Observation and Study on the Therapeutic Effect of Endoscopy Combined with Minimally Invasive Abdominal Surgery Robot in the Treatment of Gallstones

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Abstract: Cholecystolithiasis is a common and frequent disease in clinic. Open cholecystectomy, common bile duct exploration and T-tube drainage are the classic methods for the treatment of this disease. The success rate of lithotomy is higher, but the patients have more trauma, slow recovery, more complications, and longer time to retain T-tube. In this paper, endoscopy combined with minimally invasive laparoscopic surgery robot is used to treat cholecystolithiasis. The key technologies of laparoscopic cholecystectomy are introduced and the kinematics of minimally invasive surgery robot is analyzed. Through the observation and study of curative effect, it was found that the treatment group had shorter operation time, less bleeding, shorter exhaust time, earlier eating time and shorter hospitalization time, which indicated that EST combined with LC treatment was beneficial to patients' recovery as soon as possible, reduced patients' pain and reduced the financial burden of patients' families.

1. Introduction

Cholecystolithiasis is a common and frequently occurring disease in clinic. The incidence of cholecystolithiasis is about 10%. Among them, 10%-15% patients have extrahepatic bile duct stones [1]. In the past, laparotomy cholecystectomy, common bile duct exploration and T-tube drainage were used as traditional treatment methods. However, they have some limitations, such as large trauma, slow recovery and more bile loss, and have been gradually replaced by minimally invasive surgery [2-4]. Laparoscopic cholecystectomy (LC) has become the standard operation for the treatment of calculous biliary tract diseases due to its advantages of small trauma and quick recovery. Endoscopic lithotripsy is an effective treatment for extrahepatic bile duct stones [5-8]. At present, the treatment of cholecystolithiasis with extrahepatic bile duct stones is still controversial. Endoscopy combined with minimally invasive abdominal surgery robot was used to treat cholecystolithiasis complicated with extrahepatic bile duct stones. Good results were achieved. The report is as follows.

2. Laparoscopic Cholecystectomy

Cholecystolithiasis is a benign disease, LC is its gold standard operation, and has been widely accepted by most surgeons. Laparoscopy has not yet been popularized in all levels of hospitals, LC still has a certain range of indications, such as atrophic cholecystitis has been taboo, especially if there is a malignant possibility of laparoscopic surgery is still controversial. However, more and more surgeons, especially hepatobiliary surgeons in affiliated hospitals of larger medical colleges, believe that laparoscopic cholecystectomy can be performed even for gallbladder cancer. Therefore, LC seems to have no absolute contraindication at present, unless massive intraoperative hemorrhage or abdominal adhesions are serious, it is necessary to switch to laparotomy. With the continuous development and maturity of endoscopy technology, especially the development of natural endoscopic surgery, LC alone is no longer the topic of discussion of minimally invasive cholecystectomy, but more of the matters needing attention in discussing single-port LC [9-10]. It is true that single-hole laparoscopic surgery is more ideal in cosmetology and less traumatic to patients, but the manipulation skills of single-hole laparoscopic surgery robot are higher than

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traditional three-hole or four-hole methods. Generally, the grass-roots medical units are less developed at present. Single-hole laparoscopic surgery mainly focuses on the more mature medical units above the municipal level. Fortunately, the single-port laparoscopic surgery robot has become a technical challenge pursued by minimally invasive surgeons. It is believed that the single-port LC will soon become the mainstream of cholecystectomy.

Compared with traditional laparotomy, laparoscopic choledocholithotomy has the advantages of less trauma, faster recovery of gastrointestinal function and shorter hospital stay. In recent years, laparoscopic choledocholithotomy has gradually become the mainstream method for biliary surgeons to treat choledocholithiasis [11-12]. Compared with endoscopic choledocholithotomy, laparoscopic choledocholithotomy has its corresponding indications: (1) obvious dilatation of common bile duct (> 1.0 cm); (2) loose stones in common bile duct (> liver); (3) patients with massive upper gastrointestinal bleeding and severe esophagogastric varices were unsuiTable for EST; (4) unsuccessful EST. With the continuous development of endoscopy technology, these are not absolute indications. There are also reports of successful choledocholithotomy for patients with choledocholithiasis less than 0.8 cm in diameter.

In recent years, the main clinical controversy is whether the incised common bile duct should be sutured or T-tube drainage. At present, most clinical surgeons advocate that T-tube indwelling is relatively safe. They believe that T-tube can reduce the pressure of common bile duct after operation, avoid biliary tract infection or pancreatitis caused by high pressure, and help to avoid common bile duct obstruction caused by temporary obstruction of Oddi sphincter function after operation. We believe that laparoscopic choledocholithotomy can completely remove the stones, the lower part of the common bile duct is unobstructed and the diameter of the common bile duct is large enough (> 2.0 cm), so that primary suture of the common bile duct is feasible to avoid many inconveniences caused by T-tube indwelling after operation [13-15]. For simple common bile (liver) duct stones, some surgeons believe that if the gallbladder function is normal or inflammation is mild, the gallbladder can be preserved and only the gallbladder (liver) duct stones can be removed. But at present, most scholars believe that cholecystolithiasis (hepatolithiasis) is more common in the gallbladder clinically, and the function of gallbladder after choledochotomy is affected to a certain extent. It is easy to cause gallbladder diseases such as cholecystitis or calculi after choledochotomy. Therefore, endoscopy combined with minimally invasive abdominal surgery robot is advocated for the treatment of gallbladder stones.

3. Kinematics Analysis of Minimally Invasive Surgical Robot

The minimally invasive surgical robot is mainly composed of moving joints and rotating joints connected with the manipulator pole. In Cartesian coordinate system, the joint variables and parameters of the manipulator pole are related to the position and attitude of the end effector (including the telecentric mechanism). Robot kinematics describes the relationship between the size parameters of each joint and rod and the position and attitude of the end-effector. It is generally divided into forward kinematics analysis and inverse kinematics analysis. Positive kinematics is the variable of each joint of the robot, and the kinematics equation of the robot is established to obtain the position and attitude of the end-effector. Inverse kinematics is based on the position and attitude of the end effector of the robot, and the variables of each joint and the parameters of the rod are obtained. Kinematics analysis of robots is the basis of structure design and motion control of robots.

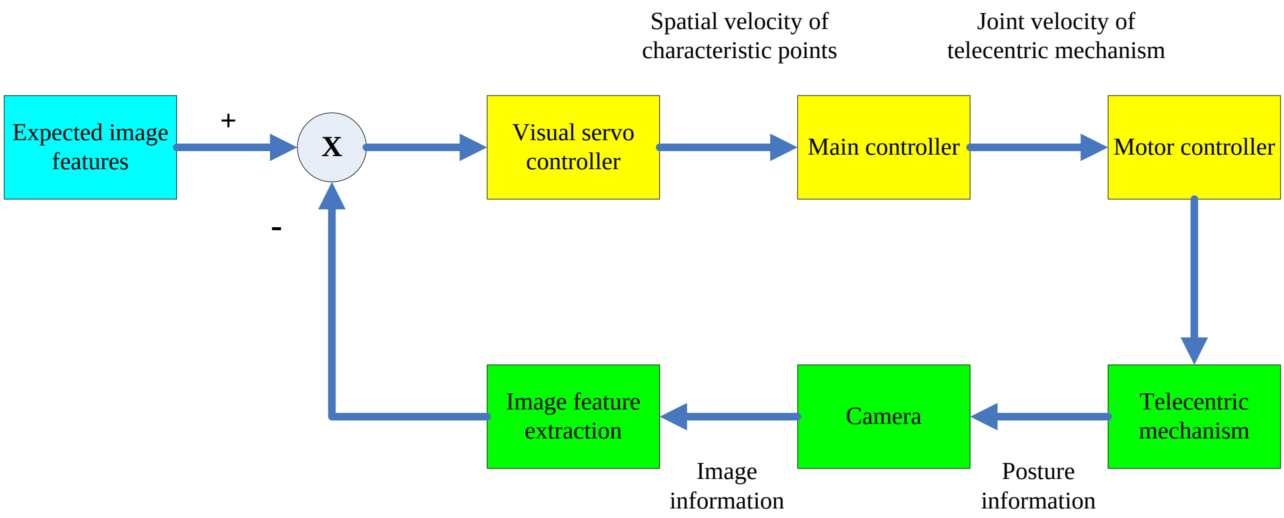

Figure 1. Structure diagram of visual servo system based on kinematics

There are two main solutions to common kinematics analysis:

(1) The exponential product formula method (POE) expresses the kinematics equation of the robot as the exponential product of the spinor of the motion, and the solution of the equation is not restricted by the configuration of the joint.

(2) D-H parametric modeling method establishes the coordinate system for each joint of the robot, and obtains the position relationship of adjacent joints through the change of homogeneous matrix, thus establishes the relationship between the terminal coordinate system and the basic coordinate system, and deduces the kinematics equation of the surgical robot. In this paper, a simple D-H method is used to solve kinematics more intuitively.

In kinematics-based visual servo system, the output signal of the visual servo controller is usually the Cartesian space velocity at the end of the manipulator, or the joint velocity of the manipulator. This kind of servo system is designed according to the kinematics equation of the robot, without considering the non-linear dynamic part of the robot. It is relatively simple to design. In the case of low speed, this kind of servo system is reasonable and can complete various tasks well. The structure of the control system is shown in Figure 1.

The minimally invasive surgical robot is composed of joints connected with manipulator rods, each of which can be regarded as a rigid Q. The spatial position of the rigid body Q depends on the position and attitude of a point on the rigid body. The position of rigid body Q coordinate system in basic coordinate system O can be expressed by matrix:

$$ {}_{Q}^{O}P = \left[p_x \ p_y \ p_z \ 1 \right]^T \tag{1} $$

The attitude of the rigid body Q in the basic coordinate system O can be expressed by the component of the unit direction vectors n, O and a of each coordinate axis in the rigid body Q coordinate system on the basic coordinate system O (the component is the direction cosine of the unit vector).

$$ n = \left[n_x \ n_y \ n_z \ 0 \right]^T \ O = \left[o_x \ o_y \ o_z \ 0 \right]^T \ a = \left[a_x \ a_y \ a_z \ 0 \right]^T \tag{2} $$

Therefore, the position and attitude of a rigid body in space can be written in a matrix form of 4*4, as follows:

$$ T = \left[n \ o \ a \ P \right] = \begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{3} $$

The matrix describes the translation and rotation transformation of the rigid body relative to the basic coordinates.

According to the D-H algorithm, the coordinate system at the joint number n+1 is labeled n. The principle of establishing the joint coordinate system is as follows: the origin on is located at the intersection of the joint n axis and the joint n+1 axis with the joint n+1 axis; the direction of the X_n axis is the same as that of the joint n+1 axis; the Y_n axis is established according to the right hand principle, and the zinc axis coincides with the joint axis of A_{n+1}. Among them, A_{n+1} is the n+1 joint, A is the length of the connecting rod, D is the joint variable of the mobile joint, θ is the joint variable of the rotating joint, and α is the joint twist angle.

$$A_n = Rot(z,\theta_n)\times Trans(0,0,d_n)\times Trans(a_n,0,0)\times Rot(x,\alpha_n) \quad (4)$$

4. Experiments and Analysis

4.1 Method

In LC group, LC was performed by four-hole laparoscopic cholecystectomy.

EMIC group: general anesthesia, establishment of pneumoperitoneum, umbilical puncture Trocar; laparoscopic observation of gallbladder congestion, edema and adhesion. If the gallbladder has adhesions, try to release the adhesions. If the gallbladder can be put out of the abdominal cavity, an incision of about 1 cm is cut at the abdominal wall of the bottom of the gallbladder, the gallbladder is put out in vitro, and a incision of about 1 cm at the bottom of the gallbladder is cut to insert the choledochoscope into the gallbladder. The gallbladder incision was sutured horizontally with absorbable suture line, and the abdominal drainage tube was placed in the ventral foramen of Wen's, which was extracted from the axillary anterior puncture hole under the liver. If the gallbladder cannot be presented in vitro, the above procedure is performed under laparoscopy.

Observation indicators: The operation time (min), intraoperative bleeding volume (ml), hospitalization cost (yuan), anal exhaust time (h) and postoperative hospitalization time (d) were observed and compared between the two groups.

Statistical methods: All data were processed by SPSS11.5 software package. Measuring data were analyzed by t test and counting data χ^2 test. The statistical significance was $P < 0.05$.

4.2 Result

Relevant clinical indicators in the course of different surgical methods were compared between the two groups. The results showed that there was no significant difference between the two groups in terms of operative time, intraoperative bleeding volume and hospitalization expenses, and the comparison between the two groups was $P > 0.05$, with no significant difference. Details are given in Table 1 and Figure 2.

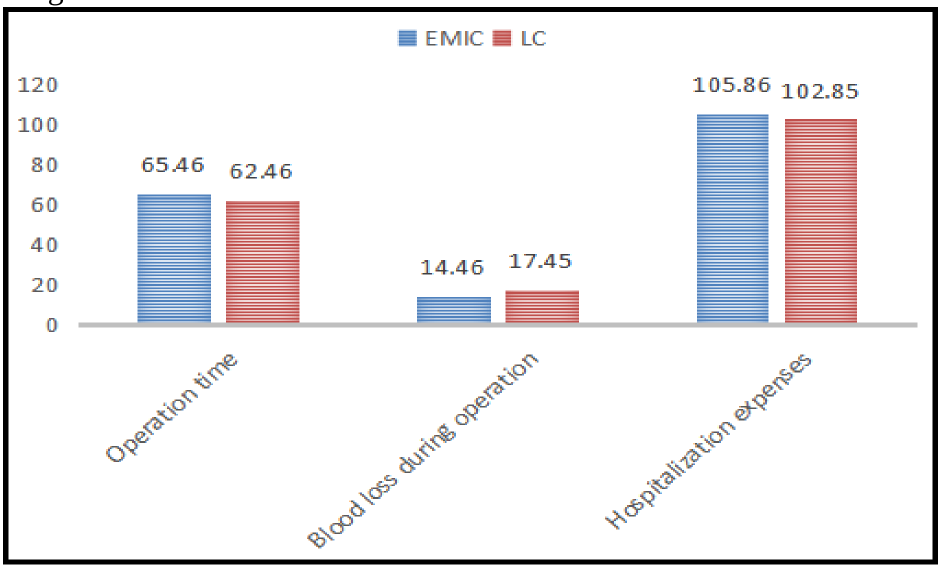

Figure 2. Comparisons of related clinical indicators during operation

Table 1. Comparisons of related clinical indicators during operation

Group	n	Operation time(min)	Blood loss during operation (ml)	Hospitalization expenses (yuan)
EMIC	96	65.46±14.43	14.46±5.47	10586.56±876.45
LC	96	62.46±16.54	17.45±7.69	10285.54±986.45
P		>0.06	>0.06	>0.06

Relevant clinical indicators in the recovery process of two groups of patients after different surgical methods were compared as follows: On the two indicators of anal exhaust time and post-operative hospital stay, EMIC group was significantly lower than LC group, and the comparison between the two groups was $P < 0.05$, the difference was statistically significant. Details are given in Table 2.

Table 2. Comparison of relevant clinical indicators during recovery

Group	n	Anal exhaust time (h)	Postoperative hospital stay (d)
EMIC	96	20.45±3.45	4.12±1.36
LC	96	25.46±8.74	5.98±1.67
P		<0.06	<0.06

5. Conclusion

From the current clinical studies and reports, it is concluded that laparoscopic cholecystectomy combined with endoscopic minimally invasive Cholelithotripsy has better clinical practical advantages in the treatment of cholecystectomy. The analysis of comparative data in this paper further confirms this view: in the three indicators of operation time, intraoperative bleeding volume and hospitalization costs, there is no significant difference between the two groups, and the comparison between the two groups $P > 0.05$, there is no significant difference. In the two indicators of anal exhaust time and hospital stay after operation, EMIC group was significantly lower than LC group, and the comparison between groups $P < 0.05$, the difference was statistically significant. Therefore, through the above analysis and elaboration, the author believes that: in the clinical treatment of cholecystolithiasis, compared with laparoscopic cholecystectomy, laparoscopic combined with endoscopic minimally invasive cholecystolithotomy is a reliable choice for clinical treatment of cholecystolithiasis.

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