



### Discovering Variability in Infusion Device Flow Rates by Automated Gravimetric Measurement

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**Introduction:** Precise and accurate flow rates are important when infusing vasoactive drugs, especially in the case of infants. While syringe pump flow rates vary [1,2], imprecise measurement methods make it difficult to accurately quantify pump performance. The ability to precisely calculate how changes in pump height affect fluid flow rate depends on the ability to precisely measure vertical displacement, mass, and time.

**Methods:** We have developed and tested a device that measures syringe pump fluid delivery with a high level of precision. The device (Fig.1) makes it possible to precisely measure how variations in height affect pump infusion rate. The device enables the researcher to model a variety of clinically relevant conditions and to determine their effects on infusion flow rate. The microcomputer controlled system allows the experimenter to program complex sequences of precise movement ( $\pm 6.35 \times 10^{-3}$ mm over 175cm) and measurement 0.001 mL ( $\pm 0.0005$ ). The device provides accurate measures of time to start drug delivery, time to steady-state rate of infusion, zero drug delivery time, aspiration volume, and bolus volume associated with changes in infusion pump height.

**Results:** We have found that pump flow rates do vary significantly under the influence of clinically relevant changes in height. For example, drug delivery (at 2cc/hr) begins within 6.5 minutes if the pump is purged at the start of an infusion. In contrast, failure to use the pump's purge feature delays the start of drug delivery by an additional 13.5 minutes (total of 20 minutes). When infusing at a rate of 4 cc/hr, elevating the pump 50cm produces a bolus of 0.120mL over 5 seconds and lowering the pump 50cm results in no flow and low flow for 2 minutes, 20 seconds (Fig.2)

**Discussion:** The manner in which pump height changes affect infusion rate and volume is both poorly understood and far greater than appreciated. Our apparatus can be used to simulate clinically relevant situations by programming complex sequences of movements and measurements. Any infusion device can be evaluated to determine the influence of height on the infusion's hydrostatic pressure. We are using the device to test various pumps to determine the effects of changes in height on infusions.

[1] Clarkson DM. Accuracy estimations of testing of infusion devices using weighing balances. *Medical Engineering & Physics* 2002; 24:229-35

[2] Neff TA, Fisher JE, Schulz G, Banziger O, Weiss M. Infusion pump performance with vertical displacement: effect of syringe pump and assembly type. *Intensive Care Med* 2001; 27:287-91.

### Why This Matters

Precise rates of flow are needed for controlled drug delivery, especially when treating infants and neonates with short acting, potent medications such as vasoactive agents. Measuring rate of flow automatically allows for better control as environmental variables change.

The hydrostatic pressure changes that occur when the height of patient or device is changed critically influence instantaneous flow. Neff *et al* [2] have shown that even modest changes in height can alter infusion rates significantly. During a two month research period, we developed a means to automate the measurement of these effects. This automation makes it easy to conduct experiments with a wide variety of devices and tubing assemblies. It provides a platform for measuring properties of low-rate infusion devices.

### How We Studied It

We developed and tested a device (Fig.1) that makes it possible to precisely calculate pump infusion flow rate while controlling infusion device vertical displacement. The device enables the researcher to model a variety of clinically relevant conditions and to determine their effects on infusion flow rate. The system permits vertical travel up to 175 cm and automatic acquisition of data on static and dynamic properties over long (e.g., 12 hour) periods of time.

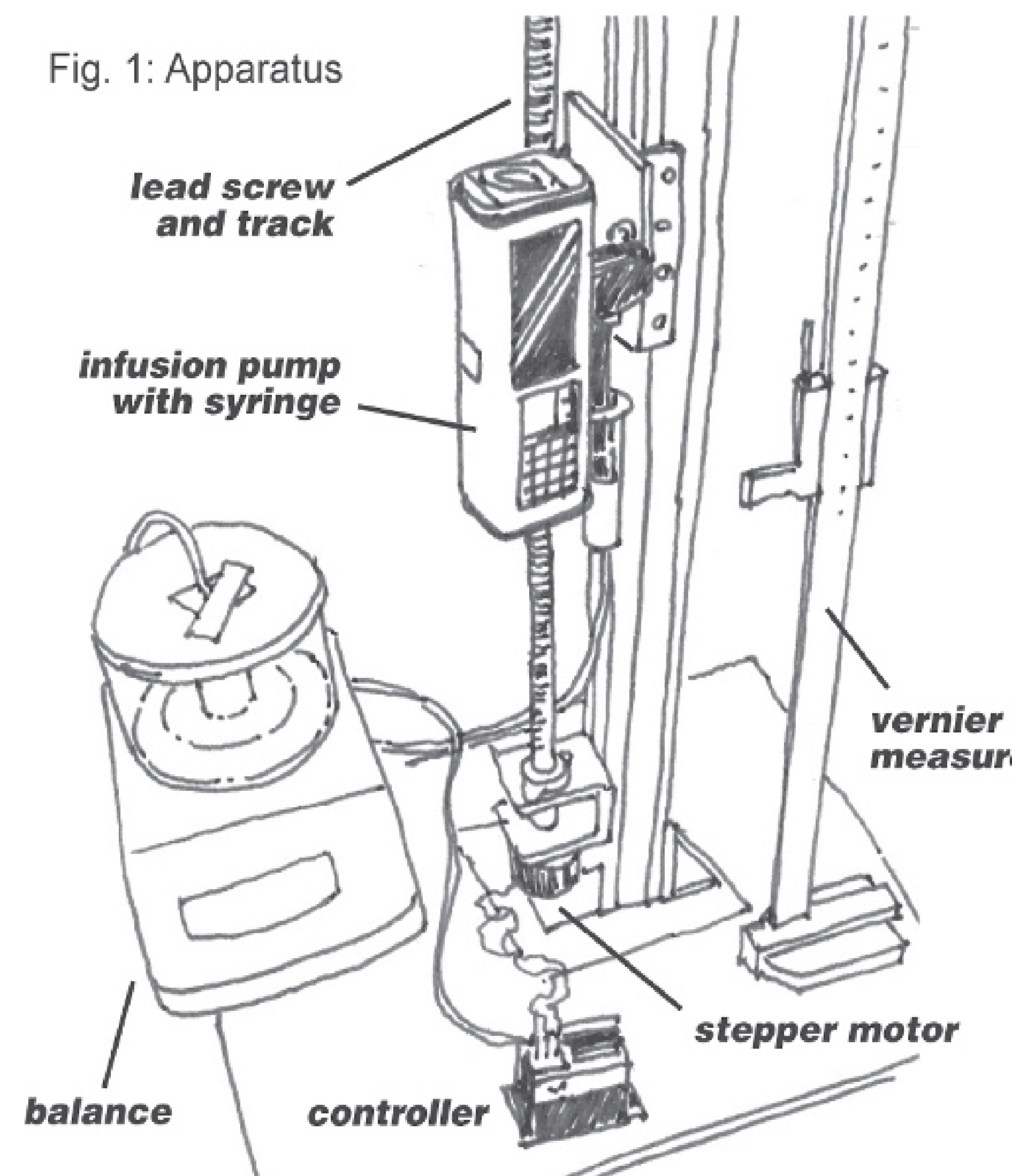


Fig. 1: Apparatus

### What We Learned

Pump flow rates do vary, and to a degree that is clinically significant. While infusing at a rate of 4 cc/hr, elevating the pump 50 cm produces a bolus of 0.120 mL over 5 sec. and lowering the pump 50 cm results in no flow and low flow for 2 min. 20. sec.

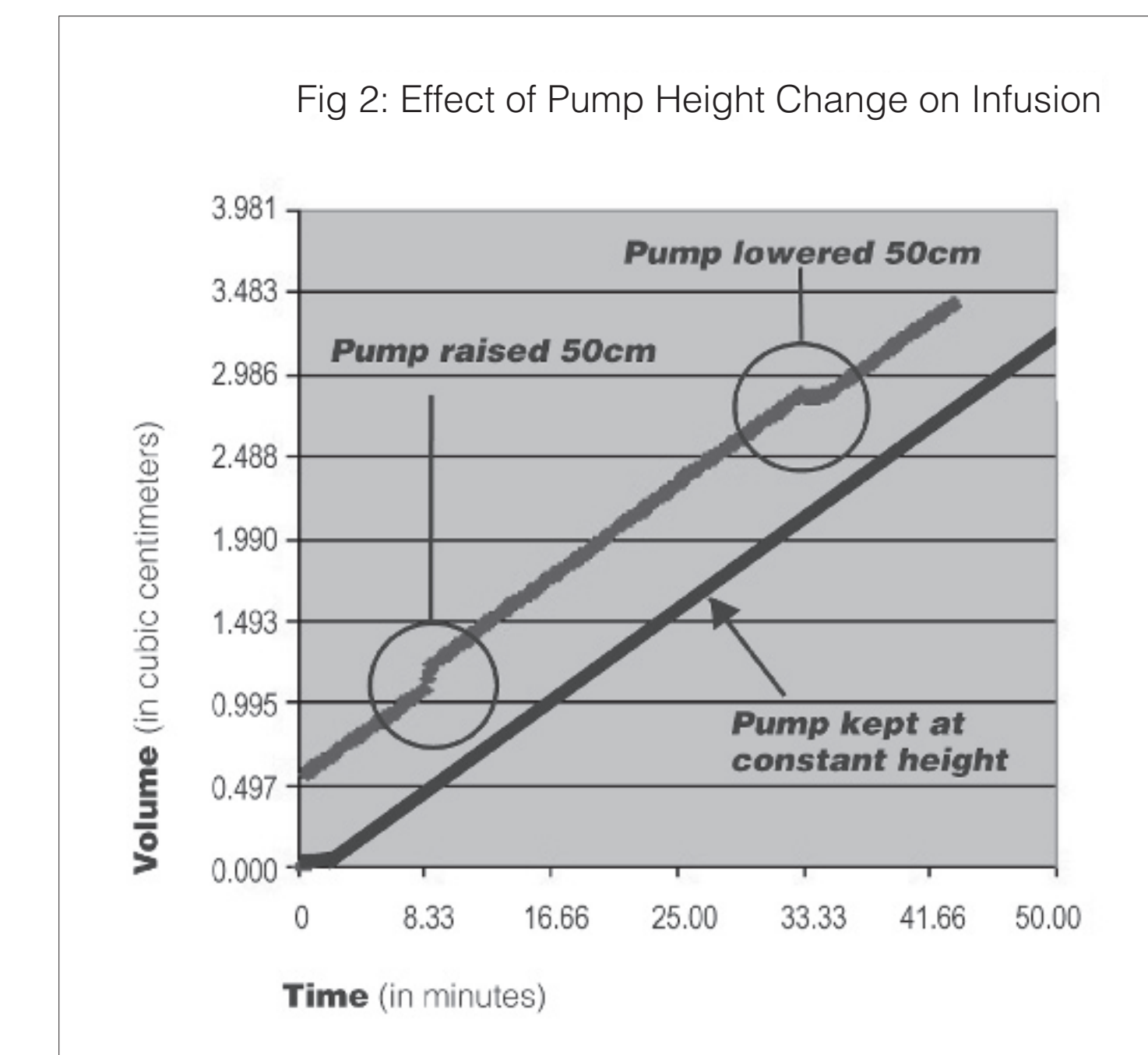


Fig 2: Effect of Pump Height Change on Infusion

Figure 3 shows drug delivery (at 2cc/hr) begins within 6.5 min if the pump is purged at the start of an infusion. Failure to purge the pump delays the start of drug delivery to 20 min.

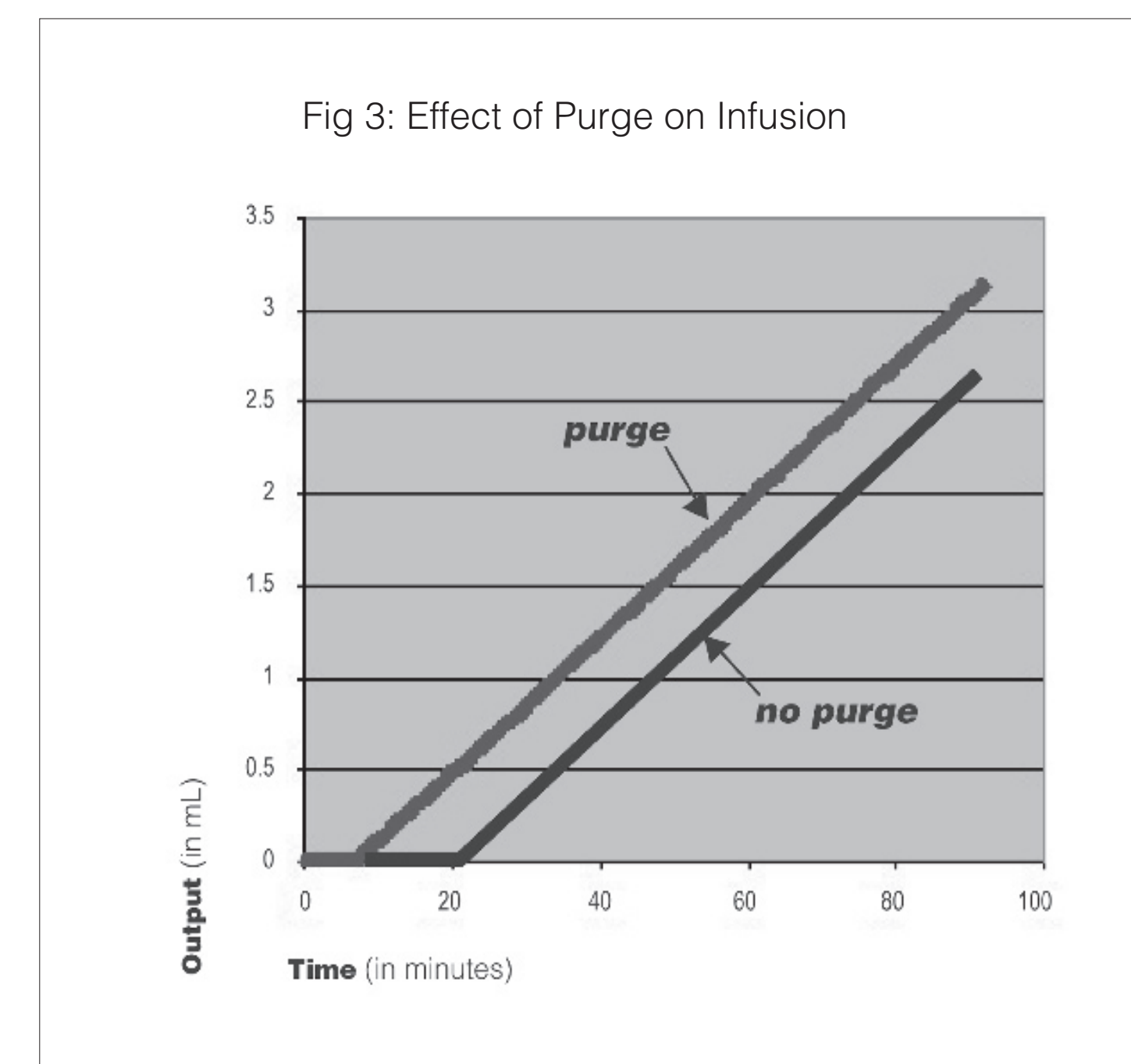


Fig 3: Effect of Purge on Infusion

### What This Means

Clinically relevant situations can now be simulated using this device, which can automatically measure volumes as low as 0.001 mL ( $\pm 0.0005$ ) and control vertical displacement to within  $\pm 6.35 \times 10^{-3}$ mm over a 175 cm range.

Any infusion device can be evaluated to determine the influence of height on the infusion's hydrostatic pressure.

### What Lies Ahead

New technologies may make low flow rate infusions easier to manage. The ability to make precise measurements easily is critical to the development of such devices. This automated test bench permits precise, repeatable, and highly accurate measurements of device performance under both extreme and ordinary conditions of use. This work continues in our laboratory.

### Acknowledgements

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