Hospira

Infusion Pump Therapy

A Guide for Clinicians and Educators

Denise Macklin, BSN, RN

About the Author

Denise Macklin, BSN, RN, is the President and founder of Professional Learning Systems, Inc. (PLS) and the editor-in-chief of ceuzone.com, a nursing continuing education Internet site. PLS's programs and online CE offerings are being used to educate nurses worldwide. She has over 30 years of nursing experience with 23 years in the specialty of IV Therapy. She is the recipient of the Suzanne Herbst Award for vascular access and a research grant related to vascular access education from the National Institute for Nursing Research. She has lectured around the United States on a wide variety of IV Therapy topics. She has published articles in various publications, including *Oncology Nurse Forum, Journal of Vascular Access, American Journal of Nursing, Nursing Management* and *Dimensions of Critical Care*. She has published six nursing textbooks through Eslsevier with one specifically on IV therapy practice.

Hospira

Infusion Pump Therapy
A Guide for Clinicians and Educators

Table of Contents

Introduction

The purpose of this booklet is to provide clinicians and educators some basic principles of infusion therapy, describe principles that affect infusions and delineate specific interventions to troubleshoot some common clinical problems. The material in the first two sections provides a general overview, while the remaining chapters contain more specific information to help users become familiar with the principles behind infusion pumps and accurate delivery of intravenous medication/therapy.

LifeCare PCA™ Infusion System

Omni-Flow 4000™ Plus Infusion System

Plum A+™ Infusion System

GemStar™ Infusion System

Hospira

Section 1

Basics of Infusion Therapy

The infusion of solutions into a patient's venous system is central to today's therapeutic regimens and occurs in many settings: inpatient, outpatient, physician offices and at home. Patients receive infusions through a myriad of devices: peripheral venous catheters, central venous catheters, PICCs (peripherally inserted central catheters), implanted ports and epidural catheters, to name a few. Each site, solution, medication, device and method of delivery is chosen specifically for that patient and needs to be evaluated on an ongoing basis (i.e., the patient's therapy may change, IV sites need to be rotated, sites may infiltrate, etc.). Patients can receive IV therapy on a continuous or intermittent basis and may have multiple IV sites with different types of catheters. While gravity infusions are still used in some care settings—such as emergency departments, obstetrics and clinics—most care settings utilize electronic infusion devices. And with the advent of home infusion therapy, more caregivers are learning how to administer medications using home infusion pumps.

In order to understand any infusion pump, it is helpful to understand the anatomical factors that impact successful infusions. Veins and arteries

differ in their ability to expand—veins being more compliant than arteries. Other differences between these vessels include wall thickness (veins are thinner than arteries) and the presence of valves (veins alone have valves). Blood moving through the circulatory system exerts pressure on the walls of veins and arteries, and since veins are more compliant the flow rate is slower. Vascular pressure is lower in veins. The venous pressure must be overcome by the pump for successful infusion.

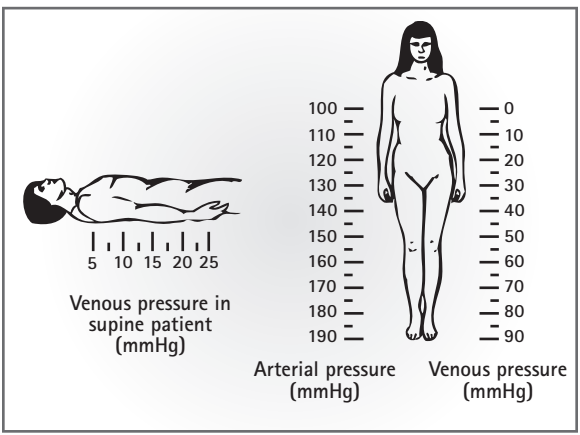

Figure 1: Pressures and the Human Body

Other Factors That Impact Infusion Are

- *Quality of vasculature:* This may vary by patient depending upon the disease process. For instance, the peripheral veins of a patient in shock are constricted, may be very difficult to access and will experience many hemodynamic changes during treatment. Cardiac patients have increased potential for venous spasm and the presence of edema can make venous access difficult. Peripheral neuropathy associated with diabetes limits the patient's ability to feel and to acknowledge early symptoms of phlebitis or infiltration.

- *Age of the patient:* Access, medication dosage and fluid volume are different for a child than an adult. Geriatric patients require special attention as skin integrity, vessel elasticity, fluid balance and muscle mass change with advancing age. All of these differences affect site preparation, catheter selection, vein visualization and stabilization, catheter stabilization, dressing management and fluid administration.

- *IV Solution/Medication:* The choice of solution or medication also affects the selection of the vein and access device. Medications such as mannitol require special filters, and some medications that are more irritating require use of a larger vein to promote hemodilution. Other medications can only be infused via an infusion pump because they must be administered in precise doses.

A complete patient assessment prior to initiating an infusion is essential for the clinician to determine the potential for complications based on the therapy prescribed. This "risk" assessment assists the clinician in developing a plan of care that minimizes complication occurrence. Patient age and condition, as well as the medication prescribed, are the most common factors impacting outcome. Pediatric, geriatric and critically ill patients require special attention to catheter and site selection to achieve positive patient outcomes. Some vesicant medications, such as total parenteral nutrition or those containing a high amount of dextrose, require central venous access. Because the clinician is responsible for the infusion process, selecting the administration set, the appropriate pump and add-ons (i.e., filter and extension) requires an organized approach.

Section 2

Keep It Simple: Safe and Effective Infusion Therapy

Clinicians today are faced with numerous decisions on a daily basis. Administering effective and safe infusion therapy involves assessment of the relationship between the patient, the infusion method and the clinical outcome. Some basic questions for clinicians to ask include the following:

Patient

- Current status?
- Change in the patient's status?
- Why this infusion therapy/medication?
- If a change occurred in the patient's blood pressure/condition, should the PSI alarm on the pump be reset? See Section 3.b (Pressure) for more information on pressure/PSI.

Infusion Method/Therapy

- Has the catheter been assessed?
- Has the entire infusion set-up been assessed from the catheter insertion site to the solution container?

- Is the tubing free of kinks? Is the IV catheter free of kinks?
- Is the catheter size appropriate for the infusion?
- Is there enough solution left in the container to ensure delivery to the patient and to keep the vein open?
- PSI:
    1. To what PSI limit is the pump set?
    2. Current PSI of the patient? (*see Figure 1*)
    3. Does the PSI limit on the pump make sense given the current PSI of the patient, the viscosity of the solution and the infusion rate?
    4. If there has been a recent change in IV rate (increase), will this affect the current PSI setting of the pump?
- Is this the correct pump for this patient?
- For medications that require a filter, is there a filter incorporated in the IV administration set-up? Is it the correct filter size?
- Precipitates visible in the tubing?
- Tubing free of air?
- Is the pump battery charged or plugged into an AC power source? If the patient is sent to another area, is there enough charge left on the battery to continue infusing for the amount of time needed?

- If the IV insertion site was changed, was the tourniquet removed from the patient?
- If the device has safety software, is the unit-specific medication library being utilized?
- Did someone else have access to the pump?

Clinical Outcome

- What is the goal of treatment/expected clinical outcome for this patient?
- Has the patient achieved the expected outcome within the anticipated amount of time?
- If not, what may have prevented this from happening?
  - Is the IV access intact? (i.e., no clotting or infiltration)
  - Is the correct solution being infused?
  - Is the solution infusing at the prescribed rate?
  - Have the orders been checked to determine if any changes in IV therapy were made?
  - Is there anything that may be interfering with the infusion?
  - Is the medication compatible with the other solution(s) infusing through the same IV administration set?
- If the outcome has not been reached, has a new plan of care been formulated in conjunction with the medical team?

The above review is useful when a complete assessment of the overall therapy is indicated (i.e., initiation of a new therapy, change of shift, new admissions, transfers, etc.). When infusion pumps alarm, an assessment is required to resolve the issue in a timely manner. Keeping the patient, the infusion therapy and the clinical outcome in mind assists the clinician in achieving optimal patient outcomes.

Section 3

What Factors Affect the Physics of Flow?

Delivering safe and effective therapy to a patient remains the caregiver's responsibility. While the intelligent pumps with safety software promote safe medication delivery, the clinician needs to be aware of the principles governing the use of the pump in order to deliver the best outcome for the patient. An understanding of the physics of flow is helpful to safely use all the available pump options, including selecting the appropriate device; delivering the indicated therapy problem free; evaluating and altering parameters; and assessing the fluid pathway.

Factors that affect the physics of flow are comprised of the following:

A. Rate

Definition: Fluid flow rate (FR) occurs as a result of the relationship of pressure (P) and resistance (R).

$$FR = \frac{P}{R}$$

Principle: Flow rate impacts resistance and resistance impacts the amount of pressure required to achieve the flow rate.

Clinical Consideration: The following principles apply to flow rates:

- High-resistance systems require the most amount of pressure (e.g., infusing into a hypertensive patient with left ventricular hypertrophy or pulmonary hypertension).
- High flow rates in low resistance systems will require less pressure than in high resistance systems (e.g., infusing fluid rapidly into a hypotensive patient in shock).
- Low flow rates in high resistance systems will require less pressure than high flow rates (e.g., infusing at the keep vein open [KVO] rate into the hypertensive patient).
- Low flow rates in low resistance systems will require the least amount of pressure. For example, KVO rate into a hypotensive patient.

Troubleshooting: Repeated distal occlusion alarms can be frustrating. Understanding pressure and resistance enables the practitioner to minimize their occurrence and successfully eliminate them by understanding a little physics and basic pump

technology. The practitioner can then compare the prescribed flow rate with the resistors to flow in order to identify the best pump pressure setting for successful infusion. When the pump pressure is set properly, distal occlusion alarms are minimized.

B. Pressure

Definition: Pressure (P) is a measure of the force (F) applied to overcome resistance in a system, across a given area (A).

$$P = \frac{F}{A}$$

The area is the internal fluid pathway or internal diameter (tubing, add-ons and catheter).

Pressure is the result of force and is measured in either PSI (pounds per square inch) or mmHg (millimeters of mercury).

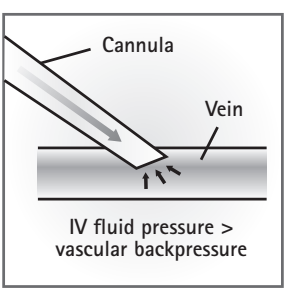

Figure 2.

Principle: A pressure gradient between the IV solution container and the venous pressure is necessary for flow to occur. The gradient depends on static pressure (height of the solution container in relation to the patient's heart) and the patient's activity (blood pressure is lower when the patient is lying down vs. standing and walking) and dynamic pressure (resistance generated by the fluid flowing through the IV system). The infusion pump is a source of constant force that produces a constant flow rate, with the force exerted equal to the rate times the amount of resistance existing within the system. The PSI threshold is the PSI limit set either by the manufacturer or the practitioner. This threshold alerts the practitioner when the required force exerted by the pump has reached the threshold—increased resistance necessitates an increase in force.

Clinical Consideration: With gravity infusions, gravity alone is the force. However, with an infusion pump, the pump applies the force to move the fluid. The infusion pump is more sensitive to changes in the fluid pathway's resistance than gravity systems.

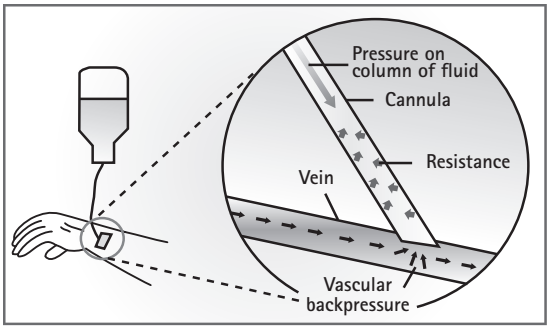

Figure 3.

Infusion pumps utilize different mechanisms to infuse the fluid. Some use a cassette system where a fluid volume is pulled into a chamber and then pushed out of the chamber at the prescribed rate (e.g., the Omni-Flow 4000™ Plus, Plum A+™, GemStar™, Symbiq™). The internal software of the pump ensures delivery accuracy. Resistance within the fluid pathway is dependent upon the pathway length, the internal diameter of the pathway and the viscosity of the fluid (*full description below*).

Pressure is dynamic in response to changes in resistance. A distal occlusion alarm occurs when the PSI threshold has been reached. While an occluded catheter may be the source of the resistance, the distal occlusion alarm does not specifically identify the exact cause.

Other possible causes include kinked tubing, a tourniquet left on a patient after obtaining IV access or a change in the patient's position, resulting in pressure on the tubing.

Common Pressures

Pressure 50 mmHg = approximately 1 PSI	Distal Occlusion Alarm Settings (PSI)	Distal Occlusion Alarm Settings (~mmHG)	PSI Increment (PSI)	Default Setting (PSI)
Peripheral	0.2 – 0.6	10 – 30		
Central Venous	0.1 – 0.4	5 – 20		
Plum A+™ Infusion System	Up to 15	Up to 750	1.0	6
GemStar™ Infusion System-Low	7 (+/- 5)	350 (+/- 250)	1.0	26 (+/-14)
GemStar™ Infusion System-Medium	12 (+/- 8)	600 (+/- 400)	1.0	26 (+/-14)
GemStar™ Infusion System-High	26 (+/-14)	1300 (+/- 700)	1.0	26 (+/-14)
Symbiq™ Infusion System	Up to 15	Up to 750	0.5	6
LifeCare PCA™ Infusion System	15 (+/-5)	750 (+/- 250)		15
Omni-Flow 4000™ Plus Infusion System	Up to 12	Up to 600	1.0	10
Power injectors	300-1000+	15,000 – 50,000 +		

Table 1.

Some infusion pumps allow the PSI/mmHg threshold to be set/altered by the practitioner; setting the PSI limit correctly helps to minimize downstream or distal occlusion alarms. It may seem, for instance, that the lowest PSI setting would always be the safest choice. *However, since greater force is required to overcome increased dynamic pressure in a fluid pathway, high-resistance systems with a low PSI setting would yield the greatest number of distal occlusion alarms.* With low-resistance systems, a low PSI setting would not increase occlusion alarms.

Troubleshooting: The key to successful troubleshooting is identifying the cause of the resistance; evaluate the entire system when trying to determine a cause for a distal occlusion alarm. Problems can occur when the fluid rate is dramatically changed from a slower to a faster rate. It is also important to understand that occlusion alarms do not necessarily mean that the catheter is occluded, only that the preset PSI threshold has been reached. **Use the following checklist when distal occlusion alarms occur:**

- Have there been any changes to the tubing or add-ons below the pump?
- Are clamps open?

- Are there any kinks in the system?
- If a filter is present, is it filled with fluid and not air locked or clogged with precipitate?
- Was the infusion rate changed recently?

Other Issues Affecting Pressure:

Flushing IV Catheters: Sometimes after flushing a peripheral catheter (and finding it to flush clear), the pump continues to alarm for a distal occlusion. This occurs because the force applied to the syringe plunger is resulting in a higher PSI than the pump PSI threshold. Syringe pressure does not have a threshold. The pump PSI threshold is lower; therefore, it is more sensitive to changes in the system.

Resistance Related to Internal Diameters: IV tubing, extensions and IV catheters come with different internal diameters. Small internal diameters (microbore) such as those used with neonates, infants and PCAs are high-resistance systems; therefore, administration requires increased force to overcome the high resistance. Low PSI settings may result in frequent distal occlusion alarms. Since a higher pump force is necessary, a higher PSI threshold would help alleviate these distal occlusion alarms. Non-PCA

standard adult administration sets, blood administration sets and catheters use larger gauges (macrobore) and are low-resistance systems; the pump PSI/mmHg required to overcome resistance is less.

Fragile Veins: Venous fragility is associated with the elderly, neonates, some chronic illnesses (e.g., chronic obstructive pulmonary disease, renal failure and diabetes) and some medications (e.g., steroids, warfarin and vesicants). Infiltration is associated with venous fragility; a normal vein can withstand 1.9 PSI (burst pressure), while the burst pressure of a fragile vein may be much lower.

Solution Height: When using an infusion pump, there should be approximately 30-36 inches between the solution container access port and the patient's IV catheter.

C. Resistance

Resistance is anything that impedes flow. The greater the resistance in the fluid pathway, the greater the force required to move through it. Fluid viscosity, fluid pathway length (tubing, extensions and the catheter) and internal diameter of the administration set are the major resistors to flow.

D. Viscosity

Definition: Viscosity is defined as a fluid's resistance to flow. Temperature directly affects fluid viscosity. Colder fluids exhibit greater resistance to flow than warm fluids.

Principle: Viscosity directly impacts resistance. Using the exact same set-up, doubling the viscosity would reduce the flow rate by half and reducing the viscosity by half would double the flow rate.

Clinical Consideration: Many fluids—such as albumin and lipids—have a higher viscosity than common hydration fluids and hence will increase resistance in the fluid pathway. To better understand the concept of viscosity, think about the infusion of blood via gravity. When the drip rate is initially calculated and not adjusted over time, the infusion rate increases as the blood warms and thins; the resistance is lowered, allowing the infusion rate to increase.

Troubleshooting: With a pump capable of having a low PSI setting, changing from a low viscosity fluid to a high viscosity fluid may trigger a distal occlusion alarm. Increasing the PSI/mmHg threshold will eliminate the alarm. If this is a patient with venous fragility, when the fluid warms, the PSI/mmHg can again be lowered.

E. Length

Definition: *Each component of the IV administration system (tubing, extension and catheter) has a length. Often the calibration uses the metric system.*

1 inch = 2.54 centimeters

Principle: Length directly impacts resistance. Doubling the length reduces the flow rate by half.

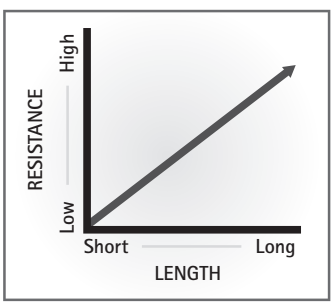

Figure 4.

Clinical Consideration: The increased length of central lines and PICCs dramatically increases resistance when compared to a short peripheral catheter. Actions such as the addition of tubing, extensions, filter and/or flow control device

below the pump increase administration set length. Each addition increases the fluid pathway length as well as resistance and the force required, thereby increasing dynamic pressure.

Troubleshooting: Assess the devices added to the administration set distal to the infusion pump. It is best to remove anything that is not required for the infusion. If tubing is added below a pump to enable greater patient mobility, the resistance to flow is increased, raising pump force. Take additional tubing length into consideration when setting the PSI threshold.

F. Internal Diameter

Definition: Internal diameter (ID) is the distance from one inside edge of the catheter lumen to the opposite inside edge; internal radius is half of the internal diameter. Gauge is standardized and reflects the outside circumference of a catheter. Catheters may be the same gauge while having different internal diameters. This is due to differences in catheter wall thickness. With peripheral catheters, wall thickness is a design characteristic, so a catheter is either thick wall or thin wall. With central venous catheters, the actual material is the determining factor. Silicone derives its strength with thickness, so any catheter made with silicone is thick walled

and will have a smaller internal lumen. Polyurethane catheters are almost always thin walled. In regards to tubing, macrobore tubing has a large internal diameter and microbore tubing has a small internal diameter.

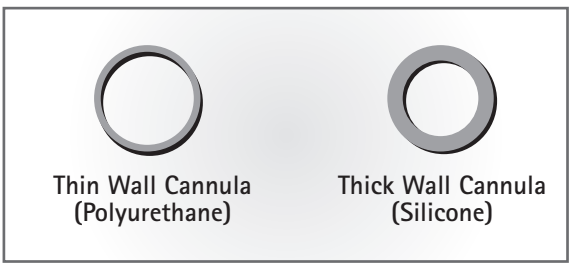

Figure 5.

Principle: Internal radius impacts resistance exponentially to the fourth power. If you double the radius of the fluid pathway, the flow rate increases by a factor of 16. A 19% decrease in radius halves the flow rate.

Clinical Consideration: A roller clamp works by either decreasing the internal diameter when tightening or increasing the internal diameter when the clamp is opened. A partially closed clamp will increase resistance, resulting in an increase in dynamic pressure, and may, over time, cause a distal occlusion alarm. All clamps should be in the open position when using an infusion pump.

Comparison of Thin Wall vs. Thick Wall Peripheral Catheters

Gauge	Thin Wall (Instye™)		Thick Wall (Angiocath™)	
	Length (Inches)	Flow (mL/min)	Length (Inches)	Flow (mL/min)
24	½	24.4	¾	16.4
22	1	36.4	1	27.6
18	1¼	107.9	1¼	85.2
16	2	204.7	5	108

Table 2: Notice in the table that the 24 gauge thin wall catheter has a similar flow rate as the 22 gauge thick wall catheter. Comparing the 18 gauge thin wall catheter (length + ID) with the 16 gauge 5" thick wall catheter demonstrates how combining resistors impacts flow rates.

Resistance Troubleshooting: Identifying resistors that may impede fluid flow is necessary to complete an infusion assessment. When resistors are combined and the flow rate continues undisturbed, the dynamic pressure requirements increase. A systematic approach to infusion assessment by identifying resistors and their relation to the pump PSI/mmHg will result in effective interventions. As the rate changes, the impact of the resistors also changes. Low-rate infusions with high resistance systems, such as those with neonates and infants, may not result in distal occlusion alarms. This is because the

resistance generated with the low-flow rate is low. However, when a low rate is changed to a higher rate, the resistance increases and the PSI/mmHg may need to be altered to prevent or eliminate distal occlusion alarms. In the adult population, if an infusion rate is changed from KVO to a high fluid rate, the PSI/mmHg may require a change to prevent a distal occlusion alarm.

G. Infiltration

Infiltration is a complication primarily of peripheral catheters, occurring when fluid infuses from the vascular space into the tissue. This can be caused by leaking around the catheter vein insertion site, when the catheter actually punctures the vein back wall or with venous injury. A common misunderstanding is that an infusion pump alarm can alert the practitioner that infiltration has occurred. *Infusion pumps cannot identify infiltration.* Regardless of cause, with infiltration, fluid will continue to infuse into the tissue until the interstitial compartment becomes tight enough to provide sufficient resistance to reach the PSI threshold. Depending on the size of the tissue compartment and/or the tissue turgor, the infiltration can be very large and never trigger an occlusion alarm.

With low-flow rates, it is especially important to visually assess the patient for signs of infiltration since it will take an extended time for fluid to accumulate. With very fragile veins (e.g., elderly, diabetes, warfarin, steroids), providing the lowest PSI required for proper infusion may minimize vein damage.

Section 4

Frequently Asked Questions About Pounds per Square Inch (PSI)

The following Questions and Answers section provides guidance to questions frequently asked by clinicians:

Is there a PSI setting based on a prescribed medicine?
No. A pump applies a force to overcome the resistance in the fluid pathway in order to achieve the prescribed flow rate. The PSI threshold is set as a safety warning system. It tells the practitioner that a specified resistance level is present and that either the resistance must be lowered or the pressure must be raised if the prescribed fluid rate is to continue. Infiltration is a complication of infusion. It is vital that patients at high risk for infiltration be identified and that attempts are made to minimize this risk. Vesicant infiltration is a serious complication. When administering a vesicant through a pump in the absence of visual site inspection, it is safest to use a central venous catheter. Check the institutional policy for administration of vesicants before administration.

Is there a PSI setting based on the type of catheter?
The length of the catheter and the internal diameter of the catheter are important resistors. With small-gauge, long catheters—such as 25-gauge PICC—the resistance to flow will be very high. Therefore, a very low PSI limit would not be appropriate because the high resistance to flow would trigger the alarm. The PSI limit would be set based on the prescribed rate. If a selected PSI resulted in a distal occlusion alarm, the PSI was set too low.

Is there a PSI limit that will prevent occlusion alarms with catheters placed in areas of flexion?
No. Mechanical kinking of the catheter is an intermittent occlusion. The highest PSI threshold the pump can be set at is not sufficient to overcome a mechanical kink. Peripheral catheter tips should not be placed in areas of flexion.

Will setting PSI lower catch infiltration sooner?
No. Pumps do not detect infiltration. PSI alarms or changes in PSI values notify the practitioner of increased dynamic pressure in the fluid pathway. Only visual assessment of the catheter and palpating lightly above the catheter tip will alert the practitioner to infiltration. Signs of infiltration may include changes in skin temperature (cool is a sign of infiltration) or skin tightness, swelling, blanching or leaking at the insertion site.

If the PSI reading is higher, does it mean that the line is about to infiltrate?

No. When PSI rises, it means the resistance in the vascular pathway is rising. Dynamic pressure reflects the amount of resistance there is in the fluid pathway. It does not relate to infiltration. It does relate to changes in fluid pathway length, fluid pathway internal diameter (clamps not fully opened, change of a smaller catheter gauge), fluid viscosity and/or flow rate.

While giving lipids to a neonate, we used a 0.22 micron filter into an umbilical artery catheter (UAC) line. We had a lot of distal occlusion alarms. The PSI was set at 6. Should we go higher?

No. A larger micron filter is required with lipids, such as a 1.2 micron filter. Since the rate is probably very low, it will take some period of time for the pump to reach the PSI threshold, triggering the distal occlusion alarm. The 0.22 micron filter was the resistor in the system, acting like a partial or total occlusion (the filter was clogged with lipids).

Section 5

What Is Low-Flow Continuity and How Does It Affect the Care of the Patient?

Sometimes it is necessary to deliver a dose of a drug using a very slow infusion rate; this occurs more frequently in neonatal and pediatric ICUs and in patients with fluid restrictions. This section explains concepts pertinent to low-flow continuity, including a list of drugs commonly given at a slow rate.

Definition: Low-flow continuity occurs when the pulsatile flow of an infusion pump has no activity for 20 seconds or greater; this occurs when the calculated rates are extremely low, typically below 0.5 mL/hr (AAMI definition – Association for the Advancement of Medical Instrumentation). Low flow continuity is primarily of clinical concern when delivering drugs with a short half-life. Half-life is the time required for the amount of drug in the body to decrease by 50%. The shorter the half-life of the drug, the more frequently it needs to be administered.

Drugs with short half-lives include, but are not limited to, the following:

dopamine, dobutamine, epinephrine, epoprostenol, esmolol, isoproterenol, lidocaine, nitroglycerin, nitroprusside, norepinephrine, oxytocin, and procainamide

Principle: Any pump (i.e., Plum A+™) that uses a stepper motor actually delivers fluid in discrete pulses. The net result is that these IV pumps are actually delivering fluid in a series of discrete, fixed volume pulses, not a continuous stream. If the time between pulses is large relative to the elimination half-life of the drug being infused, this pulsatility may influence the patient's status as the drug's volume circulates within the patient.

Clinical Consideration: Low flow continuity issues arise with very short half-life drugs (i.e., half-life less than 2 minutes). Drugs with very short half-lives must be given continuously to maintain therapeutic efficacy. Pumps that meet the standard of delivering every 20 seconds *usually* do not encounter this problem; however, if the amount of drug delivered every 20 seconds varies widely, there can still be concerns.

Diluting the drug so the pump flow rate is increased to deliver the desired dose can potentially ameliorate the problem; however, it is important to follow the facility's policies and procedures. Keep in mind that other drugs may affect the metabolism and half-life of the drug being administered. Also, patients may metabolize drugs at different rates (e.g., the elderly metabolize drugs more slowly). Organ function (liver and kidney) can also impact the rate at which patients metabolize drugs.

Significance of flow rate: At very low rates, changes in flow represent large percent changes in delivery. For example, increasing the rate from 0.1 to 0.3 is tripling the dose; however, going from 50.1 to 50.2 is insignificant. For the great majority of patients who require rates > 1 mL/hr, there tend to be no continuity issues.

Section 6

Concurrent Flow: Demystifying the Complexity of Multiple Infusions

The care patients receive has become increasingly complex, sometimes requiring the caregiver to administer multiple infusions through a single line. The following section reviews information pertinent to concurrent flow.

Definition: Concurrent flow occurs when medications are delivered through the same venous access site via a single catheter/administration set or through one port of a multi-lumen catheter (i.e., any two or more infusions/medications/therapies that flow together at any point in the intravenous process constitute concurrent flow).

Principle: Giving medications concurrently reduces the number of IV sites necessary to administer medications, potentially decreases the opportunity for infection, decreases the amount of equipment "attached" to a patient and subsequently eases ambulation.

There are two common methods used to manage the delivery of multiple medications: "Multi-Line In/Multi-Line Out" and "Multi-Line In/Single-Line Out."

Multi-Line In/Multi-Line Out: This method allows two or more medications to be administered via separate tubing to a patient at different access points.

Multi-Line In/Single-Line Out: This method allows two or more medications to be independently controlled and administered via a single administration set to the patient. The fluids are combined in a single pumping chamber known as a cassette, and are then delivered through the distal line of a single administration set during the pump cycle.

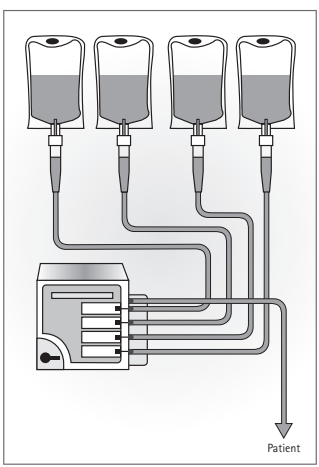

Figure 6: Example of Omni-Flow 4000™ Plus Infusion System (4 lines in and 1 line out).

Clinical Considerations: In its simplest form, concurrent flow occurs with a primary IV solution (i.e., Lactated Ringer's Injection) infusing simultaneously with a secondary (piggyback) IV solution (i.e., antibiotic, anti-nausea medication). If a pump is not used (i.e., the clinician connects the distal end of the secondary set into the lower Y-site of the primary administration set), the rate of infusion and thus the patient's response to the medication(s) might be affected. With the advent of more complex treatments, pumps are more frequently used to ensure accurate administration of drug(s) to the patient. The following pumps are designed to deliver concurrent flow: Plum A+™ and Omni-Flow 4000™ Plus.

Compatibility: Medications may only be infused concurrently if they are compatible. While some incompatibilities may not be detectable, others can produce precipitates in the IV tubing, color changes in solutions or (rarely) gas evolution. Chemical incompatibility can result in the loss of the potency of the medication. Be sure to check with the pharmacy or current reference book to determine the compatibility of the medications to be infused concurrently.

Half-Life: Drugs with short half-lives may be affected by the rate of the infusions. See list under Low-Flow Continuity.

- If the critical medication (half-life < 6 minutes) is to be infused at less than 2.0 mL/hr, the other infusion should be no faster than five times the critical drug's rate. For example, dopamine delivered at 1.5 mL/hr should not be accompanied by an infusion programmed any faster than 7.5 mL/hr.

- If the critical medication (half-life < 6 minutes) is to be infused at 2.0 to 5.0 mL/hr the other infusion should be no faster than 10 times the critical drug's rate. For example, dopamine delivered at 3.5 mL/hr should not be accompanied by an infusion programmed any faster than 35 mL/hr.

- If the critical medication (half-life < 6 minutes) is to be infused at 5.1 mL/hr or greater, the other infusion can be programmed at any desired rate.

Troubleshooting: If a second infusion is programmed and/or an attempt is made to start a delivery rate that would exceed the concurrent upper delivery limit or be less than the concurrent lower delivery limit, a concurrency violation occurs. In both cases, the user can enter new values using the numeric keypad, or use [Select] arrows to move to another field to change the entry. The user can also press [Clear].

Utilization of the Plum A+™: For concurrent delivery, there is a 0.5 mL/hr minimum for each line and a 500 mL/hr cumulative maximum (A+B). KVO is 1.0 mL/hr or the last primary delivery rate, whichever is less.

NOTE: The total of the primary rate plus the secondary rate cannot exceed 500 mL/hr.

Utilization of the Omni-Flow 4000™ Plus:

- When infusing 2 channels, 1.0 mL/hr minimum – 700 mL/hr maximum flow rate.
- When infusing 3-4 channels, 1.0 mL/hr minimum – 600 mL/hr maximum flow rate.

Section 7
Conclusion

IV therapy today is an integral part of patient treatment. Clinicians need to understand the basics of IV therapy along with the more complex utilization of infusion pumps (i.e., low-flow continuity and concurrent flow) in order to optimize care for their patients. While infusion pumps are quite intelligent, they can only achieve their full potential when operated by a clinician who understands the full range of available options and uses them in accordance with prescribed recommendations.

When administering IV therapy, it is very important to take a "time out" and reflect on what is going on with the patient; is the outcome being achieved? If not, are there any changes related to IV therapy that, if made, may make a difference?

The world of infusion therapy is dynamic and changes on an ongoing basis. Maintain ongoing communication with your infusion pump representative to keep abreast of changes in the infusion pump arena.

Section 8
Glossary

Compatibility	Two or more medications "getting along well" when delivered concurrently. An interaction between drugs can cause changes in the appearance or character of either or both drugs. This incompatibility can render either or both drugs inactive or toxic. This occurs most commonly when drugs are combined in IV solutions.
Concurrent flow	Two or more intravenous infusions being delivered together via the same tubing. Can also include two or more infusions being delivered together via the same catheter lumen, manifold or y-site.
Distal line	The tubing which is below the pumping mechanism. In the case of Plum A+™ and Omni-Flow 4000™ Plus, the distal line includes the cassette.
Half-life	The time required for the amount of drug in the body to decrease by 50%.
Proximal line	The tubing which is above the pumping mechanism.
Vasoactive	A drug which affects the cardiovascular system—this may be either a vasoconstrictor (which makes the blood vessels constrict) or vasodilator (which relaxes the blood vessels and makes them dilate).

Section 9
Bibliography

Aspects of Concurrent Delivery in Intravenous Therapy (Self Study Module). Abbott Park, Illinois: Abbott Laboratories; 2002.

Clinical Connections Module 1: Concurrent Flow. Lake Forest, Illinois: Hospira, Inc.

Criteria and Test Methods for General Purpose Infusion Pumps. *Health Devices.* ECRI; October 2007.

Floyd RA. Effect of infusion pump fill-stroke flow interruptions on simulated serum concentrations of short half-life drugs. *American Journal of Hospital Pharmacy.* November 1984;41(11):2399-2400.

Fluid Dynamics: The Relationship Between Fluid Dynamics and Infusion Therapy (Self Study Module). Abbott Park, Illinois: Abbott Laboratories; 2002.

GemStar™ Infusion Pump System Operating Manual. Lake Forest, Illinois: Hospira, Inc.; 2007.

LifeCare PCA™ System Operating Manual. Lake Forest, Illinois: Hospira, Inc.; 2007.

Macklin, D. What's physics got to do with it? A review of the physical principles of fluid administration. *Journal of Vascular Access Devices.* Summer 1999: 7-11.

Mann HJ, Fuhs DW, Cerra FB. Effect of infusion pump fill-stroke flow interruption on response to sodium nitroprusside in surgical patients. *Clin Pharm.* March 7,1988;3:214-219.

Omni-Flow 4000™ Plus System Operating Manual. Lake Forest, Illinois: Hospira, Inc.; 2004.

Plum A+™ Pump System Operating Manual. Lake Forest, Illinois: Hospira, Inc.; 2006.

Stowe CD, Storgion SA, Lee KR, Phelps SJ. *Hemodynamic response to intentionally altered flow continuity of dobutamine and dopamine by an infusion pump in infants. Pharmacotherapy.* November-December 1996;16(6):1018-1023.

Symbiq™ System Operating Manual. Lake Forest, Illinois: Hospira, Inc.; 2007.

For more information on Advancing Wellness™, contact your Hospira representative at 1-877-9Hospira (946-7747) or visit www.hospira.com

 P11-3241-Apr., 11