The Variable Flow Characteristics for Different Brands of 3-Way Urinary Catheters: Proposing an Alternate and Accurate Standardised Labelling System

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OBJECTIVE To evaluate an alternative catheter labelling approach for 3-way catheters based on the drainage channel and irrigation channel cross-sectional area (CSA), which impacts catheter flow rate characteristics.

MATERIALS AND METHODS Three-way 22Fr catheters from Bard (Bard Limited), Rusch Simplastic (Teleflex Medical), Dover (COVIDIEN), and Rusch Golden were included in the study. Irrigation channel, drainage channel, and overall CSAs were digitally measured with an image-processing program. Irrigation channel and drainage channel flow rates were measured and correlated with their corresponding catheter CSA values.

RESULTS Catheter CSA and French value did not predict flow-rate characteristics, but irrigation channel CSA and drainage channel CSA were predictive. The 22Fr Rusch Simplastic catheter had the largest irrigation channel CSA (2.87 mm^2) and drainage channel CSA (12.6 mm^2), and had the greatest irrigation (5.27 ± 0.02 ml/s) and drainage flow rates (14.42 ± 0.22 ml/s). Twenty-two French gauge Rusch Golden catheters had the smallest irrigation channel CSA (1.34 mm^2) and drainage channel CSA (7.82 mm^2) and the lowest irrigation (1.83 ± 0.03 ml/s) and drainage flow rates (1.83 ± 0.03 ml/s).

CONCLUSION An alternative catheter labelling system to include overall CSA, irrigation channel CSA, and drainage channel CSA values would provide more accurate and transparent data relevant to anticipated drainage and irrigation flow rates. The proposed labelling method will assist urologists in selecting 3-way catheters for bladder irrigation. UROLOGY ■■: ■■–■■, 2016. © 2015 Elsevier Inc.

The irrigation characteristics of 3-way catheters used for continuous bladder irrigation (CBI) are important for preventing intravesical clot formation following transurethral resection of the prostate and transurethral resection of the bladder tumour surgery. Several CBI system methodologies have traditionally been described but investigatory comparative data between CBI systems is lacking.[1,2] In the 19th century, Charriere proposed measuring catheter size based on French gauge (Fr) corresponding to the catheter's diameter (millimeter multiplied by 3).[3] Manikanden et al suggested that 22French (Fr) and 24Fr 3-way catheters had equivalent irrigation and drainage flow characteristics.[4] This study may be limited because comparative overall catheter cross-sectional area (CSA), irrigation channel CSA, and drainage channel CSA were not investigated.

Urinary catheter flow is governed by the principles of Poiseuille's law.[5] The law states that Poiseuille flow (steady flow in a straight, rigid, circular pipe) is determined by the resistance to flow (R_f) and is expressed by equation (1).

$$R_f = \frac{8\mu L}{\pi R^4} \qquad (1)$$

where μ is the fluid viscosity, L is the length of flow channel, and R is the radius of the flow channel.

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The pressure drop across the flow channel (ΔP) is equal to the product of R_f and the flow rate (Q). Consequently, measured irrigation and drainage flow rates are very sensitive to changes in channel radius and CSA as the flow resistance is inversely related to the 4th power of the radius (2nd power of the CSA). In the present study, we digitally measured luminal CSAs for 3-way catheters and explored the relationship between luminal CSA and flow-rate characteristics.

MATERIALS AND METHODS

Four commercially available 3-way urethral catheters were randomly selected to compare their irrigation and drainage properties. Studies were performed in the Centre for Applied Biomedical Engineering Research, Co. Limerick, Ireland. Twenty-two French gauge 3-way catheters from Bard (Bard Limited) (n = 3), Rusch Simplastic (Teleflex Medical) (n = 3), Dover (COVIDIEN) (n = 3), and Rusch Golden (n = 3) were investigated. Irrigation channel, drainage channel, and overall CSAs for each 22Fr 3-way catheter were measured. The primary endpoints included a comparison of the luminal CSAs for each catheter and the relationship between luminal CSA and flow rate.

CSAs (mm^2) were calculated using Image J, a freeware image-processing program that accurately records imported image-based measurements (imagej.nih.gov/ij/). Initially, a scale is set using a defined reference based on "calibration length" from the imported image. The irrigation channel, drainage channel, and overall circumferential CSA were measured after dividing the catheter proximal to the anchoring balloon and imaging the relevant lumen with a Nikkai digital microscope (Fig. 1A-D). CSA at each location was calculated using the circle or polygon section function, depending on the internal design shape of each channel (ie regular [circular] or irregular [noncircular], respectively) (Fig. 1E-H).

The experimental setup for measuring irrigation flow rate is illustrated in Figure 2A. Irrigation flow rates, maintained at constant pressure, were measured by draining water from a refilling reservoir at a height of 130 cm. Flow rate was measured through the catheter's irrigating channel into a container for 60 seconds. A constant pressure head was sustained by a pump that transferred water from a lower reservoir to the upper reservoir which contained an overflow pipe. The constant pressure head height was thus maintained by the constant volume of water in the upper reservoir. The collected volume was used to calculate irrigation flow rate values (ml/s) for each catheter. Each experiment was performed in triplicate and 2 catheters were tested for each brand.

The experimental setup for measuring drainage flow rates is illustrated in Figure 2B. The irrigation port for each catheter was spigoted and water from the upper reservoir drained through the drainage channel for 60 seconds. Again, the collected volume was weighed to calculate drainage flow-rate values (ml/s) for each catheter. Each experiment was performed in triplicate and 2 catheters were tested for each brand.

RESULTS

CSAs for each catheter are demonstrated in Table 1. 22Fr Bard catheters had the largest overall CSA (52.8 mm^2) and

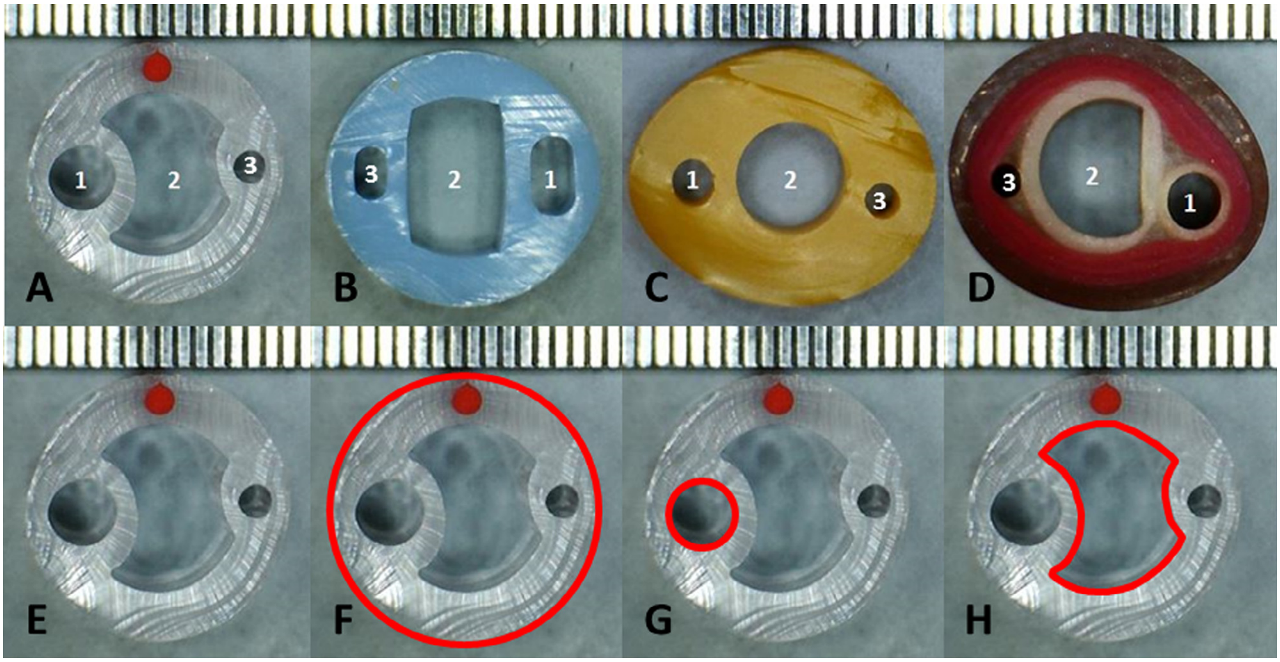

Figure 1. **(A-D)** CSA for each of the 22Fr 3-way catheters investigated as part of this study with number 1 indicating the irrigation port, number 2 indicating the drainage port, and number 3 indicating the anchoring balloon inflation channel. **(A)** 22Fr Rusch S, **(B)** 22Fr Dover, **(C)** 22Fr Rusch G, and **(D)** 22Fr Bard. **(E-H)** Measuring CSA with the image processing programme Image J. **(E)** The catheter section examined. **(F)** The overall CSA measured using the circle select function and fitting the circle to the outside of the catheter section. **(G)** CSA for the irrigation port measured using the circle select function and fitting it to the outer parameter of the irrigation port. **(H)** CSA for the drainage port measured using the polygon selection function. (Color version available online.)