PEDIATRIC CONTINUOUS INFUSION STANDARDS

STANDARDIZE 4 SAFETY INITIATIVE

Standardize 4 Safety is the first national, interprofessional effort to standardize medication concentrations to reduce errors, especially during transitions of care.

These national standards will cover:

- Concentrations and dosing units for intravenous continuous medications for adult patients.
- Concentrations for compounded oral liquid medications.
- Concentrations and dosing units for intravenous continuous medications for pediatric patients.
- Doses for oral liquid medications.
- Concentrations for intravenous intermittent medications.
- Concentrations for PCA and epidural medications.

The Standardize 4 Safety initiative began in 2008 when a multi-stakeholder IV summit was held to address preventing patient harm and death from intravenous (IV) medication errors. Among the recommendations made by the participants was to establish national standards for IV medications in hospitals including standardized concentrations and dosing. In addition, it was recommended that the national standards be created in collaboration with the Food and Drug Administration (FDA), the pharmaceutical industry, and other stakeholders. Since the summit, establishing standardized concentrations has garnered strong support from ASHP members, the Joint Commission, the Institute for Safe Medical Practices (ISMP), and others. [1] [2] [3] [4]

In 2015 the FDA, through its Safe Use Initiative, awarded ASHP a grant to develop and implement national standardized concentrations for IV and oral liquid medications. The aims of the grant were to: (1) identify a nationwide expert interprofessional panel consisting of physicians, nurses, and pharmacists; (2) create standards for adult continuous IV infusions, compounded oral liquid medications, pediatric continuous IV infusions, doses for liquid medications, intravenous intermittent infusions, and PCA and epidural medications; (3) disseminate the standards and assess their adoption.

1 ASHP Best Practices: Position and guidance documents of ASHP. 2014. ASHP, Bethesda, Maryland.

2 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–e25.

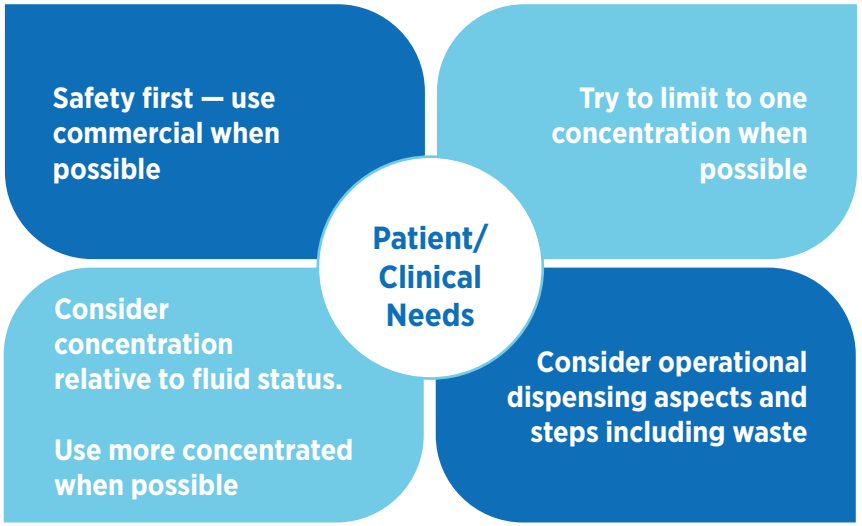
3 Joint Commission. Preventing Pediatric Medication Errors. https://www.jointcommission.org/-/media/tjc/documents/resources/patient-safety-topics/sentinel-event/sea-39-ped-med-errors-rev-final-4-14-21.pdf. (accessed March 15, 2024)

4 Shekelle PG, Wachter RM, Pronovost PJ, et.al. An Updated Critical Analysis of the Evidence for Patient Safety Practices. Comparative Effectiveness Review No. 211. (Prepared by the Southern California-RAND Evidence-based Practice Center under Contract No. 290-2007-10062-I.) AHRQ Publication No. 13-E001-EF. Rockville, MD: Agency for Healthcare Research and Quality. March 2013. www.ahrq.gov/research/findings/evidence-based-reports/ptsafetyuptp.html. (accessed September 20, 2020)

WHY STANDARDIZE

To Err is Human was published in 1999 and highlighted the harm to patients from healthcare error. In that report, medication errors were stated to be responsible for one of 131 outpatient and one of 854 inpatient deaths.[5] Healthcare continues to struggle to eliminate harm to patients. A systematic review and meta-analysis in 2019 estimated one in 20 patients are exposed to preventable medical harm with the highest incidence of events due to medications. Compounded medications,[6] especially those given intravenously, are known to be high risk for error due to added complexity and multiple steps required for determining dosing when ordering, concentrations for preparation, and rates of infusion for administering.[7] [8] Using standardization as a quality improvement tool decreases variation, improves safety, and is the foundation for using clinical pathways and evidence-based guidelines. Standardization allows providers to manage excessive and unintended variation as they customize care for patients.[9]

PRINCIPLES FOR PEDIATRIC CONTINUOUS INFUSION STANDARDS



5 Kohn LT, Corrigan J, Donaldson Molla S, eds; Institute of Medicine Committee on Quality of Health Care in America. To Err is Human: Building a Safer Health System. Washington, DC: National Academy Press; 2000.

6 Panagioti, M, Khan K, Keers RN, et.al. Prevalence, severity, and nature of preventable patient harm across medical care settings: systematic review and meta-analysis. BMJ 2019;366:l4185 | doi: 10.1136/bmj.l4185.

7 Hedlund N, Beer I, Hoppe-Tichy T, Trbovich P. Systematic evidence review of rates and burden of harm of intravenous admixture drug preparation errors in healthcare settings. BMJ Open. 2017; 7(12): e015912.

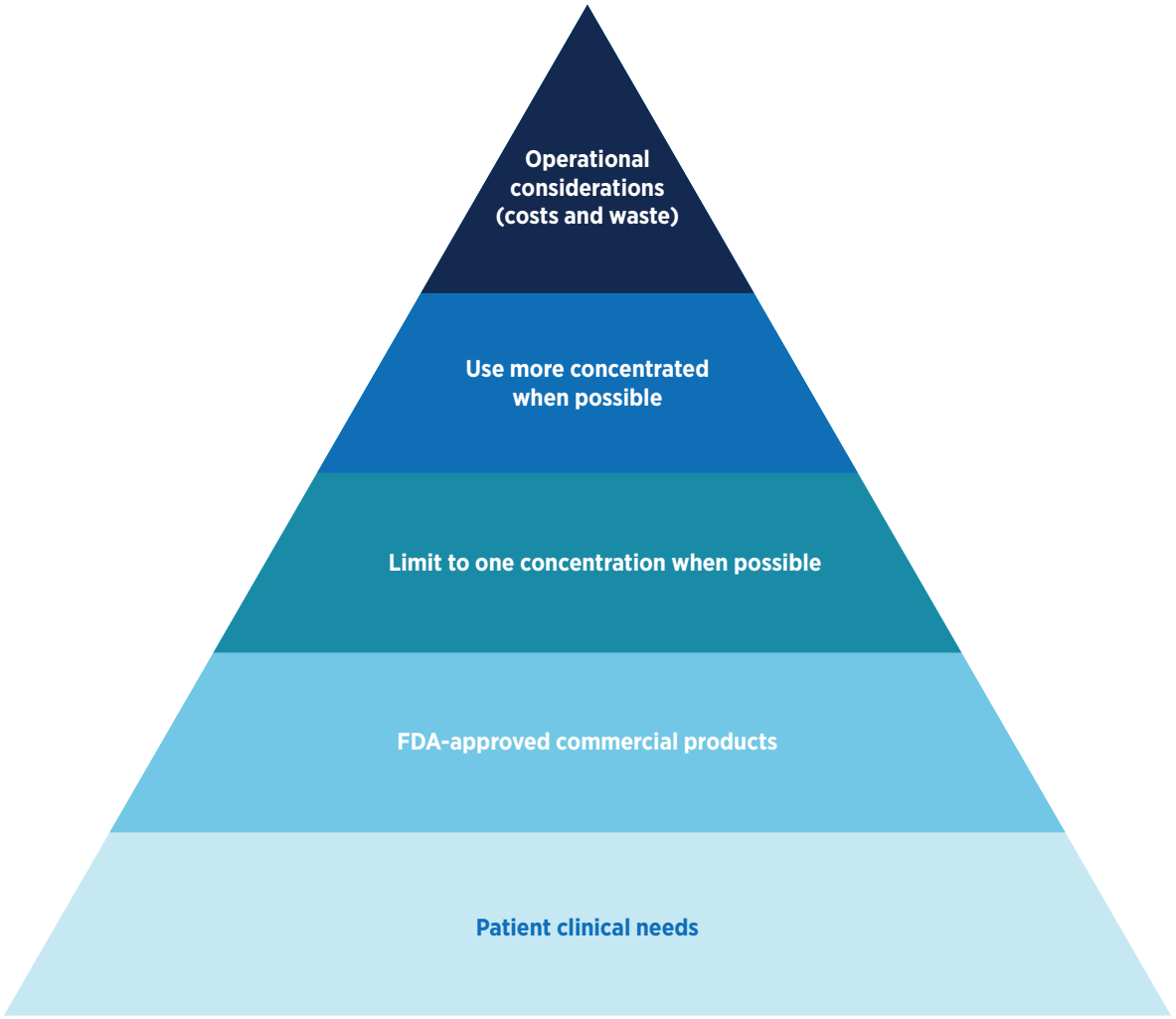
8 Sutherland A, Canobbio M, Clarke J, et.al. Incidence and prevalence of intravenous medication errors in the UK: a systematic review. Eur J Hosp Pharm. 2020 Jan; 27(1): 3–8.

9 Lloyd R. Does Standardization Mean the End of Autonomy? Institute for Healthcare Improvement. https://www.ihi.org/insights/does-standardization-mean-end-autonomy. (accessed March 20, 2024)

HOW THE NATIONAL MEDICATION CONCENTRATION STANDARDS WERE DEVELOPED

A comprehensive environmental scan was conducted to identify the appropriate medications to be addressed in the respective standard concentrations. A multi-disciplinary expert panel was convened for each standard concentration category. Members were selected based on their expertise in the subject matter and identified with assistance from organizations such as The American Society of Anesthesiologists, Society of Critical Care Medicine, and American Association of Critical-Care Nurses. Each expert panel was charged to establish standard principles to guide their decisions in creating the respective standard concentration recommendations. Once a draft of standards was established, it was released for public comment and review by ASHP staff and ISMP. The expert panel subsequently met to address all comments and generate the National Medication Concentration Standards.

PRINCIPLES FOR EXPERT PANEL DELIBERATIONS



EXPERT PANEL

PHYSICIANS

Mitchell Goldstein
Loma Linda University Health

Randi Trope
Cohen Children's Northwell Health

Vinay Vaidya
Phoenix Children's Hospital

NURSES

Wendy Cross
American Association of Critical-Care Nurses

Rebecca Isbell

Rachel Joseph

Kimberly Whalen
Massachusetts General Hospital

Lori Williams
University of Wisconsin Health

PHARMACISTS

Jared Cash
Primary Children's Hospital

Regine Cauthers White
Wolters Kluwer

Brandon Clubb
Riley Hospital for Children

Kim Jeong-eun
New York Presbyterian Hospital

Jake Luke
Primary Children's Hospital

Rachel Meyers
Rutgers

Shelly Morvay
Nationwide Children's Hospital

DISCLAIMERS

- Suggested concentrations may differ from the package insert (PI) information for a drug. This is due to clinical needs that may have transpired postmarket. When this is the case, studies are available to support the use of a concentration different than what the parent company originally pursued through the new drug application (NDA) process.
- Please use the utmost caution when using a concentration different than the PI, especially if rate information is used from the PI.
- Dosing units were derived from PI information, commonly used drug-reference guides, and clinical practice guidelines.
- Of special note, the expert panel is recommending that weight-based dosing be used for vasopressors (i.e., per kg, per minute), which may differ from institution specific guidelines. We strongly encourage that drug libraries and electronic health records (EHRs), including the electronic medication administration record, make distinct differences for weight-based vs. non-weight-based dosing so nurses can easily distinguish what pump programming is needed.
- These concentrations are guidelines only and are not mandatory. It is our hope that organizations will voluntarily adopt these concentrations and join a national movement to use standardization across the care continuum as an error-prevention strategy for patient safety.
- The information contained in this table is subject to the professional judgment and interpretation of the practitioner. ASHP has made reasonable efforts to ensure the accuracy and appropriateness of the information presented. However, any reader of this information is advised that ASHP is not responsible for the continued currency of the information, for any errors or omissions, and/or for any consequences arising from the use of the information in the self-assessment tool. Any user of the table is cautioned that ASHP makes no representation, guarantee, or warranty, express or implied, as to the accuracy and appropriateness of the information contained in it, and will bear no responsibility or liability for the results or consequences of its use.

CONSIDERATIONS IN USING THE PEDIATRIC CONTINUOUS INFUSION STANDARDS

The 80/20 rule was applied by the expert panel to determine recommended standard concentrations. The concentrations listed reflect those applicable to most patient care circumstances. The panel recognizes situations occur where the most appropriate concentration for a patient may not be the recommended standard.

Whenever possible one standard infusion concentration is the recommendation. When more than one standard concentration was recommended it was to accommodate patient care needs for extremely small neonates, fluid restrictions, differences required for peripheral versus central lines, to simplify calculations and accommodate limitations of pump infusion rates.

Medications with more than one recommended concentration are listed from lowest to highest concentration, with the numbering corresponding to the respective stability reference(s).

The concept of bracketing was employed for references for stability. For more information review: https://www.fda.gov/regulatory-information/search-fda-guidance-documents/q1d-bracketing-and-matrixing-designs-stability-testing-new-drug-substances-and-products.

The Pediatric Continuous Infusion Standards are intended for children less than 50 kg.

Drug	Concentration Standards	Dosing units	Commercially available	Concentration vs. unit mismatch	References
Alprostadil	1. 5 mcg/mL 2. 10 mcg/mL	mcg/kg/min	No	Possibly depending on vial	1. Pharmacia & Upjohn Company. Prostin VR Pediatric® (alprostadil sterile solution) injection prescribing information. Kalamazoo, MI; 2013 April. AHFS 2. Pharmacia & Upjohn Company. Prostin VR Pediatric® (alprostadil sterile solution) injection prescribing information. Kalamazoo, MI; 2013 April. AHFS
Alteplase	1 mg/mL	mg/kg/hour	No	No	1a. Frazen BS, Maximal Dilution of Activase. *Am J Hosp Pharm*, 1990;47:2016. 1b. Product Information: Activase(R) intravenous injection, alteplase intravenous injection. Genentech, Inc.(per Manufacturer), South San Francisco, CA, 2015- Micromedix
Amiodarone	1. 1.8 mg/mL 2. 3.6 mg/mL	**mcg/kg/min***	Yes - 1.8 mg/mL	Yes	1a. Campbell S, Nolan PE, Bliss M et al. Stability of amiodarone hydrochloride in admixtures with other injectable drugs. *Am J Hosp Pharm*. 1986; 43:917–21. 1b. Product Information: amiodarone HCl intravenous injection, amiodarone HCl intravenous injection. Teva Canada Limited (per Health Canada), Toronto, ON, Canada, 2016. - Micromedix 2. Product Information: amiodarone HCl intravenous injection, amiodarone HCl intravenous injection. Teva Canada Limited (per Health Canada), Toronto, ON, Canada, 2016. - Micromedix

Drug	Concentration Standards	Dosing units	Commercially available	Concentration vs. unit mismatch	References
Argatroban	1 mg/mL	**mcg/kg/min***	Yes	Yes	1a. Product Information: argatroban injection, argatroban injection. GlaxoSmithKline, Research Triangle Park, NC, 2009. 1b. Product Information: argatroban IV injection aqueous solution, argatroban IV injection aqueous solution. The Medicines Company (per DailyMed), Parsippany, NJ, 2011.
Bumetanide	1. 0.04 mg/mL 2. 0.25 mg/mL	**mcg/kg/hour***	Yes - 0.25 mg/mL undiluted drug from the vial	Yes	1. Cornish LA, Montgomery PA, Johnson CE. Stability of Bemetanide in 5% dextrose injection. AJHP 1997;54:422-3 2. Roche Laboratories. Bumex® (bumetanide) tablets and injection prescribing information. Nutley, NJ; 1999 Feb.
Cisatracurium	1. 1 mg/mL 2. 2 mg/mL	mg/kg/hour	Yes, undiluted from the 2 mg/mL vial	Yes	1. Pignard J. Physiochemical stability study of injectable solutions of cisatracurium besilate in clinical conditions. Ann Fr Anesth Reamnim. 2014; 33:304-9. 2. Abbvie. Nimbex® (cisatracurium besylate) injection prescribing information. North Chicago, IL; 2016 Dec.
Clevidipine	0.5 mg/mL	**mcg/kg/min***	Yes	Yes	1. Product Information: Cleviprex (clevidipine) injectable emulsion. Chiesi USA Inc. Cary, NC. 2021 April
Dexmede**TOMID**ine	4 mcg/mL	mcg/kg/hour	Yes		1. Hospira. Precedex® (dexmedetomidine) injection prescribing information. Lake Forest, IL; 2016 Apr.

Drug	Concentration Standards	Dosing units	Commercially available	Concentration vs. unit mismatch	References
DOBUTamine	1. 1000 mcg/mL 2. 2000 mcg/mL 3. 4000 mcg/mL	mcg/kg/min	Yes	Possibly, depending on pharmacy or outsourcing facility lab	1. Hospira. Dobutamine in 5% dextrose injection prescribing information. Lake Forest, IL; 2006 June. 2. Hospira. Dobutamine in 5% dextrose injection prescribing information. Lake Forest, IL; 2006 June. 3. Hospira. Dobutamine in 5% dextrose injection prescribing information. Lake Forest, IL; 2006 June.
DOPamine	1. 800 mcg/mL 2. 1600 mcg/mL 3. 3200 mcg/mL	mcg/kg/min	Yes	Possibly, depending on pharmacy or outsourcing facility label	1. Hospira. Dopamine hydrochloride and 5% dextrose injection prescribing information. Lake Forest, IL; 2014 May. 2. Hospira. Dopamine hydrochloride and 5% dextrose injection prescribing information. Lake Forest, IL; 2014 May. 3. Hospira. Dopamine hydrochloride and 5% dextrose injection prescribing information. Lake Forest, IL; 2014 May.

Drug	Concentration Standards	Dosing units	Commercially available	Concentration vs. unit mismatch	References
EPINEPHrine[1]	**1.** 10 mcg/mL[2] **2.** 20 mcg/mL **3.** 40 mcg/mL	mcg/kg/min	No	Possibly, depending on pharmacy or outsourcing facility label	1. Hook R, Neault A, Scharrer, et.al. Chemical stability of epinephrine 10 mcg/mL diluted in 0.9% sodium chloride and stored in polypropylene syringes at 4 degrees and 25 degrees C. Int J Pharm Compd. 2023;27:347-351. 2a. Allwood MD. The stability of four catecholamines in 5% glucose infusions. *J Clin Pharm Ther*. 1991:16:337-40. 2b. VanMatre ET, Ho KC, Lyda C, et.al. Extended Stability of Epinephrine Hydrochloride Injection in Polyvinyl Chloride Bags Stared in Amber Ultraviolet Light-Blocking Bags. *Hospital Pharmacy*. 2017;52:570-573. 3a. Carr RR, Decarie D, EnsomMHH. Stability of Epinephrine at Standard Concentrations. *Can J Hosp Pharm*. 2014;67:197-202. 3b. Peddicord TE, Olsen KM, ZumBrunnen TL, et.al. Stability of high-concentration dopamine hydrochloride, norepinephrine bitartrate, epinephrine hydrochloride and nitroglycerin 5% dextrose injetion. *Am J Health-Syst Pharm*. 1997;54:1417-19.

Drug	Concentration Standards	Dosing units	Commercially available	Concentration vs. unit mismatch	References
Esmolol	1. 10 mg/mL 2. 20 mg/mL	**mcg/kg/min***	Yes	Yes	1. Baxter. Brevibloc® injection (esmolol hydrochloride) prescribing information. (dated 1998 Jun). In: Physicians' desk reference. 54th ed. Montvale NJ: Medical Economics Company Inc; 2000:655-7. 2. Baxter. Brevibloc® injection (esmolol hydrochloride) prescribing information. (dated 1998 Jun). In: Physicians' desk reference. 54th ed. Montvale NJ: Medical Economics Company Inc; 2000:655-7.
Fenta**NYL**	1. 10 mcg/mL[2] 2. 50 mcg/mL	mcg/kg/hour	Yes, as undiluted from 50 mcg/mL vial	Possibly depending on pharmacy or oursourcing facility label	1. Extedned Stability for Parenteral Drugs 6th Edition, 2017. Ed. Bing, CD et. al. ASHP, 4500 East-West Highway, Suite 900, Bethesda, MD 20814 2. Hospira, INC. Fentanyl Citrate injection, solution. prescribing information. Lake Forest, IL; 2019, December.
Furosemide	1. 2 mg/mL 2. 10 mg/mL	mg/kg/hour	Yes, as undiluted from 10 mg/mL vial	No	1. Negro S, Rendon AL, Azuara M, et.al. Compatibility and Stability of Furosemide and Dexamethasone Comined in Infusion Solutions. Arzneimittelforschung. 2006;56:714-20. 2. American Pharmaceutical Partners, Inc. Furosemide Injection, USP prescribing information. Schaumburg, IL; 2002 Apr.
Heparin (anticoagulation therapy)	1. 50 units/mL 2. 100 units/mL	units/kg/hour	Yes	No	1. B.Braun Medical Inc. Heparin Sodium in Dextrose Injection prescribing information. Bethlehm, PA. 2018. April 2. B.Braun Medical Inc. Heparin Sodium in Dextrose Injection prescribing information. Bethlehm, PA. 2018. April
Heparin (arterial line maintenance)	2 Units/mL		Yes	No	1. Butt W, et.al. Effect of heparin concentration and infusion rate on the patency of arterial catheters. Crit Care Med. 1987,15:230-2.

Drug	Concentration Standards	Dosing units	Commercially available	Concentration vs. unit mismatch	References
HYDROmorphone[3]	1. 0.2 mg/mL 2. 1 mg/mL 3. 5 mg/mL	mg/kg/hr	No, but many pharmacies purchase from outsourcing facilities	Possibly depending on pharmacy label or oursourcing facility label	1. Ensom MHH, DeCarie D, Leung K, et al. Stability of hydromorphone-ketamine solutions in glass bottles, plastic syringes, and IV bags for pediatric use. *Can J Hosp Pharm*. 2009; 62(2):112b. 2. Extended Stability for Parenteral Drugs 6th Edition, 2017. Ed. Bing, CD et. al. ASHP, 4500 East-West Highway, Suite 900, Bethesda, MD 20814 3. Extended Stability for Parenteral Drugs 6th Edition, 2017. Ed. Bing, CD et. al. ASHP, 4500 East-West Highway, Suite 900, Bethesda, MD 20814
Insulin (regular)	1. 0.2 units/mL 2. 1 unit/mL	units/kg/hour	Yes	Possibly depending on pharmacy label or oursourcing facility label	1. Product Information: HUMULIN(R) R subcutaneous injection, intravenous injection, insulin human subcutaneous injection, intravenous injection. Lilly USA LLC (per FDA), Indianapolis, IN, 2018. Micromedex 2a. Nolan PE, Hoyer GL, LeDoux JH et al. Stability of ranitidine hydrochloride and human insulin in 0.9% sodium chloride injection. *Am J Health-Syst Pharm*. 1997. 2b. Product Information: HUMULIN(R) R subcutaneous injection, intravenous injection, insulin human subcutaneous injection, intravenous injection. Lilly USA LLC (per FDA), Indianapolis, IN, 2018. Micromedex

Drug	Concentration Standards	Dosing units	Commercially available	Concentration vs. unit mismatch	References
Isoproterenol	1. 20 mcg/mL 2. 64 mcg/mL	mcg/kg/min	No	Possibly depending on pharmacy label or oursourcing facility label	1. Isuprel (isoproterenol hydrochloride injection, USP) [prescribing information]. Lake Forest, IL: Hospira Inc; March 2013. Pediatric Injectable drugs 11th edition 2a. Sinclair-Pingel J, Grisso AG, Hargrove FR, Wright L. Implementation of standardized concentrations for continuous infusions using a computerized provider Order Entry System [published correction appears in *Hosp Pharm*. 2007; 42:84-85]. *Hosp Pharm*. 2006;41:1102-1106. 2b. Sturgill MG, Kelly M, Notterman DA. Pharmacology of the cardiovascular system. In: Fuhrman BP, Zimmerman JJ, eds. Pediatric Critical Care. 4th ed. Philadelphia, PA: Elsevier Saunders; 2011. Pediatric Injectable Drugs 11th edition
Ketamine	1. 2 mg/mL 2. 10 mg/mL	mg/kg/hour	Yes, undiluted drug from the vial of 10 mg/mL	Possibly depending on pharmacy label or oursourcing facility label	1. Product Information: KETALAR intravenous injection, intramuscular injection, ketamine HCl intravenous injection, intramuscular injection. Par Pharmaceutical (per FDA), Chestnut Ridge, NY, 2017. 2. Product Information: KETALAR intravenous injection, intramuscular injection, ketamine HCl intravenous injection, intramuscular injection. Par Pharmaceutical (per FDA), Chestnut Ridge, NY, 2017.

Drug	Concentration Standards	Dosing units	Commercially available	Concentration vs. unit mismatch	References
Labetalol	1. 1 mg/mL 2. 5 mg/mL	mg/kg/hour	Yes, undiluted drug from the vial of 5 mg/mL	Possibly depending on pharmacy label or oursourcing facility label	1. Product Information: labetalol HCl intravenous injection, labetalol HCl intravenous injection. Hospira, Inc. (per DailyMed), Lake Forest, IL, 2015. 2. Product Information: labetalol HCl intravenous injection, labetalol HCl intravenous injection. Hospira, Inc. (per DailyMed), Lake Forest, IL, 2015.
Lidocaine[4]	1. 4 mg/mL 2. 8 mg/mL	**mcg/kg/min***		Yes, with commercially available product	1a. Smith FM, Nuessle NO. Stability of lidocaine hydrochloride in 5% dextrose injection in plastic bags. *Am J Hosp Pharm*. 1981; 38:1745–7. 1b. Product Information: Lidocaine HCl dextrose 5% intravenous injection, lidocaine HCl dextrose 5% intravenous injection. Baxter Healthcare Corporation (per FDA), Deerfield, IL, 2017. 2a. Stewart JT, Warren FW. Stability of ranitidine hydrochloride and seven medications. *Am J Hosp Pharm*. 1994; 51:1802–7. 2b. Product Information: Lidocaine HCl dextrose 5% intravenous injection, lidocaine HCl dextrose 5% intravenous injection. Baxter Healthcare Corporation (per FDA), Deerfield, IL, 2017.

Drug	Concentration Standards	Dosing units	Commercially available	Concentration vs. unit mismatch	References
Midazolam	1. 0.3 mg/mL (easier pump programming than 0.35 mg/mL less decimal) 2. 1 mg/mL 3. 5 mg/mL	mg/kg/hour	Yes, undiluted drug from the vial of 1 mg/mL vial and 5 mg/mL vial	Possibly, depending on pharmacy or outsourcing facility label	1. Good PD, Schneider JJ, Ravenscroft PJ. The compatibility and stability of midazolam and dexamethasone in infusion solutions. J Pain Sympt Manag. 2004;27: 471-5. 2a. Karlage K, Earhart Z, Green-Boesen K, Myrdal PB. Stability of midazolam hydrochloride injection 1-mg/mL solutions in polyvinyl chloride and polyolefin bags. *Am J Health Syst Pharm*. 2011;68(16):1537-1540.[PubMed 21817086]. 2b. McMullin ST, Schaiff RA, and Dietzen DJ, "Stability of Midazolam Hydrochloride in Polyvinyl Chloride Bags Under Fluorescent Light," *Am J Hosp Pharm*, 1995, 52(18), 2018-20. 3a. Pramar YV, Loucas VA, & El-Rachidi A: Stability of midazolam hydrochloride in syringes and IV fluids. *Am J Health-Syst Pharm* 1997; 54:913-915. 3b. Product Information: MIDAZOLAM HCl intravenous intramuscular injection, midazolam HCl intravenous intramuscular injection. *Heritage Pharmaceuticals* (per DailyMed), Eatontown, NJ, 2017.

Drug	Concentration Standards	Dosing units	Commercially available	Concentration vs. unit mismatch	References
Milrinone	1. 100 mcg/mL 2. 200 mcg/mL	mcg/kg/min	Yes - 200 mcg/mL	No	1. Wilson TD, Forde MD. Stability of milrinone and epinephrine, atropine sulfate, lidocaine hydrochloride, or morphine sulfate injection. *Am J Hosp Pharm*. 1990;47(11):2504-7. 2a. Wilson TD, Forde MD, Crain AVR, Dombrowski LJ, Joyce MA. Stability of milrinone in 0.45% sodium chloride, 0.9% sodium chloride, or 5% dextrose injections. *Am J Hosp Pharm*. 1986;43(9):2218-2220. 2b. Wong F, Gill MA. Stability of milrinone lactate 200 mcg/mL in 5% dextrose injection and 0.9% sodium chloride injection. *Int J Pharm Compound*. 1998; 2(2):168b
Morphine	1. 0.2 mg/mL 2. 0.5 mg/mL 3. 1 mg/mL	mg/kg/hour	Yes, undiluted drug from the vial of 1 mg/mL vial or ready-to-use products or premix products available	Possibly depending on pharmacy label or oursourcing facility label	1. Veechio M, Walker SE, Iazzetta J et al. The stability of morphine intravenous infusion solutions. *Can J Hosp Pharm*. 1988; 41:5–9. 2a. McMullin ST, Schaiff RA, and Dietzen DJ, "Stability of Midazolam Hydrochloride in Polyvinyl Chloride Bags Under Fluorescent Light," *Am J Hosp Pharm*, 1995, 52(18), 2018-20. 2b. Altman L, Hopkins RJ, Ahmed S, et al: Stability of morphine sulfate in Cormed III (Kalex) intravenous bags. *Am J Hosp Pharm* 1990; 47:2040-2042 3. Stiles ML, Tu YH, & Allen LV Jr: Stability of morphine sulfate in portable pump reservoirs during storage and simulated administration. *Am J Hosp Pharm* 1989; 46:1404-1407.

Drug	Concentration Standards	Dosing units	Commercially available	Concentration vs. unit mismatch	References
Naloxone[5]	1. 16 mcg/mL 2. 40 mcg/mL 3. 400 mcg/mL	mcg/kg/hour	Yes, 0.4 mg/mL vials, however will most likely compound from 1 mg/mL vials	Yes	1a. Product Information Naloxone Hydrochloride Injection, solution. Hospira Inc. Lake Forest, IL. 9/2019. 4 mcg/ml. 1b. Lewis JM, Klein-Schwartz W, Benson BE, et al. Continuous naloxone infusion in pediatric narcotic overdose. *Am J Dis Child*. 1984;138(10):944–946. 8 mcg/ml 2. American Pain Society. Principles of Analgesic Use in the Treatment of Acute Pain and Cancer Pain. 6th ed. Glenview, IL: American Pain Society; 2008. 3. Product Information Naloxone Hydrochloride Injection, solution. Hospira Inc. Lake Forest, IL. 9/2019.
Ni**CAR**dipine	1. 0.1 mg/mL 2. 0.2 mg/mL 3. 0.5 mg/mL	**mcg/kg/min***	Yes - 0.1 mg/mL	Yes	1. Product Information: CARDENE(R) IV solution for IV infusion, nicardipine HCL solution for IV infusion. EKR Therapeutics, Inc, Bedminster, NJ, 2014. 2. Product Information: CARDENE(R) IV solution for IV infusion, nicardipine HCL solution for IV infusion. EKR Therapeutics, Inc, Bedminster, NJ, 2014. 3. Baaske DM, DeMay JF, Latona CA, et al. Stability of Nicardipine Hydrochloride in Intravenous Solutions. *Am J Health Syst Pharm*. 1996;53(14):1701-1705
Nitroglycerin	1. 200 mcg/mL 2. 400 mcg/mL	mcg/kg/min	Yes	No, product does have concentration in mcg/mL	1. Product Information: Nitroglycerin Injection. Abbott Laboratories, North Chicago, IL, October 2014 2. Product Information: Nitroglycerin Injection. Abbott Laboratories, North Chicago, IL, October 2014

Drug	Concentration Standards	Dosing units	Commercially available	Concentration vs. unit mismatch	References
Nitroprusside	1. 200 mcg/mL 2. 500 mcg/mL	mcg/kg/min	Yes	Possibly depending on pharmacy label or oursourcing facility label	1. Product Information: NIPRIDE RTU intravenous injection, sodium nitroprusside intravenous injection. Exela Pharma Sciences, LLC (per FDA), Lenoir, NC, 2017. 2. Product Information: NIPRIDE RTU intravenous injection, sodium nitroprusside intravenous injection. Exela Pharma Sciences, LLC (per FDA), Lenoir, NC, 2017.
Norepinephrine	1. 16 mcg/mL[2] 2. 32 mcg/mL 3. 64 mcg/mL	mcg/kg/min	Yes	Possibly depending on pharmacy label or oursourcing facility label	1. Tremblay M, Lessard MR, Trepanier CA, et al: Stability of norepinephrine infusions prepared in dextrose and normal saline solutions. *Can J Anaesth* 2008; 55(3):163-167. 2. Hasegawa GR, Eder JR. Visual compatibility of dobutamine hydrochloride with other injectable drugs. *Am J Hosp Pharm* 1984;41:949-51. 3. Walker SE, Law S, Garland J, et al: Stability of norepinephrine solutions in normal saline and 5% dextrose in water. *Can J Hosp Pharm* 2010; 63(2):113-118.
Octreotide	1. 2.5 mcg/mL 2. 10 mcg/mL 3. 50 mcg/mL	mcg/kg/hour	No, however the 50 mcg/ml concentration may be used undiluted from the available vial/ ampule.	Possibly depending on pharmacy label or oursourcing facility label	1. Novartis Pharmaceuticals. Sandostatin® (octreotide acetate) injection prescribing information. East Hanover, NJ; 2012 March. 2. Novartis Pharmaceuticals. Sandostatin® (octreotide acetate) injection prescribing information. East Hanover, NJ; 2012 March. 3. Novartis Pharmaceuticals. Sandostatin® (octreotide acetate) injection prescribing information. East Hanover, NJ; 2012 March.

Drug	Concentration Standards	Dosing units	Commercially available	Concentration vs. unit mismatch	References
Pantoprazole	0.8 mg/mL	mg/kg/hour	No	No	1a. Donnelly RF. Stability of pantoprazole sodium in glass vials, polyvinyl chloride minibags, and polypropylene syringes. *Can J Hosp Pharm*. 2011; 64:192-8. 1b. Wyeth. Protonix® (pantoprazole sodium) I.V. for injection prescribing information. Philadelphia, PA; 2012 May.
PENTobarbital	1. 8 mg/mL 2. 50 mg/mL	mg/kg/hour	Yes, undiluted drug from the 50 mg/mL vial	no	1. Walker SE, Iazzetta J. Compatibility and stability of pentobarbital infusions. *Anesthesiology*. 1981; 55:487–9. 2a. Gupta VD. Stability of pentobarbital sodium after reconstitu tion in 0.9% sodium chloride injection and repackaging in glass and polypropylene syringes. *International Journal of Pharmaceutical Compounding*. 2001, 5(6): 482-484. 2b. Nembutal(R) Sodium intravenous injection, intramuscular injection, pentobarbital sodium intravenous injection, intramuscular injection. Akorn, Inc. (per DailyMed), Lake Forest, IL, 2012.
Phenylephrine	1. 80 mcg/mL 2. 400 mcg/mL	mcg/kg/min	No	Possibly depending on pharmacy label or oursourcing facility label	1a. West-Ward Pharmaceuticals. Phenylephrine hydrochloride injection prescribing information. Eatontown, NJ; 2012 Dec. 1b. Éclat Pharmaceuticals. Vazculep® (phenylephrine hydrochloride) injection prescribing information. Chesterfield, MO; 2014 2. Jansen JJ, Oldland AR, Kiser TH. Evaluation of phenylephrine stability in polyvinyl chloride bags. *Hosp Pharm*. 2014; 49:455-7.
Propofol	10 mg/mL	**mcg/kg/min***	Yes	Yes	1. Fresenius Kabi USA, LLC. Diprivan® (propofol) injectable emulsion prescribing information. Lake Zurich, IL; 2017 Nov.

Drug	Concentration Standards	Dosing units	Commercially available	Concentration vs. unit mismatch	References
Remifentanil	1. 50 mcg/mL (non-recon vial straight drug) 2. 250 mcg/mL	mcg/kg/min	No	Possibly depending on pharmacy label or oursourcing facility label	1. Mylan Institutional LLC. Ultiva® (remifentanil hydrochloride) prescribing information. Rockford, IL; 2017 Dec. 2. Mylan Institutional LLC. Ultiva® (remifentanil hydrochloride) prescribing information. Rockford, IL; 2017 Dec.
Rocuronium	10 mg/mL	mg/kg/hr	Yes, undiluted drug from the vial of 10 mg/mL	Possibly depending on pharmacy label or oursourcing facility label	1. Hospira. Rocuronium bromide injection prescribing information. Lake Forest, IL: 2014 Feb.
Sodium Bicarbonate	1. 0.5 mEq/mL 2. 1 mEq/mL	mEq/kg/hour	Yes, undiluted if using the prefilled 0.5 mEq/mL syringes and as undiluted drug from the 1 mEq/mL vial	No	1. Hospira. Sodium Bicarbonate Injection, USP Vial dosage and administration. Lake Forest, IL. 1/2018. 2. Hospira. Sodium Bicarbonate Injection, USP Vial dosage and administration. Lake Forest, IL. 5/2018.
Sodium Chloride	0.5 mEq/mL (3%)	**mL/kg/hour vs. mEq/kg/hour, depending on institution protocols**	Yes, as 500 mL bags	Yes, based on dosing units used	1. Product information: sodium chloride 3% 5% intravenous injection, Baxter Healthcare Corporation (per DailyMed) Deerfield, IL, 20014.
Tacrolimus	0.02 mg/mL	mg/kg/day	No	Possibly depending on pharmacy label or oursourcing facility label	1. Astellas Pharma US, Inc. Prograf® (tacrolimus) capsules and injection prescribing information. Northbrook, IL; 2015 May.

Drug	Concentration Standards	Dosing units	Commercially available	Concentration vs. unit mismatch	References
Terbutaline	1 mg/mL	**mcg/kg/min***	Yes, undiluted from the 1 mg/mL vial	Possibly depending on pharmacy label or oursourcing facility label	1. Glascock JC, DiPiro JT, Cadwallader DE et al. Stability of terbutaline sulfate repackaged in disposable plastic syringes. *Am J Hosp Pharm*. 1987; 44:2291–3.
Tranexamic Acid	100 mg/mL (straight drug)	mg/kg/hour	Yes, undiluted from the 100 mg/mL vial	No	1. Pfizer Injectables. Cyklokapron® (tranexamic acid) injection prescribing information. New York, NY; 2013 May.
Vasopressin	**1.** 0.04 units/mL **2.** 0.2 units/mL **3.** 1 units/mL	VASOCONSTRICTION/ GI BLEED: **milliunits/kg/min*** DIABETES INSIPIDUS: **milliunits/kg/hr***	No	Yes	1. Wise-Faberowski L, Soriano SG, Ferrari L, et al. Perioperative management of diabetes insipidus in children. J Neurosurg Anesthesiol. 2004;16(3):220-225. 2. ASHP Interactive Handbook on Injectable Drugs Accessed July 13, 2020 3. Par Pharmaceutical Companies, Inc. Vasostrict® (vasopressin) injection prescribing information. Spring Valley, NY; 2015 Mar.
Vecuronium	1 mg/mL[2]	mg/kg/hr	No, but when the vial is diluted then no further dilution is needed	Yes	1. Product InformationL Vecuronium bromide ntravenous injection lyophilized powder for solution. Fresenius Kabi USA, LLC (per DailyMed) Lake Zurich, IL. 2016

***BOLD - dosing units differ from concentration units**

Updated: June 2024

NOTES

1 The expert panel and ISMP recommend different concentrations of epinephrine vs. norepinephrine given different indications despite same dosing units.
2 Babies under 500 gms may require a lower concentration.
3 The hydromorphone standard concentrations are intended for continuous infusion devices and NOT via PCA.
4 The recommended concentrations are intended for cardiac indications only.
5 The panel recognizes these two concentrations are 10x differences, however these are the only two concentrations studied for stability.