## ONLINE SUPPLEMENTARY TABLES

**Table S1. Systematic Review Search Terms**

| Errors | Route of Administration | Compounding | Article Type |
|---|---|---|---|
| ([Medication* or drug* or pharmaceutic* or medical or infus*] adj5 error*).mp.<br>OR<br>(Adverse adj5 [event* or reaction*]).mp.<br>OR<br>([Medication* or drug* or pharmaceutic*] adj5 [contamina* or safety or incompatib*]).mp.<br>OR<br>(Overdos* or over dose*).mp.<br>OR<br>Near miss.mp. OR (incident or incidents or accident*).mp.<br>OR<br>(Steril* or unsteril* or septic or sepsis or aseptic or asepsis).mp.<br>OR<br>([Healthcare or health care or hospital or bloodstream or blood stream or cross] adj3 infection*).mp.<br>OR<br>patient safety.mp.<br>OR<br>([Drug or medication* or pharmaceutic*] adj3 [stor*or stability or stable or instability or unstable or expir*).mp.<br>OR<br>([Wrong* or incorrect* or inappropriate* or error* or | parenteral<br>OR<br>intravenous<br>OR<br>catheter*<br>OR<br>infus*<br>OR<br>iv<br>OR<br>intraocular<br>OR<br>intravitreal<br>OR<br>intramuscular<br>OR<br>subcutaneous<br>OR<br>epidural<br>OR<br>intraosseous<br>OR<br>intraperitoneal<br>OR<br>(ei or im or io or os or ip or iv or pa).fs. use emefd | Compounding<br>OR<br>Compounded<br>OR<br>Reconstitut*<br>OR<br>Admix*<br>OR<br>(Prepar* adj5 (pharmacy or pharmacies or pharmacist or pharmaceutic* or drug* or medication* or ward or wards or nurs* or chemotherapy* or antineoplastic* or cytostatic* or nutrition* or mixture* or solution* or compound or compounds)).mp. | (clinical trial or randomized controlled trial or controlled clinical trial or multicenter study or phase 1 clinical trial or phase 2 clinical trial or phase 3 clinical trial or phase 4 clinical trial)<br>(EMBASE limits)<br>OR<br>(Evidence based medicine or consensus development or meta-analysis or outcomes research or "systematic review")<br>(EMBASE limits)<br>OR<br>(Clinical trial, all or clinical trial, phase I or clinical trial, phase II or clinical trial, phase III or clinical trial, phase IV or clinical trial or comparative study or controlled clinical trial or meta-analysis or multicenter study or observational study or randomized controlled trial or systematic reviews)<br>(Medline limits)<br>OR<br>(Chart review* or observational or systematic or prospective or cohort or retrospective or controlled study or controlled studies or controlled trial* or cross sectional or evidence based or direct observation* or audit or audits or randomized or blind or blinded or case series).mp.<br>(free text terms) |

inaccura* or deviation*]
adj5 (dose* or dosage* or
drug* or medication* or
pharmaceutic* or
concentration* or diluent*
or dilution* or strength* or
calculat* or volume or
label* or product* or
quantit*]).mp.
OR
(Missing label* or "no
label*" or "not label*").mp.
OR
particulate*.mp.

**Table S2. Details of Hawker Analysis**

| | Abstract and Title | Introduction and Aims | Method and Data | Sampling | Data Analysis | Ethics and Bias | Results | Transferability or Generalizability | Implications and Usefulness | Average Score | Overall Quality |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Anselmi et al. 2007[1] | 2 | 2 | 1 | 3 | 1 | 2 | 2 | 3 | 3 | **2** | **Fair** |
| Aruna et al. 2015[2] | 2 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 4 | **3** | **Poor** |
| Bertsche et al. 2008[3] | 3 | 3 | 3 | 2 | 1 | 2 | 2 | 2 | 2 | **2** | **Fair** |
| Campino et al. 2016[4] | 2 | 1 | 1 | 1 | 1 | 3 | 1 | 2 | 2 | **2** | **Fair** |
| Castagne et al. 2011[5] | 2 | 1 | 1 | 3 | 4 | 4 | 1 | 3 | 1 | **2** | **Fair** |
| Cousins et al. 2005[6] | 1 | 2 | 1 | 3 | 3 | 2 | 2 | 3 | 2 | **2** | **Fair** |
| Crill et al. 2010[7] | 1 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 2 | **2** | **Fair** |
| Dehmel et al. 2011[8] | 1 | 1 | 2 | 3 | 1 | 1 | 2 | 3 | 2 | **1** | **Good** |
| Ding et al. 2015[9] | 1 | 2 | 1 | 1 | 2 | 2 | 1 | 3 | 1 | **2** | **Fair** |
| Fahimi et al. 2007[10] | 2 | 2 | 2 | 3 | 4 | 2 | 3 | 3 | 1 | **2** | **Fair** |
| Fahimi et al. 2008[11] | 1 | 1 | 2 | 3 | 3 | 2 | 2 | 3 | 1 | **2** | **Fair** |
| Helder et al. 2016[12] | 3 | 2 | 1 | 1 | 2 | 2 | 1 | 2 | 3 | **2** | **Fair** |
| Hoefel et al. 2006[13] | 2 | 2 | 3 | 1 | 2 | 1 | 2 | 2 | 2 | **2** | **Fair** |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| Khalili et al. 2013[14] | 2 | 2 | 2 | 3 | 3 | 4 | 2 | 3 | 3 | **3** | **Poor** |
| Macias et al 2005[15] | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 3 | **1** | **Good** |
| MacKay et al. 2009[16] | 2 | 2 | 3 | 4 | 4 | 4 | 3 | 3 | 2 | **3** | **Poor** |
| Masini et al. 2014[17] | 2 | 2 | 3 | 2 | 1 | 4 | 2 | 2 | 3 | **2** | **Fair** |
| Moniz et al. 2014[18] | 1 | 1 | 2 | 3 | 3 | 4 | 2 | 3 | 3 | **2** | **Fair** |
| Nguyen et al. 2014[19] | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | **1** | **Good** |
| Niemann et al. 2015[20] | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | **1** | **Good** |
| Ong et al. 2013[21] | 2 | 2 | 2 | 3 | 1 | 4 | 2 | 3 | 2 | **2** | **Fair** |
| Parshuram et al. 2006[22] | 2 | 2 | 1 | 1 | 1 | 2 | 1 | 2 | 2 | **1** | **Good** |
| Rashed et al. 2016[23] | 1 | 2 | 2 | 3 | 2 | 3 | 1 | 3 | 2 | **2** | **Fair** |
| Reece et al. 2016[24] | 1 | 1 | 1 | 2 | 3 | 3 | 1 | 2 | 2 | **2** | **Fair** |
| Rodriguez-Gonzalez et al. 2012[25] | 2 | 1 | 1 | 3 | 2 | 2 | 2 | 3 | 2 | **2** | **Fair** |
| Sacks et al. 2009[26] | 1 | 1 | 1 | 3 | 3 | 1 | 2 | 3 | 2 | **2** | **Fair** |
| Seger et al. 2012[27] | 1 | 2 | 1 | 3 | 1 | 1 | 1 | 3 | 2 | **2** | **Fair** |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| Skouroliakou et al. 2005[28] | 2 | 2 | 2 | 4 | 4 | 4 | 2 | 3 | 3 | **3** | **Poor** |
| Tavakoli-Ardakani et al. 2013[29]* | 2 | 3 | 2 | 3 | 2 | 3 | 0 | 3 | 2 | **2** | **Incomplete** |
| Terkola et al. 2017[30] | 1 | 1 | 2 | 3 | 4 | 2 | 2 | 3 | 2 | **2** | **Fair** |
| van den Heever et al. 2016[31] | 1 | 1 | 1 | 2 | 2 | 3 | 1 | 2 | 1 | **2** | **Fair** |
| Westbrook et al. 2011[32] | 2 | 1 | 3 | 3 | 2 | 2 | 2 | 3 | 1 | **2** | **Fair** |
| Wheeler et al. 2008[33] | 1 | 3 | 2 | 3 | 1 | 4 | 2 | 3 | 1 | **2** | **Fair** |
| Yin et al. 2016[34] | 2 | 1 | 1 | 2 | 2 | 2 | 1 | 2 | 2 | **2** | **Fair** |

Studies are rated as good (1), fair (2), poor (3), or very poor (4) for each of the Hawker criteria, and given an overall score based on the average rating across all criteria.

*This study could not be fully evaluated due to a missing table in the available publication.

**Table S3. Study Characteristics**

| Study | Geographical Location(s) | Centers, n | Patient Population | Study Design | Observational Technique | Type of Intravenous Admixture | Location of Intravenous Admixture Preparation | Method of Intravenous Admixture Preparation | Patient Impact Measured (Yes / No) |
|---|---|---|---|---|---|---|---|---|---|
| Anselmi et al. 2007[1] | Brazil | 3 | General inpatient units | Single arm | Direct observation | Multiple IV therapies | Nursing ward | Manual | No |
| Aruna et al. 2015[2] | India | 1 | General inpatient units | Single arm | Chart review | Multiple IV therapies | Not specified | Manual | No |
| Bertsche et al. 2008[3] | Germany | 1 | General inpatient units and ICU | Single arm | Direct observation | Multiple IV therapies | Nursing ward | Manual | Yes |
| Campino et al. 2016[4] | Spain | 11 | NICU | Comparative | Final concentration of admixture | Multiple IV therapies | Central pharmacy vs nursing ward | Manual | No |
| Castagne et al. 2011[5] | France | 1 | Oncology inpatients | Single arm | Final concentration of admixture | Chemotherapy | Central pharmacy | Automated | No |
| Cousins et al. 2005[6] | France Germany UK | 3 | General medical and surgical inpatients | Single arm | Direct observation (participants in France and Germany were blinded to study purpose) | Multiple IV therapies | Nursing ward | Manual | No |
| Crill et al. 2010[7] | US | 1 | Critical care (NICU) | Single arm | Bacterial culture | Intravenous fat emulsion | Central pharmacy | Manual | Yes |
| Dehmel et al. 2011[8] | Germany | 1 | Critical care (ICU) | Comparative | Final concentration of admixture | Multiple IV therapies | Central pharmacy vs nursing ward | Automated vs manual | No |
| Ding et al. 2015[9] | China | 1 | General surgery inpatients | Single arm | Direct observation | Multiple IV therapies | Nursing ward | Manual | Yes |
| Fahimi et al. 2007[10] | Iran | 1 | Critical care (ICU) | Single arm | Direct observation | Multiple IV therapies | Nursing ward | Manual | Yes |
| Fahimi et al. 2008[11] | Iran | 1 | Critical care (ICU) | Single arm | Direct observation | Multiple IV therapies | Nursing ward | Manual | Yes |

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|---|---|---|---|---|---|---|---|---|---|
| Helder et al. 2016[12] | Netherlands | 1 | NICU, PICU, and general pediatric wards | Interventional | Direct observation | Multiple IV therapies | Nursing ward | Manual | No |
| Hoefel et al. 2006[13] | Brazil | 1 | General units and ICU | Single arm | Direct observation | Antibiotic (cefepime) | Nursing ward | Manual | No |
| Khalili et al. 2013[14] | Iran | 3 | Adult and pediatric inpatients | Comparative | Bacterial culture | Multiple IV therapies | Central pharmacy vs nursing ward | Manual | No |
| Macias et al. 2005[15] | Mexico | 1 | Critical care (NICU) | Single arm | Bacterial culture | Multiple IV therapies | Nursing ward | Manual | No |
| MacKay et al. 2009[16] | US | 1 | Pediatric trauma unit | Interventional | Cross-check | Multiple IV therapies | Central pharmacy | Automated | No |
| Masini et al. 2014[17] | Italy | 1 | Inpatient and outpatient oncology | Comparative | Final concentration of admixture | Chemotherapy | Central pharmacy | Automated vs manual | No |
| Moniz et al. 2014[18] | US | 1 | Pediatric inpatients | Single arm | Direct observation; Pharmacists reviewed digital photos of each preparation step via a web application | Multiple IV therapies | Central pharmacy | Automated | Yes |
| Nguyen et al. 2014[19] | Vietnam | 1 | Critical care (ICU / PSU) | Interventional | Direct observation (participants were blinded to study purpose) | Multiple IV therapies | Not specified | Manual | Yes |
| Niemann et al. 2015[20] | Germany | 1 | Pediatric inpatients | Interventional | Direct observation | Multiple IV therapies | Not specified | Manual | Yes |
| Ong et al. 2013[21] | Malaysia | 1 | General and acute care, adult and pediatric inpatients | Single arm | Direct observation | Multiple IV therapies | Nursing ward | Manual | No |
| Parshuram et al. 2006[22] | Canada | 1 | Pediatric oncology (not specified if inpatient or outpatient) | Single arm | Final concentration of admixture | Chemotherapy | Not specified | Not specified | No |
| Rashed et al. 2016[23] | UK | 1 | Pediatric inpatients | Comparative | Direct observation and final concentration of infusion | Morphine | Nursing ward vs operating theater | Manual | No |

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|---|---|---|---|---|---|---|---|---|---|
| Reece et al. 2016[24] | US | 1 | Oncology outpatients | Comparative | Error reports (self-reported and automated) | Chemotherapy | Central pharmacy | Manual | No |
| Rodriguez-Gonzalez et al. 2012[25] | Spain | 1 | Gastroenterology inpatients | Single arm | Direct observation (participants were blinded to study purpose) | Multiple IV therapies | Not specified | Not specified | Yes |
| Sacks et al. 2009[26] | US | 1 | General adult and pediatric inpatient units and ICU | Single arm | Incident reports | Total parenteral nutrition | Central pharmacy | Automated | Yes |
| Seger et al. 2012[27] | US | 1 | Oncology inpatients | Comparative | Direct observation | Chemotherapy | Central pharmacy | Automated vs manual | Yes |
| Skouroliakou et al. 2005[28] | Greece | 1 | Neonatal inpatients | Comparative | Cross-check and direct observation | Total parenteral nutrition | Not specified | Automated vs manual | No |
| Tavakoli-Ardakani et al. 2013[29] | Iran | 1 | Hematology and oncology inpatients and outpatients | Single arm | Direct observation | Chemotherapy | Nursing ward | Manual | No |
| Terkola et al. 2017[30] | Austria<br>Czech Republic<br>Denmark<br>Germany<br>Switzerland | 10 | Oncology | Single arm | Incident reports | Chemotherapy | Offsite pharmacy | Not specified | No |
| van den Heever et al. 2016[31] | South Africa | 1 | Obstetric surgery | Single arm | Bacterial culture | Phenylephrine | Obstetric theater | Manual | No |
| Westbrook et al. 2011[32] | Australia | 2 | General and surgical inpatients | Single arm | Direct observation | Multiple IV therapies | Nursing ward | Manual | Yes |
| Wheeler et al. 2008[33] | UK | 1 | Critical care (neurological) inpatients | Interventional | Cross-check | Multiple IV therapies | Nursing ward | Manual | No |
| Yin et al. 2016[34] | Malaysia | 1 | Critical care (ICU) | Single arm | Direct observation | Multiple IV therapies | Nursing ward | Manual | No |

Method of preparation was assumed to be manual for studies in which IV admixture preparation occurred in the nursing ward, and no other information regarding method of preparation was provided.
ICU, intensive care unit; IV, intravenous; NICU, neonatal intensive care unit; PSU, post-surgical unit; UK, United Kingdom; US, United States.

## Table S4. Patient Burden of Harm

| Study | Error Types | Burden of Harm |
|---|---|---|
| NCC MERP Medication Error Index Definition of Error Severity | | |
| **Fahimi et al. 2007[10]** | Wrong drug<br>Wrong label<br>Wrong dose | All observed errors were rated NCC MERP Index Category B ("An error occurred but the error did not reach the patient.") |
| **Rodriguez-Gonzalez et al. 2012[25]** | Wrong diluent solution<br>Wrong diluent volume | • Severity was defined according to updated medication errors taxonomy adapted from NCC MERP definitions.[35]<br>• Severity of wrong preparation errors (reconstitution and dilution) were determined to have the potential to cause "no damage." |
| **Sacks et al. 2009[26]** | Composite | Severity of errors was defined according to the NCC MERP Index:<br>• 91% of errors did not cause harm (Categories B–D)<br>• 15% of errors were "near misses" (Categories A–B)<br>• 8% of errors contributed to or resulted in temporary harm (Categories E–F)<br>No errors resulted in permanent harm, near death, or death (Categories G–I) |
| Clinician Assessment or Expert Panel Definition of Error Severity | | |
| **Bertsche et al. 2008[3]** | Inadequate aseptic technique | • A multidisciplinary committee for quality assurance established risk scores for medical errors.<br>• Errors were assigned a risk score weighted by potential risk of the drug involved and the characteristics of the error (low risk = 0.5, moderate risk = 1, high risk = 2).<br>• Rates of error by severity were reported for all types of administration combined (IV, oral, and gastric tube), but not separately. |
| **Moniz et al. 2014[18]** | Wrong dose<br>Wrong drug<br>Wrong diluent solution<br>Inadequate aseptic technique<br>Composite | A new workflow was implemented that detected IV preparation errors that would not have been detected previously. These new errors (n = 447) were rated:<br>• Little potential for harm: 62.64%<br>• Potential ADE with moderate harm: 32.66%<br>• Potential ADE with severe harm: 4.70% |
| **Nguyen et al. 2014[19]** | Wrong drug | Clinical relevance of each dose with ≥ 1 error was rated on a validated scale ranging from 0 (no harm) to 10 (death) by a panel of healthcare providers, and was categorized as follows:<br>• Minor outcome: 0–2 |

**Table S4. Patient Burden of Harm**

| Study | Error Types | Burden of Harm |
|---|---|---|
| | Wrong dose | • Moderate outcome: 3–7<br>• Severe outcome: 8–10<br>Moderate and severe outcomes were considered clinically relevant (57.9% to 64.0% of errors across the 2 study wards). |
| | Composite | |
| **Niemann et al. 2014[20]** | Wrong diluent solution | Clinical relevance of error subcategories was rated by an expert panel on a four-point scale:<br>1. No clinical relevance<br>2. Minor clinical relevance |
| | Wrong diluent volume | 3. Clinical relevance<br>4. High clinical relevance<br>The frequency of each level of severity combined oral and IV drug errors. |
| | Composite | |
| **Seger et al. 2012[27]** | Wrong drug | • Severity was rated as life-threatening, severe, significant, or little-to-no harm.<br>• Events with potential for little-to-no harm were not included in the analysis.<br>• There were no potentially life-threatening events, and the remaining events were approximately evenly distributed between significant and serious. |
| | Wrong concentration | Doses with ±5% to 10% variance were considered to have little to no potential for harm. Those with variance > ±10% were rated serious and potentially harmful. |
| **Westbrook et al. 2011[32]** | Wrong drug | • Severity was rated on a scale from 1 ("Incident is likely to have little to no effect on the patient") to 5 ("Incident is likely to lead to death"), with ratings of 1 to 2 considered minor errors and 3 to 5 considered serious errors.<br>• 25.5% of overall errors were rated as serious. |
| | Wrong diluent solution | • 23.8% of wrong diluent solution errors were rated as serious. |
| | Wrong diluent volume | • 17.4% of wrong diluent volume errors were rated as serious. |
| Other Method for Determination of Error Severity | | |
| **Crill et al. 2010[7]** | Inadequate aseptic technique<br>Bacterial contamination | • Severity of errors was not rated.<br>• Authors noted that no cases of systemic infection arose from syringes that had positive cultures. |
| **Ding et al. 2015[9]** | Wrong dose | • An error was considered clinically important if it concerned a drug listed in the ISMP list of high-alert medications (2008).<br>• 81% of TPN dose errors involved ISMP high-alert medications. |

**Table S4. Patient Burden of Harm**

| Study | Error Types | Burden of Harm |
|---|---|---|
| **Fahimi et al. 2008[11]** | Composite | An error was considered clinically important if it concerned a drug listed in the ISMP list of high-alert medications (2008). |
| | Wrong diluent solution<br>Wrong dose | There was no severity rating system, but the authors note that none of the errors identified resulted in adverse effects or major risks to patients. |

ADE, adverse drug event; ISMP, Institute for Safe Medication Practices; IV, intravenous; NCC MERP, National Coordinating Council for Medication Error Reporting and Prevention; TPN, total parenteral nutrition.

## Table S5. Error Incidence Definitions

| Admixture Preparation and Labeling Error Types | Definitions | Study |
|---|---|---|
| **Component Error** | | |
| Wrong Drug | An IV drug was prepared or administered that differed from the one that was prescribed | Anselmi et al. 2007[1] Cousins et al. 2005[6] Moniz et al. 2014[18] Nguyen et al. 2014[19] Ong et al. 2013[21] Reece et al. 2016[24] Seger et al. 2012[27] Westbrook et al. 2011[32] |
| | An unauthorized IV drug was administered, or an order was changed, that was not found in the patient chart | Fahimi et al. 2007[10] |
| | An incorrect drug or dosage form was selected | Yin et al. 2016[34] |
| Wrong Diluent Solution | An IV drug was prepared or administered with a diluent that was not compatible with drug and volume to achieve the correct concentration | Cousins et al. 2005[6] |
| | An IV drug was prepared with the incorrect diluent based on any of the following:<br>• The manufacturer's instructions<br>• Published drug preparation handbooks<br>• Other internal or external drug preparation guidelines | Fahimi et al. 2008[11] Niemann et al. 2015[20] Ong et al. 2013[21] Westbrook et al. 2011[32] |
| | An IV drug was prepared with the incorrect diluent | Moniz et al. 2014[18] Rashed et al. 2016[23] Reece et al. 2016[24] |
| | The IV medication was reconstituted or diluted incorrectly according to medication errors taxonomy adapted from NCC MERP definitions [Otero Lopez 2008] | Rodriguez-Gonzalez et al. 2012[25] |
| Wrong label | An IV drug was prepared or administered with a missing or incomplete label with respect to drug name, dose, patient name, or preparation time | Cousins et al. 2005[6] |
| | The administration rate, patient identification, date, or time of infusion was not properly documented | Fahimi et al. 2007[10] |
| | The IV drug label was incomplete with respect to patient, drug, dose, or preparation time, or the opened diluent vials were improperly labeled | Ong et al. 2013[21] |

| | | |
|---|---|---|
| | Syringes or drug infusion containers were not labeled properly | Yin et al. 2016[34] |
| | Label was incomplete or incorrect with regard to name of solution, concentration of solution, date of preparation, time or preparation, or healthcare worker's signature | van den Heever et al. 2016[31] |
| | The syringe label was illegible or missing the drug name, dose, concentration, diluent, patient name, patient location, preparer's initials, countersigned, date, or time | Wheeler et al. 2008[33] |
| **Dose or Calculation Error** | | |
| Wrong Dose | An incorrect IV drug dose or infusion volume was prepared or administered | Anselmi et al. 2007[1]<br>Cousins et al. 2005[6]<br>Fahimi et al. 2007[10]<br>Hoefel et al. 2006[13]<br>Moniz et al. 2014[18]<br>Reece et al. 2016[24] |
| | The calculated concentration deviated by >10% of that prescribed | Campino et al. 2016[4] |
| | An ingredient deviated > ±10% from the correct volume or concentration, a dose was omitted, or an extra dose was given | Ding et al. 2015[9] |
| | An IV drug that differed by ±10% of the prescribed dose was prepared | Nguyen et al. 2014[19] |
| | An incorrect dose or diluent volume was calculated that differed from the manufacturer's instructions or published drug preparation handbooks | Fahimi et al. 2008[11] |
| Wrong Concentration | The sampled IV drug preparation deviated by ±20% or more from its intended concentration | Castagne et al. 2011[5] |
| | The sampled IV drug preparation deviated by ≥ ±5% or ≥ ±10% from its intended concentration | Dehmel et al. 2011[8]<br>Masini et al. 2014[17] |
| | The sampled IV drug preparation deviated by ±10% or more from its intended concentration | Parshuram et al. 2006[22] |
| | The sampled IV drug preparation deviated by more than ±10% from its intended concentration | Campino et al. 2016[4]<br>Yin et al. 2016[34] |
| | The morphine infusion deviated from its target concentration beyond the pharmacopoeial limit for drug content of morphine sulphate injection (92.5–107.5%) | Rashed et al. 2016[23] |
| | The sampled IV drug preparation deviated by ±5% or more from its intended concentration | Seger et al. 2012[27] |
| | The concentration of any of the individual components of total parenteral nutrition was calculated incorrectly | Skouroliakou et al. 2005[28] |
| | The volume of the sampled IV drug preparation exceeded the gravimetric software's preset tolerance limit<br>• Tolerance levels were set by each site and ranged from 2.5–6% | Terkola et al. 2017[30] |

| | | |
|---|---|---|
| Wrong Diluent Volume | An incorrect diluent volume was used | Cousins et al. 2005[6]<br>Hoefel et al. 2006[13]<br>Reece et al. 2016[24] |
| | An IV drug was prepared with an incorrect diluent volume based on any of the following:<br>• The manufacturer's instructions<br>• The corresponding summaries of product characteristics<br>• Published drug preparation handbooks<br>• Other internal or external drug preparation guidelines | Niemann et al. 2015[20]<br>Ong et al. 2013[21]<br>Westbrook et al. 2011[32] |
| | The IV medication was reconstituted or diluted incorrectly according to medication errors taxonomy adapted from NCC MERP definitions [Otero Lopez 2008] | Rodriguez-Gonzalez et al. 2012[25] |
| | The total volume of the IV solution was incorrect | Skouroliakou et al. 2005[28] |
| **Aseptic Technique Error** | | |
| Inadequate Aseptic Technique | The IV drug was not prepared in accordance with local hygiene guidelines | Bertsche et al. 2008[3] |
| | Sampling of repackaged syringes resulted in positive bacterial cultures | Crill et al. 2010[7] |
| | Nonadherence to 1 or more of the following hygiene protocols:<br>• Hand disinfection by applying hand alcohol<br>• Rubbing hands for 30 seconds<br>• Using sterile gloves<br>• Disinfecting the ampoule<br>• Allowing the ampoule to dry for 30 seconds | Helder et al. 2016[12] |
| | Aseptic technique was not followed during IV infusion preparation | Rashed et al. 2016[23]<br>Yin et al. 2016[34] |
| | Needles or syringes were left uncapped during IV preparation | Moniz et al. 2014[18] |
| Bacterial Contamination | Sampling of IV drug preparations resulted in positive bacterial cultures | Crill et al. 2010[7]<br>Khalili et al. 2013[14]<br>Macias et al. 2005[15]<br>van den Heever et al. 2016[31] |
| Failure to Disinfect Vial | Vial top or ampoule was not disinfected during preparation | Cousins et al. 2005[6]<br>Helder et al. 2016[12]<br>Ong et al. 2013[21]<br>Rashed et al. 2016[23] |

| | | |
|---|---|---|
| Improper Hand Hygiene | Hands were not washed, gloves were not worn, or nonsterile gloves were worn during IV drug preparation | Cousins et al. 2005[6]<br>Ong et al. 2013[21] |
| | Gloves were not worn during IV infusion preparation | Rashed et al. 2016[23] |
| **Composite Error** | | |
| Any Admixture or Labeling Error | An IV drug dose was prepared or administered differently from how it was prescribed by the physician in the patient's medical record with regard to:<br>• Wrong patient<br>• Wrong drug<br>• Wrong dose<br>• Omitted dose | Anselmi et al. 2007[1] |
| | An IV drug was incorrectly formulated or manipulated before administration:<br>• Incorrect reconstitution or dilution<br>• Physicochemical incompatibility of drugs mixed in the same container<br>• Wrong pharmaceutical form | Aruna et al. 2015[2] |
| | Any of the following IV preparation or administration errors occurred:<br>• Unordered drug<br>• Omitted drug<br>• Wrong dose<br>• Extra dose<br>• Wrong route of administration | Ding et al. 2015[9] |
| | A drip compounding error of greater than 1 standard deviation from the calculated value for each component in parenteral nutrition preparations occurred | MacKay et al. 2009[16] |
| | IV drug preparations in the institution were prepared and verified using an IV workflow manager system. Doses that were reworked or rejected were retrospectively reviewed for errors in:<br>• Preparation<br>• Aseptic technique<br>• Documentation | Moniz et al. 2014[18] |
| | Any IV of the following IV preparation or administration errors occurred:<br>• Wrong drug<br>• Wrong dose<br>• Wrong dosage form<br>• Deteriorated drug<br>• Wrong preparation technique<br>• Omission<br>• Unordered drug<br>• Wrong administration technique | Nguyen et al. 2014[19] |
| | At least 1 deviation from internal or external drug preparation or administration guidelines, corresponding summaries of product characteristics, or manufacturer recommendations occurred during the drug handling processes (eg, preparation, storage, labeling) | Niemann et al. 2015[20] |

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|---|---|---|
| | Documented events in parenteral nutrition preparation or administration:<br>• Dose omission<br>• Extra dose<br>• Prescription or refill delayed<br>• Drug list incorrect<br>• Monitoring error<br>• Unauthorized drug<br>• Inadequate pain management<br>• Wrong events (eg, dose, drug, time, patient) | Sacks et al. 2009[26] |
| | A drug was prepared using the incorrect diluent or incorrect volume, or was not mixed properly | Yin et al. 2016[34] |
| | A deviation in handling, preparation, or administration of an IV drug occurred based on:<br>• The manufacturer's instructions<br>• *Handbook on Injectable Drugs*, 15th ed.<br>• *Drug Information Handbook,* 19th ed.<br>• American Society of Health-System Pharmacists Drug Information<br>• *Oncology Nursing Drug Handbook* | Tavakoli-Ardakani et al. 2013[29] |
| IV, intravenous; NCC MERP, National Coordinating Council for Medication Error Reporting and Prevention | | |

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