Saudi Journal of Biological Sciences 26 (2019) 2127–2131

Contents lists available at ScienceDirect

Saudi Journal of Biological Sciences

journal homepage: www.sciencedirect.com

Construction and application of urinary system model with functional bladder module

Min Liu, Yonghong Su *

Department of Urology, Cangzhou Central Hospital, CangZhou 061001, China

ARTICLE INFO

Article history:
Received 10 September 2019
Revised 24 September 2019
Accepted 29 September 2019
Available online 16 October 2019

Keywords:
Bladder module
Urinary system
Detrusor
Model
Safety volume

ABSTRACT

In order to study the construction and application of urinary system model with functional bladder module, bladder model was designed, and appropriate materials was selected to make it, and its performance was studied. The results showed that in the analysis of pressure performance of bladder model, more detrusor instability was found in the model than in the urodynamic test, and there was significant statistical difference ($P < 0.01$). In the analysis of bladder safety capacity, it was found that the bladder safety capacity in the model was much larger than that measured by urodynamics, and there was significant statistical difference ($P < 0.01$). In the analysis of detrusor workmanship and contraction rate, it was found that the normal model group was significantly smaller than the obstruction group, and there was significant statistical difference ($P < 0.01$). Comparing the detrusor contraction rate of the two groups, it was found that the normal group and the obstruction group had significant difference at t3, and there was no statistical difference between the other two groups. Therefore, through this study, it is found that the understanding of urinary system can be enhanced by building bladder model, and the basic operating skills of medical staff can be improved more easily by using bladder model, which achieves the expected results of the experiment. Although some shortcomings have been found in the course of the study, it still provides experimental reference for the clinical study of bladder in the future.

1. Introduction

With the acceleration of social industrialization, people's living standards are constantly improving, and health has become the focus of attention. Bladder, as one of the organs of urinary system, is the only way to excrete urine. The bladder is located in the pelvis and is a cystic structure consisting of smooth muscle. The posterior end of the bladder is the same as the urethra (Kim et al., 2017; Long et al., 2018). In real life, the occurrence of urinary diseases is very common. In order to understand its working principle and diagnosis and treatment more accurately, building an auxiliary model is a very meaningful method (Zhang et al., 2017).

With the development of science and technology, computer technology is also advancing rapidly. It is a very convenient and accurate method to make model objects by using computer-aided technology (Yu et al., 2017; Chu and Zhang, 2018). However, there are few studies on computer-aided bladder models, most of which are animal models. Matsuo, Tomohiro et al. (2017) used green tea dofen to inhibit the occurrence and invasion of bladder cancer and other malignant tumors in urinary system in 2017 and found that the effect was as expected (Matsuo et al., 2017). Velasquez et al. (2018) studied the effect of succinic acid expression on bladder function, and found that compared with salt-treated animals, succinic acid treatment resulted in higher urinary succinic acid levels and lower bladder volume. In SD rats, this was related to higher collagen content, lower GPR91 expression and changes in bladder nerve structure. Succinic acid treatment reduced detrusor contractility in Dahl rats, which was associated with decreased cholinergic innervation and increased collagen content. It is concluded that succinic acid has a negative effect on bladder function through its receptor GPR91, which is enhanced in the case of metabolic disorder (Velasquez et al., 2018). Shrestha et al. (2019) used rat models to implant scaffolds into the injured bladder and found that the bladder function was significantly improved (Shrestha et al., 2019). Therefore, it is very meaningful to explore and study the function of bladder model by computer-aided technology.

* Corresponding author.

Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

https://doi.org/10.1016/j.sjbs.2019.09.031
1319-562X/© 2019 Production and hosting by Elsevier B.V. on behalf of King Saud University.

In conclusion, in order to study the construction and application of urinary system model with functional bladder module, the bladder model was established and appropriate materials were chosen to make it, and its performance was discussed to provide experimental reference for the clinical treatment of bladder in urinary system.

2. Methods

2.1. Model

With the development of society, models have been applied in medicine in the 1950s, and with the progress of science, they have also transited from simple scatters to complex human figures and various organs. In the model, the development of medical simulation training and teaching makes the local functional model more specific. For instance, common cardiopulmonary resuscitation model, skin suture model and so on are all designed according to the function and structure of human body, so that the real environment can be simulated in the non-real experimental environment. The operation of these models will undoubtedly increase the opportunities for doctors in practice, thus reducing the possible medical disputes and improper operation in the operation process. The functional bladder model in urinary system is discussed here.

2.2. Principle exploration

Bladder is an indispensable organ in the urinary system. Its main function is to store urine and urinate. The whole physiological process is regulated by nerves. Ultimately, the bladder can complete three actions: detrusor contraction, bladder neck opening and urethral sphincter relaxation, as shown in Fig. 1. According to its principle, a simulation function model similar to bladder physiology (Table 1) is designed under the existing technical conditions.

Table 1
Bladder physiological processes.

	Process
Physiology of urinary storage	Human urine flows into the bladder through the kidney and ureter, and the pressure receptor emits sensory impulses, which are transmitted to the central nervous system through the pelvic nerve. At this time, the basal ganglion of the brain stem produces the first urinary intention to the cerebral cortex. Meantime, the basal ganglion of the brain stem and the cerebral cortex produce subcortical inhibition impulses and cortical inhibition impulses to the bladder pressure receptor, respectively, which inhibits the sensation of the bladder pressure receptor, causes high volume and low pressure of the bladder until the process of urine storage is formed and the maximum volume of the bladder is reached.
Physiology of bladder during micturition	When the urine in the bladder is stored to a certain amount, the parasympathetic efferent impulse makes the detrusor of the bladder contract, then causes the internal pressure to rise, stimulates the stretch receptor in the bladder wall, makes the detrusor contract strongly, opens the bladder neck, thus relaxes the urethra and forms the phenomenon of urination. During the whole process of urination, the detrusor contraction, opening of the neck of the bladder muscle and relaxation of the external urethral sphincter are three very important links.

2.3. Model design

Based on the urination process of human bladder, a retractable "urinary reservoir" was designed. Its two sides were connected with the "kidney" through the "ureter". A small hole was designed at the top of the kidney, through which liquid could be injected into the urine bag to simulate the urine storage process of human bladder. In addition, a pressure piston valve was designed at the junction of bilateral ureters and bladder to prevent liquid from flowing through the ureter when the valve was closed. The model structure diagram is shown in Fig. 2.

In the model sketch above, it can be found that the kidney and perfusion orifice, ureter, urinary reservoir, urethra and pressure sensing control valve have the following functions. The kidney is an important part of the human bladder model and the main source of urine. The perfusion orifice is located at the top of the kidney, through which the liquid is injected into the kidney and flows into the bladder through the ureter. The upper end of the ureter on both sides of the model connects the kidney through the interface, and the lower end connects the urinary reservoir. In addition, a valve was designed at the lower end of both ureters to inject the volume equivalent of human bladder muscle through the renal perfusion orifice, and the liquid entered the closed urinary reservoir through the ureter to simulate the process of human bladder muscle urine storage. The urinary reservoir is the chamber that simulates human bladder muscle urine stored, similar in shape to the human bladder muscle. The upper part connects the

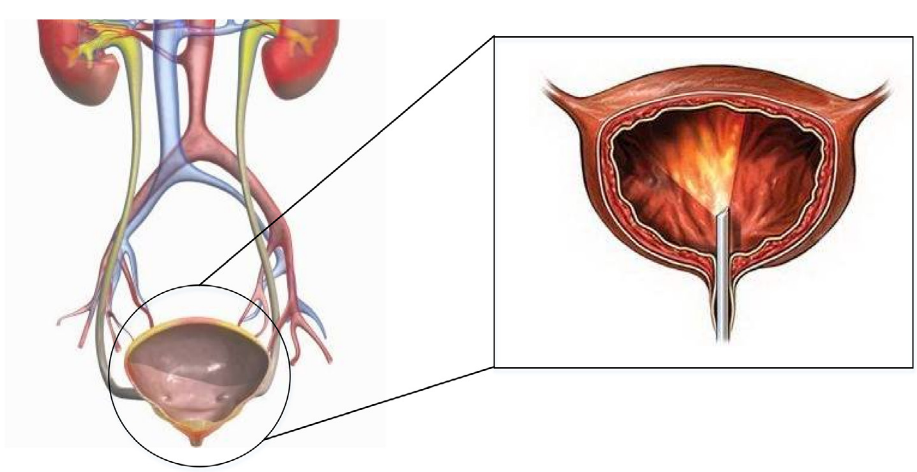

Fig. 1. Urinary system and bladder.

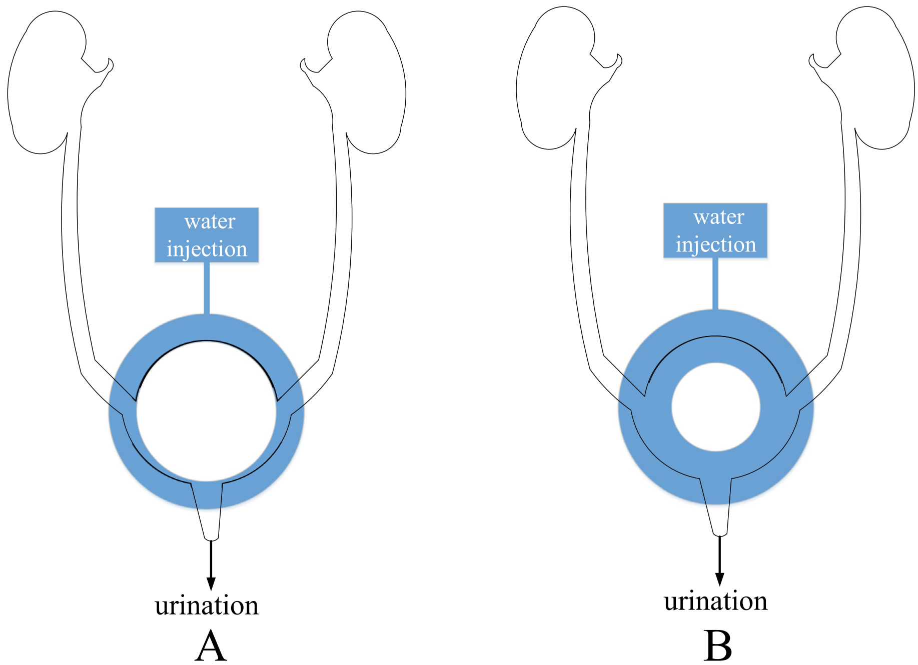

Fig. 2. Structural sketch of bladder model (A. before water injection; B. after water injection).

ureter and the lower part connects the anterior urethra. The designed length of the urethra is 20 cm, the diameter of the lumen is 0.6 mm, and the inner lumen is smooth. The shape of the penis is similar to that of the male external genitalia. A pressure sensing control valve is designed at the upper end of the urethra to open the urethra to urinate with the valve.

2.4. Model working process

The urinary reservoir was used to simulate the urine storage in the bladder. In the process, the urination booster was adopted to model the detrusor muscle of the bladder and the urinary reservoir was used to simulate the urine volume of the bladder. The process may be briefly described as follows: first, the pressure control valve of the urination orifice was closed, and then urine was injected by the urination orifice through both sides of the model (the largest equivalent fluid in the human bladder). At this time, the simulated urinary reservoir became a closed space, which was the simulation of the process of urinary storage in the bladder. Finally, the urination process in human body was simulated, the switch of the water injection device of the hydraulic pump in the model was opened and pour liquid into the booster bag. The transparent acrylic surgery on the surface cannot expand indefinitely, while the inner layer expands inward and squeezes the urinary reservoir. When the pressure reaches and is higher than the value set by the urethral pressure induction valve, it will open the valve, and the liquid in the urethra can be discharged through the urethra. Thus, a complete bladder work process is completed.

2.5. Model building

In practice, although the model with bladder function has been designed, it still needs to go through many necessary steps such as the determination of design parameters, modeling design, structural design and numerical control machining energy to turn it into a real object, and each parameter is the necessary condition that directly affects the accuracy of the real object. In traditional production, the dimension is usually determined by manual drawing, which directly leads to the low precision value of the object produced. However, with the development of computer technology, it is found that the rise of computer-aided manufacturing software for precision instruments such as CAD and Solidworks makes the modeling process more intelligent, fast and simple by utilizing this assistant software in the process of modeling and structural design. In this way, the data of the modeling software can be transformed, the numerical control programming process can be carried out directly, and the seamless transmission of the whole data process can be realized through the processing of the numerical control machine tool, resulting in a significant improvement in the physical accuracy. The production process is shown in Fig. 3.

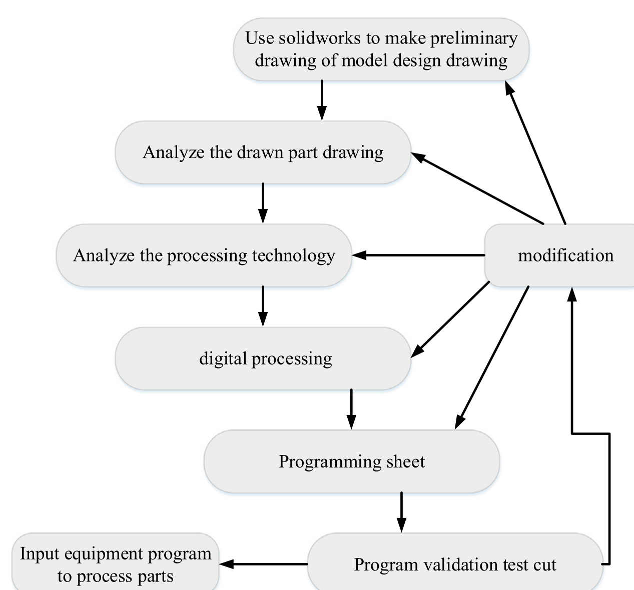

Fig. 3. Numerical control programming and CNC processing flow chart for the designed model.

Material selection in the process of model making should also be careful from the functional point of view. According to the design requirements and functional requirements of the shell of the bladder muscle model, it should have the characteristics of transparency, physical stability and plasticity. By comparison, acrylic is chosen as the shell material of the model. The acrylic chemical name is polymethylmethacrylate methyl vinegar, and the English name is ACRYLIC. The acrylic material has nearly 92% extremely high transparency and good physical stability. Its surface is smooth and has good gloss, strong wear resistance and corrosion resistance. The material quality is light and the forming process is relatively simple. According to the functional requirements of the bladder muscle model, the inner layer of the model needs to have good transparency, flexibility, and other requirements. Based on the analysis of the performance of existing materials in the market, natural latex is selected as the manufacturing material of the inner layer of the bladder muscle.

2.6. Assembly and testing of models

According to the sketch designed in this paper, the components were assembled into a "model", including acrylic shell, plastic latex inner liner and auxiliary devices. After assembly, the pressure performance and urination function of the model were tested. The test function well represents that the model has pressure and urination function.

According to the model constructed, the corresponding obstructive bladder model was constructed, and the performance of the model was evaluated by judging the detrusor's workmanship and contraction rate. All the data of the experimental results were expressed by x ± s. The data were processed by one-way analysis of variance (ANOVA) and *t*-test. All the data were analyzed by SPSS software.

3. Results

3.1. Pressure performance analysis of bladder model

For the bladder model constructed in this paper, all natural filling bladder manometry models are compliant bladder models. Through experiments, it is found that the use of the model for depression detection is higher than that of urodynamic measurement, and there is a significant statistical difference ($P < 0.01$) (Fig. 4); in the analysis of bladder safety capacity, it was found that the safe capacity of the bladder model constructed was 317.9 ± 34.2 mL, while the safe capacity of the bladder measured by urodynamics was 191.9 ± 43.1 mL. It was found that the safe

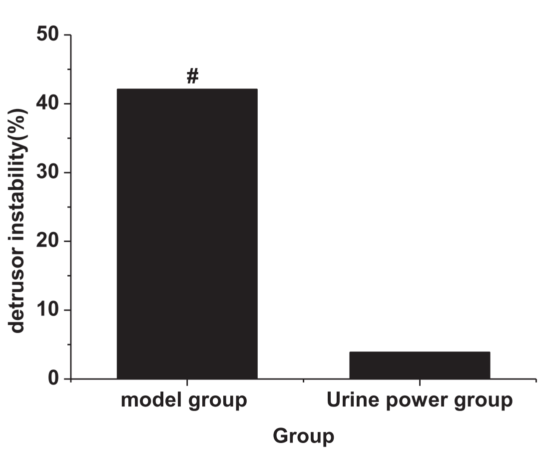

Fig. 4. Detrusor instability ratio analysis (compared with urodynamics, #P < 0.01 has significant statistical significance).

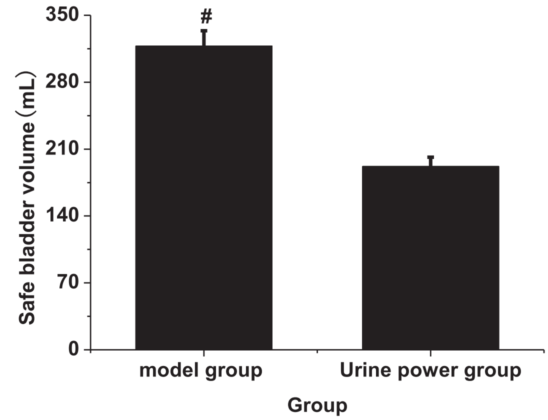

Fig. 5. Maximum bladder volume analysis (compared with urodynamics, #P < 0.01 has significant statistical significance).

capacity of the bladder in the model was much larger than that measured by urodynamics, and there was significant statistical difference ($P < 0.01$) (Fig. 5).

3.2. Analysis of detrusor workmanship and contraction rate

As shown in Fig. 6, through the comparative analysis of detrusor workmanship between model group and obstruction group, it was

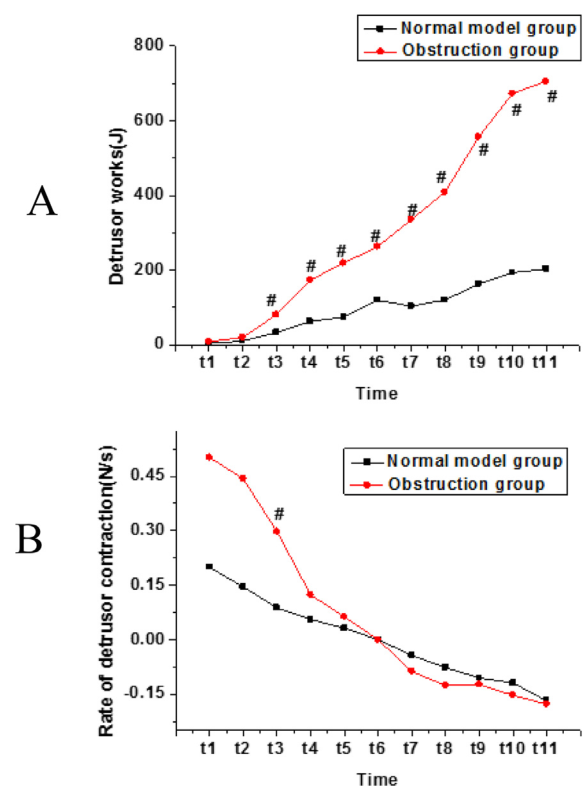

Fig. 6. Analysis of detrusor workmanship and contraction rate (t1: time from start to 10% maximum urinary flow rate; t2: time from start to 20% maximum urinary flow rate; t3: time from start to 50% maximum urinary flow rate; t4: time from start to 80% maximum urinary flow rate; t5: time from start to 90% maximum urinary flow rate; t6: time for maximum urinary flow rate; t7: time from maximum urinary flow rate to the end of 10%; t8: time from the maximum urinary flow rate to the end of 20%; t9: time from the maximum urinary flow rate to the end of 50%; t10: time from the maximum urinary flow rate to the end of 80%; t11: time from the maximum urinary flow rate to the end of 90%; A. Detrusor work comparison; B. Detrusor contraction rate comparison (compared with normal model group, #P < 0.01 has significant statistical significance).

found that the normal model group was significantly smaller than the obstruction group, with significant statistical difference ($P < 0.01$). Comparing the detrusor contraction rates between the two groups, it was found that the normal group and the obstruction group had statistical difference at t3.

4. Discussion

Bladder, as an organ of the urinary system in the body, is a necessary path for urine excretion. When bladder lesions occur, such as nearby ureteral obstruction, internal cancer and other conditions that make the urinary system unable to work properly, the construction of the model is indispensable (Obajemu et al., 2018; Xiao et al., 2017; Sole et al., 2019; Oliveira et al., 2018). In urinary clinical diagnosis, patients are often required to insert the catheter for catheterization, so modeling is one of the methods to accelerate the understanding of its principle. Through this study, in the analysis of pressure performance of bladder model, it was found that more detrusor instability was found in the model by depression test than by urodynamic test, and there was significant statistical difference ($P < 0.01$). In the analysis of bladder safety capacity, it was seen that the bladder safety capacity in the model was much larger than that of urinary power, and there was significant statistical difference ($P < 0.01$); in the analysis of detrusor workmanship and contraction rate, it was found that the normal model group was significantly smaller than the obstruction group, and there was significant statistical difference ($P < 0.01$); comparing the contraction rate of detrusor between the two groups, it was found that there was significant difference between the normal group and the obstruction group at t3 point.

In conclusion, through the research on the construction and application of urinary system model with functional bladder module, it is found that the understanding of urinary system can be enhanced through the construction of bladder model, and the basic operation skills of medical staff can be improved more easily by using the model, which achieves the expected results of the experiment. However, there are also some shortcomings in the research process. For example, this study is only to build a model for practical skills. Its application in clinical needs further in-depth study.

References

Chu, M., Zhang, C.Y., 2018. Inhibition of angiogenesis by leflunomide via targeting the soluble ephrin-A1/EphA2 system in bladder cancer. Sci. Rep. 8 (1), 1539.

Kim, A., Yu, H.Y., Lim, J.S., 2017. Improved efficacy and in vivo cellular properties of human embryonic stem cell derivative in a preclinical model of bladder pain syndrome. Sci. Rep. 7 (1), 8872.

Long, Q., Lin, T.Y., Huang, Y., 2018. Imaging-guided photo-therapeutic nanoporphyrin synergized HSP90 inhibitor in patient-derived xenograft bladder cancer model. Nanomedicine 14 (3). S1549963417305920.

Matsuo, T., Miyata, Y., Asai, A., 2017. Green tea polyphenol induces changes in cancer-related factors in an animal model of bladder cancer. Plos One 12 (1), e0171091.

Obajemu, O., Mahfouf, M., Catto, J.W.F., 2018. A new fuzzy modeling framework for integrated risk prognosis and therapy of bladder cancer patients. IEEE Trans. Fuzzy Syst. 26 (3), 1565–1577.

Oliveira, P.A., Vasconcelos-Nã3Brega, C., Rm, G.D.C., 2018. The N-butyl-N-4-hydroxybutyl nitrosamine mouse urinary bladder cancer model. Methods Mol. Biol. 1655, 155–167.

Shrestha, K.R., Jeon, S.H., Jung, A.R., 2019. Stem cells seeded on multilayered scaffolds implanted into an injured bladder rat model improves bladder function. Tissue Eng. Regener. Med. 16 (2), 1–12.

Sole, C.V., Vargas, L., Sole, V.J., 2019. Adjuvant chemoradiation in resected gallbladder cancer: a prognostic index model for predicting overall survival. J. Radiat. Oncol., 1–6

Velasquez, F.M., Mossa, A.H., Cammisotto, P., 2018. Succinate decreases bladder function in a rat model associated with metabolic syndrome. Neurourol. Urodyn. 37 (5), 1549–1558.

Xiao, D., Wang, Q., Hao, Y., 2017. Comparison of morphological and functional restoration between asymmetric bilayer chitosan and bladder acellular matrix graft for bladder augmentation in a rat model. Rsc Adv. 7 (67), 42579–42589.

Yu, J.H., Tang, H.J., Zhang, W.G., 2017. Catheterization of the gallbladder: A novel mouse model of severe acute cholangitis. World J. Gastroenterol. 23 (10), 1771–1779.

Zhang, L., Ihsan, A.U., Cao, Y., 2017. An immunogenic peptide, T2 induces interstitial cystitis/painful bladder syndrome: an autoimmune mouse model for interstitial cystitis/painful bladder syndrome. Inflammation 40 (6), 2033.