Preliminary Experience With a New High-Speed Flow Sensor for Investigating and Improving Syringe Pump Flow Performance

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Background: Much like the flight of an aircraft, intravenous (IV) pump flow may transition from take-off through descent and landing operating over a wide dynamic range of flow rates during patient care. The interaction of pump mechanical design with syringe and fluid path properties can give rise to undesirable flow behaviors requiring more complete characterization than has heretofore been possible, to permit mitigation. Present day methods and metrics[1,2] for measurement of pump performance are complex, costly and limited in ability to measure many aspects of flow behavior, such as those that adversely impact the onset and titration of vasoactive and anesthetic/sedative drugs. This is important to present-day practice, and vital to future target-control and closed loop infusion systems[3]

Methods: We investigated use of a new, low cost, miniaturized high speed thermodilution flow sensor[4] to characterize syringe pump flow behavior across a range of clinically relevant flow rates and rate changes. We then applied low-pass digital filtering inspired by a simple one compartment pharmacokinetic model, to visualize potential in vivo responses of different medications ranging from e.g. short half-life vasoactives, to e.g. long half-life antiarrythmics - see Figure 1. Flow data was acquired with the inline sensor according to a 'staircase' test protocol which, when plotted as in Figure 1 (right), provided an integrated view of pump performance across the selected range of rates, and included flow data across the entire travel of the stopper through the barrel. Quantitative indices of mean error, continuity, and uniformity were calculated at each step (not shown).

Results: Our experiments revealed previously unknown flow errors associated with time- and speed-dependent stopper-to-barrel friction forces. Our staircase plot intuitively revealed a basis for justifying the alerts that modern syringe pumps issue when flow rates for a specific syringe size/brand fall below a manufacturer's predefined minimum recommended rate.

Conclusion: The use of new, low cost, miniaturized flow sensors together with 'staircase' test protocols and a graphical presentation format, combined with calculated indices, enriches our understanding of challenging/undesirable aspects of syringe infusion pump flow performance, and will permit significant design improvements. It may be possible to manufacture IV pumps incorporating such flow sensors integrated in the sterile tubing. Flow data from these sensors could provide real-time closed loop control of the drive mechanism offering shorter startup time, smoother steady state flow, and faster detection of occlusions.

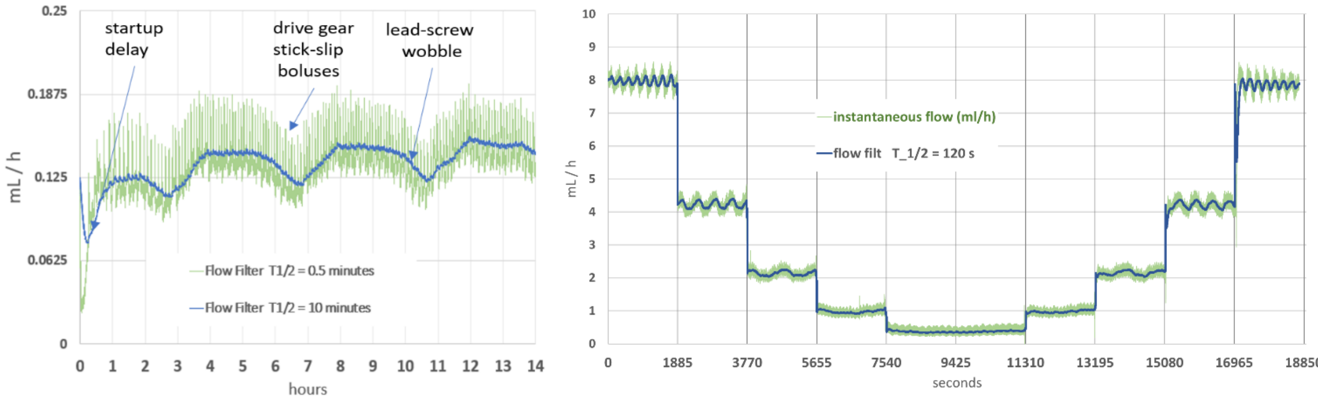

Figure 1: Measurement and characterization of a syringe pump flow by inline sensor and lowpass filtering.

References:
[1] IEC, www.iecee.org/dyn/www/f?p=106:49:0::::FSP_STD_ID:2635
[2] AAMI, Association for the Advancement of Medical Instrumentation, https://www.aami.org/detail-pages/Standards-Committee/id---infusion-device-committee
[3] J. An, “Towards the clinical translation of a physiological closed-loop control system for precise control of propofolinducedvpharmacological coma,” Thesis, Massachusetts Institute of Technology, 2019. [Online]. Available: dspace.mit.edu/handle/1721.1/122131
[4] Sensiron, https://www.sensirion.com/en/flow-sensors.