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Original Contribution

Flow rates through intravenous access devices: an in vitro study☆,☆☆

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Abstract
Study objective: Fluid administration using intravenous (IV) access devices is required in many settings. There are a lack of quantitative data comparing traditional cannulas and modern access devices. We aimed to investigate flow rates through modern intravenous access devices using an in vitro system.
Design: This is an experimental study.
Setting and measurements: Rates of flow of intravenous fluids (crystalloid and colloid) were measured through various access devices using a uroflowmeter. Standardized conditions and repeat measurements ensured validity. Fluid was administered with or without the addition of a pressure bag and needle-free valve.
Main results: Increasing the size of cannulas improved flow. Fourteen-gauge cannulas had significantly higher mean flow rates compared to 14G central venous lines in all conditions (136% higher with no pressure bag/valve; 95% CI, +130% to +152%; $P < .001$). Both the emergency infusion device and rapid infusion catheter produced significantly increased mean flows compared to a 14G cannula (12% higher for emergency infusion catheter; 95% CI, +7% to +15%; $P = .008$, and 15% higher for rapid infusion catheter; 95% CI, +12% to +21%; $P = .004$). The needle-free valve significantly impaired flow on 16G and wider IV access devices (36% lower with no pressure bag using 14G cannula; 95% CI, −29% to −46%; $P = .003$), but flow reductions in narrower IV access were insignificant. Pressure bags significantly improved flow in all devices, in all combinations.
Conclusions: Flow rates in IV devices can be maximized by pressure bag use and removal of needle-free valves. The rapid infusion catheter and emergency infusion catheter allow some increase in flow over a 14G cannula. Familiarity with varying flow rates across IV access devices could better inform clinical decisions.

1. Introduction

Intravenous access is a common requirement among patients admitted to hospital. Clinical circumstances will dictate the number and caliber of intravenous (IV) access

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devices needed. When rapid resuscitation is required, the choice of intravenous access device is important. Wide-bore access devices can be difficult to place in certain patients. This is a commonly encountered issue within pediatrics, care of older persons, patients in severe shock, and patients with a history of intravenous drug use. When urgent fluid resuscitation is required, in the face of suboptimal IV access, it is important for the clinician to be able to optimize flow to the patient and ensure that any devices that reduce flow rate are removed.

There are currently a plethora of intravenous access devices, ranging from standard cannulas more advanced access devices such as central venous catheters and rapid infusion catheters (RIC). In our institution, it is standard practice to insert a needle-free valve between the IV cannula and the giving set to facilitate change of giving set. It was the belief that this limited flow, which led to the inception of this study.

Previous studies are old or fail to address the combination of flow-determining factors which we come across in our clinical practice [1,2]. No study to date has simultaneously investigated the flow in a range of modern intravenous access devices in combination with different fluid types, needle-free valves, and pressure bags.

The aim of our study was to determine the relative influence of the various components in an intravenous line on delivered flow rates. We wanted to provide practical information on mechanisms to maximize flow rates in clinically relevant settings.

2. Materials and methods

2.1. Methods

We followed the methods of Stoneham in our standardized experimental setup (Fig. 1) [1]. A 500-mL IV fluid bag (Plasma-Lyte; Baxter, USA, or Voluven 6%; Fresenius, Australia) was suspended at its junction with the giving set spike, 100 cm vertically above the IV access device. We used a blood/solution pump set for all experiments because it was the widest bore, highest flow giving set we had available (latex-free, 200 cm set length, priming volume 70 mL; Alaris Products, Ashford, UK). We noted from Hall et al [3] that for each bag the flow rate diminished slightly when < 100 mL remained, and testing was therefore limited to the first 400 mL from each bag after which the bag was replaced. The IV flow regulator was fully open during measurements. The final 5 cm of the giving set was maintained in a horizontal orientation. A needle-free valve (Fig. 2A; SmartSite needle-free valve 2000E; Alaris Products) and/or a 500-mL pressure bag set to 300 mm Hg (InfusaScan scannable pressure infusor; GE Healthcare, USA) were added to the apparatus when indicated by the study protocol.

The following IV access devices were tested:

- 14G, 16G, 18G, 20G, and 22G cannula devices (Vasofix Safety; B. Braun, Melsungen, Germany)
- 14G central venous catheter (Quad-Lumen Central Venous Catheterization Set; Arrow-Howes, Reading, USA)
- Emergency infusion device (EID, 8.5F; Arrow-Howes; Fig. 2B)
- Rapid infusion catheter exchange set (8.5 Fr; Arrow-Howes, Reading, USA; Fig. 2C)

Flow rate was measured using a uroflowmeter (Urodyn 1000; Dantec, Rugby, UK). An explanation of how the uroflowmeter works can be found in the paper by Hall et al [3]. Flow rate was measured over at least 15 seconds. Time was measured using a stopwatch. A sample size of 3 was used for each combination as in previous published work, given the small variation in measurements [1,3].

2.2. Calibration

Calibration of the uroflowmeter was done regularly by the hospital's biomedical engineering department. We tested the calibration with colloid and crystalloid to ensure the accuracy of the uroflowmeter for both fluids. A 50-mL syringe (BD Precise, Franklin Lakes, USA) was emptied into the uroflowmeter. Various volumes of fluid from 20 to 100 mL were used for calibration.

2.3. Statistical analysis

Continuous variables are presented as means with SE. Independent samples and paired Student t tests were used where appropriate to compare variables. Two-sided $P < .05$ was considered significant. Statistical analysis was carried out using GraphPad Prism 5.

3. Results

3.1. Comparison with manufacturer-quoted figures

There was an increasing discrepancy between the manufacturer's quoted flow rates and the flow rates obtained within our model when using larger IV cannulas (Table 1).

3.2. IV access device comparisons

Increasing size of cannulas increased flow (Fig. 3). Fourteen-gauge cannulas had significantly higher mean flow rates compared to 14G central venous catheters in all conditions (136% higher with no pressure bag/valve; 95% confidence interval [CI], +130% to +152%; $P < .001$). Both EID and RIC produced significantly increased mean flows compared to a 14G cannula (12% higher for EIC; 95% CI,