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Laparoscopic Open Drainage of Hepatic Cysts Guided by Three-Dimensional Reconstruction with the Mimics Software System: A Retrospective Case Control Study

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Abstract

Objective: To investigate the clinical results of laparoscopic hepatic cyst windowing guided by three-dimensional reconstruction with the Mimics software system.

Methods: A retrospective analysis was performed on patients who underwent hepatic cyst enucleation at the Department of Hepatobiliary Surgery of Hebei Provincial People's Hospital from January 2022 to December 2023. The patients who had their 3D reconstruction model made by Mimics (Materializes interactive medical image control system) software before surgery were included in the observation group, and those who did not have 3D reconstruction were included in the control group. The relevant clinical indicators were compared between the two groups.

Results: A total of 58 patients were included, including 23 males and 35 females, aged 33 to 91 years. There were 33 patients in the observation group, and 25 patients in the control group. The operation time [60.00 (50.0-72.5) min *vs.* 65.00 (60.0-85.0) min, P=0.025], intraoperative blood loss [3.00 (2.0-5.0) mL *vs.* 5.00 (4.0-6.0) mL, P=0.028], and difference between preoperative measurements of cyst volume and intraoperative drainage volume [200.000 (101.0-310.5) mL *vs.* 342.000 (-268.5-636.5) mL, P=0.039] in the observation group were better than those in the control group. There was no statistically significant difference in the duration of abdominal drain retention, drainage tube drainage volume, postoperative hospitalization time, postoperative complications, postoperative recurrence rate, preoperative measurement of cyst volume or intraoperative drainage volume (P>0.05).

Conclusion: For patients who need to undergo open drainage of liver cysts, the preoperative use of Mimics software to create 3D can help to accurately identify the internal structure of liver cysts, shorten the operation time, reduce intraoperative bleeding, and accurately measure the volume of liver cysts, which can maximize the effect of one-stop removal of the cysts, and is worthy of clinical promotion.

Keywords: Mimics software; Three-dimensional reconstruction; Hepatic cyst; Hepatic cyst enucleation

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Introduction

Hepatic cysts are a kind of benign liver diseases with high incidence in clinic, the pathogenesis is caused by the abnormal proliferation of epithelium and secretion retention in hepatobiliary and lymphatic vessels in the liver [1], and the most common liver cysts in clinic are simple liver cysts, followed by polycystic liver disease [2]. Liver cysts have a long course, no obvious symptoms in the early stage, will not cause obvious damage to the patient's liver function, rarely life-threatening, but along with the continuous progression of the disease, some patients with abdominal pain, abdominal distension, liver function damage to the hospital to receive imaging tests to confirm the diagnosis [3], but also part of the refractory patients can be recurrent episodes leading to important organs and blood vessel compression or recurrent intracystic infections and hemorrhage, which seriously affects the quality of life. Surgery is the main procedure for the treatment of hepatic cysts, and although traditional open surgery can also achieve significant therapeutic effects, it increases the postoperative recovery time due to the greater damage to the patient, resulting in prolonged

hospitalization and increased medical expenses [4]. In recent years, laparoscopic techniques have been popularized in surgery because of the advantages of less trauma and faster postoperative recovery, but traditional CT examination cannot identify the internal structure of the cyst with or without separation, which may lead to incomplete opening of the cyst or incomplete aspiration of cystic fluid, and there is a problem of recurrence of hepatic cysts after surgery [5,6]. Mimics is a highly integrated and easy-to-use 3D image generation and editing software, which can be used to generate preoperative 3D reconstruction images of liver cyst structures in patients to guide clinical surgery. The aim of this study was to explore the clinical value of using Mimics to guide laparoscopic hepatic cyst windowing.

Materials and Methods

Clinical information and subgroups

Patients with CT-detected hepatic cysts and laparoscopic hepatic cyst windowing between January 2022 and December 2023 were retrospectively enrolled and operated on by the same group of physicians. All of them had completed preoperative abdominal CT enhancement examination, cardiopulmonary function assessment, and were able to tolerate laparoscopic hepatic cyst opening surgery, and were screened according to the inclusion and exclusion criteria.

Inclusion criteria: (1) all were diagnosed as liver cysts by ultrasound and the diameter of the cysts was >5 cm; (2) the patients or their families had a comprehensive understanding of the study and signed an informed consent form; (3) the medical history was complete.

Exclusion criteria: (1) patients with serious contraindications to surgery; (2) patients with combined underlying diseases who could not tolerate surgery; (3) patients with other serious liver diseases; (4) patients whose family members did not agree to sign; (5) patients with hepatic cystic adenoma or hepatic cystic adenocarcinoma shown by pathology or cystic fluid cytology; (6) patients who had not been rechecked after the treatment; and (7) patients who had been hospitalized again to perform the relevant treatments for the recurrence of the disease. Patients who used Mimics software to create 3D images before surgery were included in the observation group, and patients who did not undergo 3D reconstruction were included in the control group. The study was reviewed and approved by the Medical Ethics Committee of Hebei General Hospital.

Preoperative three-dimensional reconstruction

Both groups underwent enhanced CT examination of the abdomen, in which the observation group imported the data into Mimics software for three-dimensional reconstruction: The 3D models of arteries, veins, cysts and liver were extracted respectively, and the abdominal CT images were thresholded for segmentation using the Dynamic Region Growing tool in the Segment menu bar, and after extraction, the Split Mask tool was used for separating the masks, and the vacancies or stumps were filled in using the Multiple Slice Edit tool, and the images were saved as masks. Erase the mask manually with the Erase tool and the Draw tool in Edit masks, and perform the final 3D reconstruction with the Calculate Part tool. According to the CT image 3D reconstruction model color matching standard for different parts of the set to the corresponding color number, respectively, imported into the 3-matic software, further smoothing the model, set the transparency of the liver 3D model to high, the transparency of the gallbladder to medium, to facilitate the simultaneous observation of the hepatic artery, the hepatic vein, the portal vein and the cyst three-dimensional model, the use of properties on the volume of cysts for accurate calculations, according to the establishment of the three-dimensional reconstruction results of the surgical planning, to determine the cystic wall need to be resected (Figure 1).

Surgical methods

In both groups, general anesthesia was administered by tracheal intubation in the lying position. After the anesthesia took effect, a supine position was taken, and a towel was routinely disinfected and laid down, and a curved incision was made at a position of 10 mm below the umbilicus, and CO_2 was injected, and the patient's abdominal pressure was adjusted to 12 mmHg to 14 mmHg, and then a 10-mm Trocar was inserted into the abdominal cavity through the incision, and it was extended into the abdominal cavity to carry out the exploration, so as to clarify the part of the patient's cysts and its surrounding conditions, and then a 3 cm position below the patient's raphe, and this was used as the main operation hole, and the third operation hole was determined with the location of the cysts. An incision was made 3 cm below the xiphoid process of the patient, which was used as the main operation hole, and the third operation hole was determined according to the location of the cyst. The weakest point of the liver cyst was selected as the puncture point, part of the cystic fluid was aspirated out, and it was judged whether there was bile in the cystic fluid, the cystic wall was incised with the assistance of electrocoagulation knife, the cystic cavity was fully exposed, and all the cystic fluid was sucked out with the assistance of the suction device, the cystic wall was lifted up by grasping forceps and the cyst was completely removed by ultrasonic knife, and the cyst was completely removed with the help of titanium clips if there was bleeding in the process of the procedure. After the removal of the cyst, and pay attention to explore whether there is any cyst wall residue, apply tincture of iodine and electrocoagulation to destroy the endothelial cells of the residual cyst wall, so as to make it lose the function of secretion, and then finally apply saline for repeated rinsing. The cyst wall was sent for pathologic examination, then the abdominal cavity was rinsed with anti-adhesion cleaning solution, and the abdomen was closed after placing the drainage tube. In the control group, no three-dimensional reconstruction was performed, and the surgical plan was formulated and planned only by observing the two-dimensional CT images, and then laparoscopic hepatic cyst windowing was performed, which was completed with the cooperation of the same treatment group (Figure 2).

Observation indicators

Perioperative clinical indicators: operative time, intraoperative bleeding, intraoperative cyst drainage, duration of abdominal drain retention, drain drainage, and postoperative hospitalization. Statistics on the incidence of postoperative complications and postoperative recurrence in the two groups. Complications include bleeding, bile leakage, fever, infection, abdominal pain and distension, and ascites. Postoperative recurrence was defined as a reduction in the diameter of the cyst of <50% or no reduction or a larger diameter than the original cyst when the cyst was re-examined by ultrasound at 6 months after surgery.

Statistical analyses

The data of this study were included in SPSS 26.0 statistical software to analyze. Measures that are normally or approximately normally distributed are described by mean ± standard deviation ($x \pm s$), and comparisons between groups are made using the independent

samples of *t* test. Skewed distribution measures were described using the median (upper and lower quartiles) [M (P25, P75)], and comparisons between groups were made using nonparametric tests. Count data were expressed as the number of cases and composition ratio, and the χ^2 test was used for comparison between groups. $p \leq 0.05$ was regarded as statistically significant.

Results

General clinical data

A total of 58 patients were included in this study. There were 33 cases in the observation group, including 10 men and 23 women, aged 33 to 86 (63.76 ± 12.30) years, and the maximum length of the cysts ranged from 57 to 217 (104.61 ± 37.46) mm. In the control group, there were 25 cases, including 13 men and 12 women, aged 46 to 91 (63.36 ± 11.84) years, and the maximum length of the cyst was 60 to 202 (109.68 ± 39.64) mm. The difference between the two groups was not statistically significant (P>0.05). Table 1 shows the comparison of the basic general clinical data of the two groups of patients.

Perioperative results

Both groups of patients successfully completed the operation, without any intermediate open abdomen, and no perioperative death cases. The operation time and intraoperative bleeding in the observation group were better than those in the control group, and the difference was statistically significant (P < 0.05). Table 2 shows the comparison of perioperative clinical indicators, postoperative complication rate, and postoperative recurrence rate between the two groups. The difference between preoperative measurements and intraoperative drainage volume was better in the observation group than in the control group, and the difference was statistically significant (P<0.05). Table 3 shows the comparison between the volume of liver cysts calculated by Mimics software and CT measurements.

Follow up results

The number of postoperative complications and postoperative recurrence were basically the same in both groups. There were 4 cases of complications in the observation group and 3 cases in the control group, including 1 case of postoperative infection and 3 cases of abdominal pain and distension in the observation group. In the control group, there were 2 cases of postoperative infection and 1 case of abdominal pain. There was 1 case of postoperative recurrence in the observation group and 3 cases in the control group. The difference was not statistically significant (P>0.05).

Discussion

Liver cysts, with a global prevalence of about 4.5% to 7%, are benign diseases of the liver, and about 5% require treatment [7]. In recent years, the incidence of hepatic cysts in China has shown a gradual increasing trend, but the pathogenesis of hepatic cysts is not yet completely clear, and they are generally considered to be congenital. In clinical practice, more than 90% of liver cysts are congenital [8]. Liver cysts can be single or multiple, small cysts are asymptomatic, while larger cysts (>5 cm) may present with symptoms such as epigastric fullness, vague pain and postprandial fullness [9]. Except for a very small number of people, patients with this disease do not have clinical symptoms, and the disease progresses slowly, resulting in some patients delaying their condition, larger cysts extrusion of surrounding organs or cyst rupture bleeding, affecting the patient's life or even a crisis of their lives. The preferred treatment option for hepatic cysts is surgical resection, usually by laparoscopic windowing, which has been shown to have the advantages of high lesion clearance, low symptomatic recurrence, and short recovery time. It has been demonstrated that conventional laparotomy can be used to treat liver cysts to the level of eradication [10]. However, there are still a number of shortcomings, such as the location of the cyst coupled with the problem of the laparoscopic angle leads to difficulties in surgical localization, is not applicable to patients with deeper cysts or thicker cystic walls, and incomplete opening and drainage, and so on [11]. Finding more precise, convenient, safe and efficient treatment options for liver cysts is important.

In this study, three-dimensional reconstruction of patients was performed using Mimics software to assist laparoscopic open drainage, and the results suggest that it can effectively shorten the operation time, reduce the amount of intraoperative bleeding, and more accurately measure the cystic fluid volume, which facilitates cystic open drainage. Mimics software is an interactive medical image control system developed by Materialize Belgium that can threshold segmentation, extraction and rendering of 2D image information including CT and MRI [12,13]. The final realization of three-dimensional digital reconstruction, later according to the different needs of the output of different modules, combined with other software can realize computer-aided design, finite element analysis and 3D printing and so on [14,15]. Mimics software can intuitively

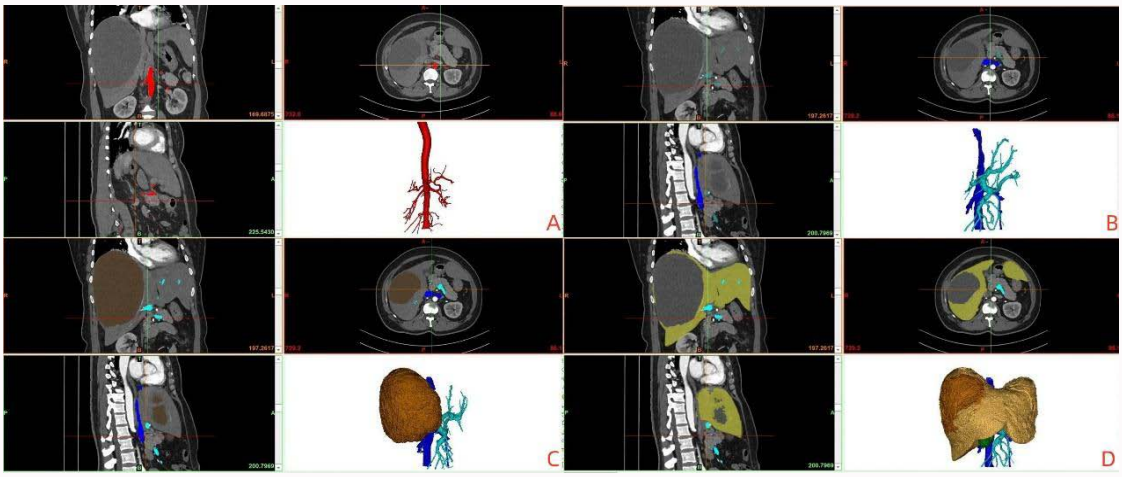

Figure 1: A) Arterial reconstruction; B) Venous reconstruction; C) Cystic reconstruction; D) Reconstruction of the liver.

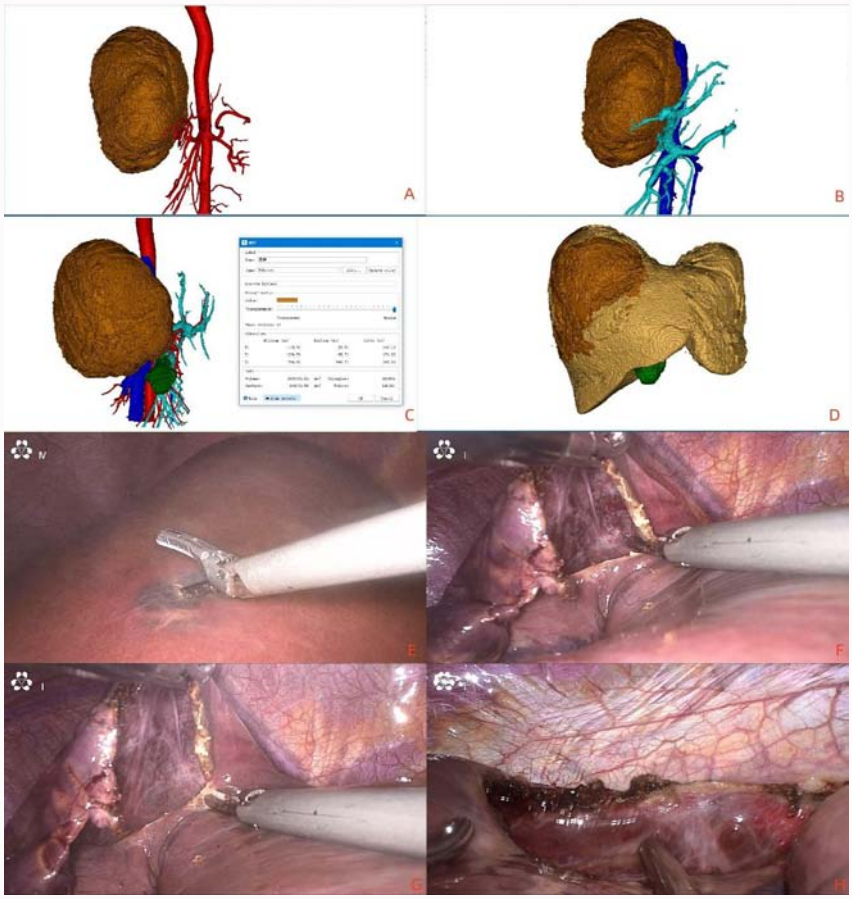

Figure 2: A) 3D reconstruction of arteries; B) 3D reconstruction of veins; C) 3D reconstruction of cysts and measurement of cyst volume; D) 3D reconstruction of liver; E) Intraoperative open-windowed cyst view; F, G) Intraoperative resection of cyst wall view; H) Intraoperative cyst wall resection completion view.

Table 1: Comparison of general clinical data between the two groups (*: *t* test; #: χ^2 test).

Clinical data	Observation group (n=33)	Control group (n=25)	t/χ^2	P
Age (years):	63.76 ± 12.30	63.36 ± 11.84	0.124	0.902*
Genders			2.798	0.094#
Men	10 (30.30%)	13 (52.00%)		
Women	23 (69.70%)	12 (48.00%)		
BMI	25.35 ± 2.99	26.39 ± 3.27	-1.265	0.211*
Number of cysts	2.55 ± 1.66	3.04 ± 1.95	-1.043	0.302*
Maximum length of cysts	104.61 ± 37.46	109.68 ± 39.64	-0.498	0.620*
Cysts are mainly located in the liver segment			23.486	0.266#
S2, S3	3 (9.09%)	3 (12.00%)		
S2, S3, S4	5 (15.15%)	1 (4.00%)		
S2, S7	1 (3.03%)	0 (0.00%)		
S3, S5, S6, S7	1 (3.03%)	0 (0.00%)		
S4	1 (3.03%)	2 (8.00%)		
S4, S5, S6, S7, S8	2 (6.06%)	0 (0.00%)		
S4, S5, S8	1 (3.03%)	0 (0.00%)		
S4, S8	2 (6.06%)	0 (0.00%)		
S5	2 (6.06%)	0 (0.00%)		
S5, S6	3 (9.09%)	1 (4.00%)		
S5, S6, S7	1 (3.03%)	1 (4.00%)		
S5, S6, S7, S8	4 (12.12%)	3 (12.00%)		

S5, S6, S8	1 (3.03%)	0 (0.00%)		
S5, S7, S8	0 (0.00%)	1 (4.00%)		
S5, S8	0 (0.00%)	1 (4.00%)		
S6	0 (0.00%)	2 (8.00%)		
S6, S7	2 (6.06%)	2 (8.00%)		
S6, S7, S8	0 (0.00%)	4 (16.00%)		
S7	1 (3.03%)	0 (0.00%)		
S7, S8	0 (0.00%)	1 (4.00%)		
S8	3 (9.09%)	3 (12.00%)		

Table 2: Comparison of perioperative clinical indicators, postoperative complication rates, and postoperative recurrence rates between the two groups of patients [M (P25, P75); MD: Difference between the medians of the two groups; RR: Rate Ratio].

Clinical data	Observation group (n=33)	Control group (n=25)	Effect size (95% CI)	P
Operative time (min)	60.00 (50.0,72.5)	65.00 (60.0,85.0)	MD= -10.0 (-18.000,0.000)	0.025
Intraoperative bleeding (ml)	3.00 (2.0,5.0)	5.00 (4.0,6.0)	MD= -1.0 (-3.000,0.000)	0.028
Duration of abdominal drain retention (day)	3.00 (3.0,5.0)	4.00 (4.0,5.5)	MD= -1.0 (-1.000,0.000)	0.124
Drain drainage (ml)	180.00 (100.0,420.0)	250.00 (80.0,500.0)	MD= -15.0 (-140.000,85.000)	0.783
Postoperative hospitalization(day).	5.00 (4.0,7.0)	6.00 (4.5,7.0)	MD=0.0(-2.000,1.000)	0.400
Postoperative complication	4 (12.12%)	3 (12.00%)	RR=1.01(0.248,4.112)	0.989
Postoperative recurrence	1 (3.03%)	3 (12.00%)	RR=0.253(0.028,2.285)	0.215

Table 3: Comparison of Mimics Software calculated liver cyst volume with CT measurements [M (P25, P75); MD: Difference between the medians of the two groups].

Clinical data	Preoperative measurements of cysts (ml)	Intraoperative drainage (ml)	Difference (ml)
Observation group (Abdominal CT measurements) (n=33)	657.000 (390.0,978.5)	500.000 (250.0,700.0)	200.000 (101.0,310.5)
Control group (Mimics software measurements) (n=22)	650.000 (371.5,1703.0)	600.000 (275.0,950.0)	342.000 (-268.5,636.5)
Effect size (95% CI)	MD= -9.648 (-295.920,238.151)	MD= -100 (-300.00, 150.00)	MD= -149.496 (-323.503, -6.196)
p	0.969	0.498	0.039

and quickly construct 3D models, and the reconstructed 3D models can reflect the three-dimensional structural position and shape of the patient's living organs, and can be displayed in any combination of colors according to the needs of the model, and part of the model is transparent and can be viewed on a personal computer. For the development of liver surgery plan, the patient's personalized 3D model can be used as a reference for clinicians and provide relevant information [16], which can assist clinical surgery. It can also clearly explain the condition of patients and their families, which is conducive to communication and understanding. In this study, the 3D reconstruction by Mimics software allows us to visualize the size, volume, location and distribution of the surrounding blood vessels of the liver cysts, so that we can detect the variations in time and formulate the surgical access and surgical planning. At the same time, by using mobile devices, the assistant can adjust the observation in real time during the operation, so that the target cyst can be handled more accurately and faster.

The control group could not be well familiarized with the location of the cyst due to the lack of guidance from 3D reconstruction technology, which was searched for through intraoperative luminal scopes, in addition to the precise avoidance of hepatic blood vessels in order to minimize unnecessary bleeding; therefore, the observation group under the guidance of 3D reconstruction had a shorter operative time, and was much less prone to unnecessary bleeding due to blood vessel variations. In addition, by reconstructing the hepatic cyst with Mimics software, the operator is able to further clarify the location of the cyst through 360° rotation, transparency, and other operations to form an intuitive three-dimensional image, and determine whether the target segment could be completely removed through the establishment of the safety ball at the incisal edge, reducing unnecessary intraoperative injuries. Mimics software has many advantages. First, the software is cheap; second, the software system is simple, highly automated, time-saving, labor-saving, convenient, and can be installed and used in personal computers; last but not least, it improves computational accuracy, precision, and speed, and even though the hepatobiliary system is structurally complex, it is still able to rebuild the system quickly and then restore it to a high degree.

In summary, preoperative three-dimensional reconstruction using Mimics software to guide laparoscopic hepatic cyst opening and drainage can shorten the operation time, reduce the amount of intraoperative bleeding, improve the precise measurement of preoperative cyst volume, and facilitate the planning of the surgical plan in advance, which is worthy of clinical promotion. However, there are some limitations in this study, the sample size is small, there is a certain bias, the follow-up needs to be further studied in large samples and multi-center clinical trials.

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