INTRAVENOUS MEDICATIONS

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ABSTRACT

It is important to provide nurses with up-to-date and complete data. However, for some drugs and for certain aspects of their use, i.e., pharmacokinetics and dosages, in certain clinical situations the data is limited and/or incomplete. A complete list of adverse effects and side effects for each medication would be quite lengthy, impractical, to include in this study; and, for most of the drugs their frequency is not known. Yet, nurses need to be concerned about and familiar with some of the more common medication adverse effects and side effects, such as are explained. Intravenous compatibility as it pertains to the medications discussed in this study module will be discussed. If commonly known and used, brand names for the drugs are also provided.
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Statement of Need:
Although information on infusion therapy can vary, there are basic guidelines that nurses are expected to know in order to meet knowledge needs and practical experience requirements in the performance of infusion therapy. All nurses, whether they are certified in infusion therapy or not should understand the basic principles of administering certain infusion medications, benefits and risks.

Course Purpose:
To provide nurses with the knowledge needed to safely administer some of the more common intravenous medications.
Learning Objectives:
1. Identify two benefits and two risks specific to IV infusion of medications.
2. Identify two precautions for administering IV insulin
3. Identify two precautions for administering IV heparin.
4. Identify two precautions for administering IV vasopressors and inotropes.
5. Identify two precautions for administering beta-blockers and calcium channel blockers.
6. Identify two precautions for administering vasodilators.
7. Identify two precautions for administering antiarrhythmics.

Target Audience:
Advanced Practice Registered Nurses, Registered Nurses, Licensed Vocational Nurses, and Associates

Course Author & Director Disclosures:
Dana Bartlett, RN, BSN, MA, MSN, William S. Cook, PhD,
Douglas Lawrence, MA, Susan DePasquale, CGRN, MSN, FPMHNP-BC – all have no disclosures.

Acknowledgement of Commercial Support: There is none.

Activity Review Information:
Reviewed by Susan DePasquale, CGRN, MSN, FPMHNP-BC.

Release Date: 3/3/2015            Termination Date: 3/3/2018

Please take time to complete the self-assessment Knowledge Questions before reading the article. Opportunity to complete a self-assessment of knowledge learned will be provided at the end of the course.
1. Which of the following are benefits of IV administration of drugs?
   a. Rapid onset of action and 100% bioavailability.
   b. No risk of tissue damage and precise titration of dosage.
   c. Simpler to administer than PO route, steady state drug concentrations.
   d. Less expensive than PO preparations, fewer adverse effects.

2. Which of the following are risks specific to IV administration of drugs?
   a. Slow onset of action, decreased bioavailability.
   b. Imprecise dose titration, easier to administer than PO route.
   c. Tissue damage from infiltration/extravasation, complicated administration.
   d. Thrombophlebitis, higher frequency of allergic reactions.

3. Which of the following are adverse effects caused by IV insulin?
   a. Hypocalcemia and hyperglycemia.
   b. Hypokalemia and hypoglycemia.
   c. Hyperkalemia and metabolic acidosis.
   d. Hypercalcemia and metabolic alkalosis.

4. Which of the following are relatively common adverse effects caused by IV heparin?
   a. Bradycardia and hypotension.
   b. Hepatotoxicity and renal damage.
   c. Bronchospasm and Stevens-Johnson syndrome.
   d. Bleeding and thrombocytopenia.

5. The vasopressors and inotropes may cause:
   a. Peripheral vasoconstriction and dysrhythmias.
   b. Bleeding and hypoglycemia.
   c. Bronchospasm and hypokalemia.
   d. Thrombocytopenia and seizures.
6. When using a vasopressor or an inotrope it is critical to periodically assess:
   a. Serum magnesium and serum calcium.
   b. Urine output and mental status.
   c. Serum glucose and aPTT.
   d. Pulmonary capillary wedge pressure and temperature.

7. IV infusion of a beta-blocker can commonly cause:
   a. Hypertension.
   b. Thrombocytopenia.
   c. Hypotension.
   d. Seizures.

8. IV infusion of a calcium channel blocker can commonly cause:
   a. Tachycardia.
   b. QTc prolongation.
   c. Hypoglycemia.
   d. Hypotension.

9. IV infusion of nitroprusside can cause:
   a. Bronchospasm.
   b. Cyanide poisoning.
   c. Bleeding.
   d. Dysrhythmias.

10. IV infusion of an antiarrhythmic is contraindicated if the patient has:
    a. Severe heart block.
    b. Asthma.
    c. Hyperglycemia.
    d. A bleeding disorder.
INTRODUCTION

This study module will discuss commonly used medications that are delivered by intravenous (IV) infusion: insulin, heparin, vasopressors and inotropes, beta-blockers, calcium channel blockers, vasodilators, and antiarrhythmics. The manufacturers’ package inserts and several widely used and accepted drug information databases have been used for information about dosages, pharmacokinetics, administration, IV compatibility, precautions and contraindications, and adverse effects and side effects. Labeled uses and adult dosages will be covered. Off-label uses will be discussed when it is considered appropriate and useful, however, pediatric dosages will not be provided.

INTRAVENOUS INFUSION: BENEFITS, RISKS AND DISADVANTAGES

Intravenous (IV) infusion is often the preferred route of medication administration, and for certain drugs it is the only route by which they can be given. Knowing these benefits and risks and how they apply to each medication is necessary for safe and effective IV drug administration. The benefits, risks and disadvantages of IV medications are shown in Table 1 below.

Table 1: Benefits, Risks and Disadvantages of IV Medications

<table>
<thead>
<tr>
<th>BENEFITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternate route of administration</td>
</tr>
<tr>
<td>Bioavailability is 100%</td>
</tr>
<tr>
<td>Precise titration of dose</td>
</tr>
<tr>
<td>Rapid onset of action</td>
</tr>
<tr>
<td>Steady state drug concentrations</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RISKS AND DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complicated administration</td>
</tr>
<tr>
<td>Cost</td>
</tr>
<tr>
<td>Infection: Local and systemic</td>
</tr>
<tr>
<td>Infiltration</td>
</tr>
<tr>
<td>Monitoring issues</td>
</tr>
<tr>
<td>Pain/irritation at the infusion site</td>
</tr>
<tr>
<td>Phlebitis</td>
</tr>
<tr>
<td>Thrombophlebitis</td>
</tr>
<tr>
<td>Time and labor intensive</td>
</tr>
<tr>
<td>Tissue damage</td>
</tr>
</tbody>
</table>
Nurses must also understand that the indications for medication usage, dosages, and pharmacokinetics are specific to the IV route of administration. Some of the common infusion medications are shown below, and in the following sections.

**Nitroglycerin**

Nitroglycerin relaxes smooth muscle, causes peripheral and coronary artery vasodilation, and reduces cardiac after-load and pre-load.

1. **Oral Nitroglycerin:**
   Oral nitroglycerin is prescribed for the treatment and prevention of angina pectoris. The time to onset of action is approximately 60 minutes, the duration of action is 4 – 8 hours, and the starting dose is 2.5 - 6.5 mg.

2. **Intravenous Nitroglycerin:**
   Intravenous nitroglycerin is prescribed for the treatment and prevention of angina pectoris, but it is also used to treat acute decompensated heart failure, peri-operative hypertension, and for the induction of intra-operative hypotension. The time of onset of action is approximately 3 - 5 minutes and the starting dose is 5 mcg/minute.

**Insulin**

*Mechanisms of Action and Pharmacokinetics*

Insulin is a hormone and its most important function is to facilitate the movement of glucose across cell membranes so that it can be used for energy or stored as glycogen. Insulin binds to insulin receptors on cell membranes and this binding activates glucose transporter molecules that facilitate the movement of glucose into the cells. Insulin is the *primary* hormone required for glucose metabolism. Insulin preparations are classified as rapid-acting, short-acting, intermediate-acting, or long-acting, depending on the onset of action, the peak effect, and the duration of action. *Regular insulin* is the insulin used for IV infusions. It is short-acting insulin. The onset of action for regular insulin is 30 minutes, the peak
effect is between 2.5 - 5 hours, and the duration of action is between 4 - 12 hours.¹

*Why is Insulin Used?*

The labeled use for insulin is for the treatment of type 1 or type 2 diabetes but there is considerable clinical experience that supports the use of insulin infusion in the following clinical situations:¹⁻¹¹

1. Diabetic ketoacidosis (DKA)
2. Hyperosmolar hyperglycemic state
3. Surgery (before, during, and after)
4. Patients receiving total parenteral nutrition
5. Treatment of hyperglycemia during sepsis
6. Treatment of hyperglycemia after trauma
7. Treatment of hyperglycemia after myocardial infarction or cardiac surgery
8. Treatment of hyperglycemia in patients with an acute neurological insult, *i.e.*, ischemic stroke, subarachnoid hemorrhage
9. Gestational diabetes
10. Hyperkalemia
11. Hyperglycemia caused by steroid therapy
12. Treatment of beta-blocker or calcium channel blocker overdose

*Administration*

During IV insulin therapy, blood glucose levels should be measured frequently, usually every hour. Many facilities have protocols for titrating the insulin infusion based on the hourly blood glucose level. A sample-dosing chart is shown below. Insulin is measured in units (u) and dosed in units per hour (u/hr). A typical infusion range is 1 to 20 units per hour.
<table>
<thead>
<tr>
<th>Blood glucose level</th>
<th>Insulin u/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 110</td>
<td>0</td>
</tr>
<tr>
<td>111-130</td>
<td>2</td>
</tr>
<tr>
<td>131-150</td>
<td>4</td>
</tr>
<tr>
<td>151-170</td>
<td>6</td>
</tr>
<tr>
<td>171-190</td>
<td>8</td>
</tr>
<tr>
<td>191-210</td>
<td>10</td>
</tr>
<tr>
<td>211-230</td>
<td>12</td>
</tr>
<tr>
<td>231-250</td>
<td>14</td>
</tr>
<tr>
<td>251-270</td>
<td>16</td>
</tr>
</tbody>
</table>

**Compatibility**

Insulin is Y-site compatible with amiodarone, dobutamine, esmolol, heparin, milrinone, nitroglycerin, nitroprusside, sodium bicarbonate, and vasopressin.\(^1\)

Insulin is Y-site *incompatible* with dopamine.\(^1\) In certain circumstances insulin may be compatible with diltiazem, labetalol, and norepinephrine.\(^1\)

**Precautions and Contraindications**

Frequent blood glucose checks are mandatory. Signs and symptoms of hypoglycemia include confusion, headache, dizziness, diaphoresis, and tachycardia. Intravenous administration of insulin causes movement of potassium from the extracellular space to the intracellular space. Patients receiving IV insulin must be closely monitored for hypokalemia.\(^1\)

The nurse must always check compatibility before running medications together and ensure that the insulin will not be “bolused” (a large dose of medication infused over a short period of time) if another medication is being titrated as this may cause hypoglycemia.
Heparin

Mechanisms of Action and Pharmacokinetics
Heparin is an anticoagulant that interrupts the clotting cascade by increasing the action of antithrombin and inactivating thrombin and the clotting factors Xa, IXa, XIa, and XIIa.\textsuperscript{12} The onset of action of IV heparin is immediate. The duration of action is dose dependent.\textsuperscript{12}

Why is Heparin Used?
The labeled uses for heparin are: 1) the prevention and treatment of thromboembolic disorders; and, 2) as an anticoagulant during extracorporeal and dialysis procedures. There is considerable experience for using IV heparin in the following clinical situations:\textsuperscript{13-19}

1. Anticoagulation during percutaneous coronary intervention in patients having an ST-segment elevation myocardial infarction.
2. Treating patients who are having unstable angina and/or non-ST segment elevation coronary events.
3. Prior to electro-cardioversion in patients who have atrial fibrillation.
4. Anticoagulation in patients who have atrial fibrillation and are taking warfarin but in whom warfarin therapy must be briefly interrupted.
5. Anticoagulation in critically ill patients.
6. Anticoagulation in patients undergoing abdominal surgery, cardiac surgery, major orthopedic surgery, or spinal surgery.
7. Anticoagulation for patients who have suffered major trauma, traumatic brain injury, acute spinal injury, or traumatic spine injury.
8. Treatment of disseminated intravascular coagulation (DIC). The risks and benefits of heparin as a treatment for DIC are not completely understood, but it is prescribed if DIC is caused by certain, specific etiologies.\textsuperscript{20-21}
Administration

Heparin doses are measured in units (u) and dosages are typically prescribed as units per kilogram per hour (u/kg/hr). The dosage is adjusted based on the activated partial thromboplastin time (aPTT). The aPTT should be checked prior to initiating heparin therapy, six hours after the heparin therapy has been started, and six hours after any adjustment in dosage. The treatment goal is an aPTT 1.5 - 2 times the laboratory control time and when two consecutive aPTT measurements are within the desired therapeutic range; the aPTT can be checked every 24 hours.

Learning Break:
Specific heparin dosage protocols will not be discussed in this study module because: 1) the protocols differ depending on the source; 2) the protocols differ depending on the clinical situation; 3) the patient-to-patient response to heparin can vary quite a bit; and, 4) there is a phenomenon called heparin resistance in which some patients require unusually high doses of heparin.

Compatibility

Ideally, heparin would be infused through a dedicated IV site (this can be a peripheral site) alone or only with maintenance fluids.

Heparin is Y-site compatible with dopamine, epinephrine, esmolol, insulin (regular), isoproterenol, lidocaine milrinone, nitroprusside, norepinephrine, and procainamide. It is also Y-site incompatible with amiodarone. In certain circumstances heparin may be compatible with diltiazem, dobutamine, labetalol, nicardipine, and nitroglycerin.
Precautions and Contraindications
Heparin is contraindicated in patients who have thrombocytopenia or severe bleeding.¹²

Adverse Effects, Side Effects, and Complications
The two most common and potentially serious adverse effects caused by heparin are hemorrhage and heparin-induced thrombocytopenia type II. The incidence of hemorrhage caused by heparin varies but it can be significant.²³,²⁴ The risk of bleeding increases as the dose of heparin is increased, and recent surgeries, trauma, age (greater than 60 years), hepatic dysfunction, recent invasive procedures, and co-morbidities also increase the risk of bleeding.²⁵

Heparin-induced thrombocytopenia type II occurs when antibodies bind to heparin-platelet complexes, activate the platelets, and produce a state of hypercoaguability.²⁶ The immune system-mediated thrombocytopenia and thrombosis that result can cause significant incidences of morbidity and mortality.²⁷ Heparin-induced thrombocytopenia type II typically occurs within five to ten days after initiation of heparin therapy.²⁶,²⁷ The frequency of this adverse effect has been reported to be between 1% - 5%, and it occurs most often in women and in post-operative patients.²⁶,²⁷ Heparin-induced thrombocytopenia type II is difficult to treat successfully: discontinuation of the heparin and administration of a vitamin K antagonist may not be sufficient to prevent the development of thrombosis.²⁶

Learning Break: Heparin-induced thrombocytopenia type I is more common than type II. It is mild and self-limiting and the condition will correct even if heparin therapy is continued.
Severe bleeding caused by heparin or a heparin overdose can be treated with *protamine sulfate*. Protamine sulfate binds to and inactivates heparin. One milligram (mg) of protamine sulfate will inactivate 100 units of heparin, but heparin has a short half-life so only the amount of heparin that has been given in the previous 2 - 2.5 hours should be considered when calculating the dose of protamine. Treatment of a heparin overdose would also depend on the time that has elapsed since the overdose has been given.

**VASOPRESSORS AND INOTROPES**

Vasopressors and inotropes are used when there is an urgent or emergent need to increase blood pressure and/or cardiac output. The *vasopressors* increase blood pressure, systemic vascular resistance, and mean arterial pressure (MAP). The *inotropes* increase the force of cardiac contraction, increasing cardiac output and MAP. Some of these drugs can also act as a *chronotrope* and increase the heart rate. Each of the vasopressors and inotropes has its particular mechanism (or mechanisms) of action that is mediated by specific receptor binding and agonism. Many of them bind with multiple receptor types and can have vasopressor and inotropic effects, and a chronotropic effect as well.  

**General Principles for the Use of Vasopressors and Inotropes**

Many of these drugs bind to multiple receptors and can act (to a lesser or greater degree) as an inotrope, a vasopressor, and a chronotrope. The specificity by which they can vary depends on the dosage and the patient. These drugs can cause peripheral vasoconstriction, increase myocardial oxygen consumption, and cause dysrhythmias. Considering the clinical circumstances in which they are used and the patients who need vasopressors and inotropes these effects can be a significant risk. Fluid resuscitation is critical in order for vasopressors to be effective.
Measuring hemodynamic parameters is important when using vasopressors and inotropes as these indices provide unequivocal evidence that the drugs are working. However, the goal of treatment with the vasopressors and inotropes is not to improve cardiovascular function but to attain and sustain good organ and tissue perfusion. Monitoring mental status, urine output, and signs of perfusion is as important as measuring blood pressure.  

The dosages of vasopressors and inotropes must be titrated to achieve therapeutic goals and a second or even a third drug may be needed. The vasopressors and inotropes should be delivered through a central venous catheter. If that is not possible, a well-secured peripheral IV line can be used but it must be carefully monitored.

In high doses many of the vasopressors and inotropes can decrease or increase heart rate to an undesired level, increase myocardial oxygen consumption, or cause vasoconstriction. In patients who have septic shock, a decreased sensitivity to catecholamines can occur.

If a vasopressor or an inotope infiltrates the injection site significant tissue damage called *extravasation* can occur. Basic treatment for extravasation of a vasopressor or an inotope consists of these steps:

1. Stop the infusion.
2. Do not flush the IV line.
3. Aspirate whatever drug can be removed.
4. If the IV line is not needed for local antidotal treatment, remove it.
5. Elevate the extremity. Do not apply cold or heat.
6. The affected area may need to be injected with diluted phentolamine.
Local injection with terbutaline or topical nitroglycerin paste can also be used. *Phentolamine* is no longer manufactured in the United States and obtaining it may be difficult.

Incompatibility with other medication infusions is important for the nurse to know. Many of these drugs are incompatible with sodium bicarbonate.

**Dobutamine**

*Mechanisms of Action and Pharmacokinetics*

Dobutamine binds to and stimulates the $\beta_1$ receptors in the heart and acts primarily as an inotrope. It has similar actions but to a lesser degree on the $\alpha_1$ and $\beta_2$ receptors, acting as a weak chronotrope and vasodilator.\(^{28}\) Systemic vascular resistance (SVR) is usually decreased with administration of dobutamine. Occasionally, minimum vasoconstriction has been observed.

The onset of action of dobutamine is within one to ten minutes and the peak effect is seen 10-20 minutes after the infusion has begun.\(^ {31}\)

*Why is Dobutamine Used?*

Dobutamine is used for the *short-term* management of patients who have cardiac decompensation due to heart failure.\(^{28,32}\) It has also been used to treat myocardial dysfunction related to sepsis but the evidence for its effectiveness in this situation is conflicting.\(^ {33,34}\)

*Dosing and Administration*

The initial dosage of dobutamine is 0.5-1 mcg/kg/minute, and it should be titrated at intervals of several minutes.\(^ {31}\) The maintenance dosage is 2-20 mcg/kg/minute.\(^ {28}\) The maximum dosage is typically considered to be 20 mcg/kg/minute but up to 40 mcg/kg/minute has been used.\(^ {31-33}\)
Administration of dobutamine via a central line is preferred, but it can be given peripherally if central access is not available.

Compatibility
Dobutamine is Y-site compatible with amiodarone, diltiazem, dopamine, epinephrine, insulin (regular), labetalol, lidocaine, milrinone, nicardipine, nitroglycerin, norepinephrine, and vasopressin. In certain circumstances dobutamine may be Y-site compatible with heparin.

Precautions and Contraindications
Manufacturers of dobutamine recommend that patients who have atrial fibrillation with rapid ventricular response should be treated with a digitalis preparation before therapy with dobutamine is started. Dobutamine should be used with extreme caution in patients who are taking a monoamine oxidase (MAO) inhibitor. In patients who have idiopathic hypertrophic subaortic stenosis, dobutamine is contraindicated.

Adverse Effects, Side Effects, and Complications
Adverse effects, side effects or complications include hypotension, hypokalemia, elevations of blood pressure and heart rate; and, increased ventricular response in patients who have atrial fibrillation, and dosage-related ventricular ectopi.

Dopamine
Mechanism of Action and Pharmacokinetics
Dopamine binds to and stimulates $\beta_1$ receptors, $\alpha_1$ receptors, and dopamine receptors in the cerebral, coronary, mesenteric, and renal vasculature. The clinical effects of dopamine are dosage dependent. Low dosages (0.5 - 3 mcg/kg/min) may increase renal blood flow but the clinical usefulness of this effect has been questioned. In moderate dosages, 3-10 mcg/kg/min, dopamine functions as an inotrope by stimulating $\beta_1$ receptors and causing the
release of endogenous norepinephrine.\textsuperscript{28} In high doses, 10-20 mcg/kg/min, dopamine stimulates $\alpha_1$ receptors and functions as a vasopressor as well as an inotrope.\textsuperscript{28}

The onset of action of dopamine is approximately 5 minutes. Dopamine has a short half-life and the duration of action is approximately 10 minutes.\textsuperscript{35}

\textit{Why is Dopamine Used?}
The labeled use for dopamine is as an adjunct for the treatment of shock that is unresponsive to fluid replacement therapy.\textsuperscript{35} The American College of Cardiology/American Heart Association recommends dopamine for the following conditions:

- maintaining systemic perfusion and preservation of end-organ performance in patients who have cardiogenic shock;
- patients who have stage D heart failure who are waiting for a heart transplant or mechanical circulatory support;
- short-term management of patients who have severe systolic dysfunction, low blood pressure, and significantly depressed cardiac output;
- palliative care for patients who have stage D heart failure but are not candidates for a heart transplant or mechanical circulatory support.\textsuperscript{32}

Dopamine can be used to treat septic shock but only if the patient has a low risk of tachyarrhythmias; and, only if norepinephrine cannot be used.\textsuperscript{28,33}

\textit{Administration}
Dosage must be individually titrated to the desired hemodynamic response. The dosage range is typically considered to be 0.5-2-0 mcg/kg/min,\textsuperscript{28} but dosages of 50 mcg/kg/min and higher have been used.\textsuperscript{35,38} When discontinuing the infusion, it may be necessary to gradually decrease the dose of dopamine as abrupt sudden cessation may cause hypotension.
Compatibility
Dopamine is Y-site compatible with amiodarone, diltiazem, dobutamine, epinephrine, esmolol, heparin, labetalol, lidocaine, milrinone, nicardipine, nitroglycerin, nitroprusside, norepinephrine, vasopressin, and verapamil.\textsuperscript{35} It is also Y-site incompatible with insulin (regular).\textsuperscript{35}

Precautions and Contraindications
Dopamine should be used cautiously in patients who have shock, a recent myocardial infarction, cardiac arrhythmias, or occlusive cardiac disease.\textsuperscript{35} Dopamine should be used with extreme caution in patients who are taking a MAO inhibitor.\textsuperscript{35}

Adverse Effects, Side Effects, and Complications
Adverse effects of dopamine include (but are not limited to) tachyarrhythmias, ectopic beats, and increased myocardial oxygen consumption. These adverse effects typically happen at high dosages.\textsuperscript{35}

Isoproterenol (Isuprel®)
Mechanism of Action and Pharmacokinetics
Isoproterenol is a non-selective β agonist. Its primary effect is as a positive chronotrope and positive inotrope but, because it stimulates the β\textsubscript{2} receptors and causes vasodilation, cardiac output is not increased.\textsuperscript{28} The onset of action of isoproterenol is almost immediate and the duration of action is approximately 10-15 minutes.\textsuperscript{39}

Why is Isoproterenol Used?
The manufacturer’s labeled uses for isoproterenol are as follows:\textsuperscript{39}

1. Mild or transient episodes of heart block that do not require electric shock or pacemaker therapy; significant heart block and Adams-Stokes attacks (except when caused by ventricular tachycardia or fibrillation).
2. Treatment of cardiac arrest until electric shock or pacemaker therapy is available.
3. Treatment of bronchospasm during anesthesia.
4. An adjunct to fluid and electrolyte replacement therapy and other drugs and procedures in the treatment of hypovolemic or septic shock and low cardiac output states.

Off-label uses of isoproterenol include: treatment of beta-blocker overdose; treatment of electrical storm associated with Brugada syndrome; overdrive pacing for refractory *torsade de pointes*; tilt table testing for syncope; temporary control of bradycardia in denervated heart transplant patients unresponsive to atropine; and, treating ventricular arrhythmias caused by atrioventricular nodal block.\(^{39}\)

*Administration*

The dosage of isoproterenol is 0.01 - 0.02 mcg/kg/min, but the specific dosage used will depend on the clinical situation.\(^{28,39}\) Isoproterenol should *not* be used in patients who have angina, digitalis intoxication, tachyarrhythmias, or ventricular arrhythmias.\(^{39}\)

*Compatibility*

Isoproterenol is Y-site compatible with amiodarone, heparin, milrinone, and nitroprusside.\(^{39}\)

*Precautions and Contraindications*

Isoproterenol should be used cautiously in patients who have cardiovascular disease, diabetes, or hyperthyroidism.\(^{39}\) It is contraindicated in patients who have angina, digitalis intoxication, tachyarrhythmias, or ventricular arrhythmias.\(^{39}\)
Adverse Effects, Side Effects, and Complications

Isoproterenol can cause a wide range of cardiovascular effects including, but not limited to, Adams-Stokes attacks, angina, arrhythmias, hypotension and hypertension, and tachycardia.\(^{39}\)

Norepinephrine (Levophed\(^{®}\))

Mechanisms of Action and Pharmacokinetics

Norepinephrine is a strong \(\alpha_1\) receptor agonist and it has modest \(\beta_1\) agonist activity.\(^{28}\) These mechanisms of action make norepinephrine a potent vasopressor and to a lesser degree, a positive inotrope. Chronotropic effects are minimal.\(^{28}\) Norepinephrine is also thought to dilate coronary arteries, increasing coronary circulation.\(^{40}\) The onset of action of norepinephrine is almost immediate and the duration of action is approximately 1 - 2 minutes.\(^{41}\)

Why is Norepinephrine Used?

Norepinephrine is the vasopressor of choice for the treatment of septic shock.\(^{28,30}\) It is also used for the treatment of shock and for treatment of severe cardiogenic shock caused by myocardial infarction.\(^{28,38}\)

Administration

Norepinephrine dosages are prescribed based on the clinical circumstances.\(^{38}\) Specific clinical conditions and norepinephrine dosage ranges are described below.

1. Septic shock:
   The dose is 0.01-3 mcg/kg/minute.\(^{42}\) The dosage should be titrated to attain a MAP of 65 mm Hg.\(^ {43,44}\)

2. Shock:
   The dose is 8 - 12 mcg/minute, titrated to desired response. The usual maintenance dosage is 2 - 4 mcg/minute.\(^ {41}\)

3. Post-cardiac arrest:
Involves ACLS (Advanced Cardiac Life Support) dosing range (weight-based dosing); Post cardiac arrest care: Initial dose: 0.1 - 0.5 mcg/kg/minute (7 - 35 mcg/minute in a 70 kg patient), and titrate to desired response.\(^{45}\)

**Compatibility**
Norepinephrine is Y-site compatible with amiodarone, diltiazem, dobutamine, dopamine, epinephrine, esmolol, heparin, labetalol, milrinone, nicardipine, nitroglycerin, nitroprusside, and vasopressin.\(^{41}\)

**Precautions and contraindications**
Norepinephrine should be used with extreme caution in patients who are taking a MAO inhibitor.\(^{41}\) Norepinephrine is contraindicated in the following clinical conditions or situations: hypotension from hypovolemia except as an emergency measure to maintain coronary and cerebral perfusion; mesenteric or peripheral vascular thrombosis unless the drug is a lifesaving procedure; during anesthesia with cyclopropane or halothane; and, during anesthesia due to the risk of ventricular arrhythmias.\(^{41}\)

**Adverse Effects, Side effects, and Complications**
Adverse effects of norepinephrine are arrhythmias, bradycardia, and peripheral ischemia.\(^{41}\)

**Phenylephrine (Neo-Synephrine®)**

**Mechanisms of Action and Pharmacokinetics**
Phenylephrine is a powerful vasopressor that increases systemic vascular resistance by direct \(\alpha_1\) agonism.\(^{28}\) Vasoconstriction is more prolonged than that produced by epinephrine. The onset of action of phenylephrine is almost immediate and the duration of action is approximately 15 - 20 minutes.\(^{46}\)

**Why is Phenylephrine Used?**
Phenylephrine is used to treat hypotension caused by shock.\textsuperscript{46} Phenylephrine should \textit{not} be used to treat hypotension caused by \textit{septic shock} unless: 1) the use of norepinephrine may cause serious arrhythmias; 2) the cardiac output is known to be high and the blood pressure is low; or, 3) as a salvage therapy.\textsuperscript{28}

\textit{Administration}
The dosage of phenylephrine used to treat severe hypotension is 0.5 - 2 mcg/kg/min, but higher and lower doses have been used.\textsuperscript{28,45-47}

\textit{Compatibility}
Phenylephrine is Y-site compatible with amiodarone and vasopressin.\textsuperscript{46}

\textit{Precautions and Contraindications}
Phenylephrine should be used cautiously in patients who have cardiovascular disease. In these patients phenylephrine may cause reflex bradycardia, decreased cardiac output, or precipitate angina and/or heart failure.\textsuperscript{46} Nurses should also know that acidosis may reduce the efficacy of phenylephrine.\textsuperscript{46}

Phenylephrine is contraindicated in patients who have severe hypertension or ventricular tachycardia.\textsuperscript{46}

\textit{Adverse Effects, Side Effects, and Complications}
Adverse effects, side effects or complications are reflex bradycardia, hypertension, peripheral vasoconstriction, precipitation of angina and/or heart failure, and reduced cardiac output.\textsuperscript{46}
Mechanisms of Action and Pharmacokinetics

Epinephrine is an α₁, β₁, and β₂ agonist. Epinephrine is a positive chronotrope and a positive inotrope, and it dilates the bronchial passages. Depending on the dosage, epinephrine can cause vasodilation or vasoconstriction.⁴⁸

The onset of effects is almost immediate, and epinephrine has a half-life of less than 5 minutes.⁴⁸

Why is Epinephrine Used?

Epinephrine IV infusion is used as a second-line agent for the treatment of hypotension caused by septic shock.²⁸ It is used for the treatment of hypotension caused by shock; and,⁴⁸ for the treatment of symptomatic bradycardia unresponsive to atropine.⁴⁹

Administration

The dosages for IV epinephrine in certain resuscitation scenario are outlined below.

1. The dosage for the treatment of septic shock is 0.05 – 2 mcg/kg/min. The dosage may be increased every 10 - 15 minutes by 0.05 – 2 mcg/kg/min until the desired blood pressure has been reached. Epinephrine should be weaned slowly, preferably over 12 - 24 hours.⁴⁸

2. The dosage for severe, fluid resistant shock is 0.1 - 0.5 mcg/kg/min, titrated to the desired response.⁴⁵

3. The dosage for bradycardia that is symptomatic and unresponsive to atropine is: 2 to 10mcg/minute or 0.1 to 0.5 mcg/kg/minute.⁴⁹

Compatibility
Epinephrine is Y-site compatible with amiodarone, diltiazem, dobutamine, dopamine, heparin, labetalol, milrinone, nicardipine, nitroglycerin, nitroprusside, norepinephrine, and vasopressin.48

Precautions and Contraindications
Epinephrine should be used with caution in patients who have cardiovascular disease, cerebrovascular disease, diabetes, Parkinson’s disease, or thyroid disease.48

There are no absolute contraindications to the use of epinephrine in an emergency situation.48

Adverse Effects, Side Effects, and Complications
Cardiac, gastrointestinal, and central nervous system adverse effects or side effects including but not limited to angina, hypertension, tachycardia, nausea, vomiting, anxiety, dizziness, and headache may be noted during IV infusion of epinephrine. The frequency of these is not known.48

Vasopressin
Mechanisms of Action and Pharmacokinetics
Vasopressin is a synthetic form of an endogenous hormone. Vasopressin binds to the V1 vasopressin receptors in the vascular smooth muscle, causing vasoconstriction. It also binds to the V2 vasopressin receptors in the renal collecting tubules, and this increases the collecting duct permeability and water reabsorption. These effects increase the mean arterial pressure and systemic vascular resistance and maintain intravascular volume.28

The onset of effects is less than or equal to 15 minutes, and the duration of action is less than or equal to 20 minutes.50

Why is Vasopressin Used?
The labeled use for IV infusion of vasopressin is for the treatment of shock that is unresponsive to IV fluids and catecholamines.\textsuperscript{50} Vasopressin is indicated for treatment of hypotension caused by septic shock and it appears to be particularly useful for this when used in conjunction with norepinephrine.\textsuperscript{28,51} Vasopressin is \textit{not} recommended to be used as the single vasopressor when treating hypotension caused by septic shock, but dosages up to 0.03 units/minute can be given to patients who are receiving norepinephrine.\textsuperscript{33} Dosages higher than 0.03 - 0.04 units/minute should only be used for salvage therapy, \textit{i.e.}, when an adequate mean arterial pressure cannot be achieved by other vasopressors.\textsuperscript{33}

Vasopressin can be used to treat cardiac arrest caused by anaphylaxis that is unresponsive to epinephrine.\textsuperscript{52} This is an off-label use. Other off-label uses of vasopressin include the treatment of pulseless cardiac arrest or pulseless electrical activity, and the treatment of bleeding esophageal varices.\textsuperscript{50}

\textit{Administration}

The recommended dosage of vasopressin for shock is 0.03 units/minute.\textsuperscript{50} Vasopressin should be titrated by 0.005 units per minute at 10- to 15-minute intervals to a maximum dose of 0.1 units per minute to achieve the target blood pressure. When the target blood pressure has been maintained for 8 hours without the use of catecholamines, vasopressin should be tapered by 0.005 units/minute every hour as tolerated.\textsuperscript{50}

Hypotension caused by septic shock can be treated by infusing vasopressin starting at 0.03 units per minute, used concurrently with norepinephrine, to attain the desired mean arterial pressure \textit{or} to decrease norepinephrine dose.\textsuperscript{33} Doses greater than 0.03 units per minute may have more cardiovascular side effects and should only be used for salvage therapy.\textsuperscript{33} Also, hypotension occurring after discontinuation of vasopressin has been reported.\textsuperscript{53} Vasopressin dosages should be slowly tapered after other vasopressors or inotropes have been discontinued.
Compatibility
Vasopressin is Y-site compatible with amiodarone, diltiazem, dobutamine, dopamine, epinephrine, heparin, insulin (regular), lidocaine, milrinone, nitroglycerin, norepinephrine, and phenylephrine.\textsuperscript{50}

Precautions and Contraindications
Vasopressin should be used with caution in patients who have asthma, cardiovascular disease, goiter with cardiac complications, migraines, renal disease, seizure disorder, or vascular disease. \textsuperscript{50}

Adverse Effects, Side Effects, and Complications
Adverse effects, side effects, or complications are angina, arrhythmias, bradycardia, and vasoconstriction. The frequency of these is not defined.\textsuperscript{50}

Milrinone (Primacor®)
Mechanisms of Actions and Pharmacokinetics
Milrinone is a selective phosphodiesterase inhibitor that inhibits the conversion of cAMP to AMP in the heart and the vasculature.\textsuperscript{28,54} Milrinone is a positive inotrope and a vasodilator that increases cardiac output and decreases systemic vascular resistance.\textsuperscript{28}

The onset of action of milrinone is between 5 - 15 minutes and it has a half-life of approximately 2.5 hours.\textsuperscript{54}

\textbf{Learning Break:} Phosphodiesterase is an enzyme that breaks down intra-cellular second
messengers such as cyclic adenosine monophosphate (cAMP). Adrenergic drugs such as epinephrine cannot directly affect target organs. They bind to adrenergic receptors and activate cAMP and cAMP in turn increases the activity of intra-cellular enzymatic processes. Mirinone and similar medications increase intra-cellular concentrations of cAMP and by doing so increase heart rate and cause vasodilation.

Why is Milrinone Used?
Milrinone is used for the short-term therapy of patients who have acute, decompensated heart failure. Off-label uses of milrinone IV infusion include: inotropic therapy for patients unresponsive to other therapies; palliative therapy for patients who have end-stage heart failure and who are not transplant candidates; and, rescue therapy for term infants who have pulmonary hypertension.

Administration
The American College of Cardiology Foundation/American Heart Association recommends a maintenance dosage is 0.125 mcg/kg/min - 0.75 mcg/kg/min. Higher maintenance dosages have been used, and some sources recommend a loading dosage of 50 mcg/kg administered over 10 minutes followed by a maintenance dose titrated to the clinical response. There is some evidence that starting milrinone without a loading dose is more effective. Milrinone may be effective in treating acute heart failure following myocardial infarction but the dosage and effectiveness of the drug for this purpose have not been established.

If the patient has atrial flutter or fibrillation, rate control before starting milrinone is recommended. Milrinone may increase the ventricular response in these patients.

Compatibility
Milrinone is Y-site compatible with amiodarone, diltiazem, dobutamine, dopamine, heparin, insulin (regular), isoproterenol, labetalol nicardipine, nitroglycerin, nitroprusside, norepinephrine, sodium bicarbonate, vasopressin, and verapamil. Additionally, milrinone is Y-site incompatible with procainamide.

**Precautions and Contraindications**

Certain precautions should be observed when using milrinone. Hypokalemia and hypomagnesemia should be corrected before treatment with milrinone is started. Milrinone should be used with caution in patients who have renal impairment. Concurrent use of milrinone and inamrinone is contraindicated.

**Adverse Effects, Side Effects and Complications**

Adverse effects, side effects, or complications are ventricular arrhythmias, especially in patients who have renal dysfunction. These may occur even after milrinone has been discontinued.

**BETA-BLOCKERS**

Beta-blockers competitively antagonize the effects of catecholamines at the β receptors. They can be selective or non-selective. Some beta-blockers have adrenergic receptor antagonist effects and a few have intrinsic sympathomimetic activity, as well. They are primarily given as oral preparations for the treatment of angina, hypertension, and certain arrhythmias, but some can be given as an IV bolus or a continuous IV infusion, and there are many off-label uses for the beta-blockers.

Several types of beta-blockers are outlined in the section below, which includes drug action and expected treatment outcomes.

**Esmolol (Brevibloc®)**
Mechanisms of Action and Pharmacokinetics
Esmolol is a $\beta_1$ selective beta-blocker. Esmolol has no intrinsic sympathomimetic or membrane-stabilizing activity. At high doses esmolol will inhibit the $\beta_2$ receptors in the peripheral vasculature and the bronchial tree.\textsuperscript{59,60}

The onset of action is 2 - 10 minutes. The duration of action is approximately 10 - 30 minutes, but this can be extended after cumulative doses or extended use.\textsuperscript{59}

Learning Break: Membrane-stabilizing refers to the inhibition of action potentials by the interruption of ion movements across cell membranes. Certain drugs “stabilize” cell membranes, making them less able or unable to depolarize and preventing the cell from initiating a contraction or transmitting a nerve impulse.

Why is Esmolol Used?
The labeled uses or esmolol are:\textsuperscript{59-61}

1. Treatment of supraventricular tachycardia (SVT) and controlling ventricular rate in patients who have atrial fibrillation or flutter;

2. Treatment of intraoperative and postoperative tachycardia and/or hypertension;

3. Treatment of noncompensatory sinus tachycardia.

Administration
In cases of supraventricular tachycardia or non-compensatory sinus tachycardia the loading dose (optional) is 0.5 mg/kg over 1 minute followed by an infusion of 50 mcg/kg/minute for 4 minutes. The infusion may be continued at 50 mcg/kg/minute and, if the response is inadequate, it can be titrated in 50
mcg/kg/minute increments to a maximum of 200 mcg/kg/minute; however, the dosage should not be increased at intervals less than every 4 minutes.

For a more rapid response after the loading dose and the continuous infusion, another 0.5 mg/kg bolus dosage can be given over 1 minute and the maintenance dosage can be increased to 100 mcg/kg/minute for 4 minutes. A third bolus dose can be given if needed, 0.5 mg/kg, and the infusion can be increased to 150 mcg/kg/minute after 4 minutes at that rate. Additionally, the infusion can be increased to 200 mcg/kg/minute, and no fourth bolus dose given before the increase to 200 mcg/kg/minute.⁵⁹

In cases of intraoperative or post-operative tachycardia and/or hypertension, the nurse may initiate infusion rates to achieve immediate or gradual control. For immediate control, an initial bolus of 1 mg/kg over 30 seconds is given, followed by an infusion of 150 mcg/kg/minute. The infusion rate may be titrated as needed, and the maximum dosage is 300 mcg/kg/minute. For gradual control, an initial bolus of 0.5 mg/kg over 1 minute is given, and then an infusion of 50 mcg/kg/minute infusion for 4 minutes. The infusion can be titrated in increments of 50 mcg/kg/minute; however, the dosage should not be increased at intervals less than every 4 minutes to a maximum dosage of 300 mcg/kg/minute. A bolus dose of 0.5 mg/kg over 1 minute prior can be given before each increase in the infusion rate.⁵⁹

Controlling the ventricular rate in patients who have atrial fibrillation or flutter involves a loading dose of 0.5 mg/kg given over 1 minute. This is followed by an IV infusion at 50 mcg/kg/minute for 4 minutes and, if needed, the infusion can be continued at that rate. If the initial response to the bolus and the IV infusion is not optimal, another bolus of 0.5 mg/kg over 1 minute can be given and the infusion rate can be increased to 100 mcg/kg/minute for 4 minutes and these steps can be repeated until the desired heart rate is reached or hypotension begins to occur.⁵⁹ At that point, the infusion rate should be decreased to less than
or equal to 25 mcg/kg/minute. If the safety endpoint is exceeded, the infusion should be stopped, reassessed, and restarted at a reduced dose.\textsuperscript{59}

Esmolol is contraindicated if the patient has severe sinus bradycardia or sick sinus syndrome; if there is second or third-degree heart block (except in patients with a functioning ventricular pacemaker); in patients who have cardiogenic shock or decompensated heart failure; and, in patients who have pulmonary hypertension. Esmolol should not be used in conjunction with IV administration of a calcium channel blocker or if the pharmacologic effects of the drugs will overlap.\textsuperscript{59}

\textit{Compatibility}

Esmolol is Y-site compatible with amiodarone, diltiazem, dopamine, heparin, insulin (regular), labetalol, nicardipine, nitroglycerin, nitroprusside, and norepinephrine.\textsuperscript{59} In certain circumstances esmolol may be Y-site compatible with sodium bicarbonate.\textsuperscript{59}

\textit{Precautions and Contraindications}

Certain precautions should be observed when using esmolol.\textsuperscript{59} Infusion into small veins or through a butterfly catheter should be avoided because of the risk for thrombophlebitis. There should be close monitoring of blood pressure during administration as hypotension is common. Additionally, hyperkalemia can occur in patients who have renal failure.

Esmolol is contraindicated if the patient has severe sinus bradycardia or sick sinus syndrome; if there is second or third-degree heart block (except patients with a functioning ventricular pacemaker); in patients who have cardiogenic shock or decompensated heart failure; and, in patients who have pulmonary hypertension. Esmolol should not be used in conjunction with IV administration of a calcium channel blocker or if the pharmacologic effects of the drugs will overlap.\textsuperscript{59}

\textit{Adverse Effects, Side Effects and Complications}
Adverse effects, side effects or complications of esmolol are hypotension, dizziness, nausea and vomiting.\textsuperscript{59}

**Labetalol**

*Mechanisms of Actions and Pharmacokinetics*

Labetalol is an $\alpha_1$, $\beta_1$, and $\beta_2$ antagonist. The ratio of alpha to beta blockade in the IV form of the drug is 1:7. Labetalol has weak intrinsic sympathomimetic activity and does not stabilize the cardiac membrane.\textsuperscript{62} Labetalol is a negative chronotrope, a negative inotrope, and it dilates peripheral vasculature. The onset of action is 2 - 5 minutes. The duration of action depends on the dose and the method of infusion.

*Why is Labetalol Used?*

The labeled use of IV labetalol is for the treatment of hypertensive emergencies.\textsuperscript{62} Off-label uses are for the treatment of hypertension during ischemic stroke, pediatric hypertension, treatment of a patient with subarachnoid hemorrhage, and chronic hypertension during pregnancy.\textsuperscript{62-65}

**Administration**

1. Hypertensive emergencies:
   The bolus dose is 20 mg IV push given over 2 minutes. This can be followed as needed with 40 - 80 mg bolus doses (Some sources recommend 20 – 80 mg) every 10 minutes to a total of 300 mg.\textsuperscript{62,66} The constant infusion rate dose is 0.5 - 2 mg/minute.\textsuperscript{66} However, there is limited information on how long a constant infusion can be used. The manufacturer’s recommendation is not to exceed a total dose of 300 mg and to discontinue the infusion after 2.5 hours at 2 mg/minute, but there is clinical experience using higher doses and for much longer periods of time.\textsuperscript{59}

2. Ischemic stroke:
Controlling blood pressure during and after reperfusion treatment to maintain a blood pressure less than or equal to 180/105 mm Hg. If the systolic blood pressure is greater than 180 to 230 mm Hg or diastolic greater than 105 to 120 mm Hg, labetalol 10 mg over 1 to 2 minutes should be given followed by an infusion of 2 to 8 mg/minute.64

3. Chronic hypertension during pregnancy:
To treat a hypertensive emergency in pregnancy (systolic BP greater than or equal to 160 mm Hg or diastolic BP greater than or equal to 110 mm Hg) an initial IV dose of labetalol 20 mg should be given. If the blood pressure does not respond the dose can be increased every 10 minutes in increments of 20 to 40 mg. The maximum single dose is 80 mg.63,67 A continuous infusion of 1 -2 mg per minute may be used if needed.63 After the initial dose a continuous infusion of 1 to 2 mg/minute can be used instead of intermittent dosing.63

Compatibility
Labetalol is Y-site compatible with amiodarone, diltiazem, dobutamine, dopamine, epinephrine, esmolol, lidocaine, milrinone, nicardipine, nitroglycerin, nitroprusside, and norepinephrine.62

Precautions and Contraindications
The following precautions should be observed when using labetalol:62 excessive administration of labetalol can cause prolonged hypotension and/or bradycardia; labetalol should be used with caution in patients who have diabetes, hepatic impairment, depression, peripheral vascular disease, asthma, heart failure, or myasthenia gravis. Labetalol should not be used patients with hyperadrenergic states, i.e., amphetamine or cocaine intoxication, unless α adrenergic blockade has been accomplished.62
Labetalol is contraindicated if the patient has severe bradycardia or second or third-degree heart block, unless the patient has a functioning ventricular pacemaker. Additionally, it is contraindicated in patients who have cardiogenic shock or uncompensated heart failure, asthma, and, if there is severe and prolonged hypotension.62

Adverse Effects, Side Effects, and Complications
Dizziness and orthostatic hypotension are common after administration of labetalol.62

CALCIUM CHANNEL BLOCKERS

Calcium channel blockers decrease the influx of calcium through voltage-gated calcium channels in the myocardium, the cardiac impulse forming and conduction tissues, and the peripheral vasculature. Calcium influx is needed for vascular smooth muscle and cardiac muscle contraction and for sinoatrial node and atrioventricular node depolarization; and, by inhibiting calcium influx the calcium channels blockers produce negative chronotropic, dromotropic, and inotropic effects, and relax the smooth muscle tissue of the peripheral vasculature. Heart rate and blood pressure are lowered, coronary blood vessels are dilated, and oxygen delivery to the myocardium is increased.

There are three classes of calcium channel blockers used in the US: benzothiazepine (i.e., diltiazem), dihydropyridines (i.e., nicardipine), and, phenylalkylamine (i.e., verapamil). Each of these affects the myocardium, the sinoatrial node and the atrioventricular node, the coronary circulation, and the smooth muscle of the peripheral vasculature to a greater or lesser degree.

The calcium channel blockers are primarily used for the treatment of angina and hypertension.
### Diltiazem (Cardizem®)

**Mechanisms of Action and Pharmacokinetics**
Diltiazem blocks the movement of calcium through calcium ion channels in the myocardium, the atrioventricular node and sinoatrial node, and the peripheral vasculature. Diltiazem causes coronary vascular dilation and peripheral vasodilation, lowering blood pressure and increasing myocardial blood flow.\(^{68}\)

The onset of action is 3 minutes. The duration of action is 0.5 - 10 hours.\(^{68}\)

**Why is Diltiazem Used?**
IV infusion of diltiazem is used to treat patients who have atrial fibrillation or atrial flutter and a rapid ventricular rate and for conversion of paroxysmal supraventricular tachycardia (PSVT).\(^{68}\) The off-label use for IV diltiazem is treatment of stable narrow-complex tachycardia uncontrolled or unconverted by adenosine or vagal maneuvers or for recurrent supraventricular tachycardia.\(^{49}\)

**Administration**
1. For treatment of rapid ventricular response atrial fibrillation or atrial flutter or PSVT:
   Initial bolus dose is 0.25 mg/kg actual body weight over 2 minutes. A repeat bolus dosage of 0.35 mg/kg can be given 15 minutes after the initial dose if the response is inadequate. The continuous IV infusion dosage is 10 mg/hour; this can be increased in increments of 5 mg/hour up to 15 mg/hour.

   Continuous IV infusions of greater than 15 mg/hour for more than 24 hours are not recommended.\(^{68,69}\)
2. Treatment of stable narrow-complex tachycardia uncontrolled or unconverted by adenosine or vagal maneuvers or treatment of recurrent of SVT:

   Initial dose is 15 - 20 mg (or 0.25 mg/kg) IV over 2 minutes. Additional doses of 20 - 25 mg (0.35 mg/kg) can be given every 15 minutes if needed. The continuous infusion rate should be 5 -15 mg/hour.\(^4^9\)

**Compatibility**

Diltiazem is Y-site compatible with dobutamine, dopamine, epinephrine, esmolol, labetalol, lidocaine, milrinone, nicardipine, nitroglycerin, nitroprusside, and norepinephrine.\(^6^8\) Diltiazem is Y-site *incompatible* with heparin.\(^6^8\)

**Precautions and Contraindications**

Diltiazem is contraindicated if patients have any of the following conditions:\(^6^8\) sick sinus syndrome (except in patients with a functioning artificial pacemaker); second- or third-degree heart block (except in patients with a functioning artificial pacemaker); severe hypotension (systolic less than 90 mm Hg); cardiogenic shock; administration concomitantly or within a few hours of the administration of IV beta-blockers; atrial fibrillation or flutter associated with accessory bypass tract (*i.e.*, Wolff-Parkinson-White syndrome); or, ventricular tachycardia.

**Adverse Effects, Side Effects, and Complications**

Adverse effects, side effects, or complications are bradycardia, headache, hypotension, and precipitation of heart failure.\(^4^9,^6^8\)

**Nicardipine (Cardene®)**

**Mechanisms of Actions and Pharmacokinetics**

Nicardipine blocks the movement of calcium through calcium ion channels in the myocardium and the peripheral vasculature. It decreases systemic vascular resistance and blood pressure and dilates the coronary vasculature. It has no
appreciable effect on the sinoatrial node, the atrioventricular node or the His-Purkinje system.\textsuperscript{70,71}

The onset of action is 10 minutes and the duration of action is approximately 20 minutes.\textsuperscript{71}

\textit{Why is Nicardipine Used?}
Parenteral nicardipine is used for the short-term treatment of hypertension when the use of oral medications is not possible.\textsuperscript{70} The off-label use for IV nicardipine is for the control of blood pressure in patients who have had an acute ischemic stroke.\textsuperscript{64}

\textit{Administration}
Short-term treatment of hypertension:
Nicardipine 5 mg/hour, increased in increments of 2.5 mg/hour every 5 minutes, is recommended if rapid correction is needed, \textit{or} every 15 minutes. The maximum dosage is 15 mg/hour. If the dosage is rapidly increased, reducing it by 3 mg/hour should be considered once the target blood pressure has been achieved.\textsuperscript{71}

\textit{Compatibility}
Nicardipine is Y-site compatible with dobutamine, dopamine, epinephrine, esmolol, labetalol, milrinone, nitroglycerin, nitroprusside, and norepinephrine. In certain circumstances it may be compatible with heparin.\textsuperscript{71}

\textit{Precautions and Contraindications}
Nicardipine should be used with caution if the patient has heart failure, hepatic impairment, hypertrophic cardiomyopathy, renal impairment, or a mild degree of aortic stenosis.\textsuperscript{71} Nicardipine is contraindicated if the patient has advanced aortic stenosis.\textsuperscript{71}
Adverse Effects, Side effects, and Complications

Headache, hypotension, nausea and vomiting, and tachycardia are the most common side effects.70

Verapamil

Verapamil blocks the movement of calcium through calcium ion channels in the myocardium, the SA node, the cardiac conducting system, and the peripheral vasculature. Verapamil acts as a negative inotrope, it prolongs the refractory period in the atrioventricular node, it decreases systemic vascular resistance and blood pressure, and it dilates the coronary vasculature.72,73

Why is Verapamil Used?

Verapamil is used to treat supraventricular tachycardia and for rate control in patients who have paroxysmal supraventricular tachycardia or atrial fibrillation.72

Administration

1. Supraventricular Tachycardia:
   The recommended initial dose of verapamil is 2.5 - 5 mg over 2 minutes. A second dose of 5 - 10 mg may be given 15 to 30 minutes after the initial dose if tolerated by the patient, and if the patient does not respond to the initial dose. The maximum total dose is 20 - 30 mg.72

2. Atrial fibrillation rate control:
   The recommended initial dose of verapamil is 0.075 - 0.15 mg/kg given as a bolus over 2 minutes. An additional 10 mg can be given after 30 minutes if there is no response, followed by a continuous infusion of 0.005 mg/kg/minute.69

Compatibility

Verapamil is Y-site compatible with dobutamine, dopamine, and milrinone.72
Precautions and Contraindications

Verapamil should be used with caution if the patient has hepatic impairment, renal impairment, myasthenia gravis, Duchenne’s muscular dystrophy, hypertrophic cardiomyopathy, or is being treated with a beta-blocker or digoxin. Verapamil can slow the recovery from non-depolarizing neuromuscular blocking agents.

Verapamil is contraindicated if patients have any of the following conditions: severe left ventricular dysfunction; hypotension (systolic pressure less than 90 mm Hg) or cardiogenic shock; sick sinus syndrome (except in patients with a functioning ventricular pacemaker); second or third-degree atrioventricular block (except in patients with a functioning ventricular pacemaker); atrial flutter or fibrillation and an accessory bypass tract (Wolff-Parkinson-White [WPW] syndrome, Lown-Ganong-Levine syndrome).

Adverse Reactions, Side Effects, and Complications

Adverse effects, side effects, and complications are confusion, dizziness, and hypotension.

VASODILATORS

The primary effect of the two drugs discussed in this section, nitroglycerin and nitroprusside, is vasodilation. They have similar mechanisms of action but they are used for different clinical situations.

Nitroglycerin

Mechanisms of Action and Pharmacokinetics

Nitroglycerin stimulates the formation and release of nitric oxide, an endogenous compound that relaxes vascular smooth muscle in the peripheral veins and to a lesser degree, the peripheral arteries. This effect decreases venous return to the heart, pre-load and to a lesser degree, after-load, myocardial oxygen
consumption, systemic vascular resistance and mean arterial pressure; and, lowers blood pressure and dilates coronary arteries.\textsuperscript{74,75}

The onset of action of IV nitroglycerin is immediate and the duration of action is 3 - 5 minutes.

\textit{Why is Nitroglycerin Used?}

Intravenous nitroglycerin is used to treat the following conditions and prevention strategies:\textsuperscript{74}

1. The prevention and treatment of angina pectoris.
3. Induction of intra-operative hypotension.

The off-label uses of IV nitroglycerin are the treatment of pulmonary hypertension and treatment of unstable angina or non-ST-segment myocardial infarction.\textsuperscript{74,76}

\textit{Administration}

1. Treatment of angina pectoris:
   The initial dosage is 5 mcg/minute. This can be increased in increments of 5 mcg every 3 - 5 minutes up to 20 mcg/minute. If there is no response at that point the dosage may be increased by 10 – 20 mcg/minute every 3 - 5 minutes. The generally accepted maximum dosage is 400 mcg/minute.\textsuperscript{74}

2. Treatment of unstable angina or non-ST-segment myocardial infarction: The initial dosage is 10 mcg/minute. It should be increased by 10 mcg/minute every 3 - 5 minutes until relief of symptoms or the desired blood pressure response is attained. If there is no response at 20 mcg/minute, the dosage should be increased by 10 - 20 mcg/minute.\textsuperscript{76}

\textit{Compatibility}
Nitroglycerin is Y-site compatible with amiodarone, diltiazem, dobutamine, dopamine, esmolol, epinephrine, insulin (regular) labetalol, lidocaine, milrinone, nicardipine, nitroprusside, norepinephrine, and vasopressin. In certain situations nitroglycerin may be Y-site compatible with heparin.\(^7_4\)

**Precautions and Contraindications**
Nitroglycerin binds to soft plastics so it should be administered in glass bottles and with the IV infusion set supplied by the manufacturer.\(^7_4\)

Nitroglycerin is contraindicated for patients who have any of the following conditions: hypersensitivity to nitrates, corn, or corn products; constrictive pericarditis; pericardial tamponade; or, restrictive cardiomyopathy.\(^7_4\)

**Adverse Effects, Side Effects, and Complications**
Adverse effects, side effects, and complications are bradycardia, headache, hypotension, syncope, and tachycardia.\(^7_4\)

**Nitroprusside (Nitropress®)**

**Mechanisms of Action and Pharmacokinetics**
Nitroprusside stimulates the formation and release of nitric oxide, an endogenous compound that relaxes vascular smooth muscle in the peripheral veins and to a lesser degree, the peripheral arteries. This effect decreases peripheral resistance and after-load, and lowers blood pressure.\(^7_7\)

The onset of action of nitroprusside is less than 2 minutes. The duration of action is between 1 - 10 minutes.\(^7_7\)

**Why is Nitroprusside Used?**
Nitroprusside is used for the following situations and conditions:\(^6_6,7_7\)

1. Treatment of hypertensive crisis
2. Treatment of acute, decompensated heart failure
3. Controlled hypotension to reduce bleeding during surgery.

Nitroprusside has an unlabeled use for the treatment of hypertension in patients who are having an acute ischemic stroke.\textsuperscript{64}

\textit{Administration}

1. Hypertensive crisis:
   The dosage of nitroprusside is 0.25 - 5 mcg/kg/minute. This can be titrated in increments of 0.5 mcg/kg/minute up to a maximum dosage of 10 mcg/kg/minute.\textsuperscript{66,77}

2. Acute decompensated heart failure:
   The starting dosage is 5 - 10 mcg/minute. The dosage can be titrated every 5 minutes and the dosage range that is typically effective is 5 - 300 mcg/minute. Dosages greater than 400 mcg/minute are not recommended because there is little additional benefit and an increased risk for cyanide toxicity.\textsuperscript{77}

3. Nitroprusside has a labeled use for controlled hypotension to reduce bleeding during surgery but there is no specific dosing information for this use.

\textit{Compatibility}
Nitroprusside is Y-site compatible with diltiazem, dobutamine, dopamine, epinephrine, esmolol, insulin (regular), isoproterenol, labetalol, lidocaine, milrinone, norepinephrine, nitroglycerin, and procainamide. In certain circumstances nitroprusside may be compatible with amiodarone. It is compatible in a syringe with heparin.\textsuperscript{77}

\textit{Precautions and Contraindications}
Nitroprusside solutions must be protected from light. The IV bag must be covered with aluminum foil or another opaque material.\textsuperscript{77}

Nitroprusside is contraindicated for the treatment of compensatory hypertension (aortic coarctation, arteriovenous shunting); for controlled hypotension during surgery in patients who have inadequate cerebral circulation or in moribund patients requiring emergency surgery; for the treatment of high output heart failure associated with reduced systemic vascular resistance, \textit{i.e.}, septic shock; and, in patients who have congenital optic atrophy or tobacco amblyopia.\textsuperscript{77}

\textit{Nitroprusside and Cyanide Toxicity}

Nitroprusside is metabolized to cyanide and cyanide toxicity is possible. Cyanide toxicity can be avoided by using the lowest possible dose, monitoring for changes in mental status and lactic acidosis, and avoiding if possible using nitroprusside for greater than 24 – 48 hours. Dosages of 10 mcg/kg/minute should never be used for greater than 10 minutes.\textsuperscript{77}

\textit{Adverse Effects, Side Effects, and Complications}

Adverse effects, side effects, or complications are hypotension, headache, methemoglobinemia.\textsuperscript{77} Nitroprusside can decrease cerebral, coronary, and renal perfusion; and, this is a dose-dependent effect.\textsuperscript{66,78}

\textbf{ANTIARRHYTHMICS}

Antiarrhythmics are used to prevent and treat arrhythmias. These drugs have many complex effects on the heart, \textit{i.e.}, decreasing impulse conduction and velocity, increasing the refractory period of the myocardium, and increasing the electrical stimulation threshold of the ventricles. Despite this wide variety of actions the clinical effectiveness of all of the antiarrhythmics is mediated by their ability to block the movement of calcium, sodium, or potassium through ion channels in the heart. The Vaughan Williams classification system divides the
antiarrhythmics into four categories based on their electrophysiological effects, Class I, II, II, and IV. Class I antiarrhythmics are further divided, Class IA, IB, and IC.

**Amiodarone (Nexterone®)**

*Mechanisms of Actions and Pharmacokinetics*

Amiodarone is a Class III anti-arrhythmic. The anti-arrhythmic effect of these drugs is primarily mediated by affecting the movement of potassium through ion channels in the myocardium and prolongation of the action potential. Amiodarone also has electrophysiological properties of the Class I, II, and IV antiarrhythmics; it acts as α and β adrenergic receptor antagonists; it affects the movement of calcium, potassium, and sodium through ion channels in the myocardium; and, it decreases the rate of sinoatrial depolarization and decreases conduction through the atrioventricular node. Amiodarone has negative chronotropic, inotropic, and dromotropic actions, and it also causes vasodilation.

The pharmacokinetics of amiodarone are complex and there is little information about the onset and duration of action of IV amiodarone.

*Why is Amiodarone Used?*

Amiodarone infusion is used for the treatment and prevention of hemodynamically unstable ventricular tachycardia or ventricular fibrillation that do not respond to other therapies.

The off-label uses of IV amiodarone include: treatment of heart failure in patients who have atrial fibrillation without a pre-excitation syndrome; prevention of post-operative atrial fibrillation or atrial flutter associated with cardiothoracic surgery; pharmacologic cardioversion of supraventricular tachycardia; and, the treatment of atrial fibrillation in critically ill patients who require rate control and do not have a pre-excitation syndrome.
Administration

1. Pulseless ventricular tachycardia or ventricular fibrillation:
   IV or intraosseous (IO) bolus: amiodarone 300 mg rapid IV push, undiluted. If the arrhythmia persists after the initial dose and after defibrillation, another dose of 150 mg can be given. When spontaneous circulation returns, start an amiodarone infusion of 1 mg/minute for 6 hours, then 0.5 mg/minute for 18 hours.49

2. Stable ventricular tachycardia:
   In the first 24 hours amiodarone 1050 mg is given using the following regimen:
   - Step 1: 150 mg (100 mL) over first 10 minutes (mix 3 mL in 100 mL D5W).
   - Step 2: 360 mg (200 mL) over next 6 hours (mix 18 mL in 500 mL D5W): 1 mg/minute
   - Step 3: 540 mg (300 mL) over next 18 hours: 0.5 mg/minute.79

   Note: After the first 24 hours: 0.5 mg/minute utilizing concentration of 1 to 6 mg/mL. The mL amounts in parentheses above refer to the amounts of amiodarone and the different available concentrations of the drug.

Compatibility

Amiodarone is Y-site compatible with diltiazem, dobutamine, dopamine, epinephrine, esmolol, insulin (regular), isoproterenol, labetalol, lidocaine, metoprolol, milrinone, nitroglycerin, norepinephrine, phenylephrine, procainamide, and vasopressin.79 Amiodarone is Y-site incompatible with heparin.79
Precautions and Contraindications

Infusions greater than 2 hours must be administered in a non-PVC container. PVC tubing is should be used regardless of the infusion duration.\textsuperscript{79}

Correct hypokalemia or hypomagnesemia before using amiodarone and throughout therapy.\textsuperscript{79}

Amiodarone is contraindicated in patients who have any of the following conditions: sinus-node dysfunction causing marked sinus bradycardia; second and third-degree heart block (except in patients with a functioning pacemaker); bradycardia causing syncope (except in patients with a functioning pacemaker), Wolff-Parkinson-White syndrome; and, cardiogenic shock.\textsuperscript{79}

Adverse effects, side effects, and complications

Adverse effects, side effects, or complications are bradycardia and hypotension, rate-related.\textsuperscript{79}

Amiodarone has a boxed warning. Liver toxicity is common after administration of amiodarone. It is usually mild and associated with the oral form of the drug, but severe hepatotoxicity has been reported and this effect may occur after prolonged duration of IV amiodarone.\textsuperscript{79}

Lidocaine

Mechanisms of Action and Pharmacokinetics

Lidocaine is a Class Ib anti-arrhythmic. It is also used as a local anesthetic.

Lidocaine inhibits the movement of sodium through fast-sodium ion channels in the myocardium and cardiac conducting tissue and in nerve conducting issues. This effect stabilizes the myocardium, making it less able to depolarize in
response to a stimulus. It prevents spontaneous depolarization of the myocardium; and, it decreases the automaticity of the His-Purkinje system. The onset of action of a bolus dose of lidocaine is within 45 - 90 seconds. The duration of action is 10 - 20 minutes.

Why is Lidocaine Used?
Lidocaine is used for the acute treatment of ventricular arrhythmias caused by myocardial infarction or by cardiac manipulation during surgery.

Administration

1. Ventricular fibrillation or pulseless ventricular tachycardia (after defibrillation, CPR, and vasopressor administration, and if amiodarone is not available:
The initial dosage IV or IO is 1 - 1.5 mg/kg. If needed this can be followed with boluses of 0.5 - 0.75 mg/kg every 5 - 10 minutes up to a maximum dosage of 3 mg/kg. This is followed by a continuous infusion of 1 - 4 mg/kg/minute after perfusion has been established. Endotracheal (loading dose only) is 2 - 3.75 mg/kg, diluted in 5 to 10 mL normal saline or sterile water. Absorption is greater with sterile water and there will be less of a decrease in the PaO₂.

2. Hemodynamically stable monomorphic ventricular tachycardia:
The initial IV dosage is 1 - 1.5 mg/kg. If needed repeat doses of 0.5 to 0.75 mg/kg can be given every 5 - 10 minutes as needed up to a maximum dosage of 3 mg/kg. The continuous IV infusion is 1 to 4 mg/minute.

3. Reduce maintenance infusion in patients with congestive heart failure, shock, or hepatic disease. Starting dose should be at 10 mcg/kg/minute, and with a maximum dosage of 1.5 mg/minute or 20 mcg/kg/minute.

Compatibility
Lidocaine is Y-site compatible with amiodarone, diltiazem, dobutamine, dobutamine dopamine, heparin, labetalol, nicardipine, nitroglycerin, nitroprusside, and vasopressin.\textsuperscript{81}

*Precautions and Contraindications*
Constant electrocardiographic monitoring is necessary during IV administration of lidocaine. Lidocaine should be used with caution in patients who have hepatic impairment, congestive heart failure, hypoxia, severe respiratory depression, hypovolemia, history of malignant hyperthermia, or shock.\textsuperscript{81}

Lidocaine is contraindicated for patients who have any of the following conditions: Adam-Stokes syndrome; Wolff-Parkinson-White syndrome; severe degrees of sinoatrial, atrioventricular, or intraventricular heart block (except in patients with a functioning pacemaker); and, allergy to corn or corn products (the premixed injection may contain corn-derived dextrose).\textsuperscript{81}

*Adverse Effects, Side Effects, and Complications*
Agitation, bradycardia, confusion, dizziness, hypotension, and seizures may occur in high doses or in susceptible patients.\textsuperscript{82}

**Procainamide**

*Mechanisms of actions and pharmacokinetics*
Procainamide is a Class Ia anti-arrhythmic that blocks the movement of sodium through fast-sodium in channels in the heart. Procainamide decreases myocardial excitability and decreases conduction velocity in the His-Purkinje system. It can also decrease myocardial contractility. \textsuperscript{83,84}

There is limited pharmacokinetic information about IV procainamide but therapeutic drug levels are produced within minutes of administration.\textsuperscript{84}
Why is Procainamide Used?

Procainamide is used for the treatment of life-threatening ventricular arrhythmias.\(^3\)

The off-label uses of procainamide include: arrhythmias (*i.e.*, stable monomorphic ventricular tachycardia, pre-excited atrial fibrillation, and stable wide complex regular tachycardia [*likely ventricular tachycardia*] in adults with preserved left ventricular function; arrhythmias (*i.e.*, tachycardia with pulses and poor perfusion [*probable supraventricular tachycardia unresponsive to vagal maneuvers and adenosine or synchronized cardioversion*], probable ventricular tachycardia [*unresponsive to synchronized cardioversion or adenosine*], in children [*PALS*]; paroxysmal supraventricular tachycardia; and, ventricular tachycardia [*to prevent recurrence*]).\(^3\)

**Administration**

1. Loading dose:
   
   Procainamide 15 to 18 mg/kg administered as slow infusion over 25 to 30 minutes or 100 mg/dose at a rate not to exceed 50 mg/minute repeated every 5 minutes as needed to a total dose of 1 g.

2. Maintenance dose:
   
   Procainamide 1 to 4 mg/minute by continuous infusion. Maintenance infusions should be reduced by one-third in patients with moderate renal or cardiac impairment and by two-thirds in patients with severe renal or cardiac impairment.

**Compatibility**

Procainamide is Y-site compatible with amiodarone, heparin, nitroprusside, and vasopressin. In certain circumstances procainamide is compatible with diltiazem. Procainamide is incompatible with milrinone.\(^3\) The stability of procainamide in IV dextrose solutions is varied and a pharmacist should be consulted for more information.
Precautions and Contraindications

Procainamide should not be used in conjunction with drugs that prolong the QT interval.\textsuperscript{83}

Procainamide can increase the ventricular response in people who have atrial fibrillation or atrial flutter. Hypokalemia and hypomagnesemia should be corrected before starting therapy with procainamide, and the drug should be used with caution in patients who have heart failure.\textsuperscript{83}

Procainamide is contraindicated for patients who have any of the following conditions: complete heart block; second-degree AV block or various types of hemiblock (without a functional pacemaker); SLE, and, \textit{torsade de pointes}.\textsuperscript{83}

Adverse Effects, Side Effects, and Complications

Bradyarrhythmias, hypotension, and seizures are the major adverse effects caused by procainamide.\textsuperscript{85}

\textbf{MEDICATION SAFETY ISSUES}

Medication administration is a large component of a nurse’s professional role. Medication administration is also one of the most potentially dangerous tasks a nurse can perform. Medication errors, defined as “any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of the health care professional, patient or consumer,” are costly from human, economic, and societal perspectives.

Studies show that medication errors affect three to five percent of hospitalized patients in the US. Patients may suffer discomfort, complications, prolonged hospitalization, disability, or death. Researchers estimate that medication errors
cause over 7000 deaths in the US each year; though not all medication errors cause patient harm and not all errors are recognized or reported.

Medication errors are a significant problem in the US and word-wide. The economic cost of medication errors has been estimated at $5,000 per error or an annual impact of $2.8 million for an average 700-bed teaching hospital. Patient length of stay is prolonged by approximately two days when errors occur. This financial significance is magnified if litigation occurs. Financial judgments are awarded in 13% of cases related to serious errors and average approximately $3.1 million per award.

From the human perspective, healthcare professionals and patients are affected by medication errors. The healthcare professional responsible for an error, especially errors that cause patient harm, frequently suffer severe emotional distress. Nurses frequently associate errors with harm to the patient and failure of their moral and ethical responsibility to “do no harm.” Though all medication errors are potentially serious, studies have shown that patients who are critically ill are more likely to have life-threatening consequences to adverse drug events than any other patient population. Also, intravenous route errors have the greatest potential for harm.

In 2008, the Institute for Safe Medication Practices (ISMP), a nonprofit research group that advocates for patient safety, developed a list of medications that are known to contribute to a significant number of medication errors and are associated with a risk for poor outcome with improper administration. These drugs, referred to as high-alert medications, require special safeguards to reduce the risk of injury to patients. The Institute for Safe Medication Practices warms that 20 drugs are responsible for 80% of medication error fatalities. Most of the medications described in this course are included on this list of medications.
The Joanna Briggs Institute is an International not-for-profit Research and Development Organization specializing in Evidence-Based resources for healthcare professionals in nursing, midwifery, medicine, and allied health. With over 54 Centers and groups, servicing over 90 countries, the Joanna Briggs Institute is a recognized global leader in Evidence-Based Healthcare. In 2009, the Joanna Briggs Institute published best-practice recommendations related to the preparation and administration of intravenous medications. These recommendations included:

- Medications should always be prepared in the pharmaceutical setting if possible.
- Administration sets not containing blood, lipids, or blood products can remain in place for up to 96 hours without increasing the incidence of infection.
- Methods to avoid contamination should be followed, such as accessing the port with only sterile devices, wiping the port with an appropriate antiseptic solution and capping stock ports when not in use.
- Ensure all components of an IV system are compatible to minimize possible leaks and breaks in the system.
- When utilizing piggyback systems, use care to ensure the rubber membrane of an injection port is not exposed to air or comes in direct contact with non-sterile tape to reduce infection risk.

Following these best practice recommendations and taking extra care when administering the high-alert medications will reduce the risk of medication errors and increase the safety of patients.

**SUMMARY**

Intravenous medication administration involves infusion of a medication into a patient’s vein either slowly or rapidly, and may involve a continuous infusion. Often, administering a medication by intravenous route is the preferred method.
to treat a physical condition, and sometimes the intravenous route is the only method by which a medication can be given. Another effective method of administering a medication when venous access is unavailable and rapid injection is necessary, as during a resuscitation event, is through intraosseous injection. It’s important for nurses to be informed about and remain up-to-date on the types of intravenous medications and drug actions, as well as the medication contraindications and potential side effects. Often medications administered through an infusion set are compatible with other medications, however, drug incompatibilities should be known by nurses to avoid potentially adverse outcomes. Nurses should also know how to administer a drug in the setting of blood or blood-product transfusions.

There are several helpful resources that offer guidance for nurses when practicing infusion therapy of medication. The Institute for Safe Medication Practices (ISMP), in an effort to advance patient safety, has developed a list of “high alert” medications identified as leading to poor outcomes. High-alert medications require nurses to observe recommended safety checks to reduce the risk of serious adverse outcomes as a result of medications administered intravenously. Nurses often tend to blame themselves when harm results following medication administration. However, its important for nurses to understand how system defects can lead to errors and to be part of health safety teams in their organization that review and address gaps in patient safety that occur.

Please take time to help the NURSECE4LESS.COM course planners evaluate nursing knowledge needs met following completion of this course by completing the self-assessment Knowledge Questions after reading the article. Correct Answers: page 56.

1. Which of the following are benefits of IV administration of drugs?
   a. Rapid onset of action and 100% bioavailability.
   b. No risk of tissue damage and precise titration of dosage.
   c. Simpler to administer than PO route, steady state drug concentrations.
   d. Less expensive than PO preparations, fewer adverse effects.
2. Which of the following are risks specific to IV administration of drugs?
   a. Slow onset of action, decreased bioavailability.
   b. Imprecise dose titration, easier to administer than PO route.
   c. Tissue damage from infiltration/extravasation, complicated administration.
   d. Thrombophlebitis, higher frequency of allergic reactions.

3. Which of the following are adverse effects caused by IV insulin?
   a. Hypocalcemia and hyperglycemia.
   b. Hypokalemia and hypoglycemia.
   c. Hyperkalemia and metabolic acidosis.
   d. Hypercalcemia and metabolic alkalosis.

4. Which of the following are relatively common adverse effects caused by IV heparin?
   a. Bradycardia and hypotension.
   b. Hepatotoxicity and renal damage.
   c. Bronchospasm and Stevens-Johnson syndrome.
   d. Bleeding and thrombocytopenia.

5. The vasopressors and inotropes may cause:
   a. Peripheral vasoconstriction and dysrhythmias.
   b. Bleeding and hypoglycemia.
   c. Bronchospasm and hypokalemia.
   d. Thrombocytopenia and seizures.

6. When using a vasopressor or an inotrope it is critical to periodically assess:
   a. Serum magnesium and serum calcium.
   b. Urine output and mental status.
   c. Serum glucose and aPTT.
d. Pulmonary capillary wedge pressure and temperature.

7. **IV infusion of a beta-blocker can commonly cause:**
   a. Hypertension.
   b. Thrombocytopenia.
   c. Hypotension.
   d. Seizures.

8. **IV infusion of a calcium channel blocker can commonly cause:**
   a. Tachycardia.
   b. QTc prolongation.
   c. Hypoglycemia.
   d. Hypotension.

9. **IV infusion of nitroprusside can cause:**
   a. Bronchospasm.
   b. Cyanide poisoning.
   c. Bleeding.
   d. Dysrhythmias.

10. **IV infusion of an antiarrhythmic is contraindicated if the patient has:**
    a. Severe heart block.
    b. Asthma.
    c. Hyperglycemia.
    d. A bleeding disorder.

**CORRECT ANSWERS**
REFERENCE SECTION

The reference section of in-text citations include published works intended as helpful material for further reading. Unpublished works and personal communications are not included in this section, although they may appear within the study text.


55. James AT, Corcoran JD, McNamara PJ, Franklin O, El-Khuffash AF. The effect of milrinone on right and left ventricular function when used as a rescue therapy for term infants with pulmonary hypertension. *Cardiol Young*. 2015 Jan 20:1-10. [Epub ahead of print]


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