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Abstract

Background: Peripheral intravenous catheter (PIVC) failure and difficult intravenous access (DIVA) are pervasive issues causing patient suffering and increased costs. Despite their prevalence, there is a gap in internal medicine and pediatric resident training to manage these challenges effectively.

Objective: This study aimed to assess the value of ultrasound-guided-PIVC (USGPIVC) education for internal medicine and pediatric residents and the impact of a 1-hour multidisciplinary workshop on their knowledge and confidence.

Methods: A cross-sectional survey study was conducted at an academic medical center in 2022 to assess residents' perceptions of USG-PIVC education. This was followed by a USG-PIVC simulation-based workshop with limited enrollment (11-slots). Pre- and postworkshop assessments were used to evaluate changes in knowledge and confidence. Data were analyzed using descriptive statistics.

Results: Of the 136 residents surveyed, 68 (50%) responded. Most respondents (78%) reported encountering situations where no one could obtain DIVA. While 71% (n=48) of residents considered USG-PIVC placement a useful skill, only 13% (n=9) had prior experience.

Following the workshop, the 11 participants had improvement in both confidence (mean pre-assessment score of 38.2 ±8.3 increased to 56.6 ±6.4, p

Conclusions: Most internal medicine and pediatric residents at an academic medical center lack experience with USG-PIVC insertion and express interest in acquiring this skill. A one-hour multidisciplinary workshop may be an effective strategy to increase their knowledge and confidence, making it a promising avenue for enhancing residency curricula.

Keywords

Medical Education, Simulation Training, Ultrasound, Catheterization, Difficult Intravenous Access, Multidisciplinary Workshop

Cover Page Footnote

Disclosures: The authors have no conflicts of interest relevant to this article to disclose Funding/Support: Our study utilized the Research Electronic Data Capture (REDCap) software for survey development and data collection, which was obtained through the UNMC Office of the Vice Chancellor for Researchers. Biostatistics services were provided by the College of Public Health at UNMC. The Simulation Laboratory at the Davis Global Center iEXCEL provided space and ultrasound equipment for the successful completion of the workshop. Role of Funders: The authors are solely responsible for the content of this paper, which may not necessarily reflect the official views of the funding organizations. The funding organizations were not involved in the design, preparation, review, or approval of this paper. Contributor Statements: Dr. Lamarche was responsible for the study's conceptualization and design and conducted data collection, analysis, and interpretation. Dr. Lamarche led the simulation-based workshop,

coordinated the event, developed and presented the content for the didactic session, and supervised participants during the hands-on portion of the workshop. In addition, Dr. Lamarche drafted the initial manuscript and reviewed and revised the manuscript. Dr. Claudy provided oversight for the study's conceptualization and design and supervised data collection, analysis, and interpretation. Additionally, she oversaw the workshop, contributed her knowledge to the didactic session, and supervised the participants during the hands-on session. She critically reviewed and revised the manuscript and ultimately approved the final manuscript for submission. Dr. Marx provided oversight for the study's conceptualization and design. Assisted with content development for the didactic portion of the workshop, provided pre-workshop educational videos, and supervised participants during the hands-on portion of the workshop. He critically reviewed and revised the manuscript and ultimately approved the final manuscript for submission. Ms. Ma contributed to the development of the surveys in this study. She was involved in data analysis and interpretation and assisted with drafting the methods section of the manuscript. She approved the final manuscript for submission. Acknowledgments: The authors would like to express their appreciation to Jeff Whannel, Advanced Simulation Specialist at the Simulation Laboratory Davis Global Center iEXCEL, for his assistance in accommodating sessions to refine the workshop's contents.

Perceived Importance of Ultrasound Vascular Access Education among Residents

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Abstract

Background: Peripheral intravenous catheter (PIVC) failure and difficult intravenous access (DIVA) are pervasive issues causing patient suffering and increased costs. Despite their prevalence, there is a gap in internal medicine and pediatric resident training to manage these challenges effectively.

Objective: This study aimed to assess the value of ultrasound-guided-PIVC (USG-PIVC) education for internal medicine and pediatric residents and the impact of a 1-hour multidisciplinary workshop on their knowledge and confidence.

Methods: A cross-sectional survey study was conducted at an academic medical center in 2022 to assess residents' perceptions of USG-PIVC education. This was followed by a USG-PIVC simulation-based workshop with limited enrollment (11-slots). Pre- and post-workshop assessments were used to evaluate changes in knowledge and confidence. Data were analyzed using descriptive statistics.

Results: Of the 136 residents surveyed, 68 (50%) responded. Most respondents (78%) reported encountering situations where no one could obtain DIVA. While 71% (n=48) of residents considered USG-PIVC placement a useful skill, only 13% (n=9) had prior experience.

Following the workshop, the 11 participants had improvement in both confidence (mean pre-assessment score of 38.2 ±8.3 increased to 56.6 ±6.4, p<.001) and knowledge (mean pre-test score of 13 improved to 15.6, p=0.009).

Conclusions: Most internal medicine and pediatric residents at an academic medical center lack experience with USG-PIVC insertion and express interest in acquiring this skill. A one-hour multidisciplinary workshop may be an effective strategy to increase their knowledge and confidence, making it a promising avenue for enhancing residency curricula.

Keywords

Medical Education, Simulation Training, Ultrasound, Catheterization, Difficult Intravenous Access, Multidisciplinary Workshop

Abbreviations

CVC = central venous catheter
DIVA = difficult intravenous access
USG-PIVC = ultrasound-guided peripheral intravenous catheter
PIVC = peripheral intravenous catheter
RN= Registered Nurse

Introduction

Difficult intravenous access (DIVA), mostly defined as two or more failed attempts at peripheral intravenous access, and no visible or palpable veins, is a common problem in hospitalized patients that can have adverse effects on patient care, including delays in resuscitation, nonproductive nursing time, increased costs, and patient suffering.[1-4] Studies have reported that more than one in three PIVCs fail before completion of inpatient treatment. Additionally, up to 43% of hospitalized patients and up to 59% of highly complex hospitalized patients meet DIVA criteria.[5,6] Furthermore, 36.8% of children admitted to a pediatric critical care unit were reported to have DIVA.[7]

Ultrasound-guided PIVC (USG-PIVC) insertion is a promising approach for patients with DIVA, as it is associated with an increased first attempt and overall placement success rates.[1,4,8-13] In adult and pediatric patients, USG-PIVC placement has been found to increase the longevity of access with fewer complications, improve patient satisfaction, and decrease central venous catheter (CVC) use.[1,3,4,8-18] Placement of USG-PIVC in DIVA patients may negate the need for more invasive vascular access, such as CVCs or intraosseous needles, and thus eliminate complications associated with these procedures, including but not limited to infection, pneumothorax, and fracture.[3,4]

In many academic medical centers, there is limited emphasis on training internal medicine and pediatric residents to perform peripheral intravenous catheter (PIVC) insertion. To our knowledge, no studies have explored the value of USG-PIVC insertion training from the perspective of these residents. Therefore, this study aims to explore the value of USG-PIVC training from the perspective of internal medicine, internal medicine/pediatrics, and pediatric residents. Additionally, we conducted a small (11 slots) multidisciplinary USG-PIVC insertion workshop to assess changes in knowledge and confidence after training.

Methods

This cross-sectional survey study was conducted at an academic medical center. The Office of Regulatory Affairs determined that this project does not constitute human subjects research, and no Institutional Review Board application was required.

All internal medicine (n=77), internal medicine/pediatrics (n=16), and pediatric (n=43) residents were invited to participate in the study by completing an anonymous survey on March 27, 2022, through Research Electronic Data Capture (Copyright, REDCap., Nashville, Tennessee, U.S.), which included nine questions **(Supplement 1)**. Two survey reminders were sent on April 26, 2022, and May 9, 2022, respectively. Participation in the survey was voluntary.

The same residents were also invited to participate in a multidisciplinary simulation-based USG-PIVC placement workshop on April 19, 2022. Enrollment was based on an online signup software and was limited to eleven available slots. Prior to the workshop, participants were asked to review USG-PIVC procedure videos **(Supplement 2)**. The workshop comprised a 30-minute didactic session followed by hands-on practice using chicken-breast vascular access models to simulate percutaneous vascular access (method developed by Rippey *et al*[19,20]). All participants completed pre-workshop assessments of confidence (14 items) and

knowledge (18 items) **(Supplement 3)**. Post-workshop assessments were completed four days after the workshop.

Descriptive statistics were used to summarize data, and statistical significance was set at $p < .05$. The paired t-test was used to evaluate continuous data with normal distributions from pre- and post-workshop knowledge and confidence assessments. For continuous data with non-normal distributions, Mann-Whitney U and Kruskal Wallis tests were used. Finally, categorical data were evaluated using Chi-squared and Fisher exact tests. The SAS software version 9.4 (Copyright, SAS Institute Inc., Cary, North Carolina, USA) was used for all statistical analyses.

Results

Out of 136 residents, 68 (50%) responded to the perception survey. Of these, 14 (21%) were pediatric residents, 39 (57%) were internal medicine residents, and 15 (22%) were internal medicine/pediatrics residents. The latter corresponds to 50.6% of the total internal medicine residents, 94% of the total internal medicine/pediatrics residents, and 32.5% of the total pediatric residency class **(Figure 1)**. Most residents, 71% (n= 48), perceived USG-PIVC placement as a useful skill for them. However, this perception varied by training specialty. All internal medicine/pediatrics residents indicated that USG-PIVC would be useful compared to 60% of pediatric residents and 62% of internal medicine residents ($p<0.001$).

Additionally, 72% (n=49) of all residents indicated an interest in USG-PIVC training at some point during their careers, but only 13% (n=9) had prior experience with the procedure. Fifty-three (78%) residents reported having been in a situation where a patient needed vascular access, RNs were unsuccessful at landmark-guided PIVC insertion, and the vascular access team was not readily available. Only 61% (n=24) of internal medicine residents encountered this clinical situation, compared to 100% of pediatric and internal medicine/pediatrics residents ($p=0.0004$) **(Table. 1)**.

Ninety-three percent (n = 63) of the surveyed residents held the perception that USG-PIVC placement was less likely to result in severe complications compared to CVC placement. Notably, no significant association was observed between the residents' year of residency and any of the variables included in the perception survey.

Simulation-based Training Results

Of the 136 total residents, 11 (8%) participated in a simulation-based workshop on USG-PIVC placement **(Figure 2)**. Participation was limited by simulation workshop size and enrollment proceeded on a rolling basis. Participants' confidence in this skill significantly improved following the workshop; on a scale of 1-70, mean pre-assessment score of 38.2 ±8.3 increased to 56.6 ±6.4 on post-workshop assessment ($p < .001$) **(Table. 2)**. Participants also demonstrated increased knowledge after the workshop; On a scale of 1-18, average pre-test knowledge scores of 13 improved to 15.6 on the post-workshop test ($p= 0.009$) **(Table. 3)**.

Discussion

Nearly all hospitalized patients undergo PIVC insertion with over 90% of hospitalized adults,[21] and up to 81% of pediatric patients admitted to our free-standing children's

Figure 1. Distribution of Perception Survey Respondents Across Residency Programs.

Table 1. Perception Survey Responses Reported as Number (%)

Abbreviated Items	Total	Internal Medicine	Internal Medicine/ Pediatrics	Pediatrics	*P* value
Experiencing a situation where a patient has DIVA, and no one can obtain PIVC access	53 (78)	24 (62)	15 (100)	14 (100)	0.0004*
Interest in USG-PIVC training	49 (72)	24 (62)	15 (100)	10 (71)	0.0008+
Residents that have never placed an USG-PIVC	59 (87)	37 (95)	12 (80)	10 (71)	0.04++

Abbreviations: DIVA, difficult intravenous access; PIVC, peripheral intravenous catheter; USG-PIVC, ultrasound-guided-PIVC.
*Fisher's exact test indicated significant differences between Internal Medicine & both Internal Medicine/Pediatrics (p=0.005) and Pediatrics (p=0.005); overall p-value in table.
+Fisher's exact test r showed differences between Internal Medicine & Pediatrics (p=0.74), Internal Medicine & Internal Medicine/Pediatrics (p=0.005), and Internal Medicine/Pediatrics & Pediatrics (p=0.04); overall p-value in table.
++Fisher's exact test revealed differences between Internal Medicine & Pediatrics (p=0.03), Internal Medicine & Internal Medicine/Pediatrics (p=0.12), and Internal Medicine/Pediatrics & Pediatrics (p=0.68); overall p-value in table.

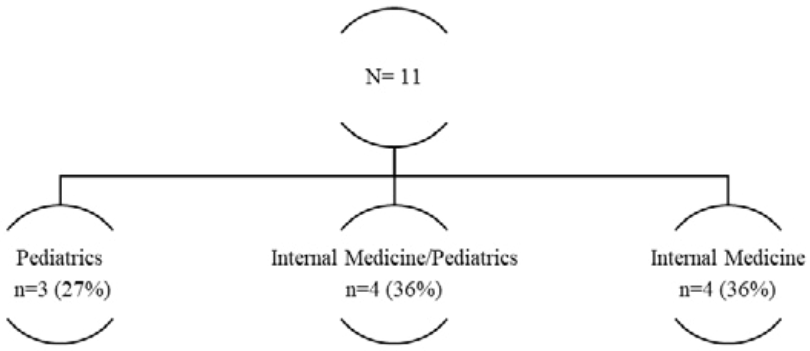

Figure 2. Workshop Participants by Training Specialty.

Table 2. Pre- and Post-workshop Confidence Assessment of USG-PIVC Placement Micro-skills. Frequency of "agree and strongly agree" Responses (N=11), Reported as Number (%)

Abbreviated Items	Pre-workshop	Post-workshop	*P* value*
I can choose the best probe to place a USG-PIVC	2 (18)	11 (100)	<0.001
I can interpret the images on the US screen in relation to the probe marker	3 (27)	11 (100)	<0.001
I can identify the vascular anatomy of the upper extremity	1 (9)	9 (81)	<0.001
I can identify veins	6 (54)	11 (100)	0.001
I can identify arteries	7 (63)	11 (100)	0.01
I can identify nerves	1 (9)	4 (36)	0.004
I can optimize depth	1 (9)	10 (91)	<0.001
I can adjust the gain to better visualize my target vessel	1 (9)	10 (91)	<0.001
I can identify the distance to the target vein	1 (9)	8 (72)	<0.001
I can select the right catheter size and length	0	5 (45)	<0.001
I can navigate the needle tip inside the vessel using US	2 (18)	10 (91)	<0.001
I can verify that I placed the catheter correctly using US	2 (18)	10 (91)	<0.001
I can properly disinfect the probes and US machine	6 (54)	11 (100)	0.004
I can obtain a USG-PIVC	0	9 (81)	<0.001

Abbreviations: USG-PIVC, ultrasound-guided peripheral intravenous catheter; US, ultrasound.
*Paired t-test was used to evaluate the difference between pre-post confidence levels.

Table 3. Pre- and Post-Workshop Knowledge Quiz Correct Response Frequency (N=11), Reported as Number (%)

Abbreviated Questions	Pre-Workshop	Post-Workshop	*P* value*
Population in which USG-PIVC can be used	10 (91)	11 (100)	0.34
Ideal probe for USG-PIVC	10 (91)	10 (91)	
CVCs versus PIVCs for volume resuscitation	11 (100)	11 (100)	
Best USG-PIVC vessel for beginners	4 (36)	8 (73)	0.1
Ideal USG-PIVC vessel characteristics	6 (54)	9 (82)	0.08
Artery identification	10 (91)	10 (91)	
Vein identification	5 (45)	8 (73)	0.19
Optimal Angle of insonation	9 (82)	9 (82)	
How to hold the US probe	10 (91)	7 (64)	0.08
Selecting the appropriate catheter length	1 (9)	5 (45)	0.03
Gain adjustment	11 (100)	11 (100)	
Depth adjustment	9 (82)	11 (100)	0.16
US machine positioning	9 (82)	10 (91)	0.58
Short axis technique	11 (100)	9 (82)	0.16
Long axis technique	9 (82)	10 (91)	0.58
USG-PIVC complications	11 (100)	11 (100)	
Process of navigating the needle tip	4 (36)	9 (82)	0.05
Next step after achieving catheter "blood-flash"	4 (36)	11 (100)	0.001

Abbreviations: USG-PIVC, ultrasound-guided peripheral intravenous catheter; CVC, central venous catheter; US, ultrasound.
*Paired t-test was used to evaluate the difference between pre-post confidence levels.

hospital requiring a PIVC. Despite the ubiquity of this procedure, PIVC failure rates and DIVA rates remain unacceptably high.[5,6] Consequently, we expected that most residents in our study would experience situations where DIVA could not be obtained. While it is important to consider the frequency of such events, our data suggest that training internal medicine and pediatric residents in USG-PIVC could improve patient care. Given that PIVC is a common and critical procedure, there is a need for further studies to investigate whether expanding vascular access expertise to internal medicine and pediatric residents could lead to improved patient outcomes. This may be particularly relevant for residents planning to care for inpatients or work in rural settings, where vascular access teams may not be available. Our survey showed that most residents found USG-PIVC training to be useful, emphasizing the importance of incorporating this skill into their training. Due to the limited workshop size, this study is underpowered to conduct a subgroup analysis of the perceived value of USG-PIVC training (comparing workshop participants to non-participants).

This study demonstrates that a majority of surveyed residents had never placed a USG-PIVC despite perceiving it as a useful skill. Residents in this study also anticipated a lower success rate for the procedure if a RN had unsuccessfully attempted landmark-guided PIVC insertions. This is consistent with prior research, which suggests that RNs have higher success rates than physicians with landmark-guided PIVC insertion (44% compared to 23%[11]). RNs trained to obtain USG-PIVCCs are capable of a greater than 70% success rate after four USG-PIVC attempts in adults[22] and nine USG-PIVC attempts in pediatric patients.[23] While the learning curve for USG-PIVC use has not been formally evaluated in residents, evidence suggests that experienced physicians have a better first-stick success rate with USG-PIVC insertion compared to RNs and technicians.[24] Furthermore, there is evidence that novice medical students perceive USG-PIVC placement as less difficult compared to landmark-guided PIVC insertion.[25] Ultimately, more research is needed to evaluate the USG-PIVC learning curve for residents.

This study shows a significant improvement in provider confidence following a 1-hour simulation-based training. All items in the confidence assessment had a statistically significant improvement between pre-and post-workshop assessments. These results are consistent with Adhikari *et al*., who demonstrated the utility of workshop-based training in improving confidence with procedural skills.[26] Interestingly, most individual items on the knowledge quiz did not show significant changes between pre- and post-workshop assessments. This could indicate that participants were already familiar with certain concepts due to prior point-of-care ultrasound education. Nevertheless, composite scores did demonstrate an improvement in knowledge (p=0.009), suggesting that the workshop improved global knowledge regarding USG-PIVC placement.

Considering the well-established benefits of ultrasound procedural guidance,[8] interdisciplinary ultrasound education presents a promising approach to broadening the pool of educators and fostering collaboration among healthcare providers.[27] Additionally, using chicken-breast vascular access models may offer a cost-effective alternative to phantom blocks for training purposes.[19]

Limitations

Our study has many limitations, including the voluntary nature of the survey, which introduces the possibility of selection bias, and the dependence of our results on the

accuracy of reported data. Although a 50% response rate is typically deemed acceptable for survey-based research, the inherent limitations of this methodology must be acknowledged. Our workshop results were susceptible to the recency effect, which was mitigated by administering the post-test four days after the training. In addition, competency assessment by direct observation in a patient care setting to determine USG-PIVC proficiency was not performed, and we did not study long-term retention of procedural skills. It is unclear whether the confidence and knowledge gained during training will translate into patient care settings.

It's worth noting that a high response rate from internal medicine/pediatrics residents (94%) compared to 32.5% and 50.6% from pediatric and internal medicine classes respectively could introduce bias, as the author was affiliated with the internal medicine/pediatrics program.

Lastly, our study lacks external validity as it is unclear whether the perceptions and results of the interventions are particular to the residents from this training program. Despite these limitations, the present study provides valuable insights into the potential benefits of incorporating USG-PIVC training into internal medicine and pediatric residency programs.

Conclusion

The results of this study reveal that the majority of residents at this academic medical center have faced situations where no one was available to obtain DIVA, and they lack experience with USG-PIVC but express interest in acquiring this skill. Based on our findings, a brief one-hour multidisciplinary workshop may be an effective strategy to increase residents' knowledge and confidence in using USG-PIVC, thereby offering a promising avenue for enhancing the internal medicine and pediatric residency curricula. The potential benefits of providing residents with this skill are significant, including improved patient care and potentially lower rates of PIVC failure. Overall, our study suggests the need for incorporating USG-PIVC training into residency programs to address the challenges of obtaining vascular access in clinical settings. ■

Disclosures

The authors have no conflicts of interest relevant to this article to disclose Funding/Support: Our study utilized the Research Electronic Data Capture (REDCap) software for survey development and data collection, which was obtained through the UNMC Office of the Vice Chancellor for Researchers. Biostatistics services were provided by the College of Public Health at UNMC. The Simulation Laboratory at the Davis Global Center iEXCEL provided space and ultrasound equipment for the successful completion of the workshop. Role of Funders: The authors are solely responsible for the content of this paper, which may not necessarily reflect the official views of the funding organizations. The funding organizations were not involved in the design, preparation, review, or approval of this paper.

Authors Contribution

Dr. Lamarche was responsible for the study's conceptualization and design and conducted data collection, analysis, and interpretation. Dr. Lamarche led the simulation-based workshop, coordinated the event, developed and presented the content for the didactic session, and supervised participants during the hands-on portion of the workshop. In addition, Dr. Lamarche drafted the initial manuscript and reviewed and revised the manuscript. Dr. Claudy provided oversight for the study's conceptualization and design and supervised data collection, analysis, and interpretation. Additionally, she oversaw the workshop, contributed her knowledge to the didactic session, and supervised the participants during the hands-on session. She critically reviewed and revised the manuscript and ultimately approved the final manuscript for submission. Dr. Marx provided oversight for the study's conceptualization and design. Assisted with content development for the didactic portion of the workshop, provided pre-workshop educational videos, and supervised participants during the hands-on portion of the workshop. He critically reviewed and revised the manuscript and ultimately approved the final manuscript for submission. Ms. Ma contributed to the development of the surveys in this study. She was involved in data analysis and interpretation and assisted with drafting the methods section of the manuscript. She approved the final manuscript for submission.

Acknowledgments

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