent study by the authors has developed an assessment strategy to identify difficult venous access scenarios well in advance [5]. We concluded that universally applicable, local factors of the puncture site, and not the plural of external factors associated with the unique circumstances of a prehospital environment will predict difficult venous cannulation. However, one major limitation of our study was that its only participants were specially trained physicians in the German EMS. Worldwide, the manual skill of venous cannulation is actually performed by many health professionals – physicians, nurses, paramedics, phlebotomists and others. In fact, a recent poll in Germany found that 66.7% of paramedics had already performed more than 100 venous cannulations in their career [6]. However, neither the study by Prottengeier and colleagues nor the available literature provides data to identify the distinct problems that a member of a certain profession might encounter in the process of venous cannulation. Physicians and paramedics definitely have different ways of teaching and training. Can this influence procedural success and time requirements?

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Legislation – not just in Germany – clearly defines the different responsibilities and competencies of each group of health professionals [7]. Reflecting on the high standards of education and training of 'nonphysicians', many procedures are already part of their manual skills repertoire. However, there are considerable differences between countries in assigning such responsibilities [8]. Current legislation in Germany draws complex lines: currently, venous cannulations by paramedics are permitted under direct physician supervision [9]. Driven by the intention that future paramedics should be allowed to perform simple invasive procedures on a regular basis, recent legislation is guiding the way to venous cannulations by paramedics being regulated by local EMS directorate standard operating procedures [10,11]. Currently, most paramedics are only entitled by the complicated legal construct of 'necessity as justification' ('rechtfertigender Notstand') – to start full panel advanced life or trauma life support including the establishment of venous access, confining their actions to a state of life-threatening emergency and/or expected permanent injury to health if a physician is not timely available [12,13].

Thus, the aim of our study is not only to deliver a practical assessment for the prediction of venous access difficulties in the hands of paramedics. Our queries into the personal views of our volunteers will also provide data on how paramedics perceive their role in terms of this invasive procedure. Finally, it should also gain data that can be used to evaluate the performance in comparison with results from emergency physicians.

Methods

The University of Erlangen-Nuremberg's ethics committee approved this prospective study (Votum No. 133_14 Bc). It waived the need for a formal informed consent from patients because of the strictly anonymous and purely observational nature of our study. We acquired two sets of data from 146 paramedics from 30 participating Bavarian EMS stations. First, each paramedic completed a questionnaire investigating his or her personal experience in and subjective attitude towards prehospital vascular access. Then, we documented in detail the venous cannulations performed by our volunteers during the study period from June till November 2014. Punctures in children younger than 14 years were excluded as a subgroup with special considerations, but insufficient group size.

All procedures were documented through an online questionnaire immediately after each mission. Participants were trained beforehand on the contents of the questionnaire and the required situational assessment – thus gaining a standardized evaluation of the cannulation procedure despite the ex-post perspective of online documentation. Cannulations were analysed in respect to 47 candidate predictor variables in relation to each paramedic and each mission, patient and invasive procedure (Supplementary Table 1, Supplemental digital content 1, *http://links.lww.com/EJEM/A118*). These variables were derived from our previous investigation into intra-hospital access [5] and amended by discussions within our multiprofessional group of paramedics and emergency physicians from Erlangen University Hospital.

Statistics

Statistical analysis was carried out using SAS 9.3 (SAS Institute, Cary, North Carolina, USA). Data from the subjective evaluation questionnaire were presented as descriptive statistics.

All values for the comparison of predictor variables as well as performance rates were derived from a previous study by the authors, whose results are summarized in Table 1 [5].

The two primary endpoints of our deductive analysis were (a) the successful intravascular placement of the catheter and (b) the undercut of the 2 min threshold of time consumption for the procedure – as defined by the Consensus on Cardiopulmonary Resuscitation provided by the European Resuscitation Council (ERC) [14]. The outcomes of interest were assessed analogously by logistic regression. In a stepwise approach, candidate predictive variables were first evaluated by a univariate logistic regression. Variables with a likeliness of influence on the outcome – represented by a *P*-value less than 0.25 from univariate regression – were subjected to multivariable logistic regression. For variables remaining in the model after backward selection, odds ratios were calculated and the area under the corresponding receiver operating characteristic curve was derived as a measure of predictive accuracy (Table 2). For comparison, a further reduced model including only those variables with an AUC more than 0.6 was fitted (Figs 1 and 2).

Results

All 146 volunteers completed our questionnaire and contributed a mean of 4.03 (median = 1, SD = 8.03) intravenous cannulations. Professional experience was well distributed, with a balanced 54% versus 46% rate of above versus below 5 years of service and a mean of 3841 (median: 1500; SD: 4617) emergency missions carried out in their career. Volunteers rated their mean personal capabilities as 2.34 out of 6 (median: 2, SD: 0.73) and had a mean personal experience of 3.41 cannulations per week (median: 2; SD: 4.19). There was a unanimous vote (100%) that venous cannulations should be officially assigned to the competencies of paramedics. In all, 47% (68/146) believed prehospital cannulations to be more difficult than those inside a hospital. Overall, 56% considered their personal capabilities sufficient enough to perform cannulations anytime, whereas 25% expressed the need for refreshment and 19% expressed the need for basic training, respectively. However, only 11% would prefer phantom manikins as their method of choice for the training of their skills.

Table 1 **Results from the previous study by Prottengeier *et al.* [5] as a basis for a comparison of predictive factors and performance rates**

Number of data sets	762 intravenous cannulations			
Primary endpoints Success rates [95% CI]	Success at first attempt 77.95% [0.75–0.81]		Undercut of 2 min time limit 86.52% [0.84–0.89]	
Predictive value	Area under ROC curve (point estimate, 95% Wald-CI)	Odds ratio estimate[a] (point estimate, 95% Wald-CI)	Area under ROC curve (point estimate, 95% Wald-CI)	Odds ratio estimates[a] (point estimate, 95% Wald-CI)
Vein visible without tourniquet	0.67 [0.63–0.71]	0.49 [0.31–0.76]	0.72 [0.68–0.77]	0.35 [0.20–0.61]
Vein visible with tourniquet	Not included		0.62 [0.57–0.66]	0.27 [0.14–0.55]
Vein palpable with tourniquet	0.68 [0.63–0.72]	0.28 [0.18–0.43]	0.67 [0.62–0.73]	0.38 [0.22–0.64]
Dark/insufficient ambient lighting	0.63 [0.59–0.67]	0.49 [0.32–0.74]	0.64 [0.58–0.69]	0.53 [0.32–0.89]

AUC, area under the curve; CI, confidence interval; ROC, receiver operating characteristic.
[a]Estimated by multivariable logistic regression accounting for specified variables.

A total of 552 intravenous cannulations – a mean of 4.2 per volunteer (SD 8.2) – were enroled, of which 85% were successful on the first attempt. In 11% of cases, two attempts were required and three or more in 4%, respectively. Participants documented up to 56 cannulations, mainly (88%) one to six cannulations. In all, 59% of the participants documented only one cannulation, of which 88% were successful. In total, 9, 8 and 12% documented two, three and four to six cannulations, respectively. Success rates were comparable. Primary model selection from multivariable analysis yielded a model of fair accuracy [area under curve (AUC) = 0.76] with six influencing factors (Table 2), of which only three (patient age, vein palpable with tourniquet and insufficient lighting) had a predictive accuracy of AUC more than 0.60 and were therefore included in the final model of prediction.

In terms of the second endpoint of our investigation, cannulation was successful in less than 2 min in 91% of all procedures. Selection for the outcome of time consumption again yielded a model of fair accuracy (AUC = 0.75) with eight influencing factors (Table 2). However, seven of these had a predictive accuracy of AUC less than 0.60. In analogy to the model of success, these second-rated factors were excluded from the final time-threshold model of prediction.

In summary, there resulted in two structurally congruent statistical models: puncture failure can be predicted by assessing the three factors of (a) patient age, (b) vein palpability with tourniquet and (c) sufficiency of ambient lighting, resulting in an area under the receiver operating characteristic curve of 0.72 (Fig. 1). The prediction model of exceedance of a 2 min time threshold is conspicuously simple, with only one predictive factor of vein palpability with tourniquet, towards an AUC of 0.60 (Fig. 2).

Establishment of intravenous access by paramedics was not possible in 22 cases (4%). In 86% ($n = 19$) of these cases, a physician could successfully cannulize in the end. Alternative access devices were then used once. However, in two cases, the team abstained from further attempts at venous access.

Post-hoc evaluation of the procedures at the time of patient handover at the hospital found 96% of all intravenous drips fully functional and inspection/palpation of the puncture site was also normal in 97% of cases. The subjective rating of the perceived difficulty of all 552 procedures was balanced with a slight predominance of perceived easiness (Fig. 3).

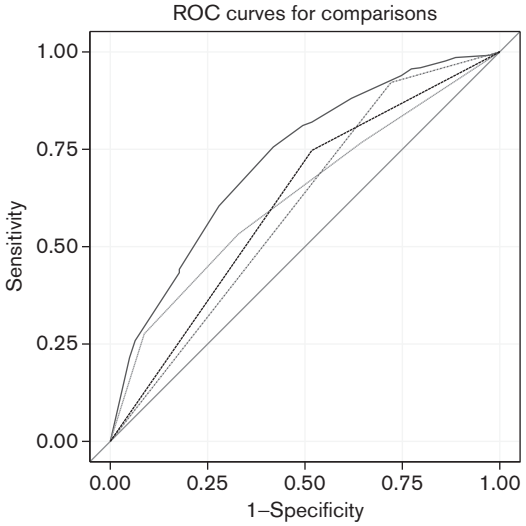
Inter-professional comparison data are shown in Table 3, reflecting comparable results in terms of success and undercut of the 2 min time limit.

Table 2 Results for multivariable logistic regression models found by backward selection

	Endpoint			
	Successful intravenous placement on first attempt		Exceedance of the 2 min time limit	
	AUC (point estimate, 95% Wald-CI)	Odds ratio (point estimate, 95% Wald-CI)	AUC (point estimate, 95% Wald-CI)	Odds ratio (point estimate, 95% Wald-CI)
Model	0.76 [0.70–0.81]	Not applicable	0.75 [0.68–0.83]	Not applicable
Patient age categorized into quartiles (3: ≥ 79 years, 2: ≥ 63.5 years, 1: ≥ 44 years, 0: < 44 years)	0.63 [0.57–0.69]	1 vs. 0: 0.34 [0.13–0.88] 2 vs. 0: 0.27 [0.11–0.70] 3 vs. 0: 0.22 [0.09–0.55]	Not included	
Nature of emergency: mission with request for doctoral assistance	0.57 [0.51–0.63]	0.51 [0.29–0.89]	0.57 [0.50–0.64]	0.49 [0.25–0.94]
Major complaint: impaired consciousness	0.53 [0.48–0.59]	0.68 [0.39–1.19]	Not included	
Vein visible with tourniquet	0.55 [0.49–0.60]	0.59 [0.32–1.09]	Not included	
Vein palpable with tourniquet	0.60 [0.55–0.66]	0.23 [0.12–0.43]	0.60 [0.54–0.67]	0.30 [0.14–0.62]
Insufficient lighting	0.62 [0.56–0.68]	0.47 [0.28–0.80]	0.59 [0.52–0.66]	0.61 [0.32–1.17]
Indication: saline infusion	Not included		0.55 [0.48–0.62]	1.88 [0.97–3.64]
Myocardial infarction	Not included		0.53 [0.50–0.56]	4.88 [1.07–22.2]
Centralization	Not included		0.55 [0.49–0.61]	0.56 [0.26–1.21]
Local oedema	Not included		0.56 [0.50–0.63]	0.52 [0.25–1.08]
Exsiccosis	Not included		0.59 [0.52–0.66]	0.37 [0.19–0.70]

AUC, area under the curve; CI, confidence interval.

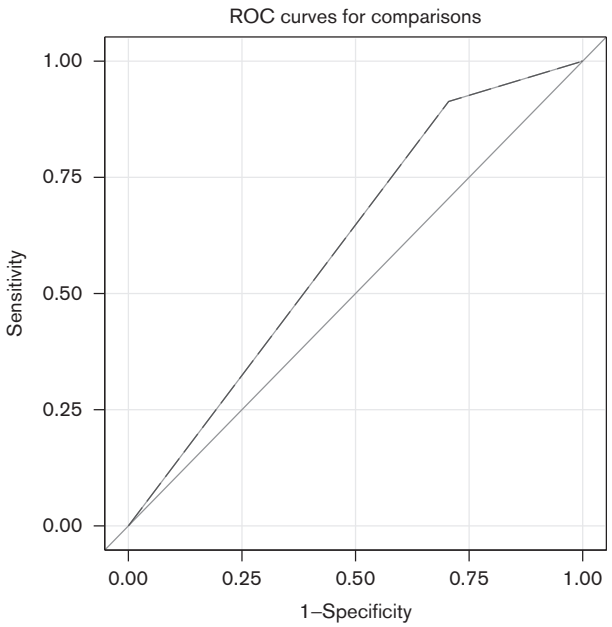
Fig. 1



ROC model	AUC	SE	95% Wald confidence limits	
Model (solid line)	0.7241	0.0313	0.6628	0.7854
Patient age categorized in quartiles (dashed line)	0.6282	0.0305	0.5684	0.6880
Vein palpable with tourniquet (dashed dotted line)	0.6003	0.0262	0.5490	0.6517
Insufficient lighting (medium dashed line)	0.6143	0.0302	0.5551	0.6735

ROC curves of the reduced model for the outcome parameter: 'successful intravenous placement on first attempt.' The solid line shows an ROC curve for the reduced model and discontinuous lines show ROC curves for univariate models. AUC, area under the curve; ROC, receiver operating characteristic.

Fig. 2



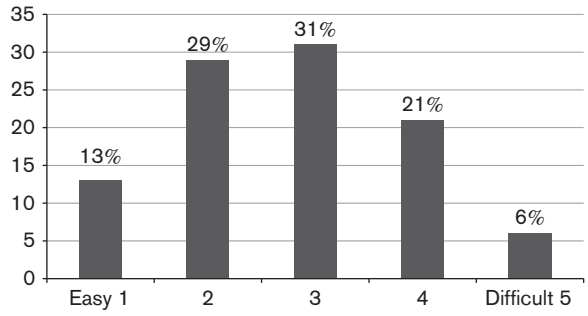
ROC model	AUC	SE	95% Wald confidence limits	
Model	0.6036	0.0329	0.5391	0.6681
Vein palpable with tourniquet	0.6036	0.0329	0.5391	0.6681

ROC curve for the reduced model for the outcome parameter: 'exceedance of the 2 min time limit' comprising only the variable, vein palpable with tourniquet' with AUC = 0.6036 (95% CI = 0.5391–0.6681). AUC, area under the curve; CI, confidence interval; ROC, receiver operating characteristic.

Discussion

Venous cannulations are an essential prerequisite for life-saving measures and have been established in prehospital emergency medicine for many decades. Against this long history, however, stands a still unresolved debate arguing where, when and by whom venous access should best be established within the succession of prehospital and in-hospital care. One aspect to consider is the delay caused by difficult or failed venous cannulations. The authors have therefore previously investigated factors that might influence the success and speed of this task in the hands of emergency physicians in the German EMS [5]. On the one hand, it has to be seen as advantageous that such a focus on only one rather homogenous group of emergency care providers can facilitate the identification of patient-related obstacles more clearly. On the other, this focus generated a limitation by itself in terms of any venous access established by other professionals within the EMS. As a consequence, the present study assesses the subjective views of paramedics towards venous cannulations, investigates their specific influencing factors on access failure and delay and enables a comparison of

Fig. 3



Subjective rating of perceived difficulty of puncture scenario. Likert scale ratings (1/easy to 5/difficult).

Table 3 Inter-professional comparison of the overall success rates of venous cannulation

Profession	Number of documented venous cannulations	Success rate: success at first attempt [95% CI]	Success rate: undercut of 2 min threshold [95% CI]
Emergency physician	762	77.95% [0.75–0.81]	86.52% [0.84–0.89]
Paramedic	552	84.60% [0.82–0.88]	90.16% [0.88–0.93]

Physicians' data derived from the authors' previous investigation [5].
CI, confidence interval.

those factors – and performance in general – between medical professions.

The complex legal situation in Germany is reflected in a vast variability of how often paramedics will actually be asked to perform the task of venous cannulation [6,13]. Despite all legal ramifications, our data set indicates that most of our volunteers have had ample experience in the procedure and they showed a sound, but not improper confidence in their skills. Paramedics with lesser skill levels had clear and considerate ideas under what premises further training should be performed. It is not surprising that none (0%; $n = 0/146$) of our volunteers voted for regulations to remain unchanged and all of them favoured the idea that peripheral venous cannulations should no longer be exclusive to emergency physicians – that paramedics should be made equally eligible.

Our calculations of the prediction of cannulation failure and delay showed similar results compared with our principal study involving emergency physicians. Not those multiple external factors unique to the field of prehospital emergency medicine, but universally valid factors for the assessment of any puncture site are shown to influence the success and speed of venous cannulation (Table 3 and Figs 1 and 2). This may not be totally unexpected. However, bearing in mind the vastly different modes of education and the sometimes contrasting daily routine of physicians for one and paramedics for the other, we consider this finding anything but self-evident. However, there appears to be one novel, previously not described factor associated with cannulation failure: patient age was not included before in the prediction model for physicians. Lacking further insight into this factor, we would like to speculate that older age may not only be associated with increasing numbers of comorbidities, medications and previous cannulations. It also may be accompanied by deteriorated soft tissue structure resulting in – again underlining our general conclusion – equally deteriorated local puncture site properties.

When related to the performance rates of physicians, our paramedics achieved generally comparable results (Table 3). As a tool of internal (secondary) control to objectivize cannulation success, we asked not only for documentation of primary success but also for a short assessment of the function of the drip and the puncture site at the time of patient handover inside the emergency room. Abnormalities were only detected in less than 3% of cases, thus reconfirming our positive findings on procedural success.

Summarizing our findings, it seems safe to assume that paramedics can – experience and training provided as a precondition – accomplish peripheral vascular access fairly comparable with their physician counterparts, will reach adequate success rates and will be influenced by the same limiting factors. Therefore, we would like to offer our findings to all decision-makers in prehospital emergency care to be used for possible future amendments to paramedics' skills training and their catalogue of requirements [7,10].

Naturally, there are some limitations to reflect on. Our investigation may be limited in its power by a likely selection bias that will be found with all observational studies (a) relying on volunteer participation and (b) using anonymous questionnaires. It may be argued that a process of positive selection may be responsible for the documented high success rate. Unfortunately, we cannot account for those cases when paramedics saw no reasonable chance of success and passed the task down to the physician at hand or en route – without any attempt of their own. In other words, perhaps paramedics were often able to identify difficult cannulation scenarios and made the responsible choice that a physician should take responsibility for such a suspected advanced-level procedure. Finally, the high success rate may also be responsible for our inability to identify more variables of influence on the exceedance of the 2 min threshold in relation to the size of the data set.

As an interesting side note, our calculations found a prolonged duration (>45 s) of the tourniquet to be an (statistically speaking) influential factor on the success at first attempt (odds ratio 9.25, 95% confidence interval = 3.18–26.87; $P < 0.0001$) or the time limit threshold (4.44, 95% confidence interval = 1.64–12.02; $P < 0.001$). However, we did not include this variable in our predictive models as we consider it a confounder in the sense that the duration of tourniquet will not make a cannulation more difficult, but vice versa: that any difficult cannulation will lead to prolonged tourniquet – hoping to improve vein visibility and palpability for the act of puncture.

Finally, it has to be admitted that the feasibility and clinical significance of paramedics performing venous cannulations are strongly dependent on local factors and may not be generalized easily. Levels of training and

competence in the manual task itself as well as the knowledge and eligibility to use life-saving intravenous drugs must be taken into account when considering the ramifications of this study.

Conclusion

Whenever, wherever or by whoever venous access will be attempted in prehospital emergency medicine, we advocate our simple assessment:

(1) A difficult venous access will show itself independent of external factors present at a scene of emergency.
(2) Paramedics and emergency physicians will face the same difficulties.
(3) Local and universal indicators at the puncture site should guide the resulting strategy (e.g. early use of alternatives such as the intra-osseous route. See ERC guidelines).
(4) Skilled paramedics can perform the manual task of venous cannulation.

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Conflicts of interest

There are no conflicts of interest.

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