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Neonatal Intensive Care

Duration to Establish an Emergency Vascular Access and How to Accelerate It: A Simulation-Based Study Performed in Real-Life Neonatal Resuscitation Rooms

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Objectives: To compare the duration to establish an umbilical venous catheter and an intraosseous access in real hospital delivery rooms and as a secondary aim to assess delaying factors during establishment and to provide recommendations to accelerate vascular access in neonatal resuscitation.

Design: Retrospective analysis of audio-video recorded neonatal simulation training.

Settings: Simulation training events in exact replications of actual delivery/resuscitation rooms of 16 hospitals with different levels of care (Austria and Germany). Equipment was prepared the same way as for real clinical events.

Subjects: Medical teams of four to five persons with birth-related background (midwives, nurses, neonatologists, and anesthesiologists) in a realistic team composition.

Interventions: Audio-video recorded mannequin-based simulated resuscitation of an asphyxiated newborn including the establishment of either umbilical venous catheter or intraosseous access.

Measurements and Main Results: The duration of access establishment (time from decision to first flush/aspiration), preparation (decision to start of procedure), and the procedure itself (start to first flush/aspiration) was significantly longer for umbilical venous catheter than for intraosseous access (overall duration 199 vs 86 s). Delaying factors for umbilical venous catheter establishment were mainly due to the complex approach itself, the multitude of equipment required, and uncertainties about necessary hygiene standards. Challenges in intraosseous access establishment were handling of the unfamiliar material and absence of an intraosseous access kit in the resuscitation room. There was no significant difference between the required duration for access establishment between large centers and small hospitals, but a trend was observed that duration for umbilical venous catheter was longer in small hospitals than in centers. Duration for intraosseous access was similar in both hospital types.

Conclusions: Vascular access establishment in neonatal resuscitation could be accelerated by infrastructural improvements and specific training of medical teams. In simulated in situ neonatal resuscitation, intraosseous access is faster to establish than umbilical venous catheter. Future studies are required to assess efficacy and safety of both approaches in real resuscitation settings. (*Pediatr Crit Care Med* 2018; 19:468–476)

Key Words: catheters; intraosseous infusions; manikins; newborn; resuscitation; umbilical cord

***See also p. 499.**

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Neonatal resuscitation is a rare event. The majority of deliveries proceed without complications, whereas approximately 3% need assisted ventilation and the

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number of infants requiring chest compressions and epinephrine is estimated to be about 0.12% (1). The European Resuscitation Council (ERC) recommends the umbilical venous catheter (UVC) as vascular access of first choice (2). Thus far, there are no data available about how successfully UVC can be established during resuscitation. Because of the rarity of neonatal resuscitation events, possibilities of gaining experience in the placement of emergency vascular accesses are limited. This might explain why medical teams tend to choose a peripheral venous catheter (PVC) during simulated neonatal resuscitation. However, during cardiac arrest, a PVC is challenging, which is why guidelines recommend instead the use of alternative access routes.

Data regarding complications and success rates of UVC are available only for the routine setting (3–6). These data, however, do not reflect the setting of an emergency UVC placement. During resuscitation, the procedure is impeded not only by intense belly movements due to simultaneous chest compressions but also by high emotional pressure on the providers. To our knowledge, there are no data regarding efficacy or safety of UVC insertion during neonatal resuscitation.

The ERC guidelines recommend the use of an intraosseous access (IO) as first choice for resuscitation beyond the neonatal period (7). While feasibility and complications of IO in adults and children are well described (8–11), few data exist regarding the newborn population. Reports and case series describe both severe complications of IO (12–14) and successful establishment even in preterm infants (15–19). The ERC, however, does not yet recommend the use of IO during the neonatal period.

Hence, although UVC is recommended as access of first choice by the ERC, both approaches so far remain unproven in the neonate and require scientific evaluation. Because of the rarity of neonatal resuscitation events, most trials compare the establishment of UVC and IO in simulated settings in specialized centers. Within the simulation model, it has been shown that IO is faster and easier to establish than UVC (20, 21). However, these studies were performed with students or single medical staff members in the "sterile" surrounding of a simulation center and the required material was provided in preprepared access kits. The aim of our study was to compare the time to establish an emergency vascular assess (UVC or IO) and to identify delaying factors for access establishment in simulated neonatal resuscitation events in real-life surroundings and actual medical teams with different levels of care.

METHODS

Audio-video recordings of newborn resuscitation training events in Austrian and German hospitals were analyzed. The training events were initiated by each hospital for quality improvement purposes. There was no recertification of the medical personnel, but the goal was to train each staff member, who is taking care of newborns (all birth-related professions), to reaching best possible training effects for the single person and also for the entire team to improve patient safety. All training events held from 2015 to 2017 were revised and those with immediate postnatal scenarios and either IO or UVC establishment were collected. Prior to the training events every

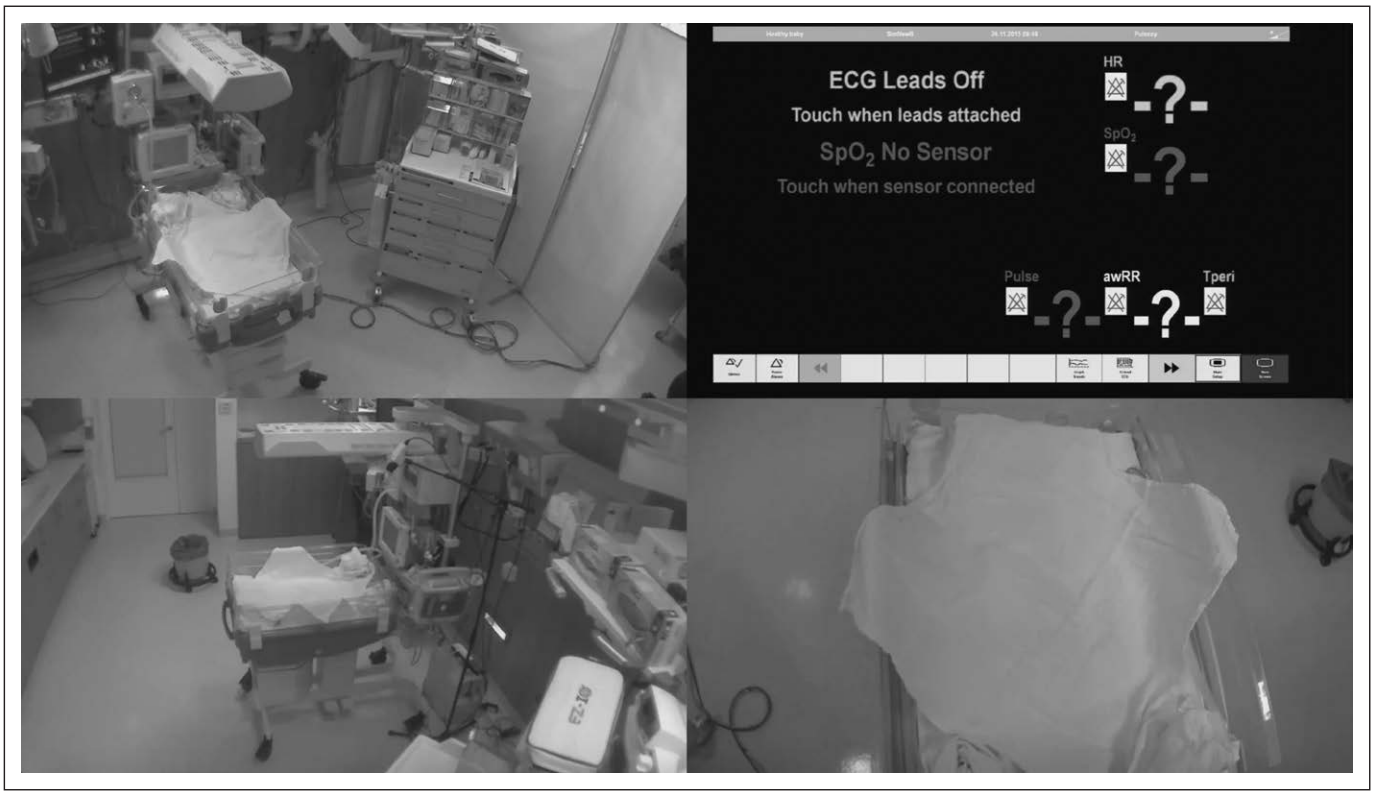

Figure 1. Example of a training setting. Exact replication of the original resuscitation room including all relevant medical equipment. awRR = airway respiratory rate, ECG = electrocardiogram, HR = heart rate, Spo_2 = peripheral capillary oxygen saturation, Tperi = peripheral skin temperature.

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participant was informed and agreed to scientific analysis. The study protocol received the approval of the Ethics Committee of the Medical University Vienna with an ethical declaration of no objection (EK 1541/2017).

Training Settings

The simulation staff team included one technician for the audio-video system, two professional experienced debriefers, and one sim-nurse. All training events were directed by the same supervisor (S. J.). To attain realistic conditions, the training was performed in an exact replication of the original resuscitation room, created in a nearby room on the same ward. For this purpose, the entire emergency equipment from the original resuscitation room was transferred into this room, including the infant resuscitaire/warmer, emergency trolley, and all other relevant material such as an UVC or IO kit, if available in the original room (**Fig. 1**). Therefore, in all training settings, equipment was prepared the same way as for a real clinical event and no more or less material was provided. Trainees were actual medical teams of four to five people with birth-related professional backgrounds (midwives, nurses, pediatricians, neonatologists, and anesthesiologists) and in a realistic team composition. The mobile audio-video system including three portable cameras, and a recording computer was installed to allow a video-based debriefing. In an initial lecture, the ERC neonatal resuscitation guidelines were explained and UVC and IO were mentioned as possibilities for emergency vascular accesses but there was no practical training before the scenarios started.

The 4-hour simulation training began with a 45-minute familiarization of the simulator (SimNewB simulator mannequin; Laerdal Medical, Stavanger, Norway), equipment, and monitoring. The teams were instructed to provide care within the context of the scenario in the same way as they would in an actual clinical situation within the limitations of the simulation setting.

Three simulation scenarios followed of approximately 10–15 minutes with a 30–45 minutes video-based debriefing for each. One of these three scenarios was used for this trial and was run as follows: a term newborn with a heavy meconium-stained fluid is delivered without a vigorous response in initial newborn resuscitation. The newborn remains bradycardic at a heart rate of 30 beats/min. The medical team must obtain vascular access and administer epinephrine and fluid to successfully resuscitate the newborn to achieve return of spontaneous circulation.

The SimNewB provides participants with the possibility to cannulate the umbilical cord, which exhibits two umbilical arteries and one vein. Blood flashback return function was not used during the training sessions. Catheter placement was declared as correct, when the catheter was inserted into the vein. Insertion depth was not assessed. The SimNewB allows the establishment of an IO in both tibiae of the legs. Blood return function of the simulator was not used. The study team considered that vascular access was established when the IO needle was inserted and the mandrin removed.

Outcome Measures and Statistical Analysis

The following time points were defined:

A) Time point at decision to place IO/UVC
B) Start of procedure
C) End of procedure (either when IO stylet was removed or UVC was inserted)
D) Time point at first flush/aspiration

According to these time points, the following durations were calculated:

1) Durprep: Duration of preparation (B–A)
2) Durproc1: Duration of procedure until first use (D–B)
3) Durproc2: Duration of procedure itself (C–B)
4) Duraccess: Overall duration of access establishment (D–A)

Statistical analysis was performed using SPSS Statistics version 24 (IBM, Armonk, NY) and SAS version 9.4 (SAS Institute, Cary, NC). For the comparison of the four durations between the groups IO and UVC for all centers, combined unpaired signed Wilcoxon rank test was used. As four hypotheses were tested, *p* values were adjusted by the Bonferroni-Holm correction for an overall level of significance of 5%. Comparisons were repeated post hoc for each center separately and adjusted for multiple testing setting number of tests equal to eight. Differences between means and corresponding 95% CIs were estimated by *n* equals to 1,000 bootstrap samples because of skewed distributions. The association of the chosen access approach and hospital type was analyzed with Fisher exact test. *p* values for comparison of durprep with and without UVC set/IO kit and use or nonuse of sterile drapes were not adjusted for multiple testing and must be only interpreted exploratively. The level of significance was set to 5% for those comparisons.

In a second part of this study, the research team analyzed the recorded scenarios according to factors, which delayed access establishment. Repeatedly observed delaying factors were described separately for UVC and IO access and frequencies were calculated.

RESULTS

In total, 59 simulated newborn resuscitations from 16 different Austrian and German hospitals were included in the analysis. The different hospital categories (levels of care) in Austria and Germany are listed in **Table 1**. Six of the analyzed hospitals were Centers of Perinatal Medicine (CPM) Level I (four Austrian, two German), and 10 were smaller hospitals (category B or general hospital; eight Austrian, two German). Neither hospital was category A (or CPM Level II) nor Basic Care. Therefore, throughout this article, the used hospital categories are large perinatal centers (CPM) and small hospitals (category B or general hospital). Characteristics of participating hospitals are described in **Table 2**.

PVC

During the course of resuscitation, 31 teams (52.5%) decided to attempt a PVC (two teams tried twice and one team three times). The mean duration for the PVC attempts was 93

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TABLE 1. Comparison of Hospital Categories in Austria and Germany

Austria		Germany	
CPM	Preterm infants of all ages	CPM level I	Preterm infants of all ages
Category A	Preterm infants from 25 wk GA onward	CPM level II	Preterm infants from 29 wk GA onward or 1,250 g
Category B	Preterm infants from 30 wk GA onward	General hospital	Preterm infants from 32 wk GA onward
Basic Care	Infants from 36 wk GA onward	Basic care	Infants from 36 wk GA onward

CPM = Centers of Perinatal Medicine, GA = gestational age.

Classification according to Austrian (22) and German (23) regulations. Throughout this study, the following two hospital categories were analyzed: Large perinatal hospitals (CPM or CPM level I) and small hospitals (category B or general hospitals).

seconds (range 24–211 s). There was no significant difference between the UVC and IO groups according to the number or duration of the PVC attempts.

UVC Versus IO

Either after unsuccessful attempts for PVC (52.5%) or as first choice (47.5%), teams decided either on UVC or IO. Seventeen (29%) chose UVC and 42 (71%) IO. After the decision for one approach was made, no switch was observed from one vascular access to the other. All IO attempts were performed using the EZ-IO semiautomatic power drill (Teleflex Medical Europe, Westmeath, Ireland). Although manual Cook needles (Cook Medical, Bloomington, IN) were also available in some hospitals, they were not used.

The overall duration (from decision for a specific vascular access to the first flush or aspiration through the catheter) was significantly shorter in IO than in UVC attempts (mean 86 and 199 s, respectively; $p < 0.001$). Further, regarding preparation and procedure separately, teams were significantly faster when the decision was made for IO (**Table 3**). The mean durations from the start of the procedure until the access was ready to use (durproc2) were 23 and 101 seconds for IO and UVC ($p < 0.001$).

Regarding the hospital categories separately, the percentage of teams who decided on UVC was higher in large perinatal centers (39% UVC and 61% IO) compared to those in small hospitals (22% UVC and 78% IO). However, the choice of UVC or IO was not significantly associated with hospital type ($p = 0.239$). There was no significant difference between the duration for access establishment in large perinatal centers compared with small hospitals. Anyhow, a trend was observed that UVC establishment took longer in small hospitals than in centers, whereas the duration for IO establishment was similar in both hospital types (**Fig. 2**). Details can be taken from Table 3.

Impeding Factors for the Establishment of Emergency Vascular Access

A preprepared UVC set including the required equipment was available in 47.5% of all analyzed hospitals (28/59). During UVC establishment, the equipment was found to be incomplete in 58.8% of UVC scenarios (10/17). Preparation with the use of a UVC set was 66 seconds (26–105 s) compared with 95 seconds seconds (8–269 s) without a set (not statistically significant; $p > 0.99$).

In 41.2% of UVC establishments, teams decided to prepare a separate sterile table for all instruments and in 29.4% the patient was covered with sterile drapes. Duration for preparation in scenarios in which no sterile drapes were used was shorter (49 s, range 17–94 s) than in those with sterile draping (104 s, range 8–269 s, which was not significant, $p = 0.118$).

Delaying factors in IO access differed from those in the UVC procedure. In 20.3% (12 of the 59 recorded scenarios), the IO kit was not routinely stored in the resuscitation room. In 11.9% (five of the 42 analyzed IO scenarios), the IO kit had to be retrieved from elsewhere. With the availability of an IO kit, equipment preparation took 38 seconds (15–83 s) and without a kit 45 seconds (20–82 s) (not significant; $p = 0.612$). Other difficulties occurred according to the unfamiliar equipment of the IO access, which is not routinely used. Teams attempted to flush with the IO mandrin still in place in seven of 42 scenarios (16.7%) and 16 of 42 teams (38.1%) experienced problems with the antiembolic valve of the EZ-IO extension tubing, which hampers syringe connection. **Table 4** summarizes the observed delaying factors and provides suggestions to facilitate access establishment in neonatal resuscitation.

DISCUSSION

Previous studies have shown that during neonatal resuscitation, performed in the setting of a simulation center, IO is faster to establish than UVC (20, 21). The goal of the present study was to compare the time to establish an emergency vascular access and delaying factors for both UVC and IO in a more realistic setting. In situ simulation offers opportunities for the training of multidisciplinary teams by conducting simulations within their home clinical environment using intact and realistic teams as well as their own equipment and work processes. Therefore, the value that this study adds is the possibility of detecting real-life challenges in emergency vascular access establishment and to provide appropriate solutions.

The establishment of a PVC is difficult during cardiac arrest. To our knowledge, there are no data available concerning success rates of PVC in newborn resuscitation settings. In the present study, 52.5% of teams decided to try a PVC at least once. This decision might be explained by the fact that neonatologists, in particular, are used to dealing with difficult venous situations and within routine settings in most cases they somehow finally manage to establish a venous

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TABLE 2. Hospital and Medical Team Characteristics

Hospital Number	Hospital Category	Births Per Year	Team Number	Team Composition	Educational Level[a]	Profession[a]	Gender[a]	UVC Set	IO kit	Access
1	Perinatal center	3,300	1	1 consultant, 1 resident, 2 nurses	Consultant	Neonatology	Male	Yes	Yes	UVC
			2	1 consultant, 1 resident, 2 nurses	Consultant	Neonatology	Male			UVC
			3	1 consultant, 1 resident, 2 nurses	Consultant	Neonatology	Female			UVC
			4	2 residents, 2 nurses	Resident	Neonatology	Female			IO
2	Perinatal center	3,000	5	1 consultant, 2 residents, 2 nurses	Resident	Neonatology	Female	Yes	Yes[b]	UVC
			6	1 consultant, 1 resident, 2 nurses	Resident	Neonatology	Female			IO
			7	1 consultant, 1 resident, 2 nurses	Consultant	Neonatology	Male			IO
3	Small hospital	900	8	1 consultant, 1 resident, 2 nurses	Consultant	Neonatology	Female	No	No	IO
			9	2 consultants, 3 nurses	Consultant	Anesthesiology	Male			IO
			10	2 consultants, 3 nurses	Consultant	Anesthesiology	Male			IO
			11	2 consultants, 2 nurses	Consultant	Neonatology	Female			IO
4	Perinatal center	3,500	12	2 consultants, 1 resident, 2 nurses	Resident	Neonatology	Female	No	Yes	IO
			13	1 consultant, 1 resident, 1 nurse	Consultant	Anesthesiology	Male			IO
			14	2 consultants, 2 nurses	Consultant	Neonatology	Female			IO
			15	2 consultants, 2 nurses	Consultant	Anesthesiology	Male			IO
5	Small hospital	800	16	1 consultant, 1 resident, 1 nurse, 1 midwife	Consultant	Neonatology	Female	Yes	Yes	IO
			17	2 consultants, 2 residents, 1 nurse	Consultant	Anesthesiology	Male			IO
			18	2 residents, 2 nurses	Resident	Neonatology	Female			IO
			19	1 consultant, 2 residents, 2N	Consultant	Neonatology	Female			IO
6	Small hospital	900	20	1 consultant, 1 resident, 2 nurses	Consultant	Neonatology	Female	Yes	Yes	IO
			21	2 consultants, 1 resident, 2 nurses	Consultant	Neonatology	Female			IO
			22	2 consultants, 1 nurse, 1 midwife	Consultant	Anesthesiology	Female			IO
7	Perinatal center	2,700	23	1 consultant, 1 resident, 2 nurses	Consultant	Neonatology	Male	Yes	Yes	UVC
			24	1 consultant, 1 resident, 2 nurses	Consultant	Neonatology	Female			IO
			25	1 consultant, 1 resident, 1 medical student, 2 nurses	Consultant	Neonatology	Male			IO
			26	1 consultant, 2 residents, 2 nurses	Resident	Neonatology	Male			IO
8	Small hospital	800	27	1 consultant, 1 resident, 3 nurses	Consultant	Anesthesiology	Female	No	Yes	IO
			28	1 consultant, 1 resident, 2 nurses	Consultant	Neonatology	Male			IO
			29	2 consultants, 2 nurses	Consultant	Neonatology	Male			UVC
			30	2 consultants, 2 nurses	Consultant	Neonatology	Male			IO
9	Perinatal center	1,700	31	1 consultant, 1 resident, 2 nurses	Consultant	Neonatology	Female	No	No	UVC
			32	1 consultant, 1 resident, 2 nurses	Consultant	Neonatology	Female			UVC
			33	1 consultant, 1 resident, 2 nurses	Consultant	Neonatology	Female			UVC
			34	1 consultant, 1 resident, 2 nurses	Consultant	Neonatology	Male			UVC
10	Small hospital	1,300	35	1 consultant, 1 resident, 2 nurses	Resident	Neonatology	Female	No	Yes[c]	IO
			36	2 consultants, 1 resident, 3 nurses	Consultant	Neonatology	Male			IO
			37	2 consultants, 1 resident, 3N	Consultant	Neonatology	Female			IO
			38	2 consultants, 1 resident, 3 nurses	Consultant	Neonatology	Female			IO

(*Continued*)

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TABLE 2. (*Continued*). Hospital and Medical Team Characteristics

Hospital Number	Hospital Category	Births Per Year	Team Number	Team Composition	Educational Level[a]	Profession[a]	Gender[a]	UVC Set	IO kit	Access
11	Small hospital	1,100	39	1 consultant, 1 resident 2 nurses	Consultant	Neonatology	Female	No	yes	IO
			40	1 consultant, 1 resident, 2 nurses	Consultant	Neonatology	Female			UVC
			41	1 consultant, 1 resident, 2 nurses	Resident	Neonatology	Female			IO
12	Small hospital	1,700	42	1 consultant, 2 residents, 2 nurses	Consultant	Neonatology	Male	No	Yes	IO
			43	1 consultant, 2 residents, 2 nurses	Consultant	Neonatology	Female			IO
			44	1 consultant, 1 resident, 2 nurses	Resident	Neonatology	Female			IO
			45	2 consultants, 1 resident, 1 nurse	Consultant	Anesthesiology	Male			IO
13	Small hospital	1,000	46	1 consultant, 1 resident, 2 nurses	Consultant	Neonatology	Female	Yes	Yes[d]	UVC
			47	2 residents, 2 nurses	Resident	Neonatology	Female			UVC
14	Small hospital	900	48	1 consultant, 2 residents, 2 nurses	Consultant	Neonatology	Female	No	No	UVC
			49	2 consultants, 1 resident, 1 nurse, 1 midwife	Consultant	Neonatology	Female			UVC
			50	2 consultants, 1 resident, 1 nurse, 1 midwife	Resident	Neonatology	Female			UVC
			51	1 consultant, 2 residents, 2 nurses, 1 midwife	Resident	Anesthesiology	Male			IO
15	Small hospital	1,000	52	1 consultant, 1 resident, 2 nurses, 1 midwife	Consultant	Anesthesiology	Female	Yes	Yes[c]	IO
			53	1 consultant, 1 resident, 1 nurse, 1 midwife	Resident	Neonatology	Female			IO
			54	1 consultant, 1 resident, 1 nurse, 1 midwife	Consultant	Neonatology	Female			IO
			55	1 consultant, 2 residents, 1 nurse, 1 midwife	Consultant	Neonatology	Male			UVC
16	Perinatal center	2,000	56	1 consultant, 1 resident, 2 nurses	Consultant	Neonatology	Female	Yes	Yes	IO
			57	1 consultant, 1 resident, 2 nurses	Consultant	Neonatology	Male			IO
			58	1 consultant, 1 resident, 2 nurses	Consultant	Neonatology	Male			IO
			59	1 consultant, 1 resident, 2 nurses	Consultant	Neonatology	Female			IO

IO = intraosseous access, UVC = umbilical venous catheter.

[a]Relating to the access performing person.

[b]IO available only in the delivery room, none in the operating room area for caesarean delivery.

[c]Cook-needle in the delivery room; EZ-IO system in the operating room.

[d]EZ-IO in the delivery room; Cook-needle in the operating room.

access. However, routine situations cannot be compared to a resuscitation situation with collapsed veins and additional high emotional pressure. Another possible explanation for the numerous and long PVC attempts could also lie in fear of failure in the very rarely used UVC or IO techniques. The mean duration for PVC attempts in this study was 93 seconds; however, this involved the use of a mannequin (simple skin puncture without realistic venous anatomy), which is why in humans, the time for PVC attempts is assumed to be even longer. For pediatric patients, the ERC recommends spending at the utmost 60 seconds on PVC attempts (24) which probably should also apply to newborns. The present study is not able to provide success rates for PVC; however, we presume that PVC attempts take valuable time and a fast switch to alternative access possibilities has to be emphasized in resuscitation training.

This study confirms previously published results because we found that the overall time for IO establishment was less than half of that for UVC (86 s compared with 199 s). Further, preparation for UVC was twice as long as that for IO, which was mainly caused by the multitude of instruments necessary compared with the simpler IO equipment. Preparation was faster when a preprepared set was used. Although this result was only a trend, the necessity of sending someone to nearby wards to collect equipment during a stressful resuscitation situation does not only leave the team with one person less but also may result in increased stress levels for all team members. Consequently, having a

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TABLE 3. Duration for Implementation of an Emergency Vascular Access

Duration	Definition	Mean Duration Intraosseous Access, in Seconds (Range)	Mean Duration Umbilical Venous Catheter, in Seconds (Range)	Difference (CI, 2.5–97.5%)	*p*
Duraccess	Decision to first flush/aspiration				
	All hospitals	86 (39–190)	199 (104–398)	113 (75.9–151.1)	< 0.001[a]
	Large perinatal centers	77 (44–150)	166 (104–238)	89 (52–128)	0.009[a]
	Small hospitals	89 (39–190)	235 (106–398)	146 (84–213)	0.002[a]
Durprep	Decision to start of procedure				
	All hospitals	39 (15–83)	82 (8–269)	42 (12.3–76.2)	0.008[a]
	Large perinatal centers	36 (20–78)	59 (8–105)	23 (–0.8 to 47)	0.179
	Small hospitals	41 (15–83)	107 (25–269)	67 (11–135)	0.059
Durproc1	Start of procedure to first flush/aspiration				
	All hospitals	46 (20–115)	117 (67–194)	71 (50.4–91.1)	< 0.001[a]
	Large perinatal centers	41 (20–115)	107 (75–158)	66 (33–90)	0.009[a]
	Small hospitals	48 (21–113)	128 (67–194)	79 (44–112)	< 0.002[a]
Durproc2	Start of procedure to end of procedure				
	All hospitals	23 (10–108)	101 (58–160)	78 (63.0–93.7)	< 0.001[a]
	Large perinatal centers	21 (10–108)	103 (72–149)	81 (59–103)	0.009[a]
	Small hospitals	23 (10–49)	99 (58–160)	75 (50–100)	0.001[a]

[a]Significant at 5% significance level after Bonferroni adjustment for multiple testing.

Comparison of durations to implement intraosseous access and umbilical venous catheter access in all hospitals and separately for large perinatal centers and small hospitals.

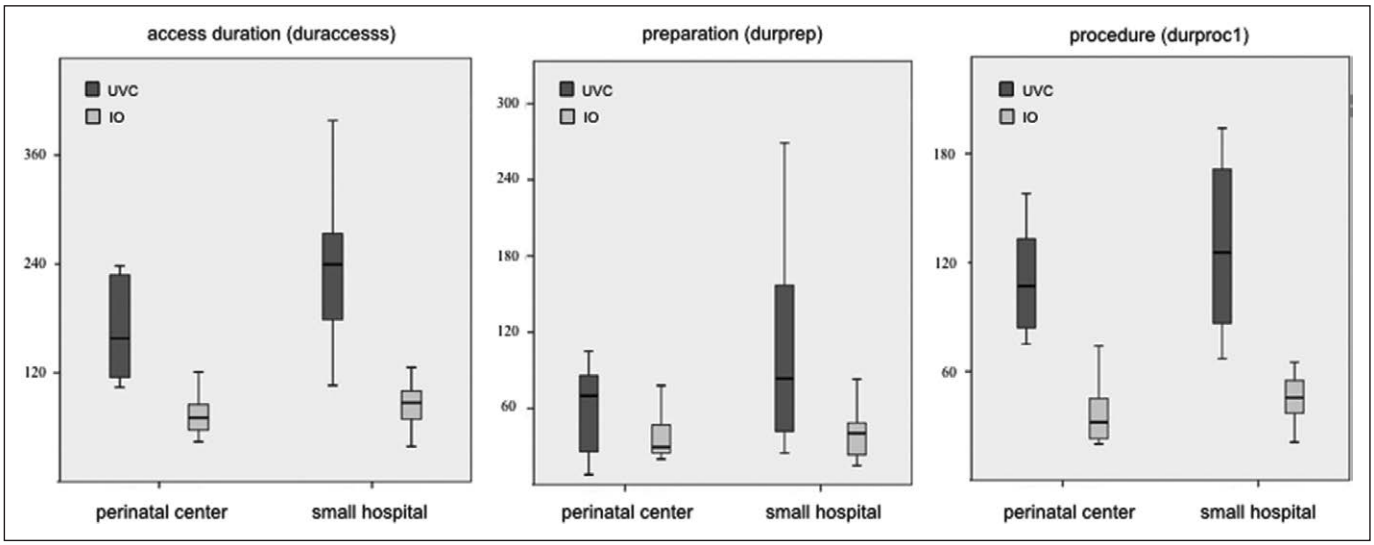

Figure 2. Comparison of access durations in large perinatal centers and small hospitals for total access duration (duraccess), duration of preparation (durprep) and duration for procedure (durproc1). Numbers are given in seconds (results not statistically significant). IO = intraosseous access, UVC = umbilical venous catheter.

preprepared UVC set and an IO kit ready to hand within the resuscitation room should be recommended in newborn resuscitation guidelines.

Furthermore, the procedure to establish an emergency vascular access itself (preparation excluded) was significantly shorter for IO compared with UVC. One reason for this

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TABLE 4. Observed Delaying Factors and Suggestions to Facilitate the Establishment of an Emergency Vascular Access in Neonatal Resuscitation

Delaying Factors	Frequency, *n* (%)[a]	Possible Solution
A) UVC (*n* = 17)		
Equipment incomplete	58.8 (10)	Availability of a preprepared UVC set including all required instruments
Excessive hygienic approaches	58.8 (10)	Medical team training at regular intervals
Sterile table	41.2 (7)	
Sterile cover	29.4 (5)	
B) IO (*n* = 42)		
No IO kit available in the resuscitation room	11.9 (5)	Provision of IO kits in the resuscitation room and in the operating room area (caesarean delivery)
Handling of the unfamiliar equipment	50.0 (21)	Medical team training at regular intervals
Mandrin removal	16.7 (7)	
Extension tubing	38.1 (16)	

IO = intraosseous access, UVC = umbilical venous catheter.
[a]Frequency according to the numbers found in this study.

observation may be the complex approach of UVC including a multitude of time-consuming steps (use of umbilical tape, cutting of the cord, vein identification, catheter insertion, and fixation). Additionally, in humans, belly motion due to chest compressions additionally hampers the maneuver. The duration of the procedure was also influenced by uncertainty of required hygiene standards. We assume that the mental model of neonatologists is to work under as sterile conditions as possible (as they act all day in routine situations). The sudden switch from routine to emergency is difficult, so that the same hygiene standards are applied. Procedure duration in the present study tended to be longer when sterile actions were applied. Therefore, educational programs have to emphasize that, during resuscitation, one should work as cleanly as possible—but more important—as fast as possible.

Regarding the actual procedure (start of the procedure until catheter/IO was in situ) without waiting for the first flush/aspiration, the establishment time for UVC was four times longer than that for IO (101 s compared with 23 s). Practical training probably could speed up both approaches, but we believe that accelerations in UVC establishment time are restricted because of the multitude of time-consuming steps required. Because the procedure to establish an IO access was mainly delayed by handling of the unfamiliar equipment, duration for establishment of IO may be further reduced by regular training and education of medical teams. However, future studies taking into consideration difficulties occurring in dealing with humans and real-life anatomy are necessary.

Altogether, 29% of the teams decided on UVC and 71% on IO. Although the teams chose the procedure on their own, these numbers cannot be definitely extrapolated to real-life settings due to a potential bias in the initial lecture, which was given slightly in favor of IO by the supervisor. In addition, during training events, teams might try out new methods, which they may not use in actual patients. These clearly are limitations in this study. Nevertheless, the study results show that in simulated neonatal resuscitation, medical teams in small hospitals more frequently tended to choose IO than UVC (78% compared to 61% in large perinatal centers)—regardless of the absence of an IO recommendation in the current ERC guidelines. It seems obvious that medical teams in larger centers with assumingly higher experience levels will find it easier to establish a complex emergency vascular access approach such as an UVC, compared with teams in smaller hospitals. In a subgroup analysis, we compared the durations needed for UVC, respectively, IO establishment in both hospital types. Although not significant, we observed a trend that indeed UVCs took longer in small hospitals than in centers, whereas the duration to establish an IO access was similar in both hospital types. This confirms our observation from simulation training that apart from large perinatal centers, due to the lack of training possibilities, the establishment of a UVC is challenging. According to these results, resuscitation guidelines should recommend both access possibilities so that medical teams can decide according to their level of experience.

As the training occurred in actual hospital settings, with actual medical teams and the use of their own equipment, durations for access preparation are indeed assumed to reflect real-life situations. On the other hand, because of the use of a mannequin, measured duration for access establishment cannot be extrapolated to real life. To our knowledge, there are no data available evaluating the realism of the SimNewB's access possibilities. The umbilical cord of the SimNewB exhibits two umbilical arteries and one vein, which can be cannulated. However, vein identification in human newborns probably is more challenging than in a mannequin, and this is even aggravated by simultaneous chest compressions and emotional stress. Therefore, actual establishment

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times of UVC are thought to be even longer in real life. For IO access, since there is no anatomically correct tibia integrated in the SimNewB's legs, correct identification of the insertion site (proximal tibia) in a human newborn might also further delay access establishment in reality. Probably more important, however, is the limited possibility of assessing success and complication rates with the use of a mannequin. Certainly, we were not able to provide information about extravasation, compartment syndrome, or bone fracture. Therefore, it has to be emphasized that as well as for the newer IO approach but also for the well-established UVC, there is no evidence that these techniques are indeed safe and efficient in neonatal emergency situations. In the next step, human studies are required, designed to evaluate the efficacy and safety of both access routes in real resuscitation settings.

The training sessions analyzed in this study all took place in Austrian or German hospitals. Education, hospital settings and also resuscitation guidelines vary in different countries. Therefore, our study results might not be generalizable to hospitals in other countries.

CONCLUSIONS

Medical teams have to be provided with the best possible infrastructure and education to be able to perform as best as they can. Infrastructural improvements and regular training of medical teams are necessary to accelerate the establishment of both access approaches, UVC and IO. In simulated in situ newborn resuscitation, the IO access was twice as fast to establish compared with the UVC. Especially, in small hospitals, the duration to establish an UVC is longer compared with large perinatal centers. Therefore, IO should be mentioned as an alternative emergency vascular access in resuscitation guidelines until clear evidence is provided.

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REFERENCES

1. Perlman JM, Risser R: Cardiopulmonary resuscitation in the delivery room. Associated clinical events. *Arch Pediatr Adolesc Med* 1995; 149:20–25
2. Wyllie J, Bruinenberg J, Roehr CC, et al: European Resuscitation Council Guidelines for Resuscitation 2015: Section 7. Resuscitation and support of transition of babies at birth. *Resuscitation* 2015; 95:249–263
3. Arnts IJ, Bullens LM, Groenewoud JM, et al: Comparison of complication rates between umbilical and peripherally inserted central venous catheters in newborns. *J Obstet Gynecol Neonatal Nurs* 2014; 43:205–215
4. Haase R, Hein M, Thäle V, et al: Umbilical venous catheters - analysis of malpositioning over a 10-year period. *Z Geburtshilfe Neonatol* 2011; 215:18–22
5. Kim JH, Lee YS, Kim SH, et al: Does umbilical vein catheterization lead to portal venous thrombosis? Prospective US evaluation in 100 neonates. *Radiology* 2001; 219:645–650
6. Ullman AJ, Marsh N, Mihala G, et al: Complications of central venous access devices: A systematic review. *Pediatrics* 2015; 136:e1331–e1344
7. Maconochie IK, Bingham R, Eich C, et al; Paediatric life support section Collaborators: European resuscitation council guidelines for resuscitation 2015: Section 6. Paediatric life support. *Resuscitation* 2015; 95:223–248
8. Hallas P, Brabrand M, Folkestad L: Complication with intraosseous access: Scandinavian users' experience. *West J Emerg Med* 2013; 14:440–443
9. Hansen M, Meckler G, Spiro D, et al: Intraosseous line use, complications, and outcomes among a population-based cohort of children presenting to California hospitals. *Pediatr Emerg Care* 2011; 27:928–932
10. Sunde GA, Heradstveit BE, Vikenes BH, et al: Emergency intraosseous access in a helicopter emergency medical service: A retrospective study. *Scand J Trauma Resusc Emerg Med* 2010; 18:52
11. Voigt J, Waltzman M, Lottenberg L: Intraosseous vascular access for in-hospital emergency use: A systematic clinical review of the literature and analysis. *Pediatr Emerg Care* 2012; 28:185–199
12. Oesterlie GE, Petersen KK, Knudsen L, et al: Crural amputation of a newborn as a consequence of intraosseous needle insertion and calcium infusion. *Pediatr Emerg Care* 2014; 30:413–414
13. Simmons CM, Johnson NE, Perkin RM, et al: Intraosseous extravasation complication reports. *Ann Emerg Med* 1994; 23:363–366
14. Suominen PK, Nurmi E, Lauerma K: Intraosseous access in neonates and infants: Risk of severe complications - a case report. *Acta Anaesthesiol Scand* 2015; 59:1389–1393
15. Ellemunter H, Simma B, Trawoger R, et al: Intraosseous lines in preterm and full term neonates. *Arch Dis Child Fetal Neonatal Ed* 1999; 80:F74–5
16. Engel WA: Intraosseous access for administration of medications in neonates. *Clin Perinatol* 2006; 33:161–8, ix
17. Kakhandki SK: Intraosseous infusion in a LBW neonate. *Indian Pediatr* 1997; 34:748–749
18. Lake W, Emmerson AJ: Use of a butterfly as an intraosseous needle in an oedematous preterm infant. *Arch Dis Child Fetal Neonatal Ed* 2003; 88:F409
19. Ramet J, Clybouw C, Benatar A, et al: Successful use of an intraosseous infusion in an 800 grams preterm infant. *Eur J Emerg Med* 1998; 5:327–328
20. Abe KK, Blum GT, Yamamoto LG: Intraosseous is faster and easier than umbilical venous catheterization in newborn emergency vascular access models. *Am J Emerg Med* 2000; 18:126–129
21. Rajani AK, Chitkara R, Oehlert J, et al: Comparison of umbilical venous and intraosseous access during simulated neonatal resuscitation. *Pediatrics* 2011; 128:e954–e958
22. Bundesministerium fuer Gesundheit, Gesundheit Oesterreich GmbH: Österreichischer Strukturplan Geundheit 2012. Available at: https://www.bmgf.gv.at/cms/home/attachments/1/0/1/CH1071/CMS1136983382893/oesg_2012_text_ohne_matrizen_-_neue_links.pdf. Accessed June 29, 2017
23. Gemeinsamer Bundesausschuss Berlin, Germany: Richtlinie fuer die Versorgung von Frueh- und Neugeborenen: G-BA beschliesst inhaltliche und strukturelle Ueberarbeitung. Available at: https://www.g-ba.de/institution/presse/pressemitteilungen/495/2013. Accessed July 25, 2017
24. Biarent D, Bingham R, Eich C, et al: European resuscitation council guidelines for resuscitation 2010 section 6. Paediatric life support. *Resuscitation* 2010; 81:1364–1388

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