Introduction
Ubiquitous throughout the hospital, large volume infusion IV pumps play a crucial role in delivering fluids and complex doses of medications to patients in a wide range of care settings. Medications administered through the IV pump are assumed to infuse at a smooth and continuous flow rate displayed on the screen. And, clinicians expect that the pump is delivering fluid at the rate programmed. However, a number of factors influence IV pump flow accuracy. Pump standards typically report flow accuracy of +/-5% but this is in controlled laboratory conditions. In real-world clinical conditions like those in hospitals today, many infusion pumps administer fluids at highly discontinuous rates, including periods of little or no infusion. This study examined the short-term flow accuracy of three large volume infusion pumps and explores the clinical impact of flow variability for high-risk medications with short half-lives.

AIMs
1) Compare the differences of flow accuracy of three large volume pumps
2) Consider the therapeutic efficacy and clinical outcome of short half-life medications if variations in the flow rate occur

Method
A flow accuracy test was conducted with three large volume infusion pumps. The test strictly followed international industry standards:
- IEC 066-004-1-24: Requirements for the safety of infusion pumps and controllers
- Infusion Pump Type 4: Continuous infusion flow, non-continuous flow
- Volumetric Infusion Pump. The delivery rate is set by the operator & indicated by the equipment in volume per unit of time

The study evaluated flow accuracy of 0.5mL/hr.

Environmental conditions such as temperature, humidity, evaporation, vibration, and ambient pressure were maintained. Head height and back pressure were at the nominal conditions defined by the pump manufacturers.

Observed variability in the test results was due to the unique characteristics of the pumping mechanism for each large volume infusion pump.

A startup time plot (T0 – first 60 minutes) was created to illustrate the instantaneous flow rate versus time, for the first two hours of the test. It's intention is to show how long it takes the device to get to the desired flow rate from zero and reveal flow performance characteristics.

A trumpet curve was generated after the pumps stabilized (T1-second 60 minutes). The minimum and maximum % error in flow rate is plotted versus the length of time used to average the data (2.5,11.3 and 31 minute observation windows).

Findings
- Although environmental factors external to the pump were controlled and unchanged, a wide range of flow variability was observed with some pumps.
- Two of the three large volume pumps administered fluids at highly discontinuous rates, including periods of little or no infusion.
- Continuous infusion pumps exhibited ‘cyclical’ variations around the programmed flow rate; some pumps varied by more than +/-30% over time periods greater than 10 minutes.
- Only one large volume infusion pump was able to deliver 5% accuracy at the 2 minute observation window.

The startup time plot is a flow of instantaneous flow rate. The curves illustrates T0 (start-up 0-60 min) and T1 (60-120 min) flow vs time data at 30 sec sample rate.

A trumpet curve is a plot of min and max % error in flow rate. Error in flow rate (%) is the error in slope between the two peaks.

Discussion
Medications with short half-lives need continuous administration to maintain therapeutic efficacy and desired clinical outcomes. These medications are mostly for the acutely ill patient, to either support or control blood pressure, control arrhythmias, provide sedation and in some cases to paralyze for therapeutic needs. For example, a septic patient who is extremely hypotensive might have norepinephrine administered to support blood pressure. Norepinephrine has a half-life of approximately 3 minutes with an even shorter duration of action of approximately 2 minutes. In essence, discontinuous delivery of the medication might lead to either the need to bolus (if appropriate), dose increase, and/or additional adjunct therapy. An infusion pump that continuously delivers the same amount of medication in a smooth and consistent fashion, versus small cycles, may lead to beneficial patient outcomes.

Conversely, a patient with a hypertensive emergency requires drastic reduction in blood pressure. Medications such as nitroglycerin and sodium nitroprusside are widely used depending on the condition. Both medications have half-lives that are less than two minutes as well as a duration of action that is about three to five minutes. For instance, sodium nitroprusside has an extremely rapid action that quickly goes away with any interruption, such as reduced flow or even an occlusion. Patients in a hypertensive emergency need careful but calculated reduction in blood pressure to avoid fatal outcomes such as stroke. As previously discussed, these patients cannot afford variations in medication delivery but rather accurate and consistent drug delivery.

Conclusion
Medications administered at a specified rate are assumed to infuse continuously and consistently at the programmed rate. However, the findings in this study prove this is not the case.

- Although environmental conditions were controlled, two of the three studied pumps administered fluids at highly discontinuous rates, reporting +/-30% variability over time periods greater than 10 minutes.
- The findings are especially meaningful if high-risk medications with short half-lives are delivered. Variations in flow with short time periods could have a profound clinical impact on the patient.
- Discontinuous delivery of the medication may lead to a medical intervention including bolus, dose increase or decrease, and/or additional therapy.
- Results demonstrate that significant differences exist in flow continuity among infusion pumps and this variation could pose a risk of hemodynamic instability in an already compromised patient.

References
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