Double J stent의 side hole이 요흐름에 미치는 영향

김경욱* · 최영호** · 김형호* · 서상호***

Effect of Side Holes of a Double J Stent on Urine Flow

Kyung-Wuk Kim*, Young Ho Choi**, Hyoung-Ho Kim*, Sang-Ho Suh***

Abstract : A double J stent has been used widely these days for the patients with a ureteral stenosis or with renal stones and lithotripsy. The stent has multiple side holes in the shaft which supply detours for urine flow. Even though medical companies produces various forms of double J stents that have different numbers and positions of side holes in the stent, the function of side holes on fluid dynamics has not been studied well. Here, flow rate and pattern around side holes of a double J stent were evaluated in curved stented ureter models based on the human anatomy and straight models for comparison.

1. Introduction

A double J stent among ureteral stents is widely used these days and many medical companies produce the stent. A double J stent is composed of a shaft and proximal and distal coils and it has multiple side holes along the axis of the stent. The role of side holes of a double J stent must be a supply of detours in a stented ureter. The role was seen well at the side holes around an in-stent stenosis in a study using a straight ureter model. Here, we made models of the curved stented ureter and evaluated the effect of number and position of side holes on urine flow rate and flow pattern.

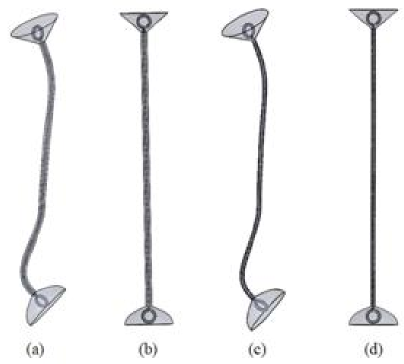

Fig. 1. Models of curved (a, c) and straight (b, d) stented ureters. They have the ureteral diameter of 4.57 mm (a, b) or 3 mm (c, d).

2. Methods

The model of a curved ureter made based on the human anatomy was used as a backbone. The diameter and length of the ureter was 4.57 or 3 mm and 226.21 mm. A double J stent has multiple side holes in the shaft. The diameter of the side holes was 1 mm, and 10 different types of stents with regard to the number and position of side holes were modeled. The first is a stent with no side holes in a shaft. The others are stents with different numbers (11, 22, 45) and angular rotations (45°, 90°, 180°) of side holes.

The governing equations, continuity equation and Navier-Stokes equation, are converted to the algebraic equations by the discretization method using finite volume method. In order to investigate the flow phenomenon in the ureter, Ansys CFX was used and CFX codes use a pressure based AMG coupled solver. The urine viscosity and density of

* 숭실대학교 일반대학원 기계공학과
** 서울대학교 보라매병원 영상의학과
*** 숭실대학교 기계공학과

0.654 mPa·s and 1003 kg/m^3 were applied here. The urine could be considered a non-compressible and Newtonian fluid. Pressure was used for the boundary condition here; the inlet (48.9, 97.8, 195.6 Pa) and outlet (0 Pa). It was for all the 40 models to enable the comparison between the models. To generate meshes in the ureter models, the same size of mesh was set up and prism mesh was used for side holes. The meshes were generated with Ansys ICEM. The bigger the number of side holes is, the smaller the area for meshing is. In this research, geometry of stent and hole is complex and so, meshes were only made into tetrahedron. Therefore, the number of nodes and elements for a model depended on the model types; nodes 1,070,687 ~ 2,545,318 and elements 5,677,350 ~ 14,519,081. These are used by the solver to construct control volumes.

3. Results and Discussion

Total flow rate was higher in the stent with a bigger number of side holes. The inflow and

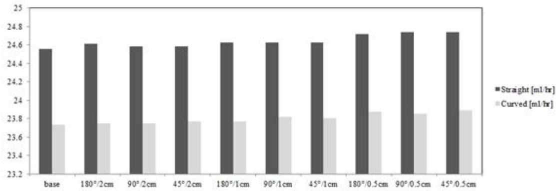

Fig. 2. Total flow rates in straight and curved stented ureters (ureteral diameter of 4.57 mm, pressure difference of 48.9 Pa).

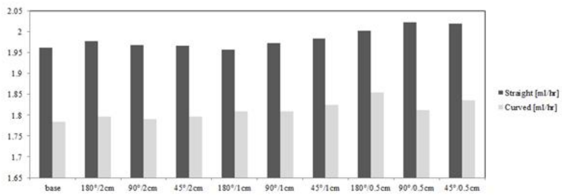

Fig. 3. Total flow rates in straight and curved stented ureters (ureteral diameter of 3 mm, pressure difference of 48.9 Pa).

outflow to the stent through the side holes in the curved ureter was more active than in the straight ureter. It means that the flow through side holes exists even in the ureter without ureteral stenosis or occlusion and even in the straight ureter. When the diameter of the ureter changed, in-stent flow rate in the ureter did not have any change and extraluminal flow rate was higher in the ureter with a bigger diameter.

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