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RESEARCH ARTICLE

SIMULATION OF THE INTERACTION OF PROSTATE ENLARGEMENT TO THE URETHRA AND THE NECK OF URETHRA BLADDER BY FINITE ELEMENT METHOD

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ABSTRACT

The purpose of this simulation is to investigate prostate enlargement affecting the urethra and the neck of the urethra bladder using finite element analysis. The simulation results showed that the change and the distortion of the urethra pinched by the zones of the prostate in cases calculated. Besides, the simulation interaction of the results between the central zone with bladder may help scientists develop a theoretical basis for the inflammation in the neck of the urethra bladder. Moreover, the simulation of flow in the urinary deformed by prostate enlargementis also studied, explanation symptoms of weak urine flow and repeated urination.

INTRODUCTION

Although prostate hypertrophy does not increase the risk for prostate cancer or sexual problems which is most common in men over 50. It affects the quality of life, especially bladder damage and infection. In severe cases, it can cause blood in the urine and kidney damage (1, 2).Modeling the prostate enlargement impact on the urethra and the neck of the urethra bladder, the impact between the central zone and the bladder may help scientists build a theoretical basis for the common symptoms of prostate hypertrophy. As a result, they will have an overview of the impact of prostate enlargement on surrounding organs. Since the doctor will diagnose the extent of the disease and provide appropriate treatment modalities.

1.Calculation

The simulation is calculated by the indirect method.

2.1. Deformity

Equation:

$$Ku = F \tag{1}$$

- $K = \sum_{e=1}^{N} k_e$: total stiffness matrix
- u : nodal displacement vector
- N : number of elements
- k_e :element stiffness matrix
- F : loading vector

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2.2. Calculate the flow of urine

From the law of conservation of mass, the continuity equation is written generalized as:

$$\frac{\partial \rho}{\partial t}+\frac{\partial(\rho V_i)}{\partial x_i}=0 \qquad (2)$$

Momentum equation:

$$\frac{\partial \rho V_i}{\partial t}+V_i\frac{\partial(\rho V_j)}{\partial x_j}=\rho g_i-\frac{\partial P}{\partial x_i}+\frac{\partial}{\partial x_j}(\mu_e\frac{\partial V_i}{\partial X_j})+T_i \qquad (3)$$

$$T_i=\frac{\partial}{\partial X_j}\left(\frac{\partial V_j}{\partial X_i}\right) \qquad (4)$$

Generalized energy equation:

$$\frac{\partial}{\partial t}(\rho C_p T_0)+\frac{\partial}{\partial x_i}(\rho V_i C_p T_0)=\frac{\partial}{\partial x_i}(K\frac{\partial T_0}{\partial x_i})+W^v+E^k+Q_v+\varphi+\frac{\partial P}{\partial t} \qquad (5)$$

C_p = heat capacity of urine
T_0 = total temperature
K = Heat transfer coefficient of urine
W^v = rate of viscous work
φ = dissipation by viscosity
E^k = Turbulent flow kinetics

With:

Turbulent flow model: when the effective viscosity is equal to the total laminar flow viscosity and turbulent flow viscosity

$$\mu_e=\mu+\mu_t \qquad (6)$$

The viscosity viscosity is calculated according to the function of Spalding and Launder

$$\frac{\partial \rho k}{\partial t}+\frac{\partial(\rho V_i k)}{\partial x_i}=\frac{\partial}{\partial x_i}\left(\frac{\mu_t}{\sigma_k}\frac{\partial k}{\partial x_i}\right)+\mu_t\phi-\rho\varepsilon+\frac{C_4\beta\mu_t}{\sigma_t}\left(g_i\frac{\partial T}{\partial x_i}\right)$$

$$\frac{\partial \rho\varepsilon}{\partial t}+\frac{\partial(\rho V_i\varepsilon)}{\partial x_i}=\frac{\partial}{\partial x_i}\left(\frac{\mu_t}{\sigma_\varepsilon}\frac{\partial \varepsilon}{\partial x_i}\right)+C_1\mu_t\frac{\varepsilon}{k}\phi-C_2\rho\frac{\varepsilon^2}{k}+\frac{C_1C_\mu(1-C_3)\beta\rho k}{\sigma_t}\left(g_i\frac{\partial T}{\partial x_i}\right)$$

k = turbulent flow kinetics và ε = Rate of energy dissipation by turbulence

The turbulent flow kinetic energy and its dissipation rate are calculated from the two equations:

The equations (2), (5), (8), (9) are solved by the finite element method for urine flow in three-dimensional space in combination with several different equations to solve the effect of flow on the membranous urethra.

Modeling of prostate enlargement

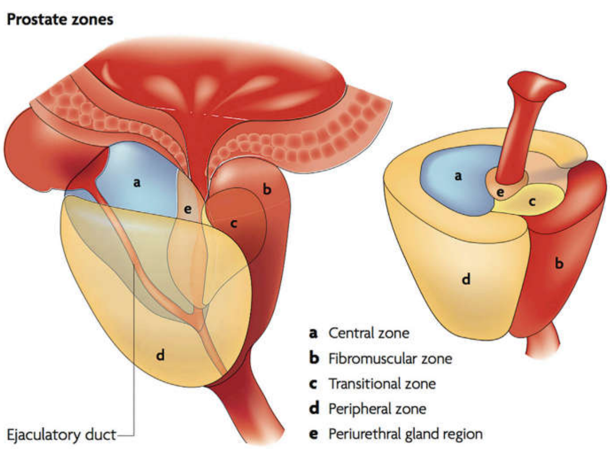


Figure 1. Zonal anatomy of the prostate(3)

The prostate gland is divided into positions (4):Peripheral Zone, Central Zone, Transition Zone, Fibromuscular Zone, Periurethral gland region.

RESULTS

The cases have the same input pressure of 3000 Pa (urine accounted for 50% of bladder volume), and the amount of urine is equal in each case. The simulation is divided into three parts: a 4.4 cm urethra segment with a diameter of 6 mm, the remaining 10 cm, bending angle is 90 degrees. Simulating the impact of the enlarged prostate on the urethra is divided into five cases.

Table 1. Input parameters

No.	Name	Parameter
1	Modulus of elasticity of the urethra and bladder	60000 N/m^2
2	Coefficient of passion	0.475
3	The pressure exerted on the urethra and bladder	8000 N/m^2

•Case 1: The prostate gland in normal state.

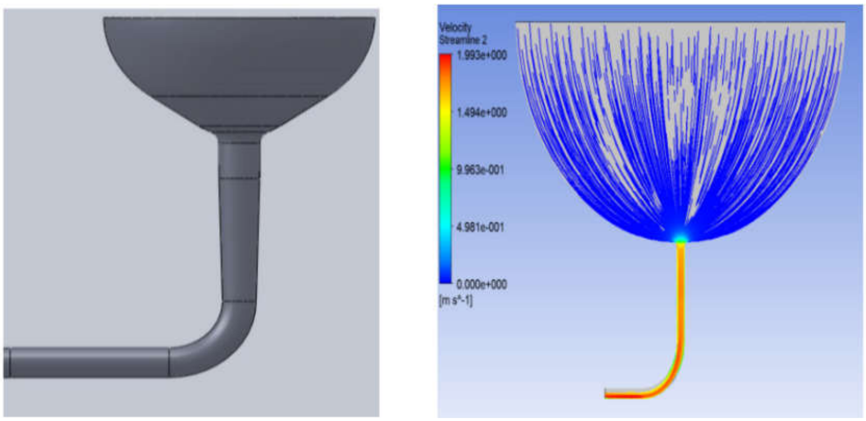


Figure 2. The shape and velocity of urine flow in the normal urethra tube

•Case 2: The central zone is enlarged which affects the urethra and bladder.

20% 30% 40%

Figure 3. Distortion of the urethra and bladder when the central zone enlarges 20%, 30%, and 40%

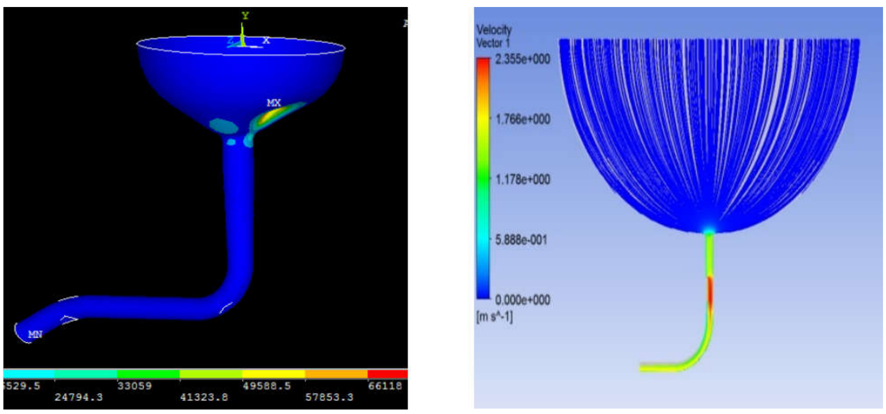
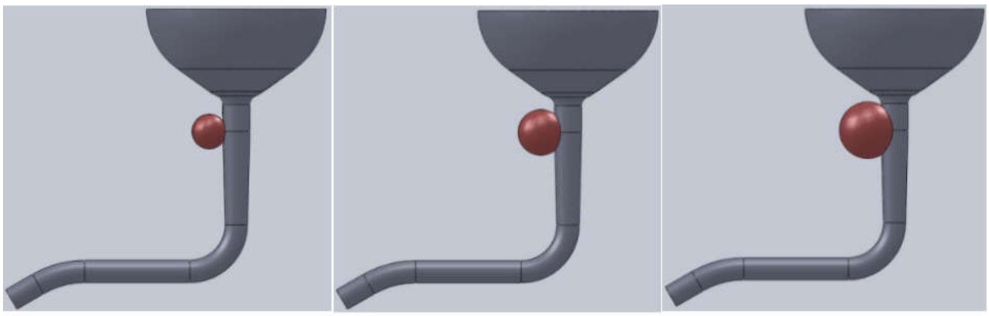


Figure 4. Stress and velocity of urine flow when the central zone enlarges 40%

•Case 3:The transitional zone is enlarged which affects the urethra and bladder.



20% 30% 40%

Figure 5. Distortion of the urethra and bladder when the transitional zone enlarges 20%, 30%, and 40%

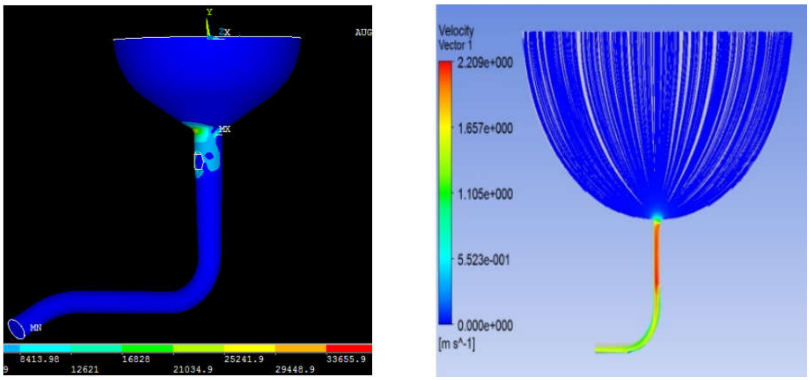
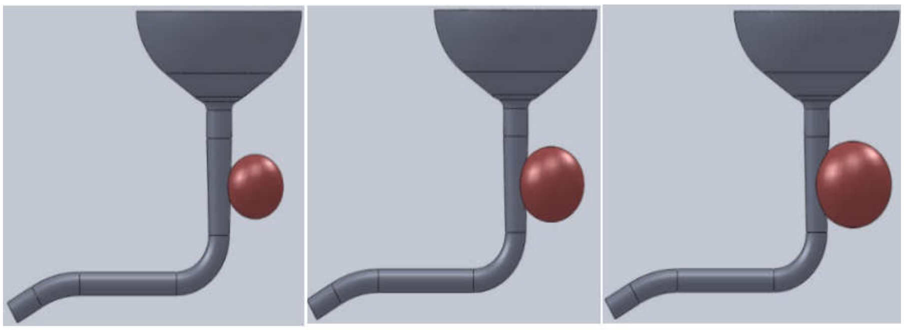


Figure 6. Stress and velocity of urine flow when the transitional zone enlarges 40%

•Case 4:The peripheral zone is enlarged which affects the urethra.



20% 30% 40%

Figure 7. Distortion of the urethra and bladder when the peripheral zone enlarges 20%, 30%, and 40%

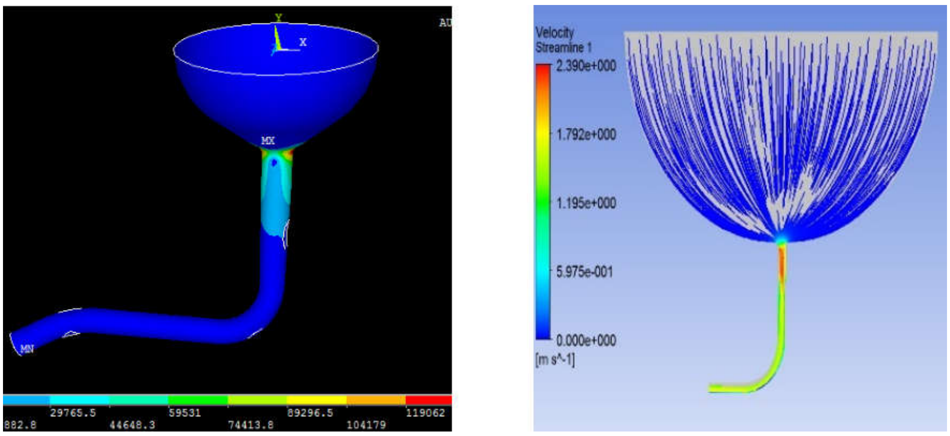
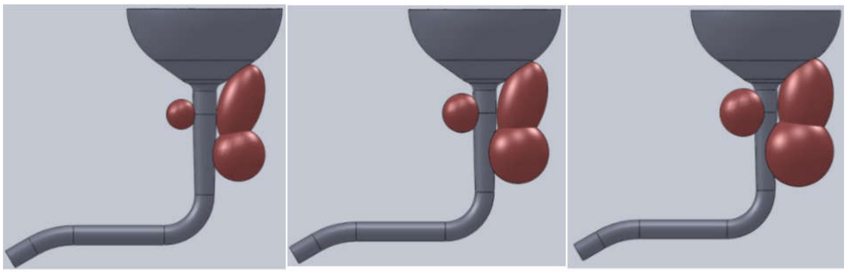


Figure 8. Stress and velocity of urine flow when the peripheral zone enlarges 40%

•Case 5:The prostate gland is enlarged which affects the urethra and bladder



20% 30% 40%

Figure 9. Distortion of the urethra and bladder when the prostate gland enlarges 20%, 30%, and 40%

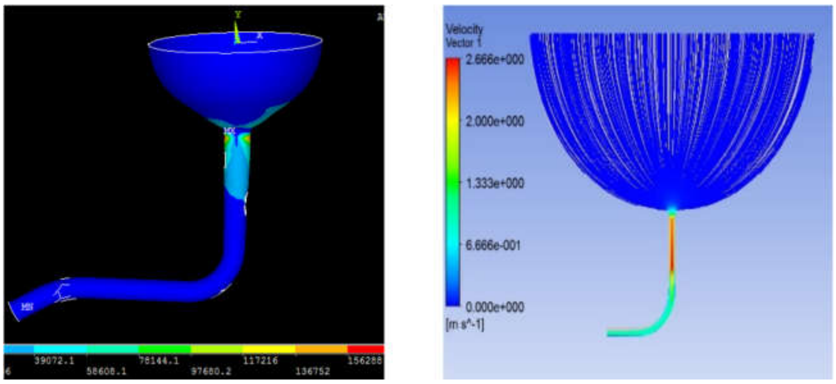


Figure 10. Stress and velocity of urine flow when the prostate gland enlarges 40%

Table 2. Output urine output when the prostate gland enlarges the urethra and bladder

Enlargement	Central zone	Transitional zone	Peripheral zone	Prostate gland
20 %	0.0421 Kg/s	0.0404 Kg/s	0.0417 Kg/s	0.0376 Kg/s
30 %	0.0404 Kg/s	0.0382 Kg/s	0.0403 Kg/s	0.0311 Kg/s
40 %	0.0387 Kg/s	0.0357 Kg/s	0.0385 Kg/s	0.0231 Kg/s

In case 1 - the normal case,the mass flow rate (outlet) is 0.0452 Kg/s.

The simulation results show the effect of benign prostatic hyperplasia on the neck of the urethra bladder: the central zone enlarges 20% which forced the bladder 0,135 mm approximately; the central zone enlarges 30% which forced the bladder 0,188 mm; the prostate gland enlarges 20% which forced the bladder 0,145mm.When the compression is greater, the flow of the urine is decreased.

DISCUSSION

Case 1: In the normal case, the urethra is the normal state which does not constrict. The velocity of urine flow is about 1.21 m/s. At this time, the state of urination is normal, not urinate many times, and no stagnation of urine in the bladder.

Case 2: The central zone is enlarged 20%, 30%, 40%which affects the urethra and bladder. Urine velocity increases. In 20% enlargement, the patient has dysuria, symptoms urinate several times. In 30% and 40% enlargement: the more difficult urination and the more urination occurs. The amount of stagnant urine in the bladder is more and more.

Case 3: The transitional zone is enlarged 20% which affects the urethra. As in case 2, the patient has dysuria, and symptoms urinate several times.

Case 4: The peripheral zone is enlarged 20%, 30%, 40%which affects the urethra. As in case 2, the patient has dysuria, and symptoms urinate several times.

Case 5: The prostate gland enlargement is 20%. The more difficult urination and the more urination occurs. The amount of stagnant urine in the bladder is little. The deformation on the neck of the urethra bladder changes little.

Conclusion

The greater the urethra compression will lead to increased pressure in the deformed segment. This makes the flow of urine from the bladder to the urethra decreases.

The prostate gland enlargement is not only the urethra compressed but also effected on the bladder. Science, the patient infection affecting health. From the simulation results, we can see the symptoms of urine velocity increases, dysuria, and symptoms urinate several times, the amount of stagnant urine in the bladder is still content. The simulation results of stress and velocity of urine flow when the prostate gland enlargement is shown the different compression levels of velocity urine in the urethra. These simulations are used under conditions of ideal parameters. In truth, these conditions are more complicated. The next problem proposed is hypertrophy of heterogeneous in each zone, how the distortion and rate of urine flow will be changed.

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