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ORIGINAL ARTICLE /*Research and new development*

In vitro evaluation of percutaneous drainage catheters: Flow related to connections and liquid characteristics

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KEYWORDS
Percutaneous drainage;
Drainage catheter;
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Stopcock

Abstract
Purpose: To evaluate the effect of catheter connections on drainage catheters' flow rate.
Materials and method: The *in vitro* model used commercially available catheters (8.5-F, 10.2-F, 12-F, and 14-F), connections - Luer-lok (2.33 mm inner diameter), and stopcocks (1.33 mm, 2.00 mm, and 2.67 mm inner diameters), water, ultrasound gel, textured vegetable protein (TVP) 2-mm particles, and collection bags. Plain water, viscous fluid (30% ultrasound gel solution in water), or water/viscous fluid with TVP were placed in collection bags and drained by gravity through each of the catheters and each connection. The flow rate was measured, recorded, and compared for each catheter and each connection as well as to the control flow rate of the catheters without connections. Ten one-minute trials were performed, and the mean flow rates were analyzed using Student *t*-test and Pearson correlation coefficient.
Results: Flow rate was significantly decreased in the 12-F and 14-F catheters with all stopcock and Luer-Lok connections with both water and viscous fluids. There was no significant reduction in flow for the 8.5-F and 10.2-F catheters with the 2.00-mm, 2.33-mm, and 2.67-mm connections; flow rate was significantly decreased in the 8.5-F and 10.2-F catheters with the 1.33-mm connection. A majority of trials with particulate fluid became occluded, and no consistent pattern between connections could be made.

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Conclusion: This *in vitro* study suggests that stopcock and Luer-Lok connections limit catheter flow rate when their inner diameter is less than that of the drainage catheter.

Image-guided percutaneous drainage (PD) of intraabdominal abscesses is among the most common procedure performed by interventional radiologists and is the standard of care for the majority of intraabdominal fluid collections [1]. One recent study querying the Medicare part B procedural databases showed that as many as 79% of abdominal abscesses are managed by interventional radiologists [2]. Despite how frequently PD is performed, there is considerable variability in catheter selection, size, number, and route [3]. Despite this variability, PD is typically universally successful with suggestive curative and partial successes of over 85% [4].

Catheter diameter is a factor that has been the focus of several *in vitro* investigations [5—8] and few clinical reports [9,10]. Catheter connectors, such as stopcocks and Luer-Lok, are devices that connect commercial catheters to drainage reservoirs. These connections may be the smallest diameter in the drainage system, potentially impeding flow.

The purpose of our study was to evaluate the effect of catheter connections on drainage catheters' flow rate.

Materials and methods

This was an *in vitro* laboratory study that did not require institutional review board approval. All experiments were conducted in a basic science laboratory. Materials in this study included commercial drainage catheters (Cook Medical, Inc., Indiana), commercial stopcocks and a Luer-Lok (Cook Medical, Inc., Indiana), both water and non-viscous fluids, and an ad hoc drainage system that was created to measure fluid flow through catheters and stopcock or Luer-Lok connections (Fig. 1).

Various sizes of single lumen percutaneous drainage catheters — sizes 8.5-, 10.2-, 14.0-French, and the multipurpose 12.0-F size catheter were interrogated. The outer and inner diameters and amount and dimensions of drainage holes of each catheter are listed in Table 1. Three stopcock connections were used: low-pressure, standard, and high-pressure three-way stopcock (Fig. 2), with their respective inner diameters listed in Table 2.

Four types of fluids were used to test drainage efficiency: water, viscous fluid, water with particulate matter, and viscous fluid with particulate matter. Viscous fluid was a 30% dilution of ultrasound gel at a viscosity of 12 mPa·sec. Fifteen grams of textured vegetable protein, < 2 mm in size, was then added to the water and viscous fluid to create particulate matter.

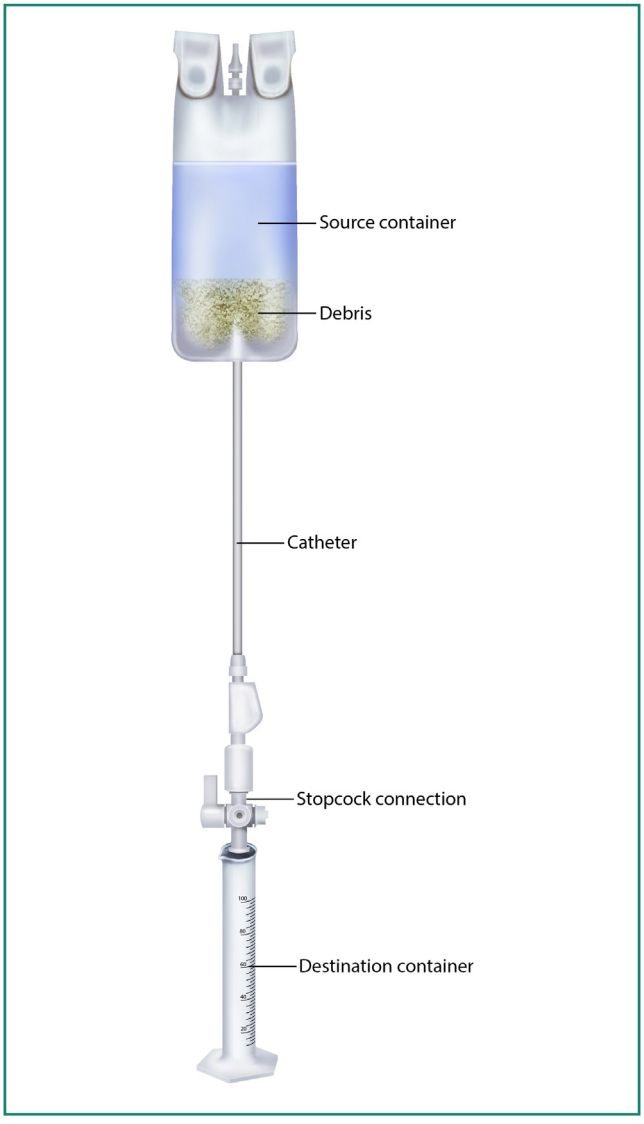

Figure 1. *In vitro* drainage system model.

The drainage model was constructed with a source reservoir (a 540-mL urine leg bag) above a catheter and a collection container (Fig. 1). Each of the four fluids was drained by gravity through the catheters, both without a stopcock connection (control) and with the stopcock connections and collected into the measuring container. The liquids flowed for 1 minute through the catheter into the measuring container in a total of 10 trials for each unique

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