Air-Driven Syringe Pump for Anesthesia in Low-Resource Settings

Authors: Christian L Petersen¹, Nancy Luo¹, Neil Merchant¹, Nicholas West¹, Stephan Malherbe¹, J Mark Ansermino¹ and Guy A Dumont²

¹Departments of Anesthesiology, Pharmacology & Therapeutics, and ²Electrical and Computer Engineering, The University of British Columbia, Vancouver, Canada

Introduction: There is a need for the delivery of safe anesthesia in low resource settings [1]. Intravenous anesthesia can be delivered safely, with less equipment (i.e. a syringe pump), than volatile anesthetics. Syringe pumps are however complex and costly. Low-cost ($100) 3D printed pumps [2] have poor usability and no encoder feedback, thus unsuited for clinical use. Here we present a $10 pump that addresses these obstacles.

Method: A 3D printed adapter holds two disposable syringes against each other (Fig 1a). An inexpensive diaphragm air pump ($3) and solenoid release valve ($2) drive one syringe, while a copper strip based capacitive encoder reads the drug level in the second syringe. Pump, valve and encoder interface directly to a small Field Programmable Gate Array (FPGA) chip ($3). The entire device is powered via USB.

Results: The capacitive encoder for piston position feedback showed excellent linearity (Fig 1b). After preliminary calibration, flow rates were tested with a precision scale, showing an accuracy of >95% at a flow rate of 60mL/h (Fig 1c). At low rates an encoder quantification of 0.5mL caused a staircase-like spread in the infusion profile. This is a limitation in the current prototype and is not fundamental to the design. Syringes are easily swapped, as the system is not pressurized when idle.

Conclusion: We have made a $10 infusion pump from a 3D printed adapter with encoder feedback, which allows easy replacement of syringes, two key requirements for practical clinical use. The performance of the prototype can be significantly improved, and the fluid sensor may be used to identify the drug in the syringe (e.g. distinguish Propofol from Remifentanil). With a closed-loop controller onboard the FPGA, an ultra-low cost hardware-only automated anesthesia system may be feasible.
1: 3D printed syringe clamp and schematic (a), encoder linearity (b) and 60mL/h flow accuracy (c).
