Is full-dose delivery the total volume delivered (eg, 250 mL) or does this also include the amount of overfill within an intravenous piggyback or the amount left in the infusion set? What is the best practice standard for the full delivery of medications via intravenous pump when only a primary bag is used? How is the remaining medication in the tubing/cassette (15-20 mL) delivered to the patient if no carrier fluid is used?

Earnest Alexander, PharmD, and Amanda Zomp, PharmD, BCPS, reply:

In today’s age of smart infusion pumps, a major focus has been placed on guardrails or limits on infusion rates, with predetermined drug concentrations, infusion rates, dose limits, and total volumes. Both safety and efficacy are key considerations for dose infusions. A great deal of focus is placed on safety, by limiting infusion rates to avoid toxic effects. There often is not as much focus on efficacy, in terms of defining what constitutes a full-dose delivery of intravenous medications.

The total volume for most intravenous piggybacks (IVPBs) with either 0.9% NaCl or 5% dextrose in water (D5W) as diluents includes a small amount (up to 10%) of manufacturer overfill within each diluent bag above the volume indicated on the bag. For example, a 100-mL bag will actually contain up to a total volume of 110 mL of diluent. This slight variation in volume is considered acceptable by Food and Drug Administration standards.1 If additional volume of drug is added to the IVPB, without removal of excess diluent, the actual total volume will be increased further. In many instances, this overfill volume is not considered to affect efficacy. However, for some agents and scenarios, overfill and drug volume added should be accounted for or removed because the total volume administered must be more exact.

Because of overfill associated with IVPBs, residual volume inevitably remains at the conclusion of the infusion if a pump is programmed to infuse the stated volume on the bag (eg, 100 mL). Because a percentage of the medication was also mixed with that overfill volume, a small amount of the medication remains as well. In addition, if an IVPB is administered as a primary infusion, an amount of volume and drug will be left in the infusion set at the end of the infusion (15-20 mL depending on the infusion set).

The clinical significance of the amount of drug lost as residual volume is unknown. Studies that evaluate clinical outcomes associated with specific medication doses often do not report specific details of intravenous administration.
such as the type of infusion pump used, type of tubing used, or standard care regarding flushing tubing or using a carrier fluid. The clinical significance of residual volume or medication dose remaining in intravenous tubing varies depending on factors outlined in the Table: medication type, total volume of the dose, and specific population of patients. For example, medications with a narrow therapeutic index (eg, phenytoin [Dilantin], digoxin) can be dangerous if serum concentrations are too high or too low. If even a small percentage of the dose remains in the infusion set or is lost as overfill, the clinical significance would be higher than with another medication that has a wide therapeutic index (eg, levetiracetam [Keppra]).

An additional example was recently highlighted in a systematic review by Lam et al,2 who evaluated the effect of residual volume in intravenous tubing following extended infusion doses of piperacillin-tazobactam (Zosyn). Researchers calculated the percentage of piperacillin-tazobactam 3.375-g or 4.5-g doses that would be lost as residual volume in the intravenous tubing using 4 different intravenous infusion pumps. For a 3.375-g dose in 50 mL, up to 60% of the dose was lost, for a 3.375-g dose in 100 mL, up to 30% of the dose was lost, and for a 4.5-g dose, up to 30% of the dose was lost. Infusion pumps using microbore tubing resulted in significantly less drug lost (1%-15% of the dose).2 Despite the fact that clinical outcomes were not assessed in this study, the results suggest that processes may need to be developed to ensure that the full dose is delivered with extended infusion antibiotics such as piperacillin-tazobactam.

The Lippincott Manual of Nursing Practice3 suggests standards that advise following procedural guidelines for administering intermittent intravenous infusions, including cleaning the intravenous port before accessing, aspirating blood, flushing the catheter site, connecting intravenous tubing, administering the medication after reviewing the order and the patient’s allergies, infusing the medication at the prescribed rate, and flushing the catheter site after completion. The practice standards also describe the procedure for administering an IVPB as a secondary infusion; however, they do not address how to handle the residual volume in intravenous tubing when an IVPB is administered as a primary infusion.3

In evaluating practice standards within 2 academic medical centers, some commonalities are noted. In children, patients receiving chemotherapy, and in instances with small-total-volume IVPBs (< 50 mL), the following steps are taken:

Step 1: 0.9% sodium chloride solution or other compatible carrier fluid is hung as the primary bag and used to prime the system.

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**Table** Factors contributing to clinical significance of lost residual volume in infusion set

<table>
<thead>
<tr>
<th>Factor</th>
<th>Clinical significance and impact</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of medication</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemotherapy (eg, oxaliplatin + fluorouracil)</td>
<td>Precision of dose is important to optimize efficacy and minimize toxic effects</td>
<td>Precision should be used in delivering the full dose, as a standard of care</td>
</tr>
<tr>
<td>Narrow therapeutic index (eg, phenytoin [Dilantin], digoxin)</td>
<td>Precision of dose is important to optimize efficacy and minimize toxic effects</td>
<td>Precision should be used in delivering the full dose, as a standard of care</td>
</tr>
<tr>
<td>Extended infusion antimicrobials (eg, piperacillin-tazobactam [Zosyn])</td>
<td>Studies have highlighted residual waste concerns; however, this has not been associated with clinical outcomes</td>
<td>Process changes to minimize drug lost should be evaluated for feasibility</td>
</tr>
<tr>
<td>Total dose volume</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 mL or less total volume (eg, clindamycin [Cleocin] premixed solution)</td>
<td>Potential for a significant portion (up to 40%) of the dose to be lost if left as residual volume in the infusion set</td>
<td>Process changes to minimize drug lost should be evaluated for feasibility</td>
</tr>
<tr>
<td>Population of patients</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pediatric and neonatal (eg, small-volume pediatric syringes)</td>
<td>Precision of dose is important to optimize efficacy and minimize toxic effects</td>
<td>Precision should be used in delivering the full dose, as a standard of care</td>
</tr>
</tbody>
</table>
Step 2: IVPB is hung with the secondary tubing.

Step 3: Carrier fluid bag gets hung on a hook (usually supplied in the secondary tubing bag) so that it is lower than the IVPB that is hung on the intravenous pole.

Step 4: Program the pump in the secondary settings.

Step 5: Once the IVPB bag is empty, the pump will automatically pull from the carrier fluid bag so that it primes the IVPB fluid out of the tubing and into the patient.

Step 6: Carrier fluid is taken down after the IVPB is complete and the line is flushed.

A note of consideration is that both centers evaluated use Alaris smart pumps. As such, the secondary setting on the Alaris pumps limits infusion rates to no faster than 270 mL/h.

If none of the preceding factors are present to prompt concern related to clinically significant residual volume, no carrier fluid is necessary and no specific orders to flush/rinse the tubing at the end of the infusions are needed, so it is suitable to discard the residual volume left in the chamber or the tubing as waste. Infusions being administered via pump are considered empty and the full intravenous dose delivered when air is on the chamber and the pump stops.

Conclusion

Understanding the key characteristics that influence when a full intravenous dose has been delivered is important for bedside nurses. This understanding includes an appreciation of the clinical significance of residual volume remaining in intravenous sets after the total ordered volume has been infused. Studies in this area are limited, although practice patterns have emerged. In light of the paucity of data, further research is needed in order to provide more clear guidance. In most patient scenarios, residual volumes play a minor role. In a select few instances, residual volumes are more important. In these cases, certain steps may be taken to ensure that the full intravenous dose is delivered.

Financial Disclosures
None reported.

References

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Best Practices: Full-Dose Delivery of Intravenous Medications via Infusion Pumps
Earnest Alexander and Amanda Zomp

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