AAMI FOUNDATION

QUICK GUIDE

Managing Smart Pump Alarms

Reducing Alarm Fatigue

The AAMI Foundation is grateful to its collaborating partners in the National Coalition for Infusion Therapy Safety:

INS INFUSION NURSES SOCIETY Setting the Standard for Infusion Care®

ISMP INSTITUTE FOR SAFE MEDICATION PRACTICES

REMEDI CENTRAL

Acknowledgments

This document was produced by the members of the AAMI Foundation's National Coalition for Infusion Therapy Safety. The coalition, launched in 2015, is made up of clinicians, industry partners, researchers, and national patient safety organizations. It addresses ongoing patient safety issues identified at the AAMI/FDA Infusion Device Summit (2010):

- Improving drug library compliance
- Reducing non-actionable pump alarms
- Promoting multiple-line education

Link to the coalition website:
www.aami.org/foundation/infusion/coalition

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Published by
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About the AAMI Foundation

The AAMI Foundation is a 501(c)(3) charitable organization. Its mission is to drive reductions in preventable patient harm and improvements in outcomes associated with the use of health technology.

The AAMI Foundation creates synergy between clinicians, researchers, regulators, biomedical and clinical engineers, industry, and patients, leading the nation to share and disseminate critically important information, building a body-of-knowledge addressing emerging and long-standing complex issues related to health technology. The Foundation accomplishes this by convening diverse expert stakeholders and engaging them in a collaborative, team-based approach to tackle specific issues in the development, management and use of health technology. The intended outcome is reduced preventable patient harm and improved patient outcomes.

To learn more about the Foundation and ways to become involved, visit **www.aami.org/foundation**.

To make a tax-deductible donation to the Foundation, visit **my.aami.org/store/donation.aspx**.

Contents

* "Alert" is the term used by most infusion pump manufacturers to indicate that a soft or hard drug library limit has been exceeded. While some manufacturers use the term "alarm signal" for this type of occurrence, most infusion pump manufacturers instead use this to refer to sounds generated to indicate that there is an occlusion in the line, air in line, door open, infusion completed, etc. Ask your pump manufacturer how it defines the terms for its alerts and alarm signals.

Who Will Benefit From This Quick Guide?

This guide will benefit all those working to reduce incidence and improve response to medical device alarms, which cause alarm fatigue for clinicians and have a detrimental effect on patient outcomes.

A few examples are the following:

- ✓ The members of the hospital alarm committee
- ✓ Directors of nursing, managers, and front-line nurses
- ✓ Directors of pharmacy
- ✓ Education coordinators
- ✓ Directors of biomedical engineering
- ✓ Procurement managers
- ✓ Quality/patient safety leads

Background

Since The Joint Commission's focus on medical device alarms, beginning with the Sentinel Alert in 2013,[1] and resulting in the national patient safety goal issued in June 2013,[2], hospitals have initiated alarm management and reduction strategies. To date, most studies have focused on reducing clinically nonactionable alarms associated with physiologic monitors, achieving as much as a 87% reduction in these alarms.[3,4,5] Much of this reduction has been accomplished by widening alarm thresholds, implementing patient-specific alarm parameters, and turning alarms off that are duplicative or have no clinical value.

Hospitals are now beginning to expand their focus to include infusion pump alarms. There are very few patients who complete a hospitalization without being on an infusion pump, and the sheer number of infusion pumps across the healthcare continuum creates a major source of noise in the clinical environment. Further, current medical device standards require infusion pumps to alarm at the device and these alarms are loud enough to be heard by the patient, staff, and visitors.

1. The Joint Commission (TJC). Medical device alarm safety in hospitals. TJC Sentinel Event Alert, April 8, 2013;50. www.jointcommission.org/sea_issue_50/ Accessed March 5, 2018.
2. The Joint Commission website: www.jointcommission.org/r3_report_issue5/ Accessed Nov 30, 2017.
3. Cvach M, Biggs M, Rothwell K, Charles-Hudson C. Medical device alarm safety in hospitals. Daily electrode change and effect on cardiac monitor alarms: an evidence based practice approach. J Nurs Care Qual, 2013;28(3):265-271.
4. Gross B, Dahl D, Neilsen L. Physiologic monitoring alarm load on medical/surgical floors of a community hospital. Biomed Instrum Technol, 2011;45(s1);29-36.
5. Whalen D, Covelle P, Piepenbrink J, Villanova K, Cuneo C, Awtry E. Novel approach to the management of clinical alarm fatigue. Cardiovascular Quality & Outcomes, 2013;6(s1).

Background (continued)

Infusion pump alarms are defined as those device alarms that provide continual or repeating auditory and visual notification, requiring the clinician to intervene to address and silence the alarm. These device alarms may or may not interrupt the infusion therapy and are different from drug library dosing alerts that provide a single audible and/or visual notification.

Unfortunately, reducing infusion pump alarms to the level of reduction achieved with physiological monitors will be more challenging because of the fundamental differences between these types of devices. Physiologic monitors issue alarm signals because the patient's condition (heartrate, SPO2, etc.) falls outside the alarm threshold set for that patient. These thresholds are set at points where a clinician should be "called" to the bedside to check on the patient because an untoward change in the patient's condition may be occurring. Conversely, infusion pump alarms occur when a specific task has been completed (infusion has completed), a potential unsafe condition is detected (air in line), or something has prevented the pump from delivering the programmed infusion (occlusion or depleted battery).

All of these pump alarms require action or clinical intervention. Although there are some pump alarm settings that are configurable, the majority of infusion pump alarms cannot be turned off. For example, air detection bubble size and occlusion pressure limit thresholds can be configured, but neither alarm can be turned off.

Infusion pumps also have audible, single notifications that contribute to alarm fatigue, with some that can be configured on or off. Examples include notifications that a secondary infusion has finished, a bolus dose has been delivered, or a delayed infusion is starting. These single notifications are not typically classified as alarms, but rather as a notification that does not require the nurse to interact with the pump. However, these notifications may only be heard by the patient and thus provide no real value to the nurse caring for the patient and can result in disturbing the rest the patient requires to get well.

With these significant differences between infusion pump and physiological monitor alarms, reducing pump alarms will require different strategic interventions. First, hospitals will need to collect data on pump alarm incidence across all care areas and begin to understand how and why specific pump alarms occur. Second, they will need to classify pump alarms and notifications, identifying which alarms can be configured or have thresholds adjusted. Third, educational intervention and practice changes will be primary components necessary for infusion pump alarm reduction. For example, one method to reduce air in line alarms is eliminating the air during priming of the intravenous (IV) tubing. Occlusion alarms can be addressed through IV catheter placement and routine assessment, and low battery alarms can be mitigated by ensuring pumps are plugged in during storage and following transport.

How to Use This Guide

The purpose of this guide is to ***provide a starting point*** for healthcare institutions to begin to explore their large-volume, and syringe pump alarms and to understand potential strategies to mitigate nonactionable alarms.

There are two sections to the guide. The first section is a table reflecting the common alarms types and their configurability across the manufacturers of large volume and syringe pumps that are participants in the AAMI Foundation's National Coalition for Infusion Therapy Safety.[6] Please note this is not the complete list of alarms that each manufacturer includes in their pumps, but *is meant to help healthcare organizations begin a conversation with their particular manufacturer* about how to reduce nonactionable pump alarms.

The second section provides practice suggestions on ways to reduce four primary categories of alarms: occlusion; air in line; infusion complete; and battery alarms. These were selected because they are commonly reported as the most frequently occurring pump alarms and because there are a number of ways to reduce these alarms through targeted clinical practice. The practice suggestions are the result of the combined experience of the team members, but some recommended reading is also provided at the end of each of the categories.

Your pump manufacturer is a great source of help in working with you to determine which pump alarms are the most problematic in your organization and how to address workflow to address those alarms.

6. The AAMI Foundation website: www.aami.org/PatientSafety/content.aspx?ItemNumber=1781&navItemNumber=3084 Accessed on Nov. 30, 2017.

Baxter

Manufacturer-Specific Information on Configurability of Basic Pump Alarms

NOTE: n/a indicates the vendor does not offer that alarm type
LVP = large volume pump **KVO** = keep vein open

Alarm Type	Baxter SIGMA Spectrum LVP	Alarm Can be Disabled	Can be Configured (ON/OFF or Threshold Adjusted)	
			In Setup (Configured by Biomed/ Pharmacy/Administration)	At Bedside (Adjusted by Clinician)
Hold Time Exceeded	Standby/Hold	N/A	N/A	Time Adjustable, Default is Infinite (If Infinate, Will Not alarm)
Infusion Complete	Primary Infusion Complete/KVO	No	No	No
Upstream Occlusion	Upstream Occlusion	Yes	Yes if Configured by Drug in Drug Library	Yes or No Depending on Drug Library Configuration
Downstream Occlusion	Downstream Occlusion/ Autorestart	No	Threshold Adjustable	Threshold Adjustable
Partial Occlusion/ Pressure Increasing/ Autorestart	N/A	N/A	N/A	N/A
Air in Line - Single Bubble	Air In Line	No	No	No
Air in Line - Cumulative	Max Air Detected	No	No	No
Door Open	Door Open	No	No	No
Inactivity	Inactivity	No	No	No
Set or Syringe Misload	Clean Load Point 2; Reload Set: Remove Clamp from Primary	No	No	No
Battery Low	Low Battery	No	No	No
Battery Empty	Battery Depleted	No	No	No
System Error	System Error	No	No	No
KVO	Refer to Primary Infusion Complete/KVO and Secondary Infusion Complete/KVO	N/A	N/A	N/A
Secondary Complete	Secondary Infusion Complete/KVO	Yes	Never, Optional, or Required	Yes if Configured as Optional or Required
Volume Near End	Bag Near Empty	Yes	Yes	Yes
Time Near End	N/A	N/A	N/A	N/A

B BRAUN
SHARING EXPERTISE

Alarm Type	BBraun Outlook ES LVP	Alarm Can be Disabled	Can be Configured (ON/OFF or Threshold Adjusted)	
			In Setup (Configured by Biomed/ Pharmacy/Administration)	At Bedside (Adjusted by Clinician)
Hold Time Exceeded	Hold Expired	No	No	Time Adjustable
Infusion Complete	Bag Empty/VTBI end	No	No	No
Upstream Occlusion	Upstream Occlusion	No	Default Threshold	Threshold Adjustable
Downstream Occlusion	Downstream Occlusion	No	Default Threshold	Time Adjustable
Partial Occlusion/ Pressure Increasing/ Autorestart	Occlusion Warning	Yes	ON/OFF	No
Air in Line - Single Bubble	Air in Line	No	No	No
Air in Line - Cumulative	Air in Line	No	No	No
Door Open	Door Open	No	No	No
Inactivity	Inactivity	No	No	No
Set or Syringe Misload	Check Set	No	No	No
Battery Low	Battery Low	No	No	No
Battery Empty	Battery Empty	No	No	No
System Error	System Error	No	No	No
KVO	KVO	No	Rate Adjustable	No
Secondary Complete	Piggyback Callback	Yes	ON/OFF	ON/OFF
Volume Near End	N/A	N/A	N/A	N/A
Time Near End	N/A	N/A	N/A	N/A

B BRAUN
SHARING EXPERTISE

Alarm Type	BBraun Infusomat Space LVP	Alarm Can be Disabled	Can be Configured (ON/OFF or Threshold Adjusted)	
			In Setup (Configured by Biomed/ Pharmacy/Administration)	At Bedside (Adjusted by Clinician)
Hold Time Exceeded	Standby Expired	No	Default Threshold	Time Adjustable
Infusion Complete	VTBI Infused	No	No	No
Upstream Occlusion	Upstream Occlusion	No	Default Threshold	Threshold Adjustable
Downstream Occlusion	Downstream Occlusion	No	Default Threshold	Threshold Adjustable
Partial Occlusion/ Pressure Increasing/ Autorestart	N/A	N/A	N/A	N/A
Air in Line - S ingle Bubble	Air in Line - Bubble Too Large	No	Default Threshold	No
Air in Line - Cumulative	Air in Line - Cumulative Over Time	No	Default Threshold	No
Door Open	Door Open	No	No	No
Inactivity	Inactivity	No	No	No
Set or Syringe Misload	Set Misloaded	No	No	No
Battery Low	Battery low	No	No	No
Battery Empty	Battery Empty; Battery Near Empty (pre-alarm)	No	No	No
System Error	System Error	No	No	No
KVO	KVO	Yes	ON/OFF, Rate Adjustable	ON/OFF
Secondary Complete	Secondary Complete	Yes	ON/OFF	ON/OFF
Volume Near End	Volume Near End (pre-alarm)	Yes	ON/OFF and Volume Adjustable	No
Time Near End	Time Near End (pre-alarm)	Yes	ON/OFF and Time Adjustable	No

B|BRAUN
SHARING EXPERTISE

Alarm Type	BBraun Perfusor Space Syringe	Alarm Can be Disabled	Can be Configured (ON/OFF or Threshold Adjusted)	
			In Setup (Configured by Biomed/Pharmacy/ Administration)	At Bedside (Adjusted by Clinician)
Hold Time Exceeded	Standby Expired	No	Default Threshold	Time Adjustable
Infusion Complete	Syringe Empty	No	No	No
Upstream Occlusion	N/A	N/A	N/A	N/A
Downstream Occlusion	Downstream Occlusion	No	Default Threshold	Threshold Adjustable
Partial Occlusion/ Pressure Increasing/ Autorestart	N/A	N/A	N/A	N/A
Air in Line - Single Bubble	N/A	N/A	N/A	N/A
Air in Line - Cumulative	N/A	N/A	N/A	N/A
Door Open	Syringe Holder Open	N/A	N/A	No
Inactivity	Inactivity	No	No	No
Set or Syringe Misload	Syringe Not Inserted Correctly; Syringe Drive Blocked	No	No	No
Battery Low	Battery low	No	No	No
Battery Empty	Battery Empty; Battery Near Empty (pre-alarm)	No	No	No
System Error	System Error	No	No	No
KVO	KVO	Yes	ON/OFF and Rate Adjustable	ON/OFF
Secondary Complete	N/A	N/A	N/A	N/A
Volume Near End	Volume Near End (pre-alarm)	Yes	ON/OFF and Volume Adjustable	No
Time Near End	Time Near End (pre-alarm)	Yes	ON/OFF and Time Adjustable	No

Alarm Type	BD Alaris LVP	Alarm Can be Disabled	Can be Configured (ON/OFF or Threshold Adjusted)	
			In Setup (Configured by Biomed/ Pharmacy/Administration)	At Bedside (Adjusted by Clinician)
Hold Time Exceeded	Restart Channel	No	No	No
Infusion Complete	Infusion Complete	No	No	No
Upstream Occlusion	Occluded - Fluid Side/Empty Container	No	No	No
Downstream Occlusion	Occluded - Patient Side	No	Unlocked or Locked, Default Adjustable	Adjustable if Unlocked
Partial Occlusion/ Pressure Increasing/ Autorestart	Partial Occlusion - Patient Side	No	No	No
Air in Line - Single Bubble	Air in Line	No	Default Adjustable	No
Air in Line - Cumulative	Accumulated Air in Line	Yes	Enabled or Disabled	No
Door Open	Close Door	No	No	No
Inactivity	Walkaway	No	No	No
Set or Syringe Misload	Check IV Set	No	No	No
Battery Low	Low Battery	No	No	No
Battery Empty	Battery Discharged	No	No	No
System Error	System Error; Channel Error	No	No	No
KVO	Infusion Complete/KVO	No	Rate Adjustable	No
Secondary Complete	Secondary	Yes	Enabled or Disabled	No
Volume Near End	N/A	N/A	N/A	N/A
Time Near End	N/A	N/A	N/A	N/A

Alarm Type	BD Alaris Syringe Pump	Alarm Can be Disabled	Can be Configured (ON/OFF or Threshold Adjusted)	
			In Setup (Configured by Biomed/Pharmacy/Administration)	At Bedside (Adjusted by Clinician)
Hold Time Exceeded	Restart Channel	No	No	No
Infusion Complete	Syringe Empty	No	No	No
Upstream Occlusion	N/A	N/A	N/A	N/A
Downstream Occlusion	Occlusion	No	Default Adjustable	Yes
Partial Occlusion/ Pressure Increasing/ Autorestart	N/A	N/A	N/A	N/A
Air in Line - Single Bubble	N/A	N/A	N/A	N/A
Air in Line - Cumulative	N/A	N/A	N/A	N/A
Door Open	Check Syringe; Drive Not Engaged	No	No	No
Inactivity	Walkaway	No	No	No
Set or Syringe Misload	Syringe Not Recognized	No	No	No
Battery Low	Low Battery	No	No	No
Battery Empty	Battery Discharged	No	No	No
System Error	Channel Error; System Error	No	No	No
KVO	KVO	Yes	Enabled or Disabled; Rate and Volume Adjustable	No
Secondary Complete	N/A	N/A	N/A	N/A
Volume Near End	Near End of Infusion	Yes	Enabled or Disabled; Time Adjustable	No
Time Near End	Near End of Infusion	Yes	Enabled or Disabled; Time Adjustable	No

icumedical
human connections

Alarm Type	ICU Medical Plum A+ LVP	Alarm Can be Disabled	Can be Configured (ON/OFF or Threshold Adjusted)	
			In Setup (Configured by Biomed/Pharmacy/Administration)	At Bedside (Adjusted by Clinician)
Hold Time Exceeded	Standby	Yes	Enable/Disable	No
Infusion Complete	VTBI Complete	No	No	No
Upstream Occlusion	Proximal Occlusion	No	Default Threshold	No
Downstream Occlusion	Distal Occlusion	No	Threshold Adjusted	Threshold Adjusted
Partial Occlusion/ Pressure Increasing/ Autorestart	N/A	N/A	N/A	N/A
Air in Line - Single Bubble	Distal air in line (single bubble)	No	Default Threshold	No
Air in Line - Cumulative	Distal air in line (Cumulative)	No	Default Threshold	No
Door Open	Door Open	No	No	No
Inactivity	Inactivity	No	No	No
Set or Syringe Misload	Cassette Test Failure	No	No	No
Battery Low	Low Battery	No	No	No
Battery Empty	Depleted Battery	No	No	No
System Error	Malfunction (System Error)*	No	No	No
KVO	KVO	No	KVO or Rate Configured	KVO or Continue Rate
Secondary Complete	Callback (Loading dose, multi-step, or piggyback)	Yes	Callback Enabled Yes/No	Callback Enabled Yes/No
Volume Near End	N/A	N/A	N/A	N/A
Time Near End	N/A	N/A	N/A	N/A

icumedical
human connections

Alarm Type	ICU Medical Plum 360 LVP	Alarm Can be Disabled	Can be Configured (ON/OFF or Threshold Adjusted)	
			In Setup (Configured by Biomed/Pharmacy/Administration)	At Bedside (Adjusted by Clinician)
Hold Time Exceeded	Standby	Yes	Enable/Disable	No
Infusion Complete	VTBI Complete	No	No	No
Upstream Occlusion	Proximal Occlusion	No	Default Threshold	No
Downstream Occlusion	Distal Occlusion/Autorestart	No	Threshold Adjusted/Restart Configured	Threshold Adjusted
Partial Occlusion/ Pressure Increasing/ Autorestart	N/A	N/A	N/A	N/A
Air in Line - Single Bubble	Distal Air in Line (Single Bubble)	No	Default Threshold	No
Air in Line - Cumulative	Distal Air in Line (Cumulative)	No	Default Threshold	No
Door Open	Door Open	No	No	No
Inactivity	Inactivity	No	No	No
Set or Syringe Misload	Cassette Test Failure	No	No	No
Battery Low	Low Battery	No	No	No
Battery Empty	Depleted Battery	No	No	No
System Error	Malfunction (System Error)	No	No	No
KVO	KVO	No	KVO or Rate Configured	KVO or Continue Rate
Secondary Complete	Callback (Loading Dose, Multi-step, or Piggyback)	Yes	Callback Enabled Yes/No	Callback Enabled Yes/No
Volume Near End	N/A	N/A	N/A	N/A
Time Near End	N/A	N/A	N/A	N/A

icumedical
human connections

Alarm Type	ICU Medical Sapphire Plus LVPww	Alarm Can be Disabled	Can be Configured (ON/OFF or Threshold Adjusted)	
			In Setup (Configured by Biomed/Pharmacy/Administration)	At Bedside (Adjusted by Clinician)
Hold Time Exceeded	Standby	Yes	Enable/Disable	No
Infusion Complete	VTBI Complete	No	No	No
Upstream Occlusion	Proximal Occlusion	No	Default Threshold	No
Downstream Occlusion	Distal Occlusion/Autorestart	No	Threshold Adjusted/Restart Configured	Threshold Adjusted
Partial Occlusion/ Pressure Increasing/ Autorestart	N/A	N/A	N/A	N/A
Air in Line - Single Bubble	Distal Air in Line (Single Bubble)	No	Yes	No
Air in Line - Cumulative	Distal Air in Line (Cumulative)	No	Yes	No
Door Open	Door Open	No	No	No
Inactivity	Inactivity	No	Yes	No
Set or Syringe Misload	Cassette Misload	No	No	No
Battery Low	Low Battery	No	No	No
Battery Empty	Depleted Battery	No	No	No
System Error	Malfunction (System Error)	No	No	No
KVO	KVO	Yes	None/Rate/KVO	No
Secondary Complete	N/A	N/A	N/A	N/A
Volume Near End	N/A	N/A	N/A	N/A
Time Near End	Near End of Infusion	Yes	Yes	No

smiths medical
bringing technology to life

Alarm Type	Smiths Medical Medfusion Syringe Pump	Alarm Can be Disabled	Can be Configured (ON/OFF or Threshold Adjusted)	
			In Setup (Configured by Biomed/Pharmacy/Administration)	At Bedside (Adjusted by Clinician)
Hold Time Exceeded	User Callback	No	No	No
Infusion Complete	Syringe Empty; Infusion Complete	No	No	No
Upstream Occlusion	N/A	N/A	N/A	N/A
Downstream Occlusion	Downstream Occlusion - "Check Infusion Line"; Restricted Flow - Bolus cancelled, Loading cancelled, Rate Reduced	No	Default Threshold Adjustable	Threshold Adjustable
Partial Occlusion/ Pressure Increasing/ Autorestart	Rapid Occlusion Detection; Pressure Increasing - "Check infusion line"	Yes	Threshold Adjustable	Threshold Adjustable
Air in Line - Single Bubble	N/A	N/A	N/A	N/A
Air in Line - Cumulative	N/A	N/A	N/A	N/A
Door Open	N/A	N/A	N/A	N/A
Inactivity	Inactivity	No	No	No
Set or Syringe Misload	Syringe Plunger Not in Place; Syringe Flange Not in Place; Check Clutch/Plunger level; Check Syringe Barrel Clamp; Check Syringe Flange Sensor; Check Syringe Plunger Sensor	No	No	No
Battery Low	Low Battery - System Advisory	No	No	No
Battery Empty	Depleted Battery - System Advisory	No	No	No
System Error	System Fault/System Failure/System Advisory	No	No	No
KVO	KVO in Progress; Set Volume Before KVO	Yes	Rate and Volume Adjustable	No
Secondary Complete	N/A	N/A	N/A	N/A
Volume Near End	Syringe Volume Near Empty	Yes	Enabled or Disabled	No
Time Near End	Syringe Near Empty	Yes	Enabled or Disabled, Time Adjustable	No

As noted in the Background, this section of the Quick Guide provides practice suggestions on ways to reduce four primary categories of alarms: occlusion, air in line, infusion complete, and battery alarms.

The practice suggestions are the result of the combined experience of the team members, but some recommended reading that also addresses managing pump alarms is provided at the end of each of the answers to the questions.

QUESTION #1: What Strategies Can We Use to Improve Management of "Air-in-Line" Alarms?

Infusion pump air-in-line alarms may include:

- Single bubble air detection
- Accumulated air (multiple small air bubbles)

Possible causes of air-in-line alarms:

- Priming of IV tubing too quickly, allowing air to be entrained in the IV fluid/medication
- Infusion of cold solutions that deposit air in the IV lines as they warm during infusion
- Viscous fluids that tend to create bubbles during administration
- Removing air in IV flexible containers (burping)
- Failing to tap injection ports or needle-free connectors during priming
- Not pausing the pump during container change
- Venting issues with IV bottles and burettes causing excessive negative pressure
- Negative pressure in the IV system that causes outgassing from dissolved air
- Infusion of solutions containing sodium bicarbonate or that generate CO_2
- Infusion tubing not correctly placed into air detection mechanism
- Air detection system contaminated with IV fluids/drugs from spillage or improper cleaning
- Configuring the air detection limit too tightly for certain populations

Potential interventions:

1. Infusion therapy setup:

    a. When possible, allow cold IV solutions to warm before administration. Unless contraindicated, agitating cold solution containers can help to free up dissolved air (like shaking a soda before opening).

    b. Consider adding an antisiphon valve (ASV) to the end of the IV tubing to slightly increase the internal pressure in the IV line. ASV may be effective for problematic fluids and drugs, such as TPN, amiodarone, vancomycin, cefalosporin antibiotics, chemo drugs such as etoposide, and protein solutions such as albumin and immunoglobulins.

2. Spiking and priming:

    a. Do not "burp" IV bags to remove air. Burping the air in the IV bag prevents full emptying, creates a negative pressure in the IV line, and causes the drip chamber to empty allowing air-fluid-air to enter the line. This air-fluid-air may not be detected when a new container is hung.

    b. During initial IV line priming, first close the tubing clamp, insert the IV spike into the container, and squeeze drip chamber to two-thirds full. Slowly open the tubing clamp and allow fluid to fill the tubing, taking care to tap Y-sites and needle-free ports to remove trapped air.

    c. Consider using an autoprime feature if available on the pump. **Never use the autoprime feature if the IV tubing is connected to the patient.**

    d. When changing IV containers, pause the infusion to prevent air from entering the tubing. If not clinically advisable during critical life support situations, take care not to invert the drip chamber and spike the new container in the hanging position. Inverting the IV spike assembly allows air to be pulled into the IV tubing, resulting in an air-in-line alarm.

    e. Air alarms with bubble size considered not clinically significant may require a change in the air bubble detection threshold. Infusion pumps with adjustable thresholds for air may require reevaluation and adjustment.

    f. If pump alarm data is available, analyze to help isolate cause of air alarms, such as frequency of air alarms with specific fluids and drugs or in specific care areas, and timing of alarms (e.g., air alarms soon after starting an infusion suggest poor priming technique).

    g. Educate staff on the potential sources of air and measures to prevent air alarms.

References and further reading:

B. Braun, Air Embolism, Risk Prevention in Infusion Therapy. www.safeinfusiontherapy.com/documents/french/air_embolism(1).pdf. Accessed February 15, 2018.

Moss, Joseph Jr., Reducing Excessive Smart Pump Alarms, www.pppmag.com/article_print.php?id=1823. Accessed February 15, 2018. (note: addresses both air in line and occlusion alarms)

Vanderveen, T., Alarm Managemet: First Things First, Patient Safety and Quality Healthcare, 11(6) 38-45; www.psqh.com/analysis/alarm-management-first-things-first. Accessed February 15, 2018. (note: provides overview of pump alarms)

QUESTION #2: What Strategies Can We Use to Improve Management of "Battery" Alarms?

Battery-related alarms may include:

- Battery low or low battery
- Battery empty pre-alarm
- Battery empty
- Battery depleted
- Battery missing

Possible causes of battery related alarms:

- Power supply/connections are not fully engaged or are accidentally disconnected
- Pumps are not plugged in after transport to/from unit, during procedures, during and after patient ambulation, and while in storage
- Policies may not support/advocate that all personnel are allowed to plug in pumps (e.g. transport, housekeeping, clean utility, procedural staff)
- Lack of available electrical outlets
- Wireless transmission and faster infusion rates increase battery depletion
- Battery at end-of-life cycle, is not performing optimally, or is defective
- Outlet failure

Potential interventions:

1. Educate and reinforce with all hospital personnel to keep pumps plugged in and charging at all times possible.
    a. Review hospital policies to assess if all staff involved in the use, transport, cleaning, repair, and storage of pumps are allowed to plug in pumps and assess charge status. If not, identify who staff should notify for assistance.
2. Include "pumps plugged in and charging" as part of routine infusion pump parameter assessments, nursing rounds, equipment checks, and transport duties.
    a. Check power status on each pump/channel and ensure all channels and power connections are intact.

3. Ensure ambulating patients can access outlets to plug in pumps after ambulating.
    a. May need to reposition bed, beside table, or equipment.
    b. Patient's physical condition may prevent ability to plug in.
    c. Assess battery level prior to transport to determine if adequate power remaining (as noted above: pump batteries are rate dependent; increasing the infusion rate will decrease battery duration. Wireless communication may also decrease battery duration).
4. If outlets not available:
    a. Remove pumps and other equipment not in use.
    b. If pump technology allows for multiple pumps/channels to share a single power source, ensure these capabilities are maximized.
5. In the case of battery performance issue/failure, send the pump to biomedical engineering with detailed description of the events leading up to the issue/failure.
6. Replace pump batteries at the manufacturer-recommended interval and avoid third party battery purchases that are not supported by manufacturer/under manufacturer warrantee.
7. Assess whether battery-related alarms/pre-alarms can be configured.

References and further reading:

FDA. 2014. Infusion pumps total product life cycle: Guidance for industry and FDA staff. Issued Dec 2, 2014. www.fda.gov/downloads/medicaldevices/deviceregulationandguidance/guidancedocuments/ucm209337.pdf. Accessed March 5, 2018.

QUESTION #3: What Strategies Can We Use to Improve Management of the "Infusion Complete" Alarms?

Infusion complete alarms may include:

- VTBI (volume to be infused) complete/infused/end
- Primary or secondary infusion complete
- Bag or syringe empty
- KVO (keep vein open)
- KVO end
- Bag or syringe volume near end/empty
- Time near end
- Secondary or piggyback callback

Possible causes of infusion complete-related alarms:

- Programmed VTBI has infused or container is empty
- VTBI is programmed for less volume than actual:
  - As a buffer to help prevent air from entering line (when VTBI is miscalculated and bag runs dry)
  - As a timer feature to call clinician back to room (alarm may not require action at the pump)
  - Bag volume overfill is not accounted for
- VTBI is programmed for more volume than actual:
  - VTBI calculation did not account for primary and secondary tubing priming volumes
- Secondary intermittent infusions:
  - Secondary callback has been enabled. When secondary programmed VTBI has infused, pump will alarm to call clinician back to restart the primary infusion
  - Clinician administered secondary intermittent infusion as a primary infusion. When secondary infuses, it alarms instead of automatically transitioning to primary infusion
  - Secondary infusion is not hung with adequate height differential, causing infusion of primary bag and actual volume to be less than programmed VTBI

  - Primary or secondary tubing was left clamped, causing premature bag emptying, occlusion, or air-in-line alarm

- KVO has been enabled. When volume is depleted, KVO will transition to infusion complete alarm.
  - Successive KVO alarms can occur when the clinician responds to KVO by adjusting VTBI based on residual volume visualized in bag or to allow enough time to get new bag and resumes infusion, but does not return before KVO alarms again.
- Volume/time near end alarm has been enabled

Potential Interventions:

1. Ensure the accuracy and standardization of programmed VTBI practices:
   a. Bag overfill should be clearly labeled on the bag and included in VTBI calculations.
   b. Include primary and secondary tubing priming volume in VTBI calculations.
   c. Adjust VTBI to account for administration of loading and bolus doses.
   d. Determine and standardize the amount of volume that will be added to VTBI calculations as a buffer to prevent air from entering IV line.
2. Discourage the use of programmed VTBI as a timing feature. Educate regarding:
   a. Interruptions in infusion/treatment and potential patient harm
   b. Increased alarm noise and fatigue
   c. Use of another timing device such as a watch, phone or computer
3. Anticipate infusions near completion:
   a. Calculate when a new bag/syringe will be needed and try to address before infusion complete/KVO alarm. Include this in nurse workflow schedule.
   b. Track infusions near completion using real-time dashboards or physical rounding

   c. Ensure infusion rate changes and bolus doses that affect total volume are documented in the medication record.

4. Ensure proper set up for secondary intermittent infusions:

   a. Ensure secondary bag height differential is adequate. Volume and rate of secondary infusion can influence flow characteristics. Refer to pump manufacturer for height differential requirements.

   b. Visually inspect drip chambers to ensure secondary is flowing.

5. Assess whether infusion complete related alarms can be configured to minimize alarm frequency (e.g., secondary callback, KVO, volume/time near end).

References and further reading:

Health Technology Safety Research Team, Institute for Safe Medication Practices Canada. (2010, June). Mitigating the Risks Associated with Multiple IV Infusions: Recommendations Based on a Field Study of Twelve Ontario Hospitals. http://s3.amazonaws.com/rdcms-aami/files/production/public/FileDownloads/Foundation/Infusion/062012_MultipleIVInfusions_Phase1bSummary_Recommendations_Rationale.pdf. Accessed February 15, 2018.

HumanEra (University Health Network). Multiple IV Infusion Safety eLearning Modules. https://secure.ismp-canada.org/elearning/course/index.php?categoryid=1. Accessed February 15, 2018.

QUESTION #4: What Strategies Can We Use to Improve Management of "Occlusion" Alarms?

Occlusion-related alarms may include:

- Upstream (fluid side) occlusion
- Partial upstream occlusion
- Downstream (patient side) occlusion
- Partial downstream occlusion

Possible causes of occlusion related alarms:

Upstream Occlusion

- A slide clamp or roller clamp is not opened
- IV tubing is kinked
- IV spike is not completely inserted into the container
- An air venting cap is not opened during infusion from rigid container
- Air vent of metered chamber or burette set is not opened
- Air vent gets wet from priming, multiple infusion containers

Downstream Occlusion

- A slide clamp, roller clamp, or manifold valve is not opened
- IV catheter is kinked or occluded
- Patient movement, especially related to catheter placement
- IV filter is clogged
- Rapid IV push delivery
- Downstream occlusion pressure threshold is set too low
- More flow desired than pump(s) can deliver with the available pressure
- A very small internal diameter catheter is in use (e.g., neonatal PIC catheters); these are highly restrictive and may result in occlusion alarms that are not true occlusions.

Potential interventions:

Upstream Occlusion

1. Consider use of IV tubing that has clamps only below the pump. Detecting occlusions below the pump is typically much faster than it is above the pump, reducing the time to alarm with no or inaccurate flow.
2. Ensure IV tubing is not kinked.
3. Ensure IV spike is fully inserted into the container.
4. When using flexible containers (bags), air vent caps should always be left closed.
5. When using rigid containers (bottles, burrettes), air vent caps or covers on IV spike/drip chambers should always be in the closed position when first spiking or re-spiking a rigid container and when turning the container upside down. During infusion, the air vent must be open and clear in order for fluid to leave the rigid container.
6. When using rigid containers/air vents, best practice should include a second check on the position of the air vent, observation of air entering the container, and careful assessment of the cause of upstream occlusion alarms that may be occurring.
7. Avoid removing excess air from the IV container (sometimes referred to as "burping") as this can cause increased upstream pressure and associated alarms.
8. Although air vent filter material is selected due to its hydrophobic characteristics (water repelling), certain fluids and drugs with high surfactant content can "wet" the filter material and reduce or prevent air from entering the container as the fluid leaves. Problematic drugs and solutions include albumin, gamma globulins, lipids, propofol, and many chemo drugs.
9. Closed or wetted air vents will prevent air from entering containers and will eventually cause upstream occlusion alarms. Failure to vent the rigid container or burette can lead to loss of volume in the drip chamber. For burettes, it can also cause an hour-glass collapse in the middle of the chamber due to the vacuum created.

Downstream Occlusion

1. Assess the slide clamp, roller clamp, or manifold valve to ensure it is open prior to starting a new infusion.
2. IV catheter placement should be carefully considered, and when possible, sites likely to result in kinking of IV catheters and occlusion alarms should be avoided. (e.g., avoid placing the catheter in the antecubital fossa).
    a. Infusion pumps may have a feature that detects increasing downstream pressure or partial downstream occlusion and alarms, then resolve spontaneously when the partial occlusion is cleared. For example, for a catheter placed in the antecubital fossa, bending an arm may cause a pending occlusion/occlusion warning alarm, but straightening the arm will resolve the alarm before reaching full occlusion.
3. Assess and change IV filters per protocol. As filters remove particulate matter, they can clog, leading to high resistance and potential occlusion alarms.
4. Prior to administering IV push medications into IV lines, pause the infusion pump to avoid occlusion alarms.
5. When the rate of infusion/interior diameter of the catheter causes pressure equal to the occlusion pressure limit setting on the pump, consider higher concentration preparations (lower infusion rate) or adjusting pump infusion pressure limit to a higher setting.

Important Note: It is a common misunderstanding that infusion pumps' downstream occlusion alarms will sound when infiltration or extravasation occurs.

Downstream occlusion alarms will not detect infiltration or extravasation.

References and further reading:

Bravery K. (2009). Pediatric intravenous therapy in practice. In Dougherty L. & Lamb J. (Eds.), Intravenous Therapy in Nursing Practice, 417-419.

Davis W. (2005). Infusion devices training tutorial: pressure in context. www.ebme.co.uk/articles/clinical-engineering/46-infusion-devices-training-tutorial#pic. Accessed March 5, 2018.

Masoorli S. (2003). Pediatrics: small children at high risk. Journal of Vascular Access Devices, 8(3), 1-2.

Pennsylvania Patient Safety Authority. (2007). IV infiltration: be alarmed even when your infusion pump isn't. PA-PSRS Patient Safety Advisory, 4 (3). Produced by ECRI Institute and ISMP. http://patientsafety.pa.gov/ADVISORIES/Pages/200709_97.aspx. Accessed February 15, 2018.

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