An autonomous economical and efficient ureteroscopic irrigation system

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Research

Keywords: flexible ureteroscopy, lithotripsy, ureteroscopic irrigation systems, RIRS

Posted Date: May 7th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-26169/v1>

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Abstract

Background

In recent years, the minimally invasive technique for treating nephrolithiasis has been developed rapidly. Particularly, the flexible ureteroscopy has been extensively applied. For flexible ureteroscopy lithotripsy, the perfusion equipment is necessary to ensure a clear intraoperative field of view. This study was aimed to prepare a set of economical and efficient ureteroscopic irrigation system by some commonly used devices in clinical diagnosis and treatment practice.

Methods

In this study, according to requirements of the endoscopic surgery, the infusion apparatus, infusion apparatus extension tube, three-way plug valve, Luer one-way valve, ordinary syringe, and negative pressure spring were used to assemble the irrigation system with different functions.

Results

The autonomous perfusion device realized the real-time conversion of manual injection, continuous perfusion or negative pressure suction. The entire equipment has many advantages, including easily accessible raw materials, low cost, simple assembly process, easy operation, strong controllability, effective control ability for the intrarenal pressure, and high safety.

Conclusions

The commonly used medical devices were applied to assemble the autonomous ureteroscopic irrigation system, which is flexible, simple and cost-effective and thus can be applied in flexible ureteroscopic surgery.

Background

Currently, flexible ureteroscopy lithotripsy is one of the major methods to treat kidney stones(1). Continuous intracavitary liquid perfusion is necessary to ensure a clear intraoperative field of view. Manual injection perfusion is regarded as one of the most extensively used perfusion modes in the clinic. However, it is necessary to consider the perfusion efficiency and safety simultaneously during the surgery process, and extremely low perfusion flow or long-term and repeated interrupted perfusion may affect the surgical field whereas an excessively high perfusion flow leads to excessive intrarenal pressure and thus induces a series of complications(2, 3). In this study, some commonly used devices in routine diagnosis and treatment practice were applied to assemble a set of syringe manual perfusion equipment, which was flexible, simple, convenient, economical and efficient.

Methods

1. Material preparation (Fig. 1)

One ordinary infusion apparatus (or one Y-type infusion apparatus)

One infusion apparatus extension tube

One or two three-way plug valves

Two medical Luer one-way valves

One 20 ml ordinary syringe

One negative pressure spring

2. Assembly Of The Standard Perfusion Equipment (Fig. 2)

2.1 The side end and head end of the three-way plug valve were connected to a Luer one-way valve, respectively.

2.2 The negative pressure spring sleeve was placed in the push rod of a 20 ml ordinary syringe.

2.3 The syringe was assembled.

2.4 The syringe was connected with the three-way plug valve.

2.5 The one-way valve at the head end of the three-way plug valve was connected to the infusion apparatus extension tube. Subsequently, it was bridged to the endoscope inlet valve. Meanwhile, the one-way valve in the side end was connected to the infusion apparatus, and then bridged to the irrigation bag.

3. Assembly of irrigation systems with other different functions (Fig. 3)

The transformation of different perfusion equipment functions was realized via bridging another three-way plug valve and rotating the regulating valve and/or changing the one-way valve position.

3.1 The head end of standard perfusion equipment was bridged to the side end of the three-way plug valve; one side of the three-way plug valve head end was connected to the endoscope, while the other side was connected to another bag of perfusate or the vacuum extractor as required. The switch of the perfusion device was regulated by rotating the one-way valve.

3.2 Simultaneously, the head end of standard perfusion equipment was bridged to the side end of the three-way plug valve; the position of the one-way valve was regulated; two interfaces on the head of the

device were bridged with the Y-infusion set and connected to the endoscope. Rotating the regulating valve can realize the conversion of syringe function, leading to the real-time negative pressure suction.

3.3 The head end of standard perfusion equipment was bridged to the tail end of the three-way plug valve; the equipment head end was connected to the endoscope; the side end was connected to another bag of perfusate or vacuum extractor as required. The switch of the perfusion device was controlled by rotating the one-way valve.

Results

In Fig. 4 shows that the autonomous standard perfusion equipment was connected to the flexible ureteroscope. An experienced assistant was responsible for manipulating the perfusion equipment, and it can be observed that stable water flow out of the ureteroscope head end. After fingers were released, perfusate can quickly and automatically fill the syringe while preventing fluid from backflow from the endoscope to the device. The liquid was continuously poured into the endoscope via rotating the regulating valve without a syringe. Based on intraoperative needs, a similar method was also applied to debug perfusion equipment with other functions, including manual injection, continuous perfusion, and negative pressure suction. Compared with other hand-assisted perfusion equipment, this whole equipment had easily available assembly materials, low cost, and it was not affected by the hospital policy and greatly reduced the financial burden of patients. Besides, the assembly process of the equipment was simple, and it can be flexibly configured as required; its simple operation greatly improved the operation efficiency and decreased the workload of assistants. Meanwhile, it can effectively control intrarenal pressure by adjusting the water flow indicating strong controllability. And it was highly safe.

Discussion

Urolithiasis is regarded as a common disease in Urology Department with increased incidence, and the recurrence rate is high (over 50% within 5 years), thus bringing tremendous financial burdens for patients(4, 5). In recent years, the minimally invasive technique for treating urolithiasis has been developed rapidly. Particularly, the flexible ureteroscopy has been extensively applied in the real world(6). For flexible ureteroscopy, the ideal perfusion equipment should possess three requirements. The first one is that it should guarantee a clear field of view, the second is that it should avoid the excessively-high renal pelvic pressure, the third is that it should be flexible, simple to operate, cost-effective, and highly stable(7). Currently, there are three used perfusion methods, including automated irrigation systems, gravity-based irrigation systems and syringe-based hand-held or foot-pump irrigation systems. Especially, the simple syringe is applied in syringe injection for manual injection. The perfusion pressure can be adjusted timely and intraoperatively according to the needs of the view field and surgical operations. For example, the washing pressure was appropriately increased to change calculus position and pyuria suction. In this way, the intrapelvic pressure can be effectively controlled, guaranteeing the safety and efficiency of surgical operation(8–10).

Generally, 50 ml syringe and infusion apparatus extension tube are used for manual injection of liquid in ordinary syringe perfusion. The used equipment is simple and low-cost, while it is limited by the syringe volume. Moreover, the syringe needs to be replaced or re-filled frequently, which leads to repeated interrupted perfusion. As a result, it has a negative impact on the operation and remarkably increases the workload of assistants. By contrast, autonomous perfusion equipment prepared in this study realizes continuous and uninterrupted perfusion; meanwhile, because the syringe can be rapidly and automatically filled with the single-hand operation, the hand fatigue induced by the frequent operation can be avoided.

Compared with other hand-held irrigation systems (like single action pumping system, Boston Scientific and Irri-flo irrigation delivery system, Gyrus ACMI and Olympus), the perfusion equipment assembled in this study exhibits more advantages in addition to the construction of an efficient and simple irrigation pathway. First, the assembled materials are commonly used devices in routine practice, which can be easily obtained and will not be affected by hospital conditions and policy. As a result, most doctors can easily assemble this equipment. Among them, the negative pressure spring frequently used in cosmetic surgery is durable and flexible. Its head and tail ends can be perfectly embedded into a syringe(11). The Luer one-way valve is made of the polycarbonate material with high strength and favorable durability. In addition, it can be used at a wide range of temperatures (-60-120°C) for a long time, and can withstand stream, cleaning agent, heating and high dose radiosterilization. Therefore, it has been extensively applied in the hemodialysis device, surgical mask as well as infusion piping system(12, 13). Its front cracking pressure is less than 0.5 Kpa, and the maximum back pressure is larger than 0.3 MPa, which effectively realizes the one-way flow of perfusate. Another advantage is that the cost for preparing the whole equipment is low (less than 10 dollars in China), which is far lower than that of other single-action-pump systems (over 150 dollars in China). In this way, it remarkably reduces financial burdens of patients. The negative pressure spring can be recycled after disinfection without compromising physical properties. In most countries, other irrigation systems like SAP with high prices are imported, which restricts their practical application. Moreover, the seal valve of the SAP system is easily to be ruptures and isolated after long-term usage. When the vacuum system is destroyed, a new set of perfusion equipment should be replaced, which evidently increases the operation cost(2). The designed device in this study is not dependent on the vacuum system, and it can be disassembled at will. Moreover, the cost will not be substantially increased if the parts are replaced during the surgery. It is easy to assemble this perfusion device, and the ports of each device are universal Luer ports, which can tightly fit with each other and guarantee the superior system leakproofness. In addition, the assembled equipment in this study can flexibly configure other devices based on intraoperative needs. For instance, by bridging another three-way valve, rotating the regulating valve and adjusting the position of the one-way valve, real-time regulation of functions of manual irrigation, continuous perfusion, and negative pressure suction can be realized, which greatly enhances the operation efficiency and shortens the operation time.

Similar to other syringe perfusion equipment, the drawback of this equipment is that an assistant is needed for water injection. The cooperation of the assistant is the key to inducing intrapelvic pressure changes during the flexible ureteroscopy lithotripsy process. An experienced assistant should be familiar

with each surgical step and endoscopic surgical process, and he/she is able to flexibly regulate the water injection pressure and reduce the perfusion flow while guaranteeing the smooth operation(14). Additionally, long-term application of the perfusion equipment also leads to the issue of hand fatigue, which may result in transient intrarenal hypertension. In addition, the equipment performance of assembled equipment may be reduced after a long-term operation, and the equipment should be replaced as required. In this study, a method to prepare the endoscopic perfusion equipment is proposed, and the equipment stability and safety should be further investigated.

Conclusions

The commonly used medical devices were applied to assemble the autonomous ureteroscopic irrigation system, which is flexible, simple and cost-effective and thus can be applied in flexible ureteroscopic surgery.

Abbreviations

SAP
single-action pump

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

Not applicable

Competing interests

The authors declare that they have no competing interests.

Funding

This study was funded by Natural Science Foundation of Shandong Province of China (ZR2016HB61)

Authors' contributions

Xunbo Jin conceived, designed, and organized this study, interpreted the results, and revised the manuscript. Tengting Wang contributed to the writing of the manuscript and conduct data analysis. All authors contributed to collect the data. All authors read and approved the final version of this manuscript.

Acknowledgements

Not applicable

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Figures

Figure 1

Materials for the preparation of the device

Figure 2

Equipment assembly

Figure 3

Irrigation systems with other different functions (3.1a turned on the perfusion device, and poured liquid into the endoscope by a syringe. 3.1b turned off the infusion apparatus perfusion device, and continuous perfusion or negative pressure suction was realized by connecting to the irrigation bag or vacuum extractor. 3.2a turned on the perfusion device, and poured liquid into the endoscope by a syringe. 3.2b turned off the perfusion device, and the suction of intrarenal effusion was realized using the syringe

under negative pressure. 3.3a turned on the perfusion device, and poured liquid into the endoscope by a syringe. 3.3b turned off the perfusion device, and continuous perfusion or negative pressure suction was realized through connecting to the perfusate or vacuum extractor.)

Figure 4

Perfusion equipment debugging