



# A Biomedical Device to Improve Pediatric Vascular Access Success

Holly A. Hess

**Purpose:** To evaluate the effectiveness of a vein-viewing device on the success of venipunctures performed by staff nurses on a pediatric surgical unit.

**Method:** This prospective, non-randomized study examined pediatric inpatients from the age of newborn to 17 years requiring vascular access at a tertiary care center in northeast Florida. The number of attempts, age of the patient, and time required to establish successful vascular access using a vein-viewing device were self-reported by nursing staff (experimental group,  $n = 91$ , mean age 9 years, range 3 days to 17 years) as well as staff, patient, and parental comments about the device. These data were compared to baseline data (control group,  $n = 150$ , mean age 5.7 years, range 11 days to 17 years) previously collected on the same unit without using the device. The outcome variables were first-attempt success rate, the number of attempts per patient, and the time to procedure completion.

**Findings:** When comparing the two groups, the first-attempt success rate increased from 49.3% to 80.2%, the mean number of attempts per patient decreased from 1.97 to 1.29, and the percentage of procedures completed in 15 minutes or less increased from 52.8% to 86.7%. Results were statistically significant for all outcome variables between the two groups and also when re-analyzed in subgroups controlling for age.

**Conclusions:** Use of a vein-viewing device significantly improved first-attempt venipuncture success rate, decreased the number of attempts per patient, and decreased procedure time for the study population. The device was well received by patients, families, and staff.

**W**hether for laboratory testing or peripheral intravenous (PIV) access, venipuncture is a necessary and nearly universal intervention in the pediatric patient (Bulechek, McCloskey, Titler, & Denehey, 1994; Singer, Richman, Kowalska, & Thode, 1999). Though a cornerstone of medical treatment, venipuncture remains one of the most common and severe sources of pain and anxiety experienced by hospitalized children (Crowley, 2003; Cummings, Reid, Finley, McGrath, & Ritchie, 1996; Goodenough et al., 1999; Gupta et al., 2006; Wong & Baker, 1988).

Although the technical goal of pediatric vascular access should be success on the first attempt, this is often not the case. In fact, intravenous success rates of staff nurses in pediatric patients are reported to be between 44% and 53% (Frey, 1998; Lininger, 2003). Many factors affect vascular access success or failure, and several are summarized in Table 1.

Holly A. Hess, BSN, RN, CRNI, is a Pediatric Vascular Access Nurse, Wolfson Children's Hospital, Jacksonville, FL.

**Acknowledgment:** The author would like to acknowledge the editorial assistance of Pamela Turner, PhD, APRN, CPN, NEA-BC, and Danielle S. Walsh, MD, FACS.

Table 1.

Factors Affecting Vascular Access Success/Failure

Patient-Related	Clinician-Related
Physical <ul style="list-style-type: none"> <li>Poor vein quality (blown, rolling, sclerotic, phlebotic, fragile, small)</li> <li>Uncooperative patient</li> <li>Dark skin</li> <li>Obesity</li> </ul>	<ul style="list-style-type: none"> <li>Age</li> <li>Years experience as an RN</li> <li>Years experience inserting IVs</li> <li>Number of IV's inserted per week</li> <li>Self-rated IV skills</li> <li>Specialty certification</li> </ul>
Physiologic <ul style="list-style-type: none"> <li>Hypotension</li> <li>Peripheral vasoconstriction (acidosis, sepsis, cold, vasopressors, fear, anxiety)</li> <li>Anemia</li> <li>Polycythemia</li> </ul>	

**Sources:** Alexander & Corrigan, 2004; Jacobson & Winslow, 2005.

The **Practice Applications of Research** section presents reports of research that are clinically focused and discuss the nursing application of the findings. If you are interested in author guidelines and/or assistance, contact *Pediatric Nursing*, East Holly Avenue Box 56; Pitman, NJ 08071-0056; (856) 256-2300 or FAX (856) 256-2345.

## Background

Nurses with more experience and those with specialty training and certification, such as intravenous (IV) teams, will be more successful in starting IVs (Jacobsen & Winslow, 2005). However, many facilities do not employ IV teams, and nursing unit staff typically have a variety of skill and experience levels. Many patient-related factors can also contribute to the challenges of pediatric vascular access. Small vein diameter and lack of cooperation are among the most common factors, resulting in multiple attempts (Alexander & Corrigan, 2004). Dark skin and obesity make visualizing veins more difficult. Lengthy or frequent hospitalizations, multiple medications, and disease processes (such as dehydration or sepsis) may further complicate vascular access. In addition, multiple unsuccessful attempts make future attempts more difficult by damaging veins and causing vessel and tissue bruising. Although many of these injuries are minor and self-limiting, for children who require multiple IVs and/or lab draws during a hospitalization, vascular access will be made more difficult simply by the reduction of viable sites until tissue damage and vessel injury have resolved.

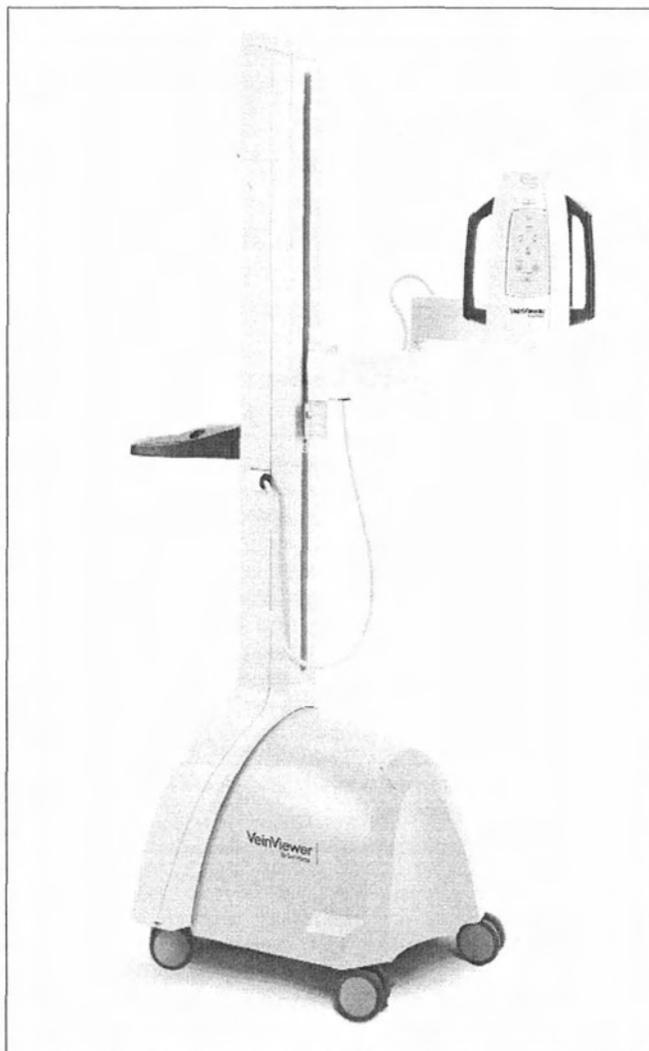
Each venipuncture attempt is a source of additional pain and emotional distress (Bijttebier & Vertommen, 1998; Fradet, McGrath, Kay, Adams, & Luke, 1990; Humphrey, Boon, van Linden van den Heuvall, & van de Wiel, 1992; Kennedy, LuHmann, & Zempsky, 2008; Van Cleve, Johnson, & Pothier, 1996). Repeated needlestick experiences in children can even lead to avoidance of medical care as adults (Pate, Blount, Cohen, & Smith, 1996). In addition, the impact of the pediatric venipuncture is not limited to children. Family members and health care providers also experience distress when observing children undergoing vascular access procedures (Smith, Shah, Goldman, & Taddio, 2007). Conversely, improving the experience of the child has a positive impact on both the family and health care providers. In a recent study, nurses who helped improve the vascular access experience in children reported improved job performance and job satisfaction (Papa, Morgan, & Zempsky, 2008).

Repeat attempts to achieve successful vascular access are costly both in supplies and labor expenses. Costs are multiplied by increased procedure time and the use of additional staff members needed to restrain children. A study at an urban pediatric teaching hospital reporting a 44% first-attempt success rate ( $N = 656$ ) for PIVs performed by staff nurses demonstrated a labor and supply cost for unsuccessful IV attempts of \$10,392 for a two-week period (Frey, 1998).

At the study facility, a 180-bed tertiary care pediatric hospital in northeast Florida, it is the responsibility of the bedside nurse to obtain lab draws and start PIVs. However, the Pediatric Vascular Access Team (PVAT), whose primary responsibility is to place and maintain peripherally inserted central catheter (PICC) lines, serves as a resource to assist with patients who have a history of difficult access or who have had unsuccessful attempts by the nursing staff. As a result of being consulted to assist with vascular access, the PVAT became interested in improving the success rate of venipunctures performed by the nursing staff.

Biomedical devices can be a way to improve vascular access success and have been used as an "equalizer" in an attempt to compensate for either patient or staff-related variables that make vascular access more challenging. For example, ultrasound-guided peripheral vascular access has been shown in adult studies to be very successful (Blaivas, 2005; Costantino, Parikh, Satz, & Fojtik, 2005). Trans-

**Figure 1.**  
The VeinViewer by Luminetx



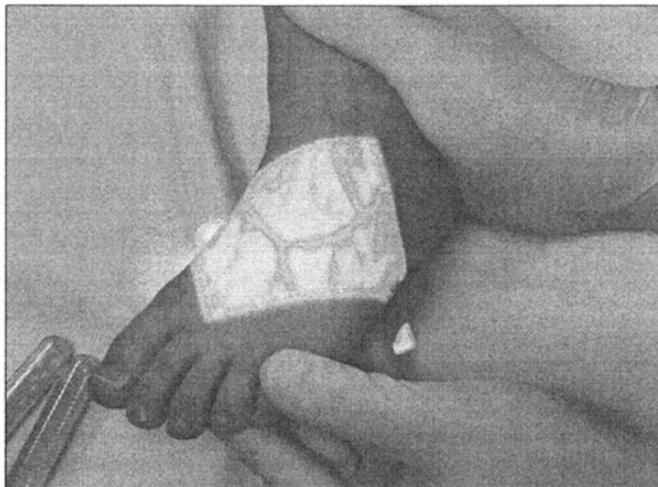
**Note:** Luminetx changed its name in May 2010 to Christie Digital Systems, Inc., and there is a new generation of the VeinViewer device available from Christie Digital Systems, Inc. The study presented in this article was conducted using the VeinViewer device by Luminetx shown here.

illuminators have been used for many years in the neonatal population, and more recently, have been modified for use in all ages (Katsogridakis, Seshadri, Sullivan, & Waltzman, 2008; Krueger, 2007).

The VeinViewer (Luminetx Corporation, 2006) is another biomedical device designed to facilitate vascular access by using near-infrared light directed on the patient's skin to detect the presence of hemoglobin (see Figure 1). A camera, computer, and projector are used to analyze and project an image of the veins back onto the patient's skin. The veins will appear as black lines against a green background (see Figure 2). The VeinViewer emits no heat or radiation, and does not come into contact with the patient's skin.

The purpose of this study was to evaluate the effectiveness of the VeinViewer on the success rate of venipunctures performed by staff nurses on pediatric patients measured by the 1) percent of first-attempt success, 2) number of attempts per patient, and 3) time needed to complete the procedure.

**Figure 2.**  
Visualization of an Infant's Veins Using the  
VeinViewer



**Table 2.**  
Number of Data Sets by Age

	Younger Than 6 Years	6 to 12 Years	Older Than 12 Years	Total
Control	91	21	38	150
Experimental	31	25	35	91

## Methods

### Sample

All patients on the study unit between the ages of newborn through 17 years who required vascular access were eligible for the study. Baseline data without the use of a vascular assist device was recorded from August 2006 through January 2007 and were designated as the control group values. Subsequently, the experimental group data (with the use of the VeinViewer) were collected over a 10-month period from April 2007 through January 2008. The range of ages in the control group was 3 days to 17 years (mean 5.7 years). The range of ages in the experimental group was 11 days to 17 years (mean 9 years). Table 2 shows group comparisons with respect to age.

Because a patient often has several vascular access attempts during a hospitalization, multiple data entry points could be recorded on one patient throughout his or her hospital stay. One-hundred and fifty data ( $n = 150$ ) sets were obtained for the control group. After the introduction of the VeinViewer, data collection for the experimental group continued until an observed increase of first-attempt success rate from 49.3% to 80.2% was noted, resulting in 91 data sets ( $n = 91$ ).

Patients were excluded from the study if the study protocol was not followed or if any of the access attempts were not performed by the unit nurse. The hospital's Institutional Review Committee approved the study. Participation in the study required provision of informed parental consent and child assent for 6 to 17 years of age.

### Data Collection

The data collection tool consisted of a self-report form that was kept in the treatment room where most vascular access procedures take place. A patient's nurse was asked to record the patient's age (in days, weeks, months, or years), the number of attempts needed to achieve success, the number of nurses involved in the procedure, and the amount of time needed to complete the procedure (grouped in categories of less than 15 minutes, 15 to 30 minutes, or over 30 minutes). In addition, the collection tool permitted the nurse to provide personal, patient, or family impressions of the device.

### Procedure

Over a three-month period, nurses on a 24-bed pediatric surgical unit received instruction on the basic operation of the VeinViewer and coaching on its use by supervised venipunctures. Upon initiation of the study, nurses were expected to use the VeinViewer for the first three venipuncture attempts. The use of the VeinViewer was optional if further attempts were required. No differentiation was made between venipunctures to obtain specimens for laboratory tests and those to establish intravenous access for the administration of fluids or medications. The first-attempt success, number of attempts per patient, and time needed to complete the procedure were collected on both the control group (prior to the use of the VeinViewer) and the experimental group (using the VeinViewer).

### Data Analysis

Data from the control and experimental groups were compared and analyzed using the Statistical Package for the Social Sciences (SPSS v. 16, for Windows®, Microsoft, Inc, 2007). The outcome variables were:

- The percent of first-attempt success.
- The mean number of attempts per patient.
- The amount of time required to complete the procedure.

In addition, staff, patient, and family comments were collected and grouped by themes.

### Results

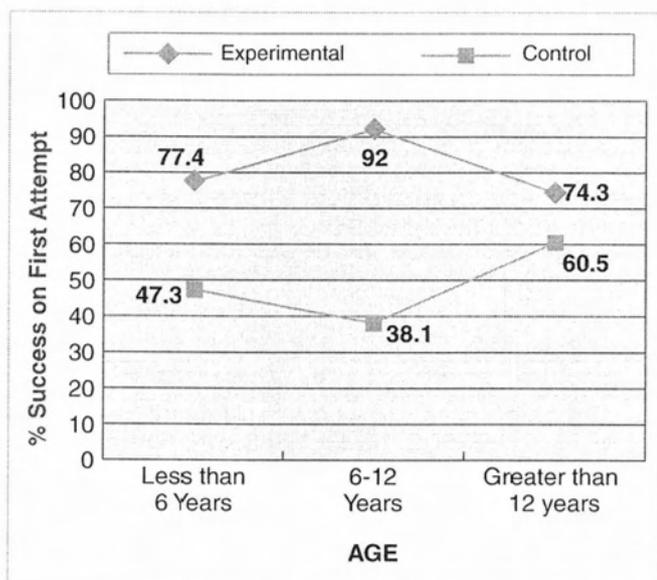
The first-attempt success rate increased from 49% in the control group to 80% in the experimental group, ( $X^2[1] = 22.71, p < 0.001$ ). The mean number of attempts per patient decreased from 1.97 to 1.29, ( $t[227.8] = 5.198, p < 0.001$ ). The percentage of procedures completed within 15 minutes increased from 52.8% in the control group to 86.7% in the experimental group ( $X^2[1] = 28.107, p < 0.001$ ). These results are summarized in Table 3.

The mean age of children in the experimental group was significantly higher than in the control group ( $t[191.1] = -4.06, p < 0.0001$ ), raising the possibility the apparent improvements are associated with a difference in age. Therefore, results were analyzed controlling for age and categorized into three groups, a) less than 6 years, b) 6 to 12 years, and c) greater than 12 years. The percentages of success on first attempt by age category are shown in Figure 3. A binary logistic regression showed a significant increase in the percentage after controlling for age (Wald  $X^2[1] = 18.676, p < 0.001$ ). A nonparametric two-way ANOVA was used to analyze the number of attempts, with four or more attempts grouped as a single category. After controlling for age, the mean number of attempts was less in the experimental group (bootstrap  $p < 0.005$ ).

**Table 3.**  
**Summary of Results by Group**

Group	N	First-Attempt Success	Mean Number of Attempts per Patient	Procedure Time 15 Minutes or Longer	Mean Age (Years)
Control	150	49%	1.97	52.8%	5.7
Experimental	91	80%	1.29	86.7%	9.0
Significance		$X^2(1) = 22.711$ $p < 0.001$	$t(227.8) = 5.198$ $p < 0.001$	$X^2(1) = 28.107$ $p < 0.001$	$t(191.1) = -4.056$ $p < 0.0001$

**Figure 3.**  
**Success of First Attempt by Age Group**



Fifteen additional data sets were excluded because the protocol was not followed as stated. However, examining data from that group revealed even when nurses initially chose not to use the VeinViewer on the first attempt, 9 of 12 patients (75%) were successfully accessed using the device on the second or third attempt.

Thirty-two extemporaneous comments from the nurses, patients, and families were recorded. Themes that emerged included a) increased ease of venipuncture with the device in those patients who had prior venipuncture experiences without an assistive device, b) increased ability to visualize veins, and c) overall appreciation of the technology. Eighty-three percent of nursing comments were positive, such as, "Unable to see veins without VeinViewer," and "[I] found veins [I] couldn't see otherwise." One hundred percent of patient/family comments were positive and included "It took eight sticks last admit, this time it took one," and "He's usually a very hard stick." Children tended to express appreciation of the technology of the device with comments such as, "This thing is great," and "Pretty awesome."

### Limitations

A limitation of the study is the use of self-reported data collection allowing the potential for nurses to under- or over-report venipuncture attempts, possibly as a result of

perceived institutional, investigator, or peer expectations. Although the control and experimental data were collected on the same pediatric surgical unit with a fairly consistent type of patient population, no attempt was made to match patients by diagnosis or co-morbidities, which could affect successful venipuncture. Another possible staff-related variable is the length and type of experience of the nurse performing the procedure. Future study is recommended with a larger, randomized sample size, controlling for diagnosis, co-morbidities, and nurse experience.

### Discussion

The results of this study demonstrated that a biomedical device, such as the VeinViewer, can improve vascular access success in pediatric patients. First-attempt vascular access success rates were significantly higher, the number of attempts per patient was significantly lower, and the percentage of procedures completed within 15 minutes significantly increased when nurses used the VeinViewer compared to not using the VeinViewer. Although the mean age of the two groups was significantly different, the age of the patient was not predictive of success. In addition, nursing staff, patients, and families expressed an overall improved patient experience during vascular access with the use of the VeinViewer.

### Implications

The VeinViewer is an expensive capital investment. Thus, having multiple devices can quickly become quite costly. However, the initial cost of purchasing the VeinViewer must be weighed against the benefits of significantly improved vascular access success rates: highly significant improvement in clinical outcomes, reduced labor and supply costs; and the enhanced experience expressed by nursing staff, patients, and families.

Clinical benefits of improved first-attempt vascular access success in children include reduced fear, anxiety, and pain, as well as the preservation of potential venipuncture sites that may be needed for future access. In addition, improving the vascular access process increases patient, parent, and nursing satisfaction. Many parents whose children had prior venipuncture experiences expressed a sense of relief and gratitude that their child experienced fewer attempts with the use of the VeinViewer. Of interest, patients who were subsequently rehospitalized often asked for the VeinViewer to be used on the first attempt, even if it had to be brought from another floor.

The financial implications of implementing the VeinViewer vary, depending on the facility's cost of labor and supplies. However, the overall cost benefits can be estimated by applying previously published data on financial

implications related to unsuccessful venipuncture attempts. Using Frey's (1998) model, increasing the success rate from 50% to 80% would result in a cost savings of \$720 per 100 IVs. For a facility that places 1000 IVs per month, the annual net savings would amount to \$86,400.

In the study population, use of the VeinViewer significantly improved vascular access success by increasing the first-attempt success, reduced the number of attempts per patient, and reduced the time required to successfully achieve access. A biomedical device, such as the VeinViewer, is not intended to replace the expertise of skilled clinicians, but rather, to maximize the probability of successful venipuncture. Improving vascular access success by reducing multiple attempts reduces labor and supply costs, and creates a better experience for the child, family, and staff.

## References

- Alexander, M., & Corrigan, A.M. (Eds.). (2004). *Core curriculum for infusion nursing* (3rd ed.). New York: Infusion Nurses Society.
- Bijttebier, P., & Vertommen, H. (1998). The impact of previous experience on children's reactions to venepunctures. *Journal of Health Psychology, 3*(1), 39-46.
- Blaivas, M. (2005). Ultrasound-guided peripheral IV insertion in the ED. *American Journal of Nursing, 105*(10), 54-57.
- Bulechek, G.M., McCloskey, J.C., Titler, M.G., & Denehey, J.A. (1994). Nursing interventions used in practice. *American Journal of Nursing, 94*(10), 59-64.
- Costantino, T.G., Parikh, A.K., Satz, W.A., & Fojtik, J.P. (2005). Ultrasonography guided peripheral intravenous access versus traditional approaches in patients with difficult intravenous access. *Annals of Emergency Medicine, 46*(5), 456-461.
- Crowley, J.J. (2003). Vascular access. *Techniques in Vascular and Interventional Radiology, 6*(4), 176-181.
- Cummings, E.A., Reid, G.J., Finley, G.A., McGrath, P.J., & Ritchie, J.A. (1996). Prevalence and source of pain in pediatric inpatients. *Pain, 68*(1), 25-31.
- Fradet, C., McGrath, P.J., Kay, J., Adams, S., & Luke, B. (1990). A prospective survey of reactions to blood tests by children and adolescents. *Pain, 40*(1), 53-60.
- Frey, A.M. (1998). Success rates for peripheral IV insertion in a children's hospital. *Journal of Intravenous Nursing, 21*(3), 160-165.
- Goodenough, B., Thomas, W., Champion, G.D., Perrott, D., Taplin, J.E., von Baeyer, C.L., & Ziegler, J.B. (1999). Unraveling age effects and sex differences in needle pain: Ratings of sensory intensity and unpleasantness of venipuncture pain by children and their parents. *Pain, 80*(1-2), 179-190.
- Gupta, D., Agarwal, A., Dhiraaj, S., Tandon, M., Kumar, M. Singh, R. S., ... Singh, U. (2006). An evaluation of efficacy of balloon inflation on venous cannulation pain in children: A prospective, randomized, controlled study. *Anesthesia and Analgesia, 102*(5), 1372-1375.
- Humphrey, G.B., Boon, C.M., van Linden van den Heuvell, G.F., & van de Wiel, H.B. (1992). The occurrence of high levels of acute behavioral distress in children and adolescents undergoing routine venipunctures. *Pediatrics, 90*(1 Pt. 1), 87-89.
- Jacobsen, A.F., & Winslow, E.H. (2005). Variables influencing intravenous catheter insertion difficulty and failure: An analysis of 339 intravenous catheter insertions. *Heart & Lung, 34*(5), 345-359.
- Katsogridakis, Y., Seshadri, R., Sullivan, C., & Waltzman, M. (2008). Veinlite transillumination in the pediatric emergency department: A therapeutic interventional trial. *Pediatric Emergency Care, 24*(2), 83-88.
- Kennedy, R.M., Luhmann, J., & Zempsky, W.T. (2008). Clinical implications of unmanaged needle-insertion pain and distress in children. *Pediatrics 122*(Suppl. 3), 5130-5133.
- Krueger, A. (2007). Need help finding a vein? *Nursing 2007, 37*(6), 39-41.
- Liniqer, R.A. (2003). Pediatric peripheral IV insertion success. *Pediatric Nursing, 29*(5), 351-354.
- Luminetx Corporation. (2006). *VeinViewer user's guide*. Memphis, TN: Author.
- Papa, A.M., Morgan, R., & Zempsky, W.T. (2008). *Competency, compassion, contentment: nurses' attitudes toward pain associated with peripheral venous access in pediatric patients*. Poster presented at the American Pain Society's 27th Annual Scientific Meeting, May 8-10, 2008, Tampa, FL.
- Pate, J.T., Blount R.L., Cohen, L.L., & Smith, A.J. (1996). Childhood medical experience and temperament as predictors of adult functioning in medical situations. *Children's Health Care, 25*(4), 281-298.
- Singer, A.J., Richman, P.B., Kowalska, A., & Thode, H.C. (1999). Comparison of patient and practitioner assessments of pain from commonly performed emergency department procedures. *Annals of Emergency Medicine, 33*, 652-658.
- Smith, R.W., Shah, V., Goldman, R.D., & Taddio, A. (2007). Caregivers' responses to pain in their children in the emergency department. *Archives of Pediatric Adolescent Medicine, 161*(6), 578-582.
- Van Cleve, L., Johnson, L., & Pothier, P. (1996). Pain responses of hospitalized infants and children to venipuncture and intravenous cannulation. *Journal of Pediatric Nursing, 11*(3), 161-168.
- Wong, D.L., & Baker, C.M. (1988). Pain in children: Comparison of assessment scales. *Pediatric Nursing, 14*(1), 9-17.

Reprinted from *Pediatric Nursing*, 2010, Volume 36, Number 5, pp. 259-263. Reprinted with permission of the publisher, Jannetti Publications, Inc., East Holly Avenue, Box 56, Pitman, NJ 08071-0056; (856) 256-2300; FAX (856) 589-7463; Web site: www.pediatricnursing.net; For a sample copy of the journal, please contact the publisher.