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Improving vascular access knowledge and assessment skill of hemodialysis staff

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Abstract

Context: Vascular access malfunction and failure contribute to morbidity and hospitalization in hemodialysis populations. Although controversy still exists over the identification and appropriate management of access malfunction, recognition of sentinel signs during physical examination remains an efficient way to screen for access malfunction. Dialysis staff are on the front line of providing quality care to dialysis patients, often being the first ones who could detect early physical signs of access malfunction.

Objectives: The study's purpose is to determine the effect of an advanced vascular access educational module presented to hemodialysis nurses and technicians, focusing on physical examination findings to identify a dialysis access at risk for malfunction.

Methods: Utilizing a quasi-experimental pretest and posttest group design with a nonequivalent comparison control group, the effect of an advanced vascular access education module to improve vascular access knowledge and skill in recognition of sentinel signs of access malfunction was studied in a group of hemodialysis nurses (registered nurses [RNs]) and certified patient care technicians (PCTs).

Results: Knowledge post-test scores (RN, M=94.44, SD=7.05; PCT, M=90.83, SD=7.93) were significantly higher than pretest scores (RN, M=79.54, SD=12.47; PCT M=80.67, SD=7.99) in the intervention group ($p<0.001$) but not in the comparison group. There were no statistically significant differences in mean skill scores between dialysis nurses ($p=0.38$) and PCTs ($p=0.826$) or between intervention and comparison groups ($p=0.332$).

Conclusions: This study exposes a critical gap in the transition of vascular access knowledge to the practical skill of access assessment. The findings suggest the need for restructuring the clinical training of dialysis nurses and PCTs in vascular access management and care. Newer active learning educational strategies in physical assessment of hemodialysis vascular access should be explored to further support dialysis nurses and PCTs in providing optimal patient care.

Keywords: access monitoring; dialysis nurses; hemodialysis; patient care technicians; physical assessment skill; vascular access

Hemodialysis is a life-saving treatment for patients with kidney failure, in which a machine filters waste, toxins, and excess fluid from the blood. This process requires vascular access, which provides a reliable and efficient connection to the bloodstream. For patients suffering from dialysis-dependent disease, the permanent vascular access is their survival lifeline. A well-functioning arteriovenous fistula or synthetic access graft is critical for dialysis adequacy. Each access is prone to develop hemodynamically significant stenosis. The effect of stenosis is a critical decrease in vascular access blood flow due to arterial inflow, intra-access, or venous outflow occlusive stenosis, which leads to malfunctions such as thrombosis or infection, which can compromise the effectiveness of dialysis, and increase the risk of complications and ultimate access failure. Early detection and intervention are critical to maintaining optimal access function. Hemodynamically significant stenosis can often be detected clinically by physical examination and result in pre-emptive referral for surgical or endovascular intervention to minimize the consequences of missed dialysis treatments [1]. Access failure and malfunction are major clinical problems that contribute significantly to morbidity and hospitalization in the hemodialysis population, ultimately translating to increased healthcare costs [2, 3]. Primary patency rates, or intervention-free access function, remains the elusive goal; however, we are often relegated to assisted patency through intervention, and this secondary patency ends when the access fails [4]. Therefore, the rationale of identifying a hemodialysis vascular access at risk

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for failure is intuitive and is supported by studies that show much higher access patency rates at 3 and 6 months with pre-emptive intervention [4, 5], as opposed to patency rates at 3 and 6 months after thrombectomy [5, 6].

Controversy still exists over the identification and appropriate management of access malfunction. Identification of a hemodialysis access at risk for failure by flow rate surveillance methods, while still in clinical use, are not supported by randomized controlled trials [7–10]. Other studies have indicated that vascular access flow surveillance improves access patency, reduces hospitalizations, and even though the number of pre-emptive interventions increase, the comprehensive costs are reduced [11, 12]. Utilizing noninvasive access surveillance techniques alone has demonstrated high positive predictive values for detecting hemodynamically significant stenosis and reduced per-patient thrombotic events [7, 13, 14]; however, other studies have indicated that routine surveillance with pre-emptive intervention based on established low-absolute-flow values alone has not been shown to prolong access survival and provides little to no benefit [9, 15–18].

Vascular access clinical monitoring involves repetitive physical examination and recognition of sentinel signs of access malfunction [19]. These examinations have shown to be accurate and an acceptable way to detect hemodynamically significant stenosis [20–25]. Current guidelines from the National Kidney Foundation Kidney Disease Outcomes Initiative emphasize monthly physical assessment of the vascular access by a qualified person as a preferred means of detecting hemodynamically significant stenosis and recommend against intervention referral based on an abnormal flow rate alone [26].

Dialysis registered nurses (RNs) and patient care technicians (PCTs) are on the front line of providing quality care to dialysis-dependent kidney failure patients. They are charged with the physical assessment of the vascular access prior to each patient dialysis treatment; however, the access training in the course of their short training period is only a small portion and focuses on cannulation skill. They are also often the first ones who would be able to detect a problem with the access. The primary purpose of this research study was to determine the effect of an advanced vascular access educational module presented to hemodialysis nurses and PCTs to improve vascular access knowledge and application to physical examination assessment to identify sentinel physical signs of a dialysis access at risk for malfunction.

Methods

The study was a quasi-experimental, pretest and posttest group design with the nonequivalent control group, conducted in a convenience sampling of dialysis RNs and certified PCTs in seven urban metropolitan dialysis facilities from November 2022 to April 2023. None of the participants in the study were dialysis facility access champions. After the study protocol was reviewed, Institutional Review Board (IRB) exempt approval was granted from A.T. Still University (IRB approval number KS20221130-001.is.) and approval obtained from Fresenius, N.A. Holdings, Inc. The intervention consisted of a knowledge test and an advanced education module grounded in a cognitive apprenticeship theoretical framework and developed in accordance with vascular-access best-practice recommendation guidelines set forth by the National Kidney Foundation's Vascular Access Workgroup of the Dialysis Quality Outcomes Initiative best-practice guidelines addressing access location (Guideline 3), access types and materials (Guideline 4), vascular access use (Guideline 11), and access flow dysfunction, monitoring, and surveillance (Guideline 13) [26].

After knowledge test review by two interventional nephrologists and two interventional radiologists, the test items were assessed by content validity index (CVI) [27, 28]. The content validity ratio (CVR) was calculated to determine the testing items considered essential utilizing the formula CVR=(N_e (–) N/2)/(N/2), where N_e is the number of interventionists who considered the item essential and N is the total number of interventionists [28]. Items with a CVR on the Lawshe scale of greater than 0.78 were included. The number of test items judged relevant and clear was divided by the total number of items to obtain a CVI. The CVI was calculated utilizing the formula CVI(R=N_r/N, where N_r is the number of experts giving a rating of very relevant and N is the total number of experts [27, 28]. Values for the CVI are from 0 to 1; an item rated>0.79 indicates that the item is relevant and clear, 0.7–0.79 indicates that the item needs revision, and an item rated below 0.7 causes the item to be discarded [27]. The interventionists scored the tests and returned them by email within 2 weeks of distribution. Items judged relevant and clear with a CVI greater than 0.79 were included in the testing instrument. 10 questions were eliminated, and 10 questions were revised. The reliability of the test instrument was assessed utilizing the test-retest method. The instrument was then administered in a test-retest format to a pilot group of 10 dialysis nurses 2 weeks apart and assessed by Pearson's correlation analysis. A linear relationship existed with both variables normally distributed, as assessed by the Shapiro-Wilks test. There was a moderate correlation with a Pearson's coefficient, r_8=0.52. However, this was not statistically significant, (p=0.12). This was attributed to the small sample size. The revised test item to determine vascular access knowledge had a moderate level of internal consistency, as determined by a Cronbach's alpha of 0.613. The revised final 10-question true/false testing instrument is seen in Supplementary Material.

The educational module was developed and designed to supplement initial staff training, but it was focused more on hemodialysis access physiology, pathology, and physical examination correlates. Observation of predialysis assessment skill to determine the presence or absence of sentinel signs of malfunction was completed after delivery of the educational module to the intervention group over the following 3 months. The total number of participants to achieve statistical power was calculated in G*Power. Utilizing an eight-group mixed analysis of variance (ANOVA), at an alpha level of 0.05, a power level of 0.80, and with a medium effect size of 0.25, the calculated sample size was 56.

The chairside skills observed during predialysis vascular access monitoring closely adhered to the traditional "look, listen, and feel" assessment standard and were categorized into four critical areas. These included identifying sentinel signs of access failure such as enlarging pseudoaneurysms, nonhealing cannulation sites, changes in bruits, hyperpulsatility, prolonged bleeding, or requiring a tourniquet to facilitate dialysis. Additionally, difficulties reported during cannulation or treatment completion were noted. Each skill was evaluated utilizing a scoring system ranging from 0 to 3 in which 0=not performed, 1=partially performed, 2=performed but incorrectly assessed, and 3=correctly completed and accurately assessed. Composite scores, reflecting the overall quality of the assessment, ranged from 0 to 12.

Data were analyzed utilizing IBM SPSS Statistics Version 28.0.0.0 [29]. After assumption testing, a three-way multifactorial ANOVA with two between-subjects independent variables and one within-subjects independent variable (MF- ANOVA BBW) was utilized to study the effect of an advanced vascular access module on vascular access knowledge. The assumption of normality for the pretest PCT comparison group and the posttest PCT comparison group was accepted by the Shapiro-Wilk test (p>0.05). However, the following groups failed to pass normality and required further testing: (a) pretest RN comparison; (b) pretest RN intervention; (c) pretest PCT intervention; (d) posttest RN comparison; (e) posttest RN intervention; and (f) posttest PCT intervention. The skewness statistic for each group was divided by the standard error of the skew. Each was found to have a skewness value of less than 1.79; therefore, normality was accepted. Variances were homogeneous in all eight group combinations between the clinical role and study group for knowledge pretest scores (RN comparison: $W_{3, 55}$=0.768, CI 76.10, 85.15, p=0.013, PCT comparison: $W_{1, 57}$=0.210, CI 73.45, 83.48, p=0.649) and posttest scores (RN intervention: $W_{3, 55}$, CI 76.17, 86.05, p=0.273, PCT intervention: $W_{1,57}$=1.258, CI 75.62, 87.71, p=0.267). The sphericity assumptions were not applicable to this design.

A two-way MF-ANOVA was applied to study the effect of an advanced vascular access module on skill in vascular access assessment to determine the presence or absence of abnormal examination findings. Statistical assumptions were tested prior to conducting the analysis. Each group failed normality testing as assessed by the Shapiro-Wilk test; however, each was found to have a skewness statistic divided by the standard-error skew of less than 1.75 and, therefore, normality was accepted. The homogeneity of variance of examination skill between the clinical role and the study group passed the assumption as determined by Levene's test ($W_{3, 55}$=1.29, CI 2.39, 3.59, p=0.942).

Table 1: Characteristics of the sample (n=59).

Variable	n	%
Clinical role		
RN	34	58.6
PCT	25	42.4
Comparison study group	29	49.1
RN	16	55.2
PCT	13	44.8
Intervention study group	30	51.9
RN	18	60.0
PCT	12	40.0

PCT, patient care technician; RN, registered nurse.

Results

Seven urban metropolitan dialysis facilities were approved for the study from November 2022 to April 2023. Five of the seven approved dialysis facilities participated in the study, and the personnel included 75 hemodialysis RNs and PCTs, with 59 completing all components of the study. Among the staff who agreed to participate, 13 did not complete all aspects of the study due to schedule changes, time away, fear of potential job jeopardy, or job turnover. Three withdrew prior to any testing. The total and distribution of the participants by group and clinical role is shown in Table 1.

For knowledge testing, RNs in both the comparison and intervention groups scored higher than PCTs, except for the pretest score in the intervention group. Overall comparison group means for pretest and posttest for the RN and PCT clinical role groups showed little change; however, the intervention group posttest means were markedly higher for both the RN and PCT groups. These data are presented in Table 2.

There was not a statistically significant three-way interaction between time, study group, and clinical role, F (1, 55) = 1.04, p|p=0.312, partial η2=0.02. There was a statistically significant two-way interaction between the time and the study group, F (1, 55)=30.393, p<0.001 (Figure 1).

There was no significant three-way interaction between time, study group, and clinical role, F (1, 55)=1.04, p=0.312,

Table 2: Means and standard deviations for knowledge scores.

Groups	Comparison		Intervention	
	RN n=16 M (SD)	PCT n=13 M (SD)	RN n=18 M (SD)	PCT n=12 M (SD)
Pretest	81.11 (9.00)	75.55 (12.47)	79.54 (12.14)	80.67 (7.99)
Posttest	86.47 (11.25)	78.46 (12.14)	94.44 (7.05)	90.83 (7.93)

Means are reported as percentage answered correctly. M, mean; PCT, patient care technician; RN, registered nurse; SD, standard deviation.

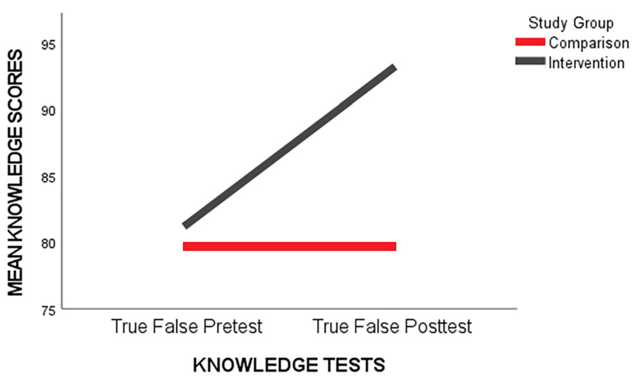

Figure 1: Mean test knowledge scores by study group.

partial η^2=0.02. However, a significant two-way interaction was found between the time and the study group, F (1, 55) =30.39, p<0.001 (Figure 1). Other two-way interactions were not statistically significant.

Utilizing a Bonferroni-adjusted alpha level of 0.025, the study group had a significant effect on posttest scores, F (1, 55)=29.48, p<0.001, but not on pretest scores, F (1, 55)=0.45, p=0.51. Posttest scores were higher in the intervention group than the comparison group, with a mean difference of 13.1 (95 % CI [83.51, 92.04]), t(57)=59.50, p<0.001, d=10.96.

For clinical skill in identifying sentinel signs of malfunction, there was no significant difference between groups. The mean skills score difference was 0.41 (95 % CI [-0.43, 1.24]), t(57) =1.13, p=0.731, d=1.56.

There was also no significant interaction between clinical role and study group, F (1, 55)=0.79, p=0.379, partial η^2=0.01. Additionally, neither the clinical role (F (1, 55)=0.049, p=0.826, partial η^2=0.01) nor the study group (F (1, 55)=0.96, p=0.332, partial η^2=0.02) significantly influenced the identification of abnormal vascular access.

Discussion

The primary purpose of this research study was to determine the effect of an advanced vascular access educational module presented to hemodialysis RNs and PCTs to improve vascular access knowledge and its application to physical assessment to identify a dialysis access at risk for malfunction. Vascular access knowledge was assessed prior to synchronous instructional intervention. A repeat knowledge test and access assessment skill test in recognizing the presence or absence of abnormal findings consistent with access malfunction were administered.

In this study, it was discovered knowledge mean posttest scores were statistically significantly higher in the intervention group for both hemodialysis RNs and PCTs. The data support previous research that showed there were improvements in vascular access knowledge in hemodialysis nurses after an educational intervention [30–32]. However, findings of this study are unique in that increases in vascular access knowledge after an advanced vascular access educational module have not been tested or reported previously in PCTs. The mean pretest scores were similar in both RNs and PCTs, suggesting that fundamental vascular access training in access knowledge is retained and is similar for both dialysis RNs and PCTs despite their differences in typical predialysis training educational requirements. However, PCTs increased their vascular access knowledge less than dialysis RNs after the intervention. Thus, PCTs should also be a focus group for vascular access training because they also perform access assessment prior to cannulation.

There were no statistically significant differences between the intervention and comparison groups in skill level to determine the presence of sentinel physical findings indicative of access malfunction. Further, there was no statistically significant difference in physical examination skill level between dialysis RNs and PCTs. This aspect of the study is unique in that it exposes a false assumption that didactic and cursory or observational education alone improves technical skill in dialysis access assessment. The lack of skill improvement highlights the need for not only advanced vascular access didactic education, but also improved practical hands-on training or experiential training in determining normal and abnormal physical assessment findings in dialysis vascular access. Combining didactic education and practical vascular access hands-on training can lead to improved accuracy in detecting access malfunction [33].

One of the major problems in training physicians, RNs, and PCTs is the gap between theory and practice. Bridging this gap should be at the heart of any program to train medical professionals [34]. An active learning approach provides the basis for future research in vascular access care at the most basic clinical level to determine the effectiveness of a problem-based, hands-on, mentored educational program geared specifically toward real patient problems in hemodialysis vascular access.

This research exposes a gap in the translation of hemodialysis vascular access didactic knowledge for dialysis RNs and PCTs to practical application in access physical assessment to determine the presence of access pathology specifically related to the dialysis treatment or its measured dialysis adequacy. Competency in physical assessment skills is considered a mainstay of nursing practice; however, it has been noted there are disparities in the skills that are taught compared with skills that are most frequently utilized [35, 36]. The age-old Halsted model approach of "see one, do one, teach one" has been a mainstay in medical procedural and physical examination skills education for well over a century and remains an effective way to mentor these skills [36, 37]. One cannot substitute hands-on education to promote experiential learning in the context of real clinical problems. It should be no different in the education of dialysis RNs and PCTs who are entrusted with the daily care of this most vulnerable patient population.

Limitations

The findings of this study should be interpreted in the context of some limitations. The study participants were volunteers; therefore, a selection bias may be present due to differential motivation. Because the research was conducted in corporate dialysis facilities, a recruiting poster was required to list the protocol of the study, which included information stating that the true-false testing instrument would be administered twice. Knowing that the questions would be administered twice may have inadvertently influenced the participants to either study for the posttest or pay particular attention to the answers included in the educational module and be a factor for the improvement in the knowledge posttest scores, thus leading to a testing effect. However, the results suggest that this may have been a minor issue because the pretest and posttest scores were very similar in the control group. Retention of knowledge gained beyond the time frame in this study cannot be fully predicted, and further studies would be needed to determine knowledge retention at longer intervals. The study was not controlled for years of dialysis-related experience. Although dialysis providers require their own standard vascular access education, there are some RNs and PCTs who may have had training in prior positions from other dialysis providers or have completed continuing education credits related to vascular access.

Baseline minimally competency skills were assumed; however, this may or may not be the case because vascular access educational training may not convey the same critical thinking and skill to every person. Additionally, even though there is a standard predialysis vascular access assessment protocol, not all dialysis facilities strictly follow the protocol, and often the PCTs rely upon the supervising RN to determine normality of the access. The findings of this study may reflect a regional selection bias and, therefore, may not be generalizable to all dialysis facilities or in all regions. Finally, increases in access knowledge cannot necessarily be correlated directly with improved assisted patency rates and may only be utilized in association with measured improvement in recognition of sentinel signs indicating access failure.

There is always the question of whether or not any intervention prolongs access longevity. A final limitation of this study is the lack of prior research demonstrating that physical examination monitoring directly prolongs access longevity. However, physical assessment for sentinel signs of access malfunction and pre-emptive intervention may enhance functionality for dialysis and provide additional time for planning alternative access strategies. Because nephrologists are concerned about dialysis prescription delivery and ensuring that patients are receiving the maximum renal replacement therapy, this may be most important.

Recommendations for future research

In addition to the traditional mentoring approach, newer active learning techniques such as virtual patient learning and simulation have proven to be effective in medical education and nursing education curricula. Further research employing simulation-based learning technologies targeted to the dialysis patient's vascular access is needed. Simulation-based medical training has been an important step in the direction of clinical curriculum development to assist in bridging the gap between knowledge and skill, and perhaps applicable in this population of caregivers. The active learning simulation technique has been applied successfully in training hemodialysisRNs and PCTs in cannulation to minimize complications of cannulation [38]. This technique can be effectively utilized to enhance the skill of clinical dialysis vascular access assessment to detect the possibility of access malfunction. Patient outcomes research in quality improvement has been applied to the area of vascular access [39]; however, further patient outcomes studies are needed in early detection of access malfunction. Finally, studies to evaluate facilitation of dialysis until alternative access planning utilizing pre-emptive intervention and timely vascular surgical referral are needed focus on goals of caring for dialysis-dependent patients.

Conclusions

A well-functioning vascular access is of paramount importance to ensure delivery of the dialysis prescription. Dialysis

RNs and PCTs are on the front lines of providing quality dialysis care to patients who are dialysis-dependent and are charged with the assessment of the vascular access prior to each dialysis treatment. These critical caregivers are often the first ones who would be able to detect and report abnormal assessment findings necessary to prevent access thrombosis and subsequent access failure. Proper knowledge of the physiology and function of the access is the first step to developing assessment skills necessary to recognize abnormal findings. This study has shown that vascular access knowledge can be improved in both dialysis RNs and PCTs with a targeted intervention grounded in education theory; however, the increase in access knowledge does not necessarily translate to significant improvement in access assessment skills in either RNs or PCTs.

Despite the limitations, the results of this research are important findings and exposed a critical gap in the transition of vascular access knowledge to the practical skill of access assessment. The findings also suggest the need for restructuring the clinical training of dialysis RNs and PCTs in vascular access management and care. Utilizing a constructivist approach, building upon the fundamental knowledge of vascular access physiology and mechanisms of failure, an active learning strategy in solid experiential learning should be employed to transfer knowledge to practical access assessment skill. Newer active learning technologies targeted to the dialysis patient's vascular access can be useful in teaching proper assessment skills and identifying problems in recognition of pathologic signs associated with access failure. On this basis, it is recommended that these newer educational strategies in physical assessment of hemodialysis vascular access should be explored to further support dialysis RNs and PCTs in providing optimal care to end-stage renal disease patients.

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Research ethics: After the study protocol was reviewed, Institutional Review Board exempt approval was granted from A.T. Still University (IRB approval number KS20221130-001.is.) and approval obtained from Fresenius, N.A. Holdings, Inc.
Informed consent: Informed consent was obtained from each participant.
Author contributions: Both authors have accepted responsibility for the entire content of this manuscript and approved its submission.
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Data availability: Data has been preserved and will be held for a period of 2 years commencing from the time the research began, ending in the spring of 2025. Data sharing is restricted and is subject to the corporate dialysis entity listed in the acknowledgements.

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