Standardizing concentrations of adult drug infusions in Indiana

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Purpose. A multidisciplinary, consensus-driven initiative to promote the use of standardized medication concentrations for adult drug infusions across the state of Indiana is described.

Methods. To accomplish development of the Indiana Standard Concentrations of Adult Drug Infusions List ("the Indiana List"), several available lists of i.v. concentrations were compiled, consolidated, and compared. Lists of adult standardized i.v. concentrations were primarily drawn from Indiana regional patient safety coalitions, published literature, and publicly available lists of recommended i.v. concentrations. The standardization project, which expanded initial work completed by the Indianapolis Coalition for Patient Safety, was conducted in conjunction with Purdue University's Center for Medication Safety Advancement, the Indiana Hospital Association, and the 11 regional patient safety coalitions across the state.

Results. After a review of 9 existing lists of standard i.v. concentrations, an initial list of 69 concentrations representing a total of 37 medications was derived; 34 of those concentrations were represented on at least 1 of the 3 evaluated Indiana regional patient safety coalition lists. A statewide interdisciplinary work group of representatives of regional patient safety coalitions and 9 health systems representing a total of 81 hospitals ranging from academic medical centers to critical access hospitals assembled to develop consensus on a final list of standard medication concentrations for adult i.v. infusions.

Conclusion. A final list of 28 concentrations of 26 medications was identified for the recommended Indiana List by an interdisciplinary work group. A checklist of considerations for implementation was also developed.

Keywords: concentration, infusion, intravenous, medication, standardization

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Patient safety remains a perpetually critical issue to address in the healthcare system. Each year approximately 1.3 million people are injured from medication errors in the United States, resulting in at least 1 death daily.[1] Medication-related errors lead to higher costs in the healthcare system.[2] Strategies aimed at reducing adverse drug events during transitions of care have been shown to increase the quality of care for patients.[3] With the passage of the Affordable Care Act and ongoing healthcare reform efforts, now is an optimal time to implement changes to improve patient safety. One such change is standardization of i.v. medication concentrations.

In the hospital setting, errors involving i.v. infusion medications have the greatest potential to cause significant harm to patients.[4] Besides reducing the potential for patient harm, there are several other prospective benefits of standardizing concentrations of high-risk i.v. medications. Standardizing concentrations will create a less complex, more consistent, and safer environment for nurses and physicians, especially those working

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in multiple hospitals. Nurses using smart-pump and barcode-scanning technology are less likely to enter the wrong medication concentration, as the medication library is simplified through elimination of duplicate product entries. In addition, with standardized concentrations the risk of human error in calculating a dose or an infusion rate due to multiple available drug concentrations is decreased. Lastly, reducing inconsistencies and the number of opportunities for high-risk i.v. medication errors is the most important benefit of standardizing medication concentrations.[5,6]

While much of the published research quantifying the benefits and reductions in errors associated with standardized i.v. concentrations has been conducted in pediatric populations, potential benefits can be extrapolated to adult patients. Upon examination of the past year's medication error reports at a California hospital pediatric intensive care unit, it was determined that 52% (26 of 50) of the reported errors were dose related, with 23% of those errors (6 of 26) involving improper drug concentrations.[7] After standardizing concentrations of the most commonly used i.v. medications, both the rate of dose-related errors and the rate of concentration-related errors as a percentage of dose-related errors decreased notably, to 25% (7 of 28 errors) and 0% (0 of 7 errors), respectively. At another pediatric hospital, in Utah, both medication errors and pharmacy preparation errors were reduced after implementation of standardized drug concentrations and smart-pump technology.[8] The rate of medication errors decreased from 3.1 to 0.8 per 1,000 doses, and pharmacy preparation errors decreased from 0.66 to 0.16 per 1,000 doses.

The Institute for Safe Medication Practices (ISMP), in collaboration with the Vermont Oxford Network (VON), has published a standardized list for neonatal drug infusions that could be applied nationally to approximately 80% of infusions for neonatal patients. However, no such national list for adult drug infusions is currently published. Across the United States, various safety organizations, including the San Diego Patient Safety Consortium and VON, have already instituted initiatives to lead the movement to standardize the concentrations of adult drug infusions.[5,9] Locally, the Indianapolis Coalition for Patient Safety (ICPS) implemented standardized names, concentrations, and dosage units of high-risk i.v. infusion medications throughout Indianapolis hospitals in 2009.[6] Further highlighting the importance of this patient safety issue, the Joint Commission has included standardizing and limiting the number of available drug concentrations as a National Patient Safety Goal.[10] In addition, the American Society of Health-System Pharmacists (ASHP) has published proceedings from a summit aimed at achieving consensus in regard to safe practices for i.v. medication use in order to decrease patient harm.[11] One priority area identified by summit participants was to "promote use of national standardized concentrations that are based on evidence" and to "request standards-setting organizations to establish an expectation for use of these standardized concentrations" during preparation and dispensing of i.v. medications.

Although national efforts surrounding this patient safety initiative began around 2003, results of a 2008 survey conducted by the U.S. Pharmacopeia (USP) Safe Medication Use Expert Committee at 229 hospitals across the United States demonstrated that this is still an area for improvement.[12] Survey responses showed that the number of hospitals using a standard concentration for a given i.v. medication ranged from 15% to 79%. Additionally, up to 4 standard concentrations of a single high-risk i.v. medication were reported to be in use in certain patient populations.

As a way to unify Indiana institutions in addressing this patient safety challenge, the requirement to standardize high-risk i.v. medication concentrations should be expanded across multiple hospitals within a system. In many instances, established i.v. concentrations in an individual hospital are based on historical processes and "professional preference" rather than a therapeutic or clinical patient need. Establishing a statewide standard for i.v. medication concentrations provides a level of credibility to an individual health system's approach to accomplishing this aim.

KEY POINTS

- In a statewide, consensus-driven initiative, an interdisciplinary work group developed a list of standard concentrations of 26 i.v. medications ("the Indiana List").
- After the project team overcame several human factors and process barriers, the standardization initiative yielded numerous benefits.
- A checklist of key considerations in implementing standard i.v. concentrations at the single-site or multisite level can aid other health systems in completing a similar project.
- In order to maximize the safety of i.v. medication use, efforts at the national level to develop a list of standardized concentrations are needed.

Background

ICPS provides a forum for Indianapolis-area hospitals to share information about best practices and work together to solve patient safety issues. A freestanding non-profit organization, ICPS comprises chief executive, medical, nursing, quality and safety, and pharmacy leaders from the 6 major health systems located in Indianapolis: Community Health Network, Eskenazi Health, Franciscan Health In-

dianapolis, Indiana University Health, Richard L. Roudebush VA Medical Center, and St. Vincent. While they are competitors in the marketplace, these hospital leaders have come together and agreed to not compete on safety. Coalition hospitals pool their expert resources to accelerate patient safety improvements through community-wide efforts.

ICPS members have a shared vision and challenge of making Indianapolis the safest city for healthcare. ICPS has historically achieved outcomes by sharing resources, performance targets, accountability, funding, and learning. By enlisting subject matter experts from ICPS member hospitals, coalitionwide multidisciplinary teams are formed. ICPS members undertake projects that focus on patient-centered strategies to improve safety. ICPS does this by addressing all of the barriers observed by patients and providers to achieve a standardized approach to patient care.

In 2009, the ICPS Medication Safety Work Group completed a project to standardize names, concentrations, and dosage units for high-risk i.v. infusion medications. Standardizing i.v. infusion drug concentrations among coalition hospitals reduces the chance of error, as nurses frequently travel among the health systems. Tools and resources to assist hospitals with implementation were developed.

The Indiana Hospital Association has 11 regional patient safety coalitions made up of dedicated professionals, including physicians, pharmacists, and nurses, who come together to collaborate to improve patient safety. In late 2013, using the initial framework from ICPS, representatives from these regional coalitions across the state of Indiana, in collaboration with the Purdue University Center for Medication Safety Advancement, formed a statewide working group to establish consensus on standard i.v. fluid concentrations.

Patient cases

Due to an overall lack of standardized i.v. concentrations for adult patients, medication errors have been documented in multiple institutions across central Indiana during transitions of care. This can be problematic both when transferring patients between health systems and when transfers occur between facilities within the same health system.

In one case, a patient was transferred between hospitals within the same health system during administration of norepinephrine 16 mg/250 mL via i.v. continuous infusion. The receiving institution's policy required that all infusions initiated at outside facilities be discontinued and reinitiated using products compounded within the institution. In compliance with the policy, the prescriber at the receiving institution ordered a norepinephrine infusion at the standard concentration (8 mg/250 mL), which the pharmacy prepared. The nurse stopped the infusion initiated at the outside hospital and initiated the new infusion but failed to notice the change in concentration and did not reprogram the pump; this resulted in the patient receiving half of the prescribed dose.

An additional incident involved a dopamine infusion. A patient was transferred between health systems while being administered an i.v. continuous infusion of a commercially available premixed dopamine solution (400 mg/250 mL). At the receiving facility, the infusion pump was programmed for administration of another commercially available premixed dopamine product (1,600 mg/250 mL). As a result, the patient was given 25% of the prescribed dose. Of note, the receiving facility's protocol was not followed (i.e., the infusion should have been discontinued on the patient's arrival, and a new order for the desired dopamine product should have been written).

In both of these incidents, an error occurred because the infusion pump was not reprogrammed to correct for a concentration change necessitated by the lack of a standardized i.v. concentration. Fortunately, both of the incidents involved medications that are dose adjusted based on patient response, and no adverse events were documented.

In another case, a patient was transferred between health systems during administration of a diltiazem i.v. continuous infusion indicated for new-onset atrial fibrillation. A prescriber at the receiving institution, noting that the concentration differed from the concentration usually administered at the institution, ordered a new diltiazem infusion. However, the infusion initiated at the outside facility was allowed to continue running on the receiving institution's infusion pump. When the patient was transferred to an intensive care unit, it was discovered that the infusion bag was empty. At that time, the new diltiazem infusion was prepared and administered. The pump was reprogrammed, and no adverse cardiac events were reported.

Additionally, an incident occurred when a patient was transferred between hospitals within the same health system during a pump-administered infusion and personnel at the receiving facility continued the infusion using the same pump. The infusion pump was subsequently placed into the receiving facility's stock and was later used to administer an i.v. continuous infusion of heparin sodium (to a different patient) at the hospital's standard concentration (25,000 units/250 mL). However, the infusion pump's drug library and settings had been configured to allow administration of heparin sodium only at a concentration specified by the outside hospital (25,000 units/500 mL); a nurse at the receiving facility selected this concentration when programming the pump, and the patient received twice as much heparin as prescribed. The infusion pump was removed from use and replaced by one with the receiving facility's drug library and standard concentrations. No adverse events were documented.

Any of the aforementioned scenarios could have resulted in a pa-

tient fatality. These cases illustrate the need for global process changes to prevent medication errors and promote patient safety. At one of the multihospital health systems mentioned above, pumps have been upgraded in order to standardize the drug libraries and concentrations to prevent errors related to pump or patient transfers between hospitals within the system. A systematic statewide approach to standardizing medication concentrations is warranted, as it is unrealistic for health systems across the state to standardize computer systems, infusion pumps, and policies. This approach should result in safer transitions of care and fewer medication errors related to end-user confusion.

Methods

In November 2013, it was determined that 3 of the 11 patient safety coalitions in Indiana had independently replicated the original work of the San Diego Patient Safety Consortium to create a regional standard list of their own. As the 3 lists varied, and to avoid further duplication of efforts on the part of the other regional coalitions, there was an opportunity to develop a statewide list of i.v. infusion concentrations for adults. Through a consensus-driven process, the Indiana Standard Concentrations of Adult Drug Infusions List ("the Indiana List") was born. This standardization project was initiated to eliminate medication administration errors related to incorrect concentrations and caregiver confusion.

To accomplish the development of the Indiana List, several available lists of i.v. concentrations were compiled, consolidated, and compared. Lists of standardized i.v. concentrations were primarily drawn from 3 sources:

1. Indiana regional patient safety coalitions—Lists of standardized i.v. medication concentrations developed by coalitions in northeastern Indiana, central southwestern Indiana, and Indianapolis were included.
2. Published literature—Published i.v. concentrations from a survey completed by the USP Safe Medication Use Expert Committee[12] were reviewed. Published work from the San Diego Patient Safety Consortium[5] was also used.
3. Publicly available i.v. concentration lists—Several hospital organizations make their i.v. concentration lists available through Internet search engines. Nonpediatric hospital lists were included as a result of the Internet search.

After a review of 9 lists of standarized drug concentrations from those sources, an initial list of 69 different medication concentrations representing 37 medications was derived. Thirty-four of the medication concentrations were represented on at least 1 of the 3 Indiana regional coalition lists; consensus regarding 19 medication concentrations was already reflected in those lists, leaving 15 concentrations for further evaluation.

A statewide interdisciplinary panel of physicians, nurses, and pharmacists from regional patient safety coalitions and 9 health systems was formed. This group, representing a total of 81 hospitals (approximately 50% of the hospitals in the state of Indiana),[13] assembled to develop consensus around the remaining 15 medication concentrations; 9 of those concentrations were ultimately added to the final list. In general, consensus was obtained for these additional medication concentrations prioritized based on the following factors: commercially available products, current concentrations included on the majority of the health systems' lists, previous medication incidents, clinical implications, compounding considerations, stability issues, and other concerns voiced by individual group members. Group members met in person and via conference call to discuss the list and its potential impact within their region and their respective health systems.

Results

A final list of 28 concentrations representing 26 unique medications was identified for the Indiana List, shown in Table 1. The following information was included when the list was distributed: "This list of medications and accompanying concentrations has been identified by a statewide group of hospitals and regional patient safety coalitions as the standard i.v. concentration to use for adult i.v. infusions in the state of Indiana. The purpose of this standardization is to minimize unnecessary clinical variation and to promote the safe administration of medications." For 2 medications on the list, a specific area in an institution was specified (i.e., dobutamine for nonprocedural areas and magnesium sulfate for obstetric areas). Participation with the recommended list did not exclude the use of an alternative medication concentration.

The final list was reviewed and distributed in June 2014 through several regular Indiana Hospital Association publications (e.g., its newsletter). Regional meetings were conducted with Indiana's safety coalitions to promote further engagement and adoption. Health systems were then expected to review and implement the standard list. Based on feedback and identified barriers, a checklist of considerations was developed to facilitate implementation at the single-site and multisite levels (appendix).

While the Indiana List provides a standard concentration, the interdisciplinary team recognizes there are unique patient populations or circumstances that warrant a nonstandard concentration (e.g., burn patients, fluid restriction, pediatrics, etc.). These unique populations were excluded from the original work as the group aimed to create a standardized list that would address the needs of the majority of patients served by member health systems. After implementation of the Indiana List, a review of a 30-day sample of all orders for continuous adult infusions eligible for standardization at 3 large, urban,

academic medical centers included in the project was conducted; the sample included 3,858 (69.5%) of the total of 5,548 infusions administered during the 30-day period. Parenteral nutrition, irrigation fluids, and maintenance i.v. fluids were excluded from the calculation, as these items were not within the scope of the project.

Discussion

Not all of the 69 i.v. concentrations identified from Indiana coalition members, published literature, and publicly available hospital lists were included in the Indiana List. Several actual or potential barriers to list development or implementation were identified throughout the standardization process.

Human factors barriers. As during any large process change, the group was faced with several human factors to manage; this challenge was magnified due to the statewide scope of the project. For example, due to the large number of participants, at times it was difficult facilitating the logistics of the project on a statewide scale and aligning the schedules of group members. There was a lack of engagement or willingness to participate from some group members, while others expressed negativity or doubt regarding the feasibility of the project or its potential impact on patient outcomes (i.e., was the perceived outcome worth the effort?). In addition, some health systems were faced with a lack of committee or leadership support and approval.

Process barriers. In addition, numerous obstacles related to specific processes or operations arose throughout the course of the project. Local practices and experiences often dictate the use of nonstandardized i.v. medication concentrations. For example, historical incidents, end-user preferences, or drug shortages may directly influence the concentrations used within a given facility or health system. Consensus regarding which drugs to include in the standardization project was also difficult to obtain due to conflicting opinions on the number of medications to target, inconsistencies among lists of high-alert medications, and differences in the types of medication errors reported at project participants' institutions and health systems. Cost was also a significant consideration during project decision-making related to securing resources for aligning systems (e.g., information technology resources, resources for updating smart-pump libraries and overcoming a lack of computer system integration), education, rollout, and compounding (e.g., the need to keep more drug product on hand to achieve higher concentrations or to use a more expensive commercially available product). Ultimately, these issues resulted in certain medications being excluded from the final list.

Table 1. Indiana Standard Concentrations of Adult Drug Infusions List[a,b]

Drug	Concentration
Amiodarone hydrochloride	1.8 mg/mL
Amiodarone hydrochloride bolus	1.5 mg/mL
Argatroban	1 mg/mL
Bumetanide[b]	0.25 mg/mL
Cisatracurium[b]	0.4 mg/mL
Dexmedetomidine	4 µg/mL
Dobutamine (for use in nonprocedural areas)[b]	4,000 µg/mL
Eptifibatide	750 µg/mL
Esmolol hydrochloride	10 mg/mL
Fentanyl	10 µg/mL
Furosemide[b]	10 mg/mL
Heparin sodium	100 units/mL
Insulin	1 unit/mL
Isoproterenol hydrochloride	4 µg/mL
Labetalol hydrochloride	2 mg/mL
Lidocaine	4 mg/mL
Magnesium sulfate (for use in obstetric patients)[b]	0.04 g/mL
Midazolam	1 mg/mL
Milrinone	200 µg/mL
Morphine sulfate	1 mg/mL
Morphine sulfate (for use in PCA)[b]	1 mg/mL
Nitroglycerin	200 µg/mL
Nitroprusside	200 µg/mL
Norepinephrine[b]	32 µg/mL
Procainamide hydrochloride	4 mg/mL
Propofol	10 mg/mL
Vasopressin[b]	0.4 unit/mL
Vecuronium bromide	1 mg/mL

[a]PCA = patient-controlled analgesia.
[b]Drug for which standard adult i.v. concentrations were newly developed for the Indiana List; standard concentrations of the other listed agents were already specified in one or more source documents reviewed by the Indiana List work group.

Overcoming barriers. To overcome the identified barriers, the group used several techniques that were critical to the success of the project. To help address the human factors barriers encountered, early in the process we identified key project champions from various sites to serve as leaders within the group and to motivate other group members to accomplish our aims. In terms of the large-scale scope of the project, we supplemented face-to-face meetings with conference calls to ensure that all members' input and opinions were realistically and feasibly considered. Members of the group also traveled around the state to present project findings, answer questions from member sites, and discuss implementation strategies. Through a consensus-driven process and using an interdisciplinary approach, we were able to address process-related barriers systematically and objectively. Issues such as historical precedence and cost were secondary to patient safety throughout this entire process.

Benefits. Development of a statewide standardized list of i.v. concentrations yielded several benefits in areas such as process change facilitation, patient safety, communication, and compliance with regulatory requirements. In terms of process changes, a more streamlined process can be realized as a result of reduced variation and complexity. Also, with numerous coalitions and health systems struggling to develop a list of standardized i.v. drug concentrations, collaborative work can lead to optimized efficiency due to decreased duplication of effort. A standardized list also creates elevated risk awareness among clinicians working with high-risk i.v. medications, allowing for safer transitions of care; this also allows for an enhanced ability to compare safety considerations for medication-related technology (e.g., barcode-assisted medication administration, smart pumps) across facilities. Additional benefits of this project include increased compliance with external regulatory standards and broader adoption of ISMP recommendations (e.g., use of premixed products when available, streamlined medication technology nomenclature). This project resulted in increased communication and networking among regional patient safety coalitions across the state, leading to future collaboration on additional safety initiatives.

Future directions. The project required a significant amount of time and effort from group members. However, we strongly believe the benefits described above outweigh any challenges faced throughout this period. Ultimately, the group was successful in achieving the creation of the Indiana List. Moving forward, we plan to continue our efforts and have discovered several opportunities for future work. Short-term efforts include addressing adoption of additional medications for the list (i.e., hydromorphone, nicardipine, epinephrine, and dopamine) and standardizing units of measure for each concentration. We also aim to address the needs of additional unique patient populations, such as pediatric or fluid-restricted patients. Long-term goals include tracking participation and adherence with the statewide list, ensuring ongoing quality review, and assessing safety outcomes by comparing adverse events involving medications on the Indiana List before and after list implementation. In addition, widespread utilization of commercially available premixed products could result in potential market share growth, thus incentivizing manufacturers to expand their lines of medications marketed as premixed infusions and leading to wider adoption of a standardized concentration list.

We also plan to conduct a follow-up project to assess project implementation across the state. We plan to survey group members regarding specific barriers encountered during implementation, acceptance rates, supply chain issues, and other operational considerations.

It was recently announced that the Food and Drug Administration has awarded ASHP a 3-year contract to "develop and implement national standardized concentrations for [i.v.] and oral liquid medications" as part of the agency's Safe Use Initiative.[14] We are hopeful that the work we have completed will be reviewed by ISMP and ASHP for adoption as the foundation for a national list of standardized concentrations for adults.

The consensus-driven process used by the Indiana Hospital Association to develop the Indiana List may be a model for other states to use. In Indiana, adoption of the standardized concentrations specified on the statewide list was highly recommended as an important contribution to patient safety. We encourage healthcare leaders in other jurisdictions to consider developing a list of standardized i.v. concentrations at the site, health-system, city, or state level and to incorporate lessons learned from organizational leaders who have completed this process. Ultimately, development of a national standard for commonly used i.v. medications, as opposed to a state-by-state approach to addressing this important practice issue, should be a priority.

Conclusion

A final list of 28 concentrations of 26 medications was identified for the recommended Indiana List by an interdisciplinary work group. A checklist of considerations for implementation was also developed.

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Disclosures

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References

1. Food and Drug Administration. Medication error reports. www.fda.gov/Drugs/DrugSafety/MedicationErrors/ucm080629.htm (accessed 2015 Nov 25).
2. American Society of Hospital Pharmacists. ASHP guidelines on preventing medication errors in hospitals. *Am J Hosp Pharm.* 1993; 50:305-14.
3. Spinewine A, Claeys C, Foulon V, Chevalier P. Approaches for improving continuity of care in medication management: a systematic review. *Int J Qual Health Care.* 2013; 25:403-17.
4. Hicks RW, Cousins DD, Williams RL. Summary of information submitted to MEDMARX in the year 2002. The quest for quality. Rockville, MD: USP Center for the Advancement of Patient Safety; 2003:1-56.
5. San Diego Patient Safety Consortium. Safe administration of high-risk i.v. medications: intra- and inter-hospital standardization: drug concentrations and dosage units (2009). www.calhospital.org/sites/main/files/file-attachments/toolkit_safe_admin_of_high_risk_iv_meds_revised_2009.pdf (accessed 2015 Nov 25).
6. Indianapolis Coalition for Patient Safety. High risk i.v. infusion medication concentrations and dosage units standardization. www.indypatientsafety.org/documents/resources/High_Risk_IV_Drug_Concentration_and_Dosage_Unit_Standardization.pdf (accessed 2015 Dec 9).
7. Bullock J, Jordan D, Gawlinski A et al. Standardizing i.v. infusion medication concentrations to reduce variability in medication errors. *Crit Care Nurs Clin North Am.* 2006; 18:515-21.
8. Larsen GY, Parker HB, Cash J et al. Standard drug concentrations and smart-pump technology reduce continuous-medication-infusion errors in pediatric patients. *Pediatrics.* 2005; 116:e21-5.
9. Vermont Oxford Network and Institute for Safe Medication Practices. Standard concentrations of neonatal drug infusions. www.ismp.org/Tools/PediatricConcentrations.pdf (accessed 2015 Dec 9).
10. Joint Commission. www.jointcommission.org/standards_information/npsgs.aspx (accessed 2015 Dec 9).
11. Proceedings of a summit on preventing patient harm and death from i.v. medication errors. *Am J Health-Syst Pharm.* 2008; 65:2367-79.
12. Phillips MS. Standardizing i.v. infusion concentrations: national survey results. *Am J Health-Syst Pharm.* 2011; 68:2176-82.
13. Health Care Quality and Regulatory Commission. Hospital directory. www.in.gov/isdh/reports/QAMIS/hosdir/wdirhos.htm (accessed 2016 Apr 19).
14. Blank C. ASHP to develop standardized concentrations of IV and oral drugs. www.drugtopics.modernmedicine.com/drug-topics/news/ashp-develop-iv-and-oral-drug-standardized-concentrations (accessed 2016 Apr 15).

Appendix—Implementation considerations

General considerations

1. Obtain committee approval
   a) Interdisciplinary group with physician support, such as medication safety or patient safety committee
   b) Smart-pump leadership committee
   c) Nursing support (shared governance/practice council)
2. Update i.v. room compounding information/dosing support for inpatient pharmacy
3. Procure drug product with appropriate concentrations
4. Standardize smart-pump dosing libraries
   a) Concentrations
   b) Profiles
   c) Drug terms
   d) Therapies (e.g., alteplase for stroke versus pulmonary embolism)
   e) Clinical advisories
5. Align computerized prescriber-order-entry and/or pharmacy systems
6. Conduct education
   a) Pharmacists
   b) Providers
   c) Nurses

Additional considerations for multisite health systems

1. Establish systemwide approach to managing
   a) Smart-pump data sets
   b) Server and storage space
   c) Wireless access points
   d) Interface for all infusion types
2. Standardize additional components
   a) Smart-pump models and manufacturers
   b) Software versions
   c) Service contracts
   d) Upgrades (manual versus wireless)
3. Align continuous quality improvement databases
4. Coordinate rollout and go-live
   a) Information systems/technology
   b) Pharmacy operations leadership
   c) Nursing leadership
   d) Biomedical engineering