ABSTRACT
Extravasation of medications during peripheral intravenous (PIV) therapy can result in harm to pediatric patients. These medications have physical and/or biologic factors that cause tissue damage. To assist in clinical decisions when using these infusates, an evidence-based table of medications stratified by their relative risk of causing harm if extravasated was developed. Local data and experience, a systematic review of the pediatric literature, and measured pH and osmolality of common pediatric preparations of PIV infusates were used to create a 3-tiered table of PIV infusates categorized by relative risk of causing harm if extravasated.

Key words: adverse effects, children, extravasation, infants, intravenous infusions, peripheral catheterization

Peripheral intravenous (PIV) insertion is one of the most common procedures undertaken for pediatric patients requiring short-term infusion therapy. Serious but uncommon risks with PIV therapy may result in predictable patient injury, and the patient safety and medicolegal consequences are well known to most institutions. PIV device is defined as any venous access device whose tip lies outside the right atrium, superior or inferior vena cava, or brachiocephalic veins.

Eloise Clark, MPH, MBA
Barbara K. Giambra, MS, RN, CPNP
John Hingl, MBA, RPh
Darcy Doellman, BSN, RN, CRNI®, VA-BC
Barbara Tofani, MSN, RN
Neil Johnson, MD

Reducing Risk of Harm From Extravasation
A 3-Tiered Evidence-Based List of Pediatric Peripheral Intravenous Infusates

Author Affiliations: Anderson Center for Health Systems Excellence (Ms Clark), Center for Professional Excellence–Research and Evidence-Based Practice (Ms Giambra), Division of Pharmacy (Mr Hingl), Vascular Access Team (Ms Doellman), Patient Services–Perioperative Administration (Ms Tofani), and Department of Radiology (Dr Johnson), Cincinnati Children’s Hospital Medical Center, Cincinnati, Ohio.

Eloise Clark, MPH, MBA, works in the Anderson Center for Health Systems Excellence at Cincinnati Children’s Hospital Medical Center as an evidence-based decision-making program administrator. Her expertise is in searching, appraising, and synthesizing published evidence so that clinicians may be able to apply it in practice to improve child health outcomes.

Barbara K. Giambra, MS, RN, CPNP, is an advanced practice nurse and evidence-based practice mentor at Cincinnati Children’s Hospital. Ms Giambra has extensive experience in nursing care of chronically ill children and their families and the use of evidence at the point of care.

DOI: 10.1097/NAN.0b013e3182798844

John F. Hingl, BS Pharmacy, MBA, RPh, is pharmacy operations manager at Cincinnati Children’s Hospital. He is responsible for pharmacy development of administration systems and implementation of automated IV dispensing systems and is a member of the Pharmacy Safety Team, Intravenous Access Group, and Chemotherapy Safety Working Group.

Darcy Doellman, BSN, RN, CRNI®, VA-BC, is a vascular access nurse at Cincinnati Children’s Hospital. She has several publications in the field of neonatal/pediatric vascular access. Darcy is certified in infusion nursing (2005) and board certified in vascular access (2011). Darcy was the 2007–2008 president of the Association for Vascular Access.

Barbara Tofani, MSN, RN, is assistant vice president of Patient Services at Cincinnati Children’s Hospital Medical Center, with oversight over Perioperative Services and Vascular Access Services at the Academic Medical Center.

Neil Johnson, MD, is a pediatric interventional radiologist practicing at Cincinnati Children’s Hospital, where he is medical director of vascular access. He was formerly chief of interventional radiology, medical director of information systems, and immediate past president of the Society for Pediatric Radiology.

Corresponding Author: Barbara K. Giambra, MS, RN, CPNP, Cincinnati Children’s Hospital Medical Center, MLC 8006, 3333 Burnet Ave, Cincinnati, Ohio 45229-3039 (Barbara.Giambra@cchmc.org).

Darcy Doellman is a consultant for Genentech and Teleflex Medical, Arrow International. All other authors disclose no potential, perceived, or real conflicts of interest or financial relationships relevant to this article.

The article was drafted and revised collaboratively, with substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data by all authors. Each author has seen and approved the submission of this version of the article and takes full responsibility for the article.
Infants and children pose challenges to optimal PIV management because of their limited communication abilities, unpredictable behavior and activity levels, and small vessel sizes. Although extravasation with temporary injury and discomfort is a far too common occurrence, significant tissue injury resulting in skin grafts and/or fasciotomies as a complication of PIV therapy should not occur. For the purposes of this article, the authors define extravasation as any inadvertent administration or leakage of infusate into the extravascular tissue, though they acknowledge that other definitions exist.

The authors’ organization is a quaternary care pediatric teaching hospital that treats more than 1 million patients per year. The hospital assembled a multidisciplinary team to create a plan to decrease the PIV extravasation rate and prevent associated permanent harm. This article presents an evidence-based table of medications, stratified according to risk of tissue damage if extravasated from a PIV, which was developed as part of that plan.

**METHODS**

The table was developed in 3 steps. First, local data from, and experience with, injuries due to PIV extravasation were used to draft a consensus list of medications stratified by risk for harm.

Next, a comprehensive, systematic search of the health care literature was conducted to address the question, “Which medications are associated with permanent harm in the context of PIV extravasation in children?” See Table 1 for details of the search strategy and selection criteria.

Finally, 4 physical or biologic factors of medications that cause tissue damage (extreme pH, osmolality, vasoactivity, and cytotoxicity) were evaluated to address the question, “What is the relative risk of harm of each medication for PIV extravasations in children?” (not including harm due solely to large extravasation volume). See Table 2 for definitions and characteristics of these factors.

Because pH and osmolality of a solution can change on the basis of the concentration of the drug and the diluent used, common pediatric preparations of PIV infusates were measured for actual pH and osmolality. See Table 3 for methods used for obtaining these measures.

**RESULTS**

The first step of the process resulted in a consensus version of the table to be used by clinicians. The table stratified the selected medications by risk into 3 color-coded tiers (higher, intermediate, and lower risk) and was named the Red/Yellow/Green list.

The second step of the process added published evidence to enhance the accuracy of the list. Of the 65 selected articles that described permanent harm due to PIV extravasation, 75% were case reports, 90% of which were reports of 1 to 4 cases; 3% of the articles were randomized controlled trials of prevention or injury management interventions; and 22% were cohort studies, prospective and retrospective, and heterogeneous in intent, study size, and design. Eight additional articles were selected that contained lists of medications of known or suspected risk for injury due to extravasation. These lists were used to identify...
TABLE 2
Definitions and Characteristics of 4 Physical and Biological Factors

| Extreme pH | • Extreme is defined as pH less than 5 or greater than 9.1
|           | • Both acidic and alkaline substances can irritate vessel walls, damage cell proteins, and cause cell death.6,7
|           | • The pH of a solution can change on the basis of the concentration of the drug and the diluent used in the preparation of the intravenous mixture.7
|           | • The pH levels of the solutions in the table were measured at the authors’ facility using the most common pediatric preparation for each intravenous solution.
| Osmolality | • A measure of the number of particles per kilogram of solvent.7
|           | • Both hypotonic and hypertonic solutions can cause cell death due to shifts in intracellular solute concentration.7
|           | • Isotonic solutions have an osmolality that approximates that of blood.7
|           | • Osmolality of a solution can change on the basis of the concentration of the drug and the diluent used in the preparation of the intravenous mixture.7
|           | • The osmolality levels of the solutions in the table were measured at the authors’ facility using the most common pediatric preparation for each intravenous solution.
| Vasoactivity | • The ability of a drug to cause constriction of small peripheral vessels, including arterioles.6
|             | • Reduced blood flow due to capillary constriction can lead to tissue necrosis.8
| Cytotoxicity | • The ability of a drug to cause cell damage or death directly, such as chemotherapeutic agents and sclerosing agents.6

medications carrying risk of harm on the basis of “expert opinion” when there were no specific published cases of harm for a particular medication. The published evidence guided a second draft of the Red/Yellow/Green list, involving additions, deletions, and changes in risk tiers for some medications.

Last, the measured pH and osmolality data for the most common PIV solutions given to patients at the authors’ organization were evaluated with respect to the second draft of the Red/Yellow/Green list. These data guided further modification to finalize the list with additions, deletions, and changes in risk tiers for some medications (Figure 1 and http://neiloz.com/vascular).

Table 4 presents the risk-stratified list with details of the measured pH and osmolality for common pediatric preparations of PIV infusates with details of the published evidence support.

CLINICAL IMPLICATIONS

This comprehensive, pediatric-focused, evidence-based table of medications, categorized by relative risk of extravasation harm, is just 1 strategy to reduce PIV extravasations. This table is not meant to be used in isolation but, rather, in combination with additional strategies, such as proper nursing assessments and modifying risk factors for PIV extravasation. It is acknowledged, however, that even with optimal assessment and monitoring of PIVs, extravasations are inevitable.80

TABLE 3
Methods of pH and Osmolality Testing

Fresh solution for each product was prepared for each specified medication concentration and diluent.

| pH | Oakton Model pHTestr2 was calibrated using GFS Chemicals buffer solution 10.0.
|    | A 10-mL aliquot of medication was placed in the testing container, the pH probe was placed in the container and was allowed to equilibrate for 60 seconds, and the reading was recorded. The pH probe was rinsed, and the process was repeated for a second aliquot to confirm the initial reading for each sample. The complete process was repeated for each medication, with recalibration between products.
| Osmolality | Each sample was tested using 50 mOsm/kg and 850 mOsm/kg standard calibration material on a Fiske Micro Osmometer. This device is capable of reading in the range of 210-2000 mOsm. Each test was repeated to verify the results for each sample.
Peripheral Venous Infusion Risk

This is an estimate of risk for phlebitis or local tissue injury due to extravasation. Risk derived from available evidence, CCHMC data and CCHMC expert opinion, subject to review and change as further evidence becomes available.

This does not apply in situations of emergency medical treatment.

If a medication is not on this list, please refer to the formulary or contact pharmacy for information.

Green Lower Risk
Aminophylline
Amphotericin B Liposomal
Ampicillin
Amoxicillin/Sulbactam
Cefazolin
Cefotaxime
Ceftriaxone
Clindamycin
D指引
Fentanyl
Fosphenytoin
Furosemide
Gentamicin
Heparin
Imipenem
IVIG
Lactated Ringer’s
Lipids
Magnesium sulfate (bolus)
Meropenem
Methylprednisolone
Piperacillin/tazobactam
Piperacillin/ticarcillin
Tobramycin

Yellow Intermediate Risk
Acetazolamide
Allopurinol
Amikacin
Amphotericin B (conventional)
Arginine
Ciprofloxacin
Dextrose 10% to 12.5%
Diazepam
Erythromycin
Ganciclovir
Lorazepam
Midazolam
Morphine
Ondansetron
Nafcillin
Nonionic Radiology Contrast
Phenobarbital
Phenytoin
Potassium ≤ 60 mEq/L
TPN > 250 mOsm/L
Vancomycin

Red Higher Risk
Acyclovir
Caffeine Citrate
Calcium (all salt forms)
Dextrose > 12.5%
Doxycycline
Mannitol 20% & 25%
Promethazine
Potassium >60 mEq/L
Sodium bicarbonate
Sodium chloride ≥ 3%
TPN > 950 mOsm/L
Vasopressors such as Dopamine
Chemotherapy Drugs

* NOTE:
No peripheral intravenous infusate is “safe.” Gross extravasation, even of normal saline, may result in serious harm including compartment syndrome, causing ischemia and loss of tissue or permanent loss of limb function.

TABLE 4 PIV Infusates Categorized by Relative Risk for Extravasation Harm—Common Pediatric Preparations

<table>
<thead>
<tr>
<th>Medication*</th>
<th>Harmb</th>
<th>pH</th>
<th>OSM</th>
<th>CONC</th>
<th>DIL</th>
<th>Citations c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher risk</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acyclovir</td>
<td>F, C</td>
<td>10.4</td>
<td>335</td>
<td>7 mg/mL</td>
<td>NS</td>
<td>8</td>
</tr>
<tr>
<td>Caffeine citrate</td>
<td>N</td>
<td>4.5</td>
<td>151</td>
<td>20 mg/mL</td>
<td>SW</td>
<td>Local consensus</td>
</tr>
<tr>
<td>Calcium (all salt forms)</td>
<td>F, C</td>
<td>Calcium chloride</td>
<td>4.4</td>
<td>572</td>
<td>20 mg/mL</td>
<td>D5W</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Calcium gluconate</td>
<td>6.4</td>
<td>308</td>
<td>50 mg/mL</td>
<td>D5W</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other or unspecified calcium salt forms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dextrose &gt;12.5% to 20%</td>
<td>N</td>
<td>Varies</td>
<td>640 to 1010</td>
<td>—</td>
<td>NA</td>
<td>34,35</td>
</tr>
<tr>
<td>Doxycycline</td>
<td>N</td>
<td>3.5</td>
<td>313</td>
<td>1 mg/mL</td>
<td>D5W</td>
<td>Local consensus</td>
</tr>
<tr>
<td>Mannitol</td>
<td>C</td>
<td>7.8</td>
<td>1369</td>
<td>20%</td>
<td>SW</td>
<td>36</td>
</tr>
</tbody>
</table>

(C) 2009 – 2011 Cincinnati Children’s Hospital Medical Center

* Peripheral venous access is defined as any venous access device whose tip lies outside the right atrium, superior / inferior vena cava, or the brachiocephalic veins.

Figure 1. Red/Yellow/Green list. Abbreviations: DSLR, 5% dextrose in lactated Ringer’s solution; IVIG, immunoglobulin; TPN, total parenteral nutrition. ©Cincinnati Children’s Hospital Medical Center.
<table>
<thead>
<tr>
<th>Medication*</th>
<th>Harm*</th>
<th>pH</th>
<th>OSM</th>
<th>CONC</th>
<th>DIL</th>
<th>Citations*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium (unknown concentration)</td>
<td>C</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Potassium (&gt;0.06 mEq/mL (&gt;60 mEq/L))</td>
<td>F</td>
<td>5</td>
<td>763</td>
<td>0.3 mEq/mL (300 mEq/L)</td>
<td>NS</td>
<td>30</td>
</tr>
<tr>
<td>Promethazine</td>
<td>F</td>
<td>4.8</td>
<td>213</td>
<td>25 mg/mL</td>
<td>D5W</td>
<td>37</td>
</tr>
<tr>
<td>Sodium bicarbonate</td>
<td>C</td>
<td>7.8</td>
<td>932</td>
<td>0.5 mEq/mL</td>
<td>SW</td>
<td>—</td>
</tr>
<tr>
<td>Sodium chloride ≥3%</td>
<td>C</td>
<td>6.8</td>
<td>939</td>
<td>3%</td>
<td>SW</td>
<td>—</td>
</tr>
<tr>
<td>TPN &gt;950 mOsm/L</td>
<td>F, C</td>
<td>Varies</td>
<td>&gt;950</td>
<td>NA</td>
<td>NA</td>
<td>—</td>
</tr>
<tr>
<td>Vasopressors such as dopamine (vasoactive)</td>
<td>F, C</td>
<td>2.9</td>
<td>997</td>
<td>80 mg/mL</td>
<td>D5W</td>
<td>27,43</td>
</tr>
<tr>
<td>Chemotherapy agents (cytotoxic)</td>
<td>F, C</td>
<td>Various</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>43,46-59</td>
</tr>
</tbody>
</table>

**Intermediate risk**

- Acetazolamide: N, 9.5, 548, 25 mg/mL, D5W, Local consensus
- Allopurinol: N, 10.3, 345, 6 mg/mL, D5W, Local consensus
- Amikacin: C, 4.5, 317, 15 mg/mL, NS, 27
- Amphotericin B (conventional): N, 7.2, 265, 0.1 mg/mL, D5W, 35,60-62
- Arginine: C, 5.6, 950, 10%, SW, 63-67
- Ciprofloxacin: N, 4.2, 279, 2 mg/mL, D5W, Local consensus
- Dextrose 10% to ≤12.5%: F, C, Varies, 505 to 640, —, NA, 1,12,16,20,22,30,47
- Diazepam: N, 6.6, >2000, 5 mg/mL, NA, 34,25,30-32,60-62,68
- Erythromycin: N, 7, 287, 5 mg/mL, NS, 61
- Ganciclovir: N, 7.2, 265, 0.1 mg/mL, D5W, 35,62
- Lorazepam: N, 7.4, >2000, 2 mg/mL, NA, 69
- Midazolam: N, 3.4, 386, 5 mg/mL, NA, Local consensus
- Morphine: N, 5, 284, 1 mg/mL, NS, 60
- Nafcillin: C, 7, 324, 15 mg/mL, D5W, 43,70,71
- Nonionic radiology contrast: C, 6.8 to 7.7, 322 to 844, Varies, NA, 72
- Ondansetron: N, 3.5, 282, 1 mg/mL, D5W, Local consensus
- Phenobarbital: C, 8.2, 2159, 10 mg/mL, SW, 73
- Phenytoin: N, 10.8, >2000, 50 mg/mL, NA, 34,35,60,62,68,74,75
- Potassium ≥0.06 mEq/mL (≥60 mEq/L): F, C, 7.5, 479, 0.06 mEq/mL (60 mEq/L), NS, 1,12,14,16,20,21,30,31,43-47
- TPN ≤950 mOsm/L: F, C, Varies, ≤950, NA, NA, 1,12,14,16,20,21,30,31,43-47
- Vancomycin: N, 3.6, 271, 5 mg/mL, D5W, 34,35,60,61,68

**Lower risk**

- Aminophylline: C, 8.7, 106, 25 mg/mL, NA, 33
- Amphotericin B liposomal: N, 5.5, 432, 2 mg/mL, D5W, Local consensus
- Ampicillin: F, C, 8.4, 354, 20 mg/mL, NS, 33,77

(continues)
### TABLE 4 Continued

<table>
<thead>
<tr>
<th>Medication</th>
<th>Harm</th>
<th>pH</th>
<th>OSM</th>
<th>CONC</th>
<th>DIL</th>
<th>Citations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ampicillin/sulbactam</td>
<td>N</td>
<td>8.2</td>
<td>471</td>
<td>30 mg/mL</td>
<td>NS</td>
<td>Local consensus</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>8.6</td>
<td>700</td>
<td>60 mg/mL</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Cefazolin</td>
<td>N</td>
<td>5.6</td>
<td>338</td>
<td>100 mg/mL</td>
<td>SW</td>
<td>Local consensus</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>5.2</td>
<td>373</td>
<td>100 mg/mL</td>
<td>SW</td>
<td></td>
</tr>
<tr>
<td>Cefazidime</td>
<td>N</td>
<td>6.4</td>
<td>389</td>
<td>100 mg/mL</td>
<td>SW</td>
<td>Local consensus</td>
</tr>
<tr>
<td>Ceftriaxone</td>
<td>C</td>
<td>6.7</td>
<td>388</td>
<td>100 mg/mL</td>
<td>SW</td>
<td></td>
</tr>
<tr>
<td>Cefuroxime</td>
<td>N</td>
<td>7.5</td>
<td>436</td>
<td>100 mg/mL</td>
<td>SW</td>
<td></td>
</tr>
<tr>
<td>Clindamycin</td>
<td>N</td>
<td>6.8</td>
<td>350</td>
<td>18 mg/mL</td>
<td>D5W</td>
<td>Local consensus</td>
</tr>
<tr>
<td>D5LR</td>
<td>N</td>
<td>5</td>
<td>525</td>
<td>—</td>
<td>—</td>
<td>Local consensus</td>
</tr>
<tr>
<td>Dextrose &lt;10%</td>
<td>C</td>
<td>4</td>
<td>&lt;505</td>
<td>10%</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Fentanyl</td>
<td>N</td>
<td>6</td>
<td>14</td>
<td>50 µg/mL</td>
<td>NS</td>
<td>Local consensus</td>
</tr>
<tr>
<td>Fosphenytoin</td>
<td>N</td>
<td>8.4</td>
<td>436</td>
<td>25 mg/mL</td>
<td>NS</td>
<td>Local consensus</td>
</tr>
<tr>
<td>Furosemide</td>
<td>N</td>
<td>8.2</td>
<td>287</td>
<td>1 mg/mL</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Gentamicin</td>
<td>C</td>
<td>3.9</td>
<td>259</td>
<td>10 mg/mL</td>
<td>D5W</td>
<td></td>
</tr>
<tr>
<td>Heparin</td>
<td>C</td>
<td>6.7</td>
<td>297</td>
<td>1000 units/mL</td>
<td>SW</td>
<td></td>
</tr>
<tr>
<td>Imipenem</td>
<td>N</td>
<td>7.1</td>
<td>326</td>
<td>5 mg/mL</td>
<td>NS</td>
<td>Local consensus</td>
</tr>
<tr>
<td>Immunoglobulin</td>
<td>N</td>
<td>4.6 to 5.1</td>
<td>240 to 300</td>
<td>10%</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Lactate Ringer’s solution</td>
<td>N</td>
<td>6.5</td>
<td>273</td>
<td>—</td>
<td>—</td>
<td>Local consensus</td>
</tr>
<tr>
<td>Lipids</td>
<td>F, C</td>
<td>8.1</td>
<td>356</td>
<td>20%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesium sulfate (bolus)</td>
<td>C</td>
<td>5.3</td>
<td>471</td>
<td>50 mg/mL</td>
<td>D5W</td>
<td></td>
</tr>
<tr>
<td>Meropenem</td>
<td>N</td>
<td>7.6</td>
<td>354</td>
<td>20 mg/mL</td>
<td>NS</td>
<td>Local consensus</td>
</tr>
<tr>
<td>Methylprednisolone</td>
<td>N</td>
<td>7.5</td>
<td>296</td>
<td>5 mg/mL</td>
<td>D5W</td>
<td>Local consensus</td>
</tr>
<tr>
<td>Normal saline</td>
<td>C</td>
<td>5</td>
<td>308</td>
<td>0.90%</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Pentamidine</td>
<td>N</td>
<td>6.5</td>
<td>293</td>
<td>6 mg/mL</td>
<td>D5W</td>
<td>Local consensus</td>
</tr>
<tr>
<td>Piperacillin</td>
<td>N</td>
<td>5.6</td>
<td>304</td>
<td>100 mg/mL</td>
<td>SW</td>
<td>Local consensus</td>
</tr>
<tr>
<td>Piperacillin/tazobactam</td>
<td>N</td>
<td>6.4</td>
<td>305</td>
<td>80 mg/mL</td>
<td>SW</td>
<td>Local consensus</td>
</tr>
<tr>
<td>Ticarcillin/clavulanate</td>
<td>N</td>
<td>6.5</td>
<td>870</td>
<td>100 mg/mL</td>
<td>SW</td>
<td>Local consensus</td>
</tr>
<tr>
<td>Tobramycin</td>
<td>N</td>
<td>5.4</td>
<td>253</td>
<td>10 mg/mL</td>
<td>D5W</td>
<td>Local consensus</td>
</tr>
</tbody>
</table>

*a Medication name, category, or type.

*b Documentation of permanent cosmetic (C) or permanent functional (F) harm in the pediatric literature.

*cited here are references for evidence of permanent harm (F, C) to infants or children. When no permanent harm has been published (N) for a listed medication in the pediatric literature, cited references are for other published lists of medications with risk for causing harm (all ages).

Abbreviations: C, permanent cosmetic harm documented in the pediatric literature; CONC, concentration of medication; D5LR, 5% dextrose in lactated Ringer’s solution; D5W, 5% dextrose in water; DIL, diluent in most common pediatric preparation; F, permanent functional harm documented in the pediatric literature; H, high risk; I, intermediate risk; L, low risk; N, no evidence of permanent harm documented in the pediatric literature; NA, not applicable; NS, normal saline; OSM, osmolality (milliosmoles per kilogram); PIV, peripheral intravenous; TPN, total parenteral nutrition.

In addition to using the table to determine the risk for a given PIV infusate, it can also be used to influence the choice of vascular access device most suited to the situation. Though harm from extravasation is a possibility with any intravenous delivery site, when a medication in the higher-risk tier is ordered, the authors advocate that consideration be given to the use of central access to reduce the risk of harm should extravasation occur. The authors reasoned that if clinicians could be influenced by the Red/Yellow/Green list to consider and trend toward central access for delivery of higher-risk medications, the combination of improvements in PIV monitoring and changes in the prescribing habits of clinicians should result in a greater overall reduction of PIV-related harm than either strategy alone. The authors acknowledge that the clinical decision-making process is complex and must take into account the cost and risks of central vascular access, including PIV central catheters.
It should also be noted that although the medications in the lower-risk tier may seem more innocuous, any infusate has the potential to cause harm. Gross extravasation, even of normal saline, may result in serious harm including compartment syndrome, causing ischemia and loss of tissue or permanent loss of limb function.76

In the search for evidence about the risk for medications that cause harm when extravasated from a PIV, several medications were reported that are no longer used in clinical practice. As new medications are approved, each will need to be rigorously assessed for risk of extravasation harm. Although case studies may increase awareness of a medication’s potential for risk, well-designed research studies should be conducted to determine actual risk.

ACKNOWLEDGMENTS
The authors acknowledge the editorial assistance of Pam Schoettker.

REFERENCES


44. Davies J, Gault D, Buchdahl R. Preventing the scars of neonatal inanition. *F50-F51.*


