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RESEARCH

Outcomes of Using a Modified Seldinger Technique for Long Term Intravenous Therapy in Hospitalized Patients with Difficult Venous Access

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Abstract

Background and Significance*: Many hospitalized patients require an intravenous (IV) catheter to maintain vascular access or for administration of fluids and medications. The best approach to attaining peripheral intravenous (PIV) access for long term therapy is unknown, particularly in patients with a history of difficult IV placement.*

Purpose*: To measure clinical outcomes using a Modified Seldinger Technique (MST) with ultrasound (US) guidance to achieve and maintain PIV for long term IV therapy.*

Methods*: Subjects were patients with a history of difficult peripheral intravenous catheter placement and need for IV therapy longer than 72 hours. Modified Seldinger Technique was used with US guidance to place all PIVs in the deep veins of the upper extremities.*

Results*: A convenience sample of 157 subjects was enrolled in the study. Mean dwell time for catheter duration was seven days. First attempt placement success was 95%, 88.5% of patients had completion of IV therapy, and a low overall complication rate (9.57/1000 catheter days).*

Conclusion*: Using MST for access for long term PIV therapy was associated with low complications and effective in our study population. Using MST requires specialized knowledge and skills, including the use of US and specialized insertion techniques. In patients who require extended PIV therapy with a history of difficult IV placement, this type of insertion technique may have benefit.*

Background and Significance

Many patients require an intravenous (IV) line when hospitalized to administer fluids and medications, and to maintain vascular access for treatment.[1-3] Registered nurses (RN) usually initiate peripheral IV (PIV) access in hospitals. Success rate for PIV cannulation within three attempts by the RN is estimated at 90%, thus leaving 10% of patients without access, leading to possible additional attempts.[4] Factors contributing to difficulty obtaining PIV access are obesity, tortuous vascular anatomy, and scarring due to frequent access and treatment.[4,5]

Various techniques are used to achieve PIV access in patients with a history of difficult access.[3,6] One method is to use ultrasound (US) to guide PIV catheter placement into a deep vein in the upper extremity.[2,6,7] Catheter placement using US guidance was first reported by Legler and Nugent in 1984.[8] Since then, many studies have shown the efficacy of ultrasound guided (USG) vascular access device (VAD) placement by physicians and RNs.[1,9-12] Traditional PIV catheters (1.18 to 1.97 inches; 30 to 50 mm) can also be placed in deep upper extremity veins with US guidance.[4,13] However, these catheters can dislodge, resulting in deep tissue extravasations and infiltrations. Catheter dislodgement can be due to the short PIV catheter length, which may not be inserted far enough into the vein along the horizontal axis of the vein lumen. This can occur when the inserter uses a steep vertical angle of decent during IV placement.[5,13]

Another method that can be used to place a VAD in a deep vein is the Seldinger technique. Introduced in 1953, this technique uses an introducer needle to place a guide wire to gain access to deep blood vessels, followed by insertion of a catheter over the wire.[14] A modified Seldinger technique (MST) is used when inserting central venous access devices (CVAD); however, this method is not typically used for PIV access. [6,15] In a recent study by Warrington and Kamps, USG MST was used to insert short PIV catheters in patients whose nurse failed to achieve PIV access for diagnostic procedures in the outpatient setting. [16] Results showed that patients in the USG MST group, when compared with those with US guidance alone, required significantly fewer sticks, experienced fewer complications, and were more satisfied with their IV insertion experience. [16] The catheters were usually discontinued after the procedure, or within 72 hours if patients were admitted to the inpatient setting following the procedure, as per the study facility policy.

Under normal conditions, most PIVs can be used for short term IV therapy without problems. However, even under routine use, these PIV catheters may dislodge from the vein, causing infiltration and extravasation of infusates, and phlebitis, after prolonged use.[17,18] In order to reduce phlebitis and risk of infection, the Centers for Disease Control (CDC) recommends replacing PIVs after 72-96 hours unless no other venous access can be established.[17]

Many patients require PIV access greater than 72 hours, particularly in the acute care setting. It is estimated that greater than 13% of patients require IV access greater than 6 days. [7] In these cases, if the CDC guideline is followed, patients who have extended IV therapies would require no less than two PIV insertion procedures over the duration of therapy. When extended PIV therapy is probable (>6 days), the CDC recommends using a peripherally inserted central catheter (PICC) or midline (MDL) catheter, which can be used for a longer period of time.[17] While most IV therapy can be accomplished using a PIV, some infusates given for therapies may cause vascular or tissue damage, such as continuous therapy of vesicant drugs, total parenteral nutrition, and medications with extremes in pH (<5 or >9) or high osmolarity (>600 mOsm/L).[18] The Infusion Nurses Society (INS) recommends using a CVAD, such as a PICC, for these types of infusions. [18]

When selecting the proper VAD for extended dwell time for IV therapy, it is important to consider catheter gauge and length and placement site.[17,18] While the use of a PICC line is an option for longer term IV infusions, the INS recommends the shortest, smallest gauge IV catheter for use. [18] Thus, using a PICC could be a more invasive catheter than needed. Another option that can be used when increased dwell time is likely or intermittent irritating IV drugs are used is a MDL catheter. [17,19,20] While historical use of MDLs made from elastomeric hydrogel was associated with increased complications, current MDL catheters are associated with lower rates of phlebitis and infection than short PIV catheters and CVADs, respectively. [17,19-21] The best type of VAD or insertion technique for extended PIV therapy is unknown, particularly in patients with a history of difficult IV placement. Currently, options for extended treatment using a PIV are limited. The use of MST for insertion of PIVs for long term therapy in hospitalized patients with difficult access has not been reported.

Purpose

The purpose of this study was to determine the outcomes of long term PIV therapy using a MST insertion technique into deep veins in the upper extremity using US guidance in hospitalized patients with a history of difficult IV access.

Research questions addressed in this study were:

- What are clinical outcomes from using MST with USG insertion of a peripheral IV into deep upper extremity veins used for long term IV therapy (past 72 hours)?
- What is the patients' satisfaction associated with using this technique for placement and long term IV therapy?

Methods

We used a prospective, descriptive design to evaluate the outcomes of using MST with US guidance for long term IV therapy in hospitalized patients in a large acute care hospital in the Southeast United States. Included subjects were adult inpatients (>18 years) who spoke English. Patients were referred for the study when the nurse was unable to successfully place a PIV after two attempts, or had a history of difficult IV access, and an anticipated need for IV therapy greater than 72 hours. Subjects excluded were those from outpatient settings, and conditions limiting deep IV access (mastectomy

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with lymph node dissection, glomerular filtration rate ≤ 30 ml/min, or medications requiring CVAD access (vesicants, parenteral nutrition, and chemotherapy). Patients with known renal failure or arterio-venous fistula required permission to enroll in the study by their nephrologist. A physician order for US placement of a PIV was required. The study site institutional review board approved the protocol for this study. An unrestricted educational research grant and materials in support of the study was provided by Access Scientific, Inc (San Diego, CA). The analysis and editorial control of the paper's content rested solely with the authors.

Sample size for the study was determined using G*Power software. [22,23] Assuming a 10% complication rate from the data report of the USG MST study by Warrington and Kamps,138 patients were required for the study group, assuming a $p<0.05$, moderate effect size (0.3) and a 95% confidence interval. [16] Microsoft Excel was used for record keeping, tracking, and initial data processing. SPSS (v. 18) was used for data management and analysis.

Study Procedures

The investigators reviewed a convenience sample of potential subjects to determine their eligibility for inclusion into the study from patients referred to the PICC team for PIV placement. In subjects meeting inclusion criteria, the investigator obtained an order from the patient's attending physician to approve study participation. Final subjects included those who signed the informed consent form after explanation by the investigator.

Once enrolled, the PICC team investigators assessed the subjects' upper extremities for optimal vein size and selection by US without a tourniquet in place. The goal of vein selection was to find a deep vein in the upper extremity away from the elbow joint suitable for PIV placement under US guidance. The inserter then selected a vein and covered the insertion site using a maximal sterile barrier. The skin was scrubbed with a chlorhexidine gluconate (CHG) 2% solution twice for 30 seconds with a minute dry time after each application. The skin was anesthetized by an injection of 1mL of 1% buffered lidocaine, followed by placing a tourniquet to expand the selected vein. The catheter used for the PIV in this study was 3.1 inches long (80mm) with a 5Fr bore, sufficient to reach deep vein access and included materials (introducer needle, guide wire and catheter) needed to perform the MST. The catheter material was constructed of carbothane, which allowed for IV therapy use up to 30 days (Power Wand™, Access Scientific, Inc., San Diego, CA).[24] Using US guidance, the 21g introducer needle was advanced into to the vessel and the echogenic needle tip visualized entering the vessel, confirmed by a flash blood return at the catheter tip. The attached guidewire was released by unclipping the wire holder on the device and advanced into the vein. At the hub connector of the catheter, a twisting motion was used to detach the catheter from a dilator, advancing it into the vein while pulling back the introducer needle with its shield cover. Advancing the catheter over the guidewire allowed its placement along the horizontal axis of the vein.

The investigators attached a 7 inch macrobore pressure injectable extension set capped with a neutral design needless connector, then flushed with saline. The skin was prepped with an adhesive skin barrier pad and a StatLock Select™ securement device was snapped onto the extension set. An antimicrobial CHG-containing sponge dressing was placed around the catheter insertion site and the entire site was covered with a large transparent semi permeable dressing, with only the end of the extension set exposed. The extension was then secured to the dressing. Catheter patency was assessed by blood return, and a second flush of normal saline followed in a push pause method. The catheter was labeled per hospital protocol. The inserter then placed a warning label on the dressing, subject's chart and the wall above the head of the bed, identifying that the PIV setup as a research device. The subject and nurses on the unit were educated on the use and care of the PIV and reinforced at each encounter.

The investigators observed the catheter site every 24hrs for signs and symptoms of complications and functionality until it was discontinued. Catheter dwell time was measured in hours, using a 24 hour clock. The nurse on the unit or an investigator changed the PIV dressing and extension set every 7 days for routine site care, or sooner, if dressing integrity was compromised. Once the catheter was discontinued by the nurse or investigator, manual pressure was applied until hemostasis was achieved. A petroleum based antimicrobial ointment was then applied to the site and an occlusive pressure dressing placed to seal the subcutaneous tract to the vein to decrease the risk of air embolism. Before discharge, patients completed two questions on a 0-10 Likert scale to assess satisfaction with their experiences during insertion of the PIV catheter using MST and the long term PIV usage compared to previous PIV experiences. Investigators observed the insertion sites of subjects up to 48 hours after removal of the catheter while in the hospital. In those subjects who were discharged prior to 48 hours after removal of PIV, the investigators called them to determine their insertion site condition.

Results

One hundred seventy-seven patients were screened for the study; 162 met inclusion criteria, and a final enrollment of 157 subjects was achieved. No subjects withdrew from the study. Five subjects expired while enrolled in the study (3.2%); all deaths were attributed to a terminal disease process. Table 1 describes the sample. The typical subject was a 58 year old Caucasian male admitted to the hospital for 14 days and discharged home. The most common vessel accessed was the basilic vein (82.8%).

First attempt placement success was achieved on 148 subjects (95%), and overall successful access was established in 156 out of 157 patients (99.4%). The average number of attempts per subject to establish PIV access under US guidance was 1.05 (SD±0.22). In one subject, USG MST PIV access was unsuccessful.

In answering the first research question on the clinical outcomes from using MST with USG insertion of a PIV for long term therapy, the following outcomes were found: Peripheral IV therapy was successfully completed in 88.5 % of all subjects (n=139). Reasons for incomplete therapy included inadvertent removal of the catheter by patients (n=3; 1.9%) or nurses (n=3; 1.9%), and chemical phlebitis (n=2; 1.3%). The average dwell

Table 1. **Sample Characteristics (n = 157)**

Characteristics	N	%	Mean	SD	Range
Age			58.0	17.4	19-90
Length of Stay (days)			13.7	12.5	0-91
Catheter Dwell Time (days)	157		6.8	5.1	0-30
		Gender			
Male	81	51.6			
Female	76	48.4			
		Race/Ethnicity			
Caucasian	88	56.1			
Black/African American	41	26.1			
Hispanic	23	14.6			
Asian	4	2.5			
Islander	1	.6			
		Vein Accessed			
Basilic	130	82.8			
Brachiocephalic	1	.6			
Cephalic	11	7.0			
Median Vein of the Forearm	3	1.9			
Median Cubital	11	7.0			
Unable to access	1	.6			
		Discharge Status			
Home, Self Care	68	43.3			
Home Health Service	30	19.1			
Skilled Nursing Facility	33	21.0			
Rehabilitation Center	10	6.4			
Short-Term Hospital	5	3.2			
Long-Term Hospital	1	.6			
Hospice, Home	2	1.3			
Hospice, Medical Facility	2	1.3			
Left Against Medical Advice	1	.6			
Expired	5	3.2			

time for the catheter was 6.8 days (SD± 5.1). Extended IV therapy past 72 hours was exceeded by 133 subjects (85%). See Table 2 for catheter dwell times.

No complications were experienced by the vast majority of subjects in this study (n=141; 89.8%). Complications possibly associated with long term use of the PIV included hub leak (n=4; 2.5%), minor hematoma (n=3; 1.9%), and chemical phlebitis (n=2; 1.3%). The overall complication rate was 9.57/1000 catheter days, or 10.2%. The most common complication encountered was a hub leak. See Table 3 for complications.

The second research question addressed patient satisfaction with the use of the PIV placed under MST with US guidance. Subjects (n=153) rated their satisfaction with the insertion of the catheter at 9.95/10 (SD±0.32) and their experience with the long term USG MST PIV catheter use compared to previous PIV therapy experiences at 9.87/10 (SD±0.85).

Other results found with the use of the USG MST PIV catheter during long term IV therapy were observed. Power injection for diagnostic procedures was successfully performed 15 times on 10 subjects (6.4%) without complications. The aver-

Table 2. Dwell Times (n = 157)

Dwell Time in Days	N	%*
Less than 3	24	15.3
3 to 5.9	63	40.1
6 to 8.9	31	19.7
9 to 11.9	22	14.0
12 to18	13	8.3
25 to 30	4	2.5

** Rounded to nearest 0.1*

Table 3. Complications (n = 157)

Complication	N	%*	Rate/1000 Catheter Days**
None	141	89.8	
Hub Leak	4	2.5	.02/1000
Minor Hematoma	3	1.9	.02/1000
Chemical Phlebitis	2	1.3	.01/1000
Deep Vein Thrombosis	2	1.3	.01/1000
Unable to Access	1	0.6	
Infiltration	1	0.6	.01/1000
Occlusion	1	0.6	.01/1000
Kinked Catheter	1	0.6	
Transparent Dressing Allergy	1	0.6	
Overall Complications	16	10.2	9.57/1000

**Rounded to nearest 0.1; **Rounded to nearest .01*

age power injection was 3.8 seconds in duration at an average psi of 279.2, with a mean of 19 mL of contrast injected per subject. The catheter was used to draw blood specimens for diagnostic testing without difficulty in 60% of subjects. Blood draws were possible in an additional 35% of subjects, but some form of manipulation was required to achieve blood return, i.e. dependent positioning, rotation of the extremity or slight tourniquet pressure above the site, all with mild negative syringe pressure being applied. No cases of mechanical phlebitis were observed as a result of this manipulation to draw blood. During the study no skin or blood stream infections were observed. No needle stick exposures for study staff or subjects occurred during insertion.

Discussion

Overall the outcomes of using MST with US guidance for insertion and long term IV therapy in hospitalized patients with difficult IV access were acceptable and with few complications. The sections below address findings related to the research questions.

Clinical Outcomes

In our study, subjects experienced a low complication rate with long term PIV therapy inserted using MST under US guidance as compared to those in other studies of PIV therapy, which have been reported from 47% to 65%. [25,26] Subjects in our study population experienced significantly less thrombosis, catheter occlusion, phlebitis, and infiltration than with other reports of complications from studies on PIV outcomes. [16,19,25,27,28] However, direct comparison between our findings and these studies is not possible since the types and sizes of PIV catheters used, insertion techniques, skill level of those performing insertion, and the method of securement varied across studies. Two subjects admitted to the trauma unit with upper body crush injuries (1.3%) experienced deep vein thrombosis (DVT). One subject developed swelling of the neck on the same side as the PIV catheter. The second subject also developed neck swelling, but on the contralateral side from the PIV catheter. Both cases of DVT were detected using Duplex US by an independent radiologist. In their report, the radiologists commented that the DVTs had most likely originated from pre-hospital trauma and were not likely to be related to PIV insertion. In both cases, the catheter had been in place for 3 days. It is not possible to know with certainty whether or not the DVTs were related to pre-hospital trauma, the study catheter, or its insertion. Regardless, both catheters were removed for subject safety reasons.

The hematoma rate in our study (n=3/157;1.9%) was lower than results from a similar study comparing the use of US guidance alone versus USG MST to establish deep PIV access in outpatients with a history of difficult IV placement (n=17/52; 32.7% and n=7/53; 13.2% respectively). [16] However, in the previous study, the PIV catheter used was a traditional 20 or 22 gauge 1 ¾ inch polyurethane catheter as compared to the one used in our study, which was a 5Fr, 3.1 inch catheter and made of a polycarbonate polyurethane composite, making direct comparison difficult.

In our study, the most common complication was related to hub leaks (n=4). In three of those cases, the connector hub leaked after nurses manipulated the connections of the IV tubing using hemostats, after which cracks in the hub were found to cause the leak. In these cases, nurses reported that when they could not disconnect or tighten the extension at the hub during dressing changes, they used hemostats to hold on to the smooth surface of the hub. The investigators discontinued the PIV catheters in these cases, interrupting therapy and requiring new PIV placement. This feedback was shared with the manufacturer, and the catheter and extension sets were returned for inspection.

Variation in methods and procedures between studies and the evolution of new technologies can potentially account for the differences in reported complication rates. In our study we strictly adhered to prepping the insertion site with CHG, and used an antimicrobial CHG-containing sponge dressing at the catheter insertion site. This may have contributed to the lack of catheter-related infections in our subjects. The use of a securement device, rather than a stabilization device, the longer length

of the catheter, and predominately basilic site access and method of placement with a guidewire and US guidance may have decreased the likelihood of infiltration and venous injury, phlebitis, and thrombosis from mechanical shifts in the catheter. Other serious complications associated with MST insertion, including wire migration, air embolism, or needle sticks were not observed. In this study, all components needed for MST insertion were included in the catheter kit, possibly reducing exposure to air and less manipulation of components during insertion.

Results from our study showed that inserting PIVs with MST under US guidance over long term IV therapy was clinically effective in several ways. Insertion of the PIV catheter using this technique was accomplished in the vast majority of subjects without problems on the first attempt (94.9%). Kokotis estimated the success rate for the first attempt at routine PIV insertion nationwide to be 40% [7] Warrington and Kamps experienced similar high success rates in their study using US guidance with MST (86.7%) versus USG alone (50%). [16] In patients with a history of difficult access by healthcare professionals, using a guidewire with US guidance is an effective means of establishing IV access.[2,4,13,16] All subjects in our study had a history of difficult IV access by healthcare professionals, so this method was highly effective for establishing PIV access in that population. It is also possible that the high level of skill of the PICC nurses inserting the PIVs in this study in large veins influenced the high rates of success of first time PIV placement found in our study.

In this study, the subjects who required more than one attempt at IV access (n=8) were related to difficulties with catheter advancement due to anatomical restrictions of the vein and catheter length. However, seven of those subjects had successful cannulation achieved in another site. So, using this technique may not be effective in some patients with torturous anatomy of peripheral veins or difficulty in advancing the catheter. Therefore, vein assessment and selection are important procedures to follow before considering any type of PIV catheter for use.[3,6,18] Additionally, US is limited as an adjunct for PIV insertion in the inability to detect deep vessel size, response to injection, and tortuosity of vessels.[10]

The ability to use the PIV to complete long term IV therapy was an important outcome in this study. The catheter was sufficiently long with a large diameter such that extended PIV therapy was possible in most patients with few complications. The catheter was short enough to avoid reaching the distal vasculature of the axilla or subclavian vein, thus remaining a PIV. The catheter remained functional without loss of IV access in the vast majority of patients, making it possible to complete long term IV therapy with fewer IV restarts beyond 72 hours. Implications for nursing are that using certain types of PIV catheters that can remain in place for longer periods of time allows for completion of IV therapy beyond 72 hours and may lead to fewer interruptions in IV therapy and need for restarting PIVs.

Finally, the availability of a PIV to use for diagnostic blood sampling procedures during the course of long term IV therapy was useful. Using traditional PIVs, MDLs and PICCs for this purpose is an acceptable practice.[6,18,29] However, PIV short catheter length and small catheter gauge can produce unintended specimen hemolysis and catheter dislodgement, resulting in necessary redraws or restarts.[30] These consequences may lead to patient dissatisfaction due to multiple IV sticks, delay of treatment and increased length of stay.[30,31] In our study, blood sampling was possible in most patients without difficulty. This may be attributable to better positioning of the catheter within the vein and sufficiently large bore of the catheter.

Satisfaction Outcomes

Patient satisfaction with nursing care, including insertion of PIVs, has become increasingly important; particularly with public reporting of satisfaction scores. [25] Reports indicate that up to 58% of subjects are dissatisfied with their nurse's skill when inserting a PIV.[7,31] Subjects in our study highly rated their satisfaction with their experience during insertion of the PIV. However, all of the PIVs were inserted by PICC nurses, who are highly experienced in PIV therapy, MST access, and US techniques, and they anesthetized the skin prior to insertion with injection of 1mL of 1% buffered lidocaine. This may have influenced the patient experience during insertion. In a study on outpatients with difficult IV access for diagnostic tests comparing USG MST versus US guidance alone, high patient satisfaction during insertion was similar to our study findings.[16] In our study, we used a 5Fr 3.1 inch PIV catheter, as compared to the outpatient study, where 1 ¾ inch 20 and 22 gauge PIVs were inserted using USG MST and local anesthesia. Therefore, we found high satisfaction rates, despite an even larger catheter inserted under MST US guidance. High satisfaction scores by our sample for the insertion experience may be related to the high success of cannulation on the first attempt by experienced PICC nurses, using a local anesthetic and the ability to perform diagnostic blood sampling procedures over a longer period.

Limitations

The study was limited in that it was conducted in one hospital only with a small sample size and findings may not be generalizable to all institutions. Another limitation to this study was that only PICC nurses who had advanced knowledge and skills related to placement inserted the PIV. This may have influenced some of the outcomes found in the study. Another limitation in this study is that we used a catheter that is larger and longer than most commercially available PIVs. Results from our study may not be comparable to other studies using different types of PIVs. In addition, while securement of a PIV is standard, variation among securement devices and clinical practice exists.

Implications for Research

Recommendations for future research include replication of this study with a larger sample size or multiple sites, and comparison of outcomes in patients with and without difficult IV access. Other investigations might include patients who require both long and short term IV therapy. Further, evaluating this technique in pediatric patients would expand knowledge for this population.

Conclusion

Placing PIVs using MST under US guidance in deep veins of

the upper extremity in patients with difficult IV access for long term IV therapy was effective and with few complications. This technique requires specialized knowledge and skills, including the use of US and specialized insertion techniques.

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References

1. Miles G, Salcedo A, Spear D. Implementation of a successful registered nurse peripheral ultrasound-guided intravenous catheter program in an emergency department[published online ahead of print April 22 2011]. *J Emerg Nurs*. 2011. http://www.sciencedirect.com/science/article/pii/S0099176711000912. Accessed May 22, 2011.
2. Stein J, George B, River G, Hebig A, McDermott D. Ultrasonographically guided peripheral intravenous cannulation in emergency department patients with difficult intravenous access: a randomized trial. *Ann Emerg Med*. 2009;54(1):33-40.
3. do Rego Furtado LC. Maintenance of peripheral venous access and its impact on the development of phlebitis: a survey of 186 catheters in a general surgery department in Portugal. *J Infus Nurs*. 2011;34(6):382-390.
4. Costantino TG, Parikh AK, Satz WA, Fojtik JP. Ultrasonography-guided peripheral intravenous access versus traditional approaches in patients with difficult intravenous access. *Ann Emerg Med*. 2005;46(5):456-461.
5. Mills CN, Liebmann O, Stone MB, Frazee BW. Ultrasonographically guided insertion of a 15-cm catheter into the deep brachial or basilic vein in patients with difficult intravenous access. *Ann Emerg Med*. 2007;50(1):68-72.
6. Alexander M, Corrigan A, Gorski L, Hankins J, Perucca R, eds. *Infusion Nursing: An Evidence-Based Approach*. 3rd ed. St. Louis, MO: Saunder Elsevier; 2010.
7. Kokotis K. Cost containment and infusion services. *J Infus Nurs*. May-Jun 2005;28(3 Suppl):S22-32; quiz S33-26.
8. Legler D, Nugent M. Doppler localization of the internal jugular vein facilitates central venous cannulation. *Anesthesiology*. 1984;60(5):481.
9. Blaivas M, Lyon M. The effect of ultrasound guidance on the perceived difficulty of emergency nurse-obtained peripheral IV access. *J Emerg Med*. 2006;31(4):407-410.
10. Panebianco NL, Fredette JM, Szyld D, Sagalyn EB, Pines JM, Dean AJ. What you see (sonographically) is what you get: vein and patient characteristics associated with successful ultrasound-guided peripheral intravenous placement in patients with difficult access. *Acad Emerg Med*. 2009;16(12):1298-1303.
11. Aponte H, Acosta S, Rigamonti D, Sylvia B, Austin P, Samolitis T. The use of ultrasound for placement of intravenous catheters. *AANA J*. 2007;75(3):212-216..
12. Lapostolle F, Catineau J, Garrigue B, Monmarteau V, Houssaye T, Vecci I, et al. Prospective evaluation of peripheral venous access difficulty in emergency care. *Intensive Care Med*. 2007;33(8):1452-1457.
13. Keys LE, Frazee BW, Snoey ER, Simon BC, Christy D. Ultrasound guided brachial and basilic vein cannulation in emergency department patients with difficult access. *Ann Emerg Med*. 1999;33(8):711-714.
14. Seldinger SI. Catheter replacement of the needle in percutaneous arteriography: a new technique. *Acta radiol* 1953;39(5):368-376.
15. Taylor RW, Palagiri AV. Central venous catheterization. *Crit Care Med*. 2007;35(5):1390-1396.
16. Warrington WG, Kamps TA. Comparison of ultrasound-guided modified Seldinger technique versus deep peripheral vein intravenous catheter placement with ultrasound alone in patients with difficult intravenous access [Abstract]. Virgina Henderson International Nursing Library Web site. http://www.nursinglibrary.org/vhl/handle/10755/150861. Accessed December 15, 2010.
17. O'Grady NP, Alexander M, Burns LA, Dellinger EP, Garland J, Heard SO, et al. Guidelines for the prevention of intravascular catheter-related infections. *Am J Infect Control*. 2011;39(4)(suppl 1):S1-S34.
18. Infusion Nurses Society. Infusion nursing standards of practice. *J Infus Nurs*. 2011;34(1)(suppl):S1-S110.
19. Anderson NR. Midline catheters: the middle ground of intravenous therapy administration. *J Infus Nurs*. Sep-Oct 2004;27(5):313-321.
20. Alexandrou E, Ramjan LM, Spencer T, Frost SA, Salamonson Y, Davidson PM, et al. The use of midline catheters in the adult acute care setting - clinical implications and recommendations for practice. *JAVA*. 2011;16(1):35-41.
21. Griffiths V. Midline catheters: indications, complications and maintenance. *Nurs Stand*. 2007;22(11):48.
22. Faul F, Erdfelder E, Buchner A, Lang AG. Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses. *Behav Res Methods*. Nov 2009;41(4):1149-1160.
23. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods*. May 2007;39(2):175-191.
24. Access Scientific Inc. The Wand: Microaccess. 2011; http://accessscientific.com/html/products-power-wand.html. Accessed January 12, 2011.
25. Frey AM, Schears GJ. Why are we stuck on tape and suture? A review of catheter securement devices. *J Infus Nurs*. Jan-Feb 2006;29(1):34-38.
26. Schears GJ. Summary of product trials for 10,164 patients: comparing an intravenous stabilizing device to tape. *J Infus Nurs*. 2006;29(4):225-231.

27. Tosini W, Ciotti C, Goyer F, Lolom I, L'Heriteau F, Abiteboul D, et al. Needlestick injury rates according to different types of safety-engineered devices: results of a French multicenter study. *Infect Control Hosp Epidemiol*. 2010;31(4):402-407.
28. Thiagarajan RR, Bratton SL, Gettmann T, Ramamoorthy C. Efficacy of peripherally inserted central venous catheters placed in noncentral veins. *Arch Pediatr Adolesc Med*. 1998;152(5):436-439.
29. Zengin N, Enc N. Comparison of two blood sampling methods in anticoagulation therapy: venipuncture and peripheral venous catheter. *J Clin Nurs*. 2008;17(3):386-393.
30. Halm MA, Gleaves M. Obtaining blood samples from peripheral intravenous catheters: best practice? *Am J Crit Care*. 2009;18(5):474-478.
31. Dark LR. Patient satisfaction has new significance for labs. *The Dark Report*. 2007;14(16). http://www.darkreport.com/inStore/dateRange.php?minDate=0000-00-00&maxDate=2007-12-03&Submit=Search. Accessed May 31, 2011.

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