ORIGINAL PAPER

UROLITHIASIS

Choice of surgical access for retroperitoneoscopic ureterolithotomy according to the results of 3D reconstruction of operational zone agreed with the patient: initial experience

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Introduction. For the procedure retroperitoneoscopic ureterolithotomy, the problems of access choice and thus visualization with utilizing minimally invasive surgical access (either with gasless single port method or gas insufflation) are solved. The decisions are based on the method of presurgery planning, grounded on matching the patient with a 3D model of the zone of surgical interest reconstructed according to the results of tomographic examination.

Material and methods. We used a hardware–software complex (HSC) for virtual modeling of the surgery zone and choosing the optimum points for minimally invasive surgical access. The HSC was recruited to choose optimum surgical access, realize presurgery planning, and estimation of the safety of the way of access chosen. The original method of matching the system of coordinates of a virtual model with the patient was offered.

Results. 12 patients with the calculus in the upper part of ureter averaging 11.5 (9–14) mm in size underwent gasless retroperitoneoscopic ureterolithotomy with use of the HSC. Mean age of the patients was 36.4 (25–49) years old. The surgeries lasted an average of 35.5 (25–40) minutes. Blood loss was averaged at 55.0 (30–90) ml. Healing by first intention was registered with all the patients. The mean hospitalization time was 6.0 (4–7) days. There were neither any complications nor difficulties, nor conversions from incorrectly chosen surgical access.

Conclusions. The choice of the optimum surgical access according to the results of a virtual 3D model of the operation zone, matching the system of coordinates of the model with patient concurrence, and presurgery planning, was effective in cases of gasless single port and with gas insufflation retroperitoneoscopic ureterolithotomy.

Key Words: minimally invasive endoscopic surgery ‹› 3D reconstruction ‹› presurgery modeling

INTRODUCTION

Urolithiasis with localization of a calculus in the ureter is contemporarily one of the most widespread diseases of the abdominal cavity organs. The basic methods of treatment of such diseases are remote shockwave and contact lithotripsy [1]. When these are infeasible, minimally invasive methods of surgical intervention, such as laparoscopic or retroperitoneoscopic ureterolithotomy, can be practiced [2, 3]. Retroperitoneoscopic ureterolithotomy allows a method with gas insufflation, or gasless method. Retroperitoneoscopic procedures with gasless, minimum incision endoscopic surgery has the following advantages: no usage of CO_2, single port access, cost–effectiveness, and reduced technical demands,

while preserving the minimal invasiveness of completely laparoscopic surgery [4–7]. When using gasless low invasive access for procedures in the retroperitoneal space, the surgeon is more likely to encounter difficulties regarding visualization and finding objects. Right choice of point of access aids in avoiding difficulties and complications during the procedures.

Presurgery planning and intrasurgery navigation based on computer tomography (CT) is a modern direction of surgery, however there lies a problem in the agreed CT coordinate system, and the patient is not definitively solved.

The purpose of the work consists in the development of a hardware–software complex (HSC) for defining and indicating optimum points of input for surgical tools (trocars or access or minimum incision endoscopic surgery) on the surface of the patient's body. The points are based on the data of tomographic examinations when carrying out minimally invasive surgeries, for example retroperitoneoscopic ureterolithotomy.

To achieve the goal of the work, various problems are tackled. Synthesis of a virtual model of a patient, choice of optimum ways of access to the zone of surgical interest, matching the body of the patient with a virtual model, presurgery planning, estimation of the safety of the way of access chosen, as well as clinical testing were solved.

MATERIALS AND METHODS

In order to solve the problems stated, the group of authors from Volga State University of Technology and State–financed Health Institution of the Republic of Mari El "Republican clinical hospital" developed a hardware–software complex (HSC) for virtual modeling of the surgery zone and choosing the optimum points for minimally invasive surgical access (Russian Federation patent No. 127615 of 10 May 2013. [17]). The complex consists of a PC, original software, and a mechanical 3D digitizer.

Prior to the presurgery planning, examination of a patient by a tomographic scanner is carried out. To provide the opportunity for further matching the body with a virtual model, 4 radiopaque markers are fixed on the patient's body. The results of the T imaging are forwarded to the surgeon.

Then the preoperative planning itself is carried out. The segmentation of fabrics is made and the three–dimensional model of the body of a person is built within the limits of the zone of surgical interest, based on the analysis of the characteristics of X–ray density of the image in the tomogram received (Figure 1). Studying the given model allows the surgeon

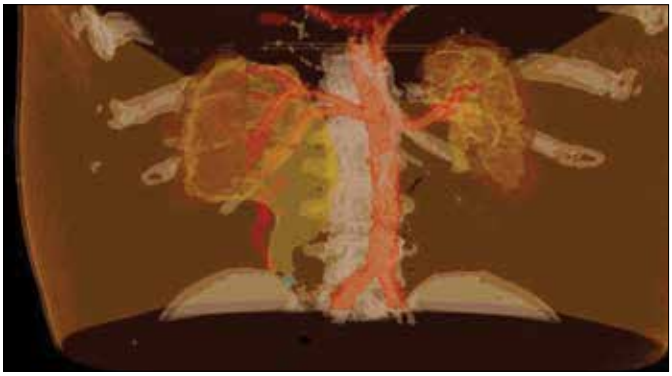

Figure 1. *Virtual model of a patient, including the zone of surgical interest (kidney, ureter and calculus with the segment of aorta are marked).*

to more precisely locate the calculi in the ureter, to estimate relative positioning of viscera, and to make the preliminary decision on the way of surgical access.

Additionally, the task of choosing the optimum ways of access to the organ being operated on is undertaken. To carry this out, the surgeon indicates the zones of surgical interest on the tomogram slices (zones that are necessary in order to get access to in the process of surgery), and on a virtual model the position of a prospective point of puncture on a patient's body surface is indicated. In some vicinity of the given point, the search for suitable ways to access the zone of surgical interest is carried out. For each probable way the program checks that there is no crossing of fabrics through which making punctures is inadmissible. As a result, the program visualizes the set of the ways allowed, among which the surgeon can choose the most preferable (Figure 2).

Then the surgeon makes a final estimation of the safety of the chosen way of access. To do this, the pro-

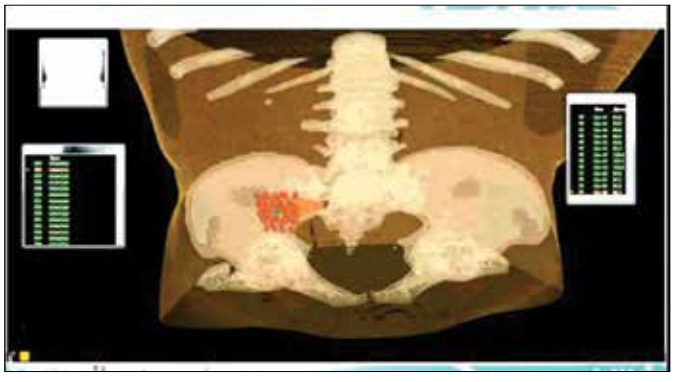

Figure 2. *Imaging of the possible ways of access to the zone of surgical interest.*

Figure 3. *Tracking the way of access through the cuts of the tomogram.*

gram makes a tracking of the way of access through the cuts of the tomogram (Figure 3). The result of tracking is displayed. Using the given data, the surgeon can finally be sure of the absence of wound tract crossing the vital organs. This marks the conclusion of the presurgery planning stage.

One of the key stages directly before carrying out the surgery is matching the virtual model with the body of the patient. For this purpose, it is necessary to execute the comparison of reference points on a 3D model with corresponding points on the patient's body. The operation is carried out with the help of a 3D digitizer, through consecutive input of reference point coordinates into the computer (Figure 4). As a result, the matrix of the system of coordinates' transformation is calculated and further movement of the digitizer pen and its symmetry axis in the space can be displayed on the virtual 3D model.

After that, the surgeon can specify the points for minimally invasive surgical access on the body of the patient that are set on the virtual model and define a required direction of the incision. At the moment of concurrence of a point and the direction of access with the required one, the program gives out a sound signal. The current direction that is pointed out by the digitizer pen is controlled simultaneously according to the 3D model.

The points of access specified by the computer program are assessed by the physician–expert, who carries out minimally invasive surgeries on the retroperitoneal space organs.

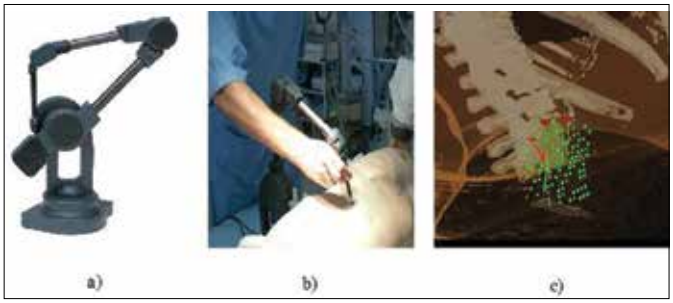

Figure 4. *Figure 4. Mechanical 3D digitizer (a), input of reference points coordinates (b) and imaging of the digitizer pen symmetry axis on the model (c).*

RESULTS

12 patients diagnosed with a calculus in the upper part of the ureter were operated on, using the method of computer optimization of minimally invasive surgical access. They consisted of 5 men and 7 women. Mean age of the patients was 36.4 (25–49) years old. According to the computer tomography, the calculi averaged 11.5 (9–14) mm in size. 8 patients had a calculus in the right ureters, 4 patients had it in the left one.

The surgery was carried out under general anesthesia. The patient was laid down on a surgical table in the lateroposition. Gasless retroperitoneoscopy was applied in all 12 cases. In the point specified by HSC, a 3–4 cm long incision of the skin and hypoderm was made and the retroperitoneum was opened with muscle–splitting access. A retroperitoneoscope and a ring with wound dilators were set into the retroperitoneum, with the surgery executed under the control of a retroperitoneoscope aided by specialized tools (Figure 5).

When comparing the way of surgical access chosen by means of the computer program and the one offered by the expert, the concurrence on the points of access is marked in all cases. There were neither difficulties nor conversions resulting from incorrectly chosen surgical access. The surgery lasted 35.5 (25–40) minutes. Blood loss was 55.0 (30–90) ml. Healing by first intention was registered with all the patients. The inpatient treatment lasted 6.0 (5–7) days (Table 1).

Table 1. *Date of the patients that underwent gasless ureterolititomy with the use of HSC*

Number of patients	12
Sex M/F	5/7
Age	36.4 (25–49)
Operation time (min)	35.5 (25–40)
Blood loss (ml)	55.0 (30–90)
Hospitalization time (days)	6.0 (5–7)

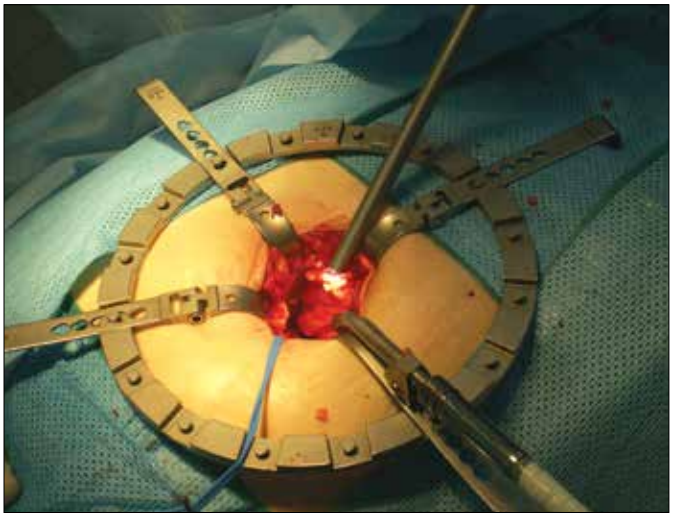

Figure 5.1. *Minimum incision endoscopic access.*

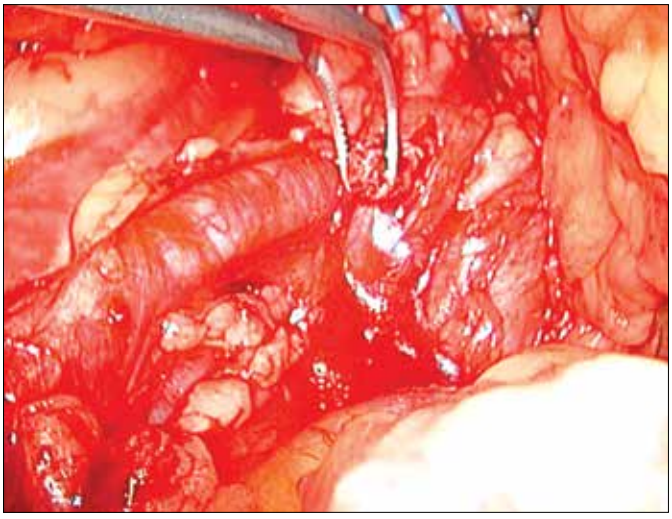

Figure 5.2. *Extraction of the calculus.*

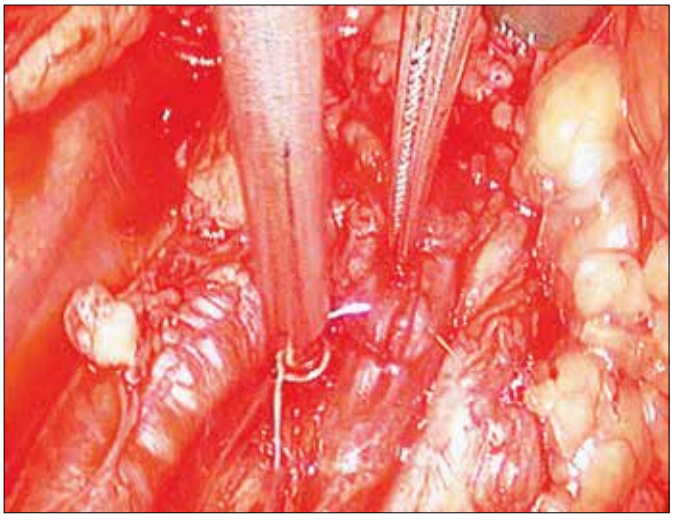

Figure 5.3. *Ureter suturing.*

DISCUSSION

Use of modern treatment methods for ureter calculi, such as remote and contact lithotripsy, allows resolution without operative intervention in most cases. However, presence of a large calculus in the proximal ureter, inefficiency or impossibility of ureteroscopy and contact lithotripsy, are surgical indications for removal of ureter calculi through retroperitoneoscopy.

The peculiarity of carrying out minimally–invasive surgical interventions on the organs of the retroperitoneum, is necessary for sound choice of access way and the facilitation of exact port installation. It is prompted by the difficulty of visualization of the objects in a surgery zone, danger of trauma of vital bodies that is related with anatomic features of the retroperitoneum. It is especially important during minimally invasive procedures [8–12].

Besides, when conducting retroperitoneoscopic ureterolithotomy, it is often difficult to define the precise localization of the calculus. This can lead to the increase of surgery duration and become the cause of conversion. The right choice of the points and direction of access to the surgery zone and their precise indication on the patient's body guarantee the effectiveness of the surgery, and provide the conditions for ergonomic and convenient work of a surgeon [13, 14].

In this connection, one of the rather new and perspective directions of modern minimally invasive surgery is the development of methods of presurgery planning based on the body virtual model, constructed according to the results of tomographic examination with its subsequent matching to a real patient directly during the surgery [15, 16]. Now there are various approaches to the creation of systems of intrasurgery navigation, for example, based on three–dimensional video cameras. However they require specialized tools, software, expensive equipment, and have a limited area of clinical application [17].

Thus, the challenge of developing systems for presurgery planning and intrasurgery navigation based on the usage of standard data formats which are not associated with concrete tomographic equipment is prevalent. Such systems should provide the opportunity for creating 3D models of the surgery zone to plan and execute urological surgery, the opportunity to choose and control the optimum points on the model and directions of access to install the surgical tool, the opportunity to match the received model with the patient for indication, control and visualization of the points and directions of the access during the surgery.

Furthermore, using the proposed HSC to select points of surgical access for retroperitoneoscopic

ureterolitotomy allows us to perform simulation and preoperative surgical planning, to explore the potential hazards associated with the location of the surrounding area of intervention, and to choose the optimal zone for the surgical approach. It is of no doubt that studies comparing surgery with or without use of the 3D HSC technique requires further research in future, with more operation time, blood loss, hospital stays, complications, etc.

The scope of our development is not limited to only executing retroperitoneoscopic ureterolithotomy, it can further be expanded to other urological operations. Creation of a virtual model of an operational zone and its matching with a real patient will eventually allow the execution of intrasurgical navigation when executing various video–endoscopic operations, and also safe, exact introduction of a probe into the zone of the disease during focal therapy.

A significant aspect of introducing minimally invasive surgery into medical practice is the system of training novice surgeons, which is implemented in specialized centers with the use of training models, operations on animals, and virtual surgical interventions. Use of the offered HSC in clinics starting to execute video–endoscopic operations will help a surgeon to plan a minimally invasive operation independently, thus having an 'assistant' when making a choice of surgical access and orientation in surgical space.

CONCLUSIONS

1. The HSC enabled the choosing of optimum surgical access during minimally invasive retroperitoneoscopic ureterlithotomy to be developed.
2. The original method of matching the system of coordinates of a virtual model with the patient is offered.
3. The technique of helping the surgeon in presurgery planning is developed.
4. The following algorithms are developed and realized:
– forming a virtual 3D model of a patient according to the results of tomography examination;
– allocation of "the zone of surgical interest";
– search of points of access and the direction of the way of access;
– controlling safety of the wound canal being formed;
– matching the system of coordinates of a virtual model with the patient.
5. The HSC developed can be used to train novice surgeons in performing minimally invasive operations.

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