Does Size Matter? Measured and Modeled Effects of Suprapubic Catheter Size on Urinary Flow

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OBJECTIVE To quantify the effects of catheter size and urinary sediment on catheter drainage, and to determine the French size at which catheter upsizing yields a diminished marginal return in flow.

MATERIALS AND METHODS Latex Foley catheters (12-26 French [Fr]) were connected to a simulated bladder. Passive drainage times of 450 mL water were measured over 5 successive trials for each catheter size. The effect of sediment was modeled by adding 2g of infant rice cereal to the water. Measurements were repeated in half-length catheters to assess the effect of catheter length. A computational model of resistance was compared to measured data. Percent differences in catheter resistance based on measured catheter dimensions were determined.

RESULTS Catheter resistance significantly decreased ($P < .001$) with increasing catheter size. All catheter sizes had significantly faster ($P < .001$) drainage times after being shortened, except for the 16 Fr catheter. All catheter sizes exhibited significantly prolonged ($P < .001$) drainage times after the addition of sediment, except for the 16 Fr catheter. Beyond 18 Fr, larger catheter sizes provided diminishing marginal returns in flow; upsizing from 18 Fr to 20 Fr reduced measured resistance by 19%, which was the lowest improvement in resistance between 2 catheter sizes. The coefficient of determination (R^2) between measured and modeled resistances was 0.9754, confirming that the model of catheter performance was accurate.

CONCLUSION Marginal improvement in urine flow occurs with catheter upsizing after 18 Fr; however, shortening catheter lengths may serve as another means of improving flow. UROLOGY 102: 266.e1–266.e5, 2017.

Suprapubic tubes provide an alternative to indwelling urethral catheters in patients requiring long-term urinary tract drainage. Suprapubic tubes offer several advantages over urethral catheters, including lower risks of urethral trauma, improved body image, and catheter-free genitalia for sexually active patients.[1] Overall patient satisfaction is higher in patients using suprapubic tubes compared to urethral catheters. Suprapubic tubes are frequently used to manage neurogenic lower urinary tract dysfunction,[2] and provide improved quality of life in these situations.[3,4] Suprapubic tubes, used on occasion acutely after prostatectomy, are associated with higher patient satisfaction, reduced bother in terms of personal and genital hygiene, less pain, and lower levels of frustration when compared to indwelling urethral catheters.[5,6] Suprapubic tubes have also been observed to impart less frustration and difficulty compared with clean intermittent self-catheterization after prolapse or incontinence surgery.[7]

Multiple sizes and lengths of suprapubic tubes exist, but currently no published recommendations on their use exist.[1] Thus, the choice of suprapubic tube size is often based on surgeon preference, which likely is influenced by prior experience, previous training, and catheter availability. With that, catheter sizing can be individualized by clinical situation; for instance, a larger-diameter catheter may be best for clot-laden hematuria. Just as larger 3-way catheter sizes produced higher flow rates that may reduce the risk of urine stagnation,[8] smaller catheters are anecdotally associated with higher rates of obstruction, one of the most common difficulties with suprapubic tubes.[9-11] However, larger catheters likely impart a higher risk of catheter tract dilation and subsequent leakage, which are other common challenges suprapubic tubes present.[10]

This project assessed the hypothesis that a given catheter French (Fr) size exists, above which further increases in catheter diameter yield diminishing marginal returns in urine flow. Additional aims of the study were to measure the relationship between catheter resistance and catheter size, determine the effects of catheter length and the presence of sediment on catheter drainage, and assess a

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model catheter resistance using catheter dimensions and the Hagen-Poiseuille equation.[12]

MATERIALS AND METHODS

Catheter Resistance Testing

A Hollister urinary leg bag (Vitality Medical, Product #9805, Salt Lake City, UT) was used to model a fluid-filled bladder (Fig. 1A). The leg bag was cut open to allow for easy pouring of fluid and also ensure that the fluid within the bag was under constant atmospheric pressure. All catheters tested in this study were 2-way, 44 cm latex Foley catheters, ranging from 12 Fr to 26 Fr in size, and were manufactured by Bardex (12 Fr and 24 Fr, Foley catheter, Covington, GA) or Dover (14 Fr, 16 Fr, 18 Fr, 20 Fr, and 22 Fr hydrogel coated latex Foley catheter, 26 Fr silicone elastomer coated latex Foley catheter, Beseri, Perlis, Malaysia). Catheters were attached to the fluid reservoir via the drainage port and a catheter clamp was placed across the hub, excluding the balloon channel, to prevent premature drainage from the reservoir. A 450 mL volume of tap water was placed in the reservoir, after which the clamp was removed and the fluid drained under gravity with drainage time recorded. Time was stopped when the fluid had drained to the level of the catheter attachment point. This was repeated for a total of 5 trials using the same catheter within each catheter size.

The effect of catheter length and the presence of sediment in the fluid were assessed. For catheter length, the catheters were cut to half-length (22 cm), with the half containing the drainage port used to repeat the experiment. For the effect of urinary sediment, the experiment was repeated with full-length catheters but using a solution of 2 g rice cereal mixed into the 450 mL of tap water. Rice cereal was chosen as a means of adding sediment into the fluid to mimic the epithelial sloughing that occurs with chronic suprapubic tube placement, as particle size and consistency closely resemble that observed in urinary catheter drainage tubes. No measurement or viscosity testing was performed to compare the rice cereal to actual urine sediment.

Using the measured drainage times of plain water in unaltered catheters, the resistance to flow of each catheter was calculated. In doing so, the assumption was made that an average, constant drainage from the bladder model occurred with hydrostatic pressure fixed as the mean fluid column height within the reservoir (see Eq. A, Fig. 1B). Percent differences in resistance were calculated between the measured resistance for each catheter size and the next smallest catheter size to determine the marginal return in decreased resistance to flow by catheter upsizing.

Catheter Resistance Modeling

The length of all tested catheters was recorded and, when cut in half, the diameters of the drainage channels were measured using digital calipers. Single measurements from 1 catheter of each size were obtained with the assumption that quality-control processes employed in catheter manufacturing result in minimal variability in their physical structure. Using these dimensions, catheter resistance was modeled by assuming a cylindrical lumen and applying the Hagen-Poiseuille equation (see Eq. B, Fig. 1B). The viscosity of water was used (0.89 mPa) to approximate that of urine.[13] A constant was added to the modeled resistances to account for fixed resistances related to the simulated bladder.

Data Analysis

Measured catheter resistances for unmodified catheters with plain water were compared via one-way analysis of variance (ANOVA). For the catheter length experiment, a two-way ANOVA was used to compare the full-length and shortened catheter drainage times. A two-way ANOVA was used to compare the drainage times of

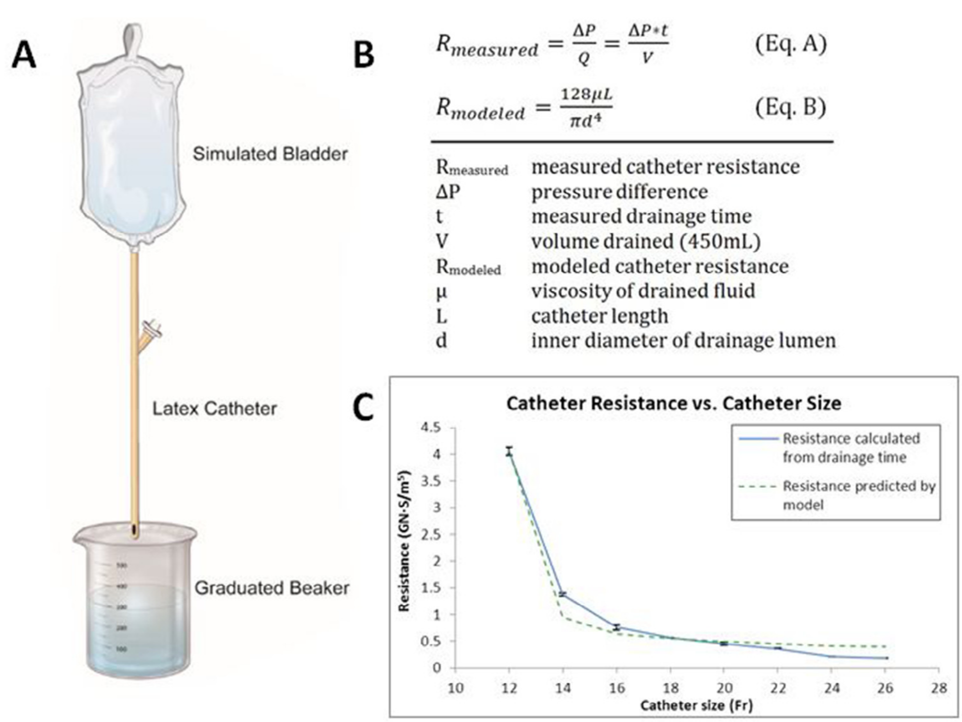

Figure 1. (A) Schematic of experimental setup; **(B)** equations used to calculate catheter resistance; and **(C)** comparison of calculated and modeled catheter resistance.