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ReachMD
www.reachmd.com
info@reachmd.com
(866) 423-7849

Improving IV Medication Accuracy with Smart Pump Safety Procedures

Announcer:
You're listening to *Clinician's Roundtable* on ReachMD, and this episode is sponsored by Fresenius Kabi. Here's your host, Dr. Shelina Ramnarine.

Dr. Ramnarine:
Welcome to *Clinician's Roundtable* on ReachMD. I'm Dr. Shelina Ramnarine, and joining me to help shed light on the role of smart pump drug libraries and medication safety features in supporting accurate IV medication delivery is Dr. Samuel Ubanyionwu. He's a Medication Management Informaticist in Pharmacy Services and an Assistant Professor of Pharmacy at the Mayo Clinic College of Medicine. Dr. Ubanyionwu, thanks for being here today.

Dr. Ubanyionwu:
Thank you for the opportunity.

Dr. Ramnarine:
So why don't we start by doing some level setting, Dr. Ubanyionwu. What's a smart pump drug library, and why has it become such an important part of safe IV medication delivery?

Dr. Ubanyionwu:
A smart pump drug library is a database of medications with organization-specific dosing parameters built to support the infusion pump device. These parameters include medication variables such as a dose, concentration, duration, dose rate, and even a flat rate, which then have soft and hard limits applied to them that are also known as DERS, or dose error reduction software systems.

The real value of the drug library is that added protection layer during pump programming and titrations. Instead of simply accepting any value that's entered into the device, the pump compares the programmed infusion against predetermined limits established by an institution or during a clinical trial. If a clinician enters a value outside the expected range, the pump can alert the user before the infusion actually begins. Those soft limits allow a clinician to reassess and override if clinically appropriate, while hard limits are designed to prevent programming outside of safe boundaries.

Dr. Ramnarine:
Building on that, not every smart pump moves medication the same way. So can you help us understand at a basic level what's happening mechanically with a peristaltic pump versus a cassette-based system and how drug library programming fits into each of those processes?

Dr. Ubanyionwu:
In a peristaltic pump, a series of mechanical fingers are rolling repeatedly and compressing the flexible IV tubing, creating a wave-like motion that pushes fluid towards the patient. It's similar to the way our esophagus moves food during the swallowing process. The pump controls how frequent and how much the tubing is compressed to achieve the programmed infusion rate.

Now let's talk about the cassette-based pumps. Cassette-based pneumatic systems, rather than squeezing the tubing itself, use a pneumatically driven diaphragm to pull the fluid from the IV bag into the pumping chamber and then deliver it to the patient. This system directly measures the volume of fluid leaving the pump and continuously adjusts the flow in real time to maintain the programmed infusion rate despite changing clinical conditions.

Now, understanding how a pump performs mechanically allows drug library administrators like myself to build safeguards that

complement the design of the pump rather than assuming that every pump behaves the same way. So for example, certain peristaltic pump designs may exhibit known performance characteristics during secondary or piggyback infusions. If a secondary infusion is programmed at high flow rates, some systems may experience a siphoning effect where additional primary fluid is unintentionally delivered along with the secondary medication. Knowing this, a drug library administrator can proactively disable secondary infusion programming for medications that require rates above those thresholds or require those medications to be administered as primary-only infusions.

Dr. Ramnarine:
Now, regardless of the pump being used, why is infusion accuracy so important from a clinical standpoint? And what are potential consequences when the prescribed and delivered dose, volume, or infusion rate don't align?

Dr. Ubanyionwu:
Infusion accuracy is fundamental because many IV medications produce their therapeutic effects based on very precise delivery over time. So unlike oral medications where absorption may vary naturally, IV medications enter directly into the bloodstream, so inaccuracies in delivery can have immediate clinical consequences.

If the delivered infusion runs at a rate that's faster than prescribed, the patient may receive an unintended overdose. Depending on the medication, this could result in excessive sedation, hypotension, arrhythmias, bleeding, electrolyte disturbances, and other serious adverse events. Conversely, if medication is delivered more slowly than intended, the patient may experience inadequate symptom control, delayed therapeutic response, or fail to achieve the desired physiological target.

Another important consideration is cumulative error. Small inaccuracies that appear insignificant over a few minutes can become substantially more important over a prolonged infusion lasting many hours or even days. So this is especially relevant in our neonatal and our pediatric patient populations where total infusion volumes are much smaller and the physiological reserve is much more limited.

Dr. Ramnarine:
For those just tuning in, this is *Clinician's Roundtable* on ReachMD. I'm Dr. Shelina Ramnarine, and I'm speaking with Dr. Samuel Ubanyionwu about how smart pump drug libraries, dose error reduction systems, and other safety procedures can support more accurate and reliable IV medication delivery.

So even when a pump is programmed correctly and everything's working as it should, the amount of medication a patient actually receives can still be affected by a few technical factors like dead volume, medication left behind in the tubing, and titration effects. So, Dr. Ubanyionwu, what exactly happens in each of those cases, and why do they matter clinically?

Dr. Ubanyionwu:
One of the most important concepts to understand is that medication delivery is not determined solely by the pump programming. The entire infusion system, including the pumping mechanism, IV tubing, connectors, and administration setup, all influence both how much medication ultimately reaches the patient and when it is delivered.

So one key consideration is residual volume, also known as dead volume. This is the amount of medication-containing fluid that remains in the IV tubing after the infusion is marked complete. So unless the tubing is intentionally flushed, this residual medication never reaches the patient, potentially reducing the delivered dose and compromising the treatment effectiveness. Now, many healthcare systems or organizations establish institutional thresholds for acceptable medication loss due to dead volume. For example, some organizations aim to limit unrecovered medication to no more than 10 percent of the ordered volume. So to achieve this, they evaluate the priming volume for IV tubing sets and determine within the drug library or institutional medication administration guidelines whether a specific medication should require a post-infusion flush.

Now, the clinical impact of medications remaining in the tubing varies by therapy. For many medications, the unrecovered amount may be insignificant. However, for high-cost biologics, pediatric medications, chemo, vasoactive medications, or drugs with very narrow therapeutic windows, the medication left in that tubing may represent a clinically significant portion of the prescribed dose.

On the other hand, pivoting over to another important concept is the titration effect. When an infusion rate is increased or decreased, the patient does not immediately experience that change. Medications already occupying the IV tubing must first travel through the infusion system before medication flowing at the newly programmed rate reaches that patient. As a result, there is an inherent delay between adjusting the pump and observing the corresponding clinical response.

Dr. Ramnarine:
You mentioned earlier about discrepancies and how they can accumulate over time. How can we use smart pump features and other protocols like dose error reduction systems and alarms to recognize problems earlier and support more reliable medication delivery?

Dr. Ubanyionwu:
One of the greatest strengths of modern smart pump technology is that it doesn't simply deliver medication. It's continuously providing opportunities to identify potential problems before it reaches the patient.

So our first line of defense, and you mentioned it, is our DERS, or Dose Error Reduction Software systems. By comparing programmed infusion parameters against institutionally approved medication limits, DERS can identify programming mistakes, such as incorrect concentration, infusion rate, or dose unit, before therapy even begins. Hard limits can prevent unsafe programming altogether, while soft limits encourage clinicians to pause and verify whether they want to truly override an infusion or a dosing parameter.

Now, beyond initial programming, pumps have provided real-time monitoring through alarms. Occlusion alarms can identify downstream resistance before therapy is significantly interrupted. Air-in-line detection helps reduce the risk of air embolism. Low volume or empty container alarms are helpful in allowing clinicians to prepare replacement infusions before therapies go dry or the bags go empty. So together, these features help maintain continuity of medication delivery, particularly for your high-risk continuous infusions.

Now, technology is only one part of the safety equation. Alarm management is equally important. If alarm thresholds aren't appropriately tailored or configured for clinician experience, excessive alarms can lead to nuisances, such as alarm or alert fatigue, and that can develop and increase the risk that meaningful alerts or alarms would be delayed or even overlooked. That's why organizations should routinely review their alarm performance and optimize settings based on clinical workflows.

Now, from a pharmacist perspective, one of the most valuable resources is the data generated by smart pumps. Data on compliance, override frequency, alert trends, or even near-miss events provide actionable information that we can leverage to improve medication safety.

Dr. Ramnarine:
So it sounds like, Dr. Ubanyionwu, that these smart pump drug libraries and infusion data have really been used to improve medication safety and support clinical decision-making. But where do you see the greatest opportunity for smart pump drug libraries and infusion data to further improve medication safety and support clinical decision-making across healthcare settings?

Dr. Ubanyionwu:
Well, one of the greatest opportunities lies in leveraging infusion analytics to drive continuous quality improvement. Now, rather than reviewing adverse events only after they occur, organizations can analyze these DERS—so again, those error reduction system alerts, override patterns, compliance rates, and programming trends—to proactively identify vulnerabilities within the medication use process.

Another significant opportunity is the integration of smart pump intelligence into our electronic medication record system. So today, DERS limits are only applied at the point of administration, serving as one of the final safeguards before medication actually reaches the patient. Now, bringing those same limits upstream into provider order entry, or CPOE, would allow clinicians to receive feedback much earlier in the medication use process, strengthening the Swiss cheese model of patient safety. If a prescribed dose or infusion rate exceeds established parameters, providers could then be alerted during order entry rather than waiting for the medication to be programmed at the bedside. This creates additional layers of protection and promotes a safer prescribing pattern.

Dr. Ramnarine:
As those final comments bring us to the end of the program, I'd like to thank my guest, Dr. Samuel Ubanyionwu, for joining me to discuss smart pump drug libraries, infusion accuracy, and clinical factors that influence safe IV medication delivery. Dr. Ubanyionwu, it was great speaking with you today.

Dr. Ubanyionwu:
Oh, the pleasure is all mine. I can't wait for us to have the opportunity to do it again.

Announcer:
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