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RESEARCH

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Application effect of enhanced recovery after surgery on patients with hepatolithiasis undergoing hepatectomy

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Abstract

Objective: To explore the application effect of enhanced recovery after surgery (ERAS) for patients with hepatolithiasis undergoing hepatectomy.

Methods: A retrospective comparative analysis was performed on the clinical data of 120 patients with hepatolithiasis who were admitted to the Department of Hepatobiliary Surgery in our hospital between December 2017 and May 2022 using convenience sampling.

Results: There were differences in the impact of different management modes on blood glucose and visual analogue scale (VAS) scores between the two groups of patients ($F_{\text{blood glucose}}=32.581$, $F_{\text{VAS}}=41.472$, all $P<0.001$). The average blood glucose levels in the traditional group were higher than those in the ERAS group at two time points, and the VAS scores in the former group were higher than those in the latter at 6, 12 and 24 h after surgery. The remifentanil dosage (49.89 ± 12.12 vs 57.84 ± 11.43 mL, $t=-2.475$, $P=0.016$), patient-controlled analgesia frequency (3.83 ± 2.23 vs 5.57 ± 3.52 times, $t=-2.481$, $P=0.015$) and analgesic supplementation frequency (0.57 ± 0.73 vs 1.07 ± 1.02 times, $t=-2.653$, $P=0.010$) in the ERAS group were all lower than those in the traditional group. Different management modes had different effects on the levels of procalcitonin (PCT), interleukin-6 (IL-6), C-reactive protein (CRP) and white blood cell count (WBC) in the two groups of patients ($F_{\text{PCT}}=45.371$, $F_{\text{IL-6}}=43.466$, $F_{\text{CRP}}=51.364$, $F_{\text{WBC}}=65.674$, all $P<0.001$). The levels of PCT, IL-6, CRP and WBC in the ERAS group were lower than those in the traditional group at three time points: postoperative day 1, 7 and 14. The postoperative hospital stay (8.41 ± 2.55 vs 11.61 ± 3.34 d, $t=-7.812$, $P<0.001$) and proportion of postoperative complications (9.61% vs 26.47%, $\chi^2=5.403$, $P=0.020$) in the ERAS group were lower than those in the traditional group.

Conclusion: The application of ERAS effectively reduces the perioperative stress response, shortens the postoperative length of hospital stay and lowers the overall incidence of postoperative complications in patients with hepatolithiasis.

Keywords: Hepatolithiasis, Enhanced recovery after surgery, Stress response, Hepatectomy

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Introduction

Hepatolithiasis is a common disease in biliary surgery in China. According to statistics, the incidence of hepatolithiasis is 15–30% in some epidemic areas [1]. With a poor understanding of the pathogenesis so far, hepatolithiasis exhibits obvious differences in regional distribution, with a high incidence in the Yangtze River basin in southwest and southern China [2]. Although the disease develops relatively slowly, the treatment and risk of serious complications remain challenging. Without an active and curative treatment, it may recur repeatedly, seriously affecting the quality of life of patients, and may even progress to cirrhosis and cholangiocarcinoma in the later stage. At present, liver lobectomy and segmentectomy can maximise the removal of stones and lesions, both of which are the preferred and key options for treating intrahepatic and extrahepatic cholangiolithiasis [3]. However, because of the considerable surgical trauma resulting from the two surgeries, as well as the complex pathological and physiological structures of the liver, patients may still experience poor nutrition, slow recovery, multiple complications, high mortality rate and other challenges after surgery. Early postoperative mobilisation, the promotion of gastrointestinal function recovery, early oral intake and nutrition, and patient comfort are still key issues of concern for medical staff. Key points and special issues for clinical research include reducing the trauma of surgery to patients, alleviating their perioperative stress response, promoting patient comfort and early recovery.

Enhanced recovery after surgery (ERAS), first proposed by Danish surgeon Henrik Kehlet in 2001, refers to the application of a series of evidence-based optimisation measures during the perioperative period to reduce patients' postoperative stress response and complications, shorten the length of hospital stay and, ultimately, accelerate patient recovery [4]. It emphasises minimising the perioperative stress response of patients and blocking the transmission of stress signals by afferent nerves, thus alleviating the psychological and physical damage to patients [5]. The optimised intervention measures of ERAS include strengthening preoperative education, cancelling preoperative intestinal preparation, shortening preoperative fasting time, avoiding gastric tube indwelling, implementing intraoperative warming and intraoperative local infiltration anaesthesia combined with thoracic epidural and general anaesthesia, avoiding fluid overload, providing sufficient postoperative analgesia and ensuring early postoperative mobilisation and eating.

Existing data verify the safe and efficient application of ERAS in procedures such as colorectal surgery, oesophageal surgery and pancreaticoduodenectomy [6, 7]. However, research on ERAS is still in its early development stage in hemihepatectomy. Compared with reports on ERAS in other fields such as digestive surgery, there are relatively few domestic reports on the application of ERAS in hepatectomy for hepatolithiasis, with only preliminary clinical practice and experience [8]. Current research in China is primarily a simple imitation of foreign strategies for ERAS in hemihepatectomy, without highlighting the underlying diseases of the liver or the impact of ERAS on stress response indicators in patients undergoing hemihepatectomy. Moreover, patients with hepatolithiasis frequently experience recurrent cholangitis caused by obstruction of the bile duct by stones, resulting in elevated white blood cell count (WBC) and transaminases before surgery and positive bile culture during surgery, increasing the incidence of postoperative complications [9].

Accordingly, applying ERAS to hepatectomy for the treatment of hepatolithiasis is vital. Therefore, this study was performed to analyse the clinical data of 120 patients with hepatolithiasis who were admitted to the Department of Hepatobiliary Surgery of our hospital between December 2017 and May 2022 to explore the safety and effectiveness of ERAS in the treatment of patients with hepatolithiasis after hemihepatectomy to accelerate postoperative recovery.

Results

General data

The ERAS group consisted of 52 patients, with 31 men and 21 women and an average age of 62.00 ± 6.62 years. The traditional group had 68 patients, 35 men and 33 women, with an average age of 63.17 ± 6.46 years. There was no statistically significant difference in gender, age, weight, height, Child–Pugh classification, ASA grade, surgical duration or proportion of surgical procedures between the two groups ($P > 0.05$) (Table 1).

Comparison of blood glucose and VAS scores

A repeated measures analysis of variance was performed to explore the effects of different management modes on postoperative blood glucose and VAS scores in the two groups of patients. A Shapiro–Wilk test demonstrated that each group's data followed an approximate normal distribution ($P > 0.05$), and Mauchly's spherical hypothesis test revealed an equal variance–covariance matrix in each group ($P > 0.05$); data were expressed as x ± s. As summarised in Table 2, there was no statistically significant difference in baseline blood glucose and VAS scores between the two groups of patients (all $P > 0.05$), suggesting good comparability between the groups. The summary of results is as follows.

There was a significant interaction between time*treatment of the postoperative blood glucose and VAS scores in the two groups ($F_{\text{blood glucose}} = 56.348$, $F_{\text{VAS}} = 67.582$, all $P < 0.001$), indicating that different management modes had different individual effects on the postoperative blood glucose and VAS scores of the two groups of patients at different time points. Furthermore, the blood glucose and VAS scores of both groups

Table 1 Comparison of general data

Items	ERAS group ($n = 52$)	Traditional group ($n = 68$)	χ^2/t value	P value
Gender (male/female)	31/21	35/33	0.790	0.374
Age (years, x ± s)	62.00 ± 6.62	63.17 ± 6.46	1.212	0.075
Body weight (kg, x ± s)	60.97 ± 8.08	59.23 ± 7.17	1.120	0.110
Body height (cm, x ± s)	164.77 ± 8.41	166.23 ± 7.72	0.891	0.121
Child classification (A/B)	45/7	53/15	1.455	0.228
ASA classification (I/II)	41/11	49/19	0.724	0.395
Surgical duration (min, x ± s)	206.07 ± 39.97	192.43 ± 35.09	0.293	0.770
Surgical procedures				
Left hemihepatectomy	6	8	0.011	0.994
Right hemihepatectomy	8	10		
Hemihepatectomy + T-tube drainage	38	50		

ASA American Society of Anesthesiologists classification, *ERAS* enhanced recovery after surgery

Table 2 Comparison of blood glucose and VAS scores

Items	ERAS group ($n=52$)	Traditional group ($n=68$)	$F_{interactive}/P_{interactive}$ value	F_{time}/P_{time} value	$F_{treatment}/P_{treatment}$ value
Blood glucose					
t0[a]	5.30 ± 0.57	5.00 ± 0.51	56.348/0.001	64.338/0.001	32.581/0.001
t1[b]	7.46 ± 0.78	8.49 ± 0.76			
t2[b]	7.00 ± 0.87	9.26 ± 0.76			
VAS scores					
Baseline[a]	0.80 ± 0.76	1.10 ± 0.80	67.582/0.001	55.485/0.001	41.472/0.001
6 h after surgery[b]	2.23 ± 1.19	3.07 ± 1.29			
12 h after surgery[b]	2.23 ± 1.04	3.27 ± 1.08			
24 h after surgery[b]	2.17 ± 1.09	2.90 ± 0.80			
48 h after surgery[a]	2.50 ± 1.11	2.60 ± 1.19			

VAS visual analogue scale, *ERAS* enhanced recovery after surgery; a: without statistically significant difference in inter-group comparison; b: with statistically significant difference in inter-group comparison

Table 3 Comparison of analgesic agent usage

Items	ERAS group (n = 52)	Traditional group ($n=68$)	*t* value	*P* value
Sufentanil (μg, x ± s))	28.29 ± 2.42	28.23 ± 2.45	0.461	0.670
Remifentanil (40 μg/mL, mL, x ± s)	49.89 ± 12.12	57.84 ± 11.43	− 2.475	0.016
Patient-controlled analgesia frequency (times, x ± s)	3.83 ± 2.23	5.57 ± 3.52	− 2.481	0.015
Analgesic supplementation frequency (times, x ± s)	0.57 ± 0.73	1.07 ± 1.02	− 2.653	0.010

ERAS enhanced recovery after surgery

fluctuated over time ($F_{\text{blood glucose}}=64.338$, $F_{\text{VAS}}=55.485$, all $P<0.001$), indicating significant changes in blood glucose and VAS scores over time. Finally, there were differences in the impact of different management modes on blood glucose and VAS scores between the two groups ($F_{\text{blood glucose}}=32.581$, $F_{\text{VAS}}=41.472$, all $P<0.001$). This study further compared blood glucose and VAS scores between the two groups of patients at different time points. The average blood glucose levels in the traditional group were higher than those in the ERAS group at two time points, and the VAS scores in the former group were higher than those in the latter group at 6, 12 and 24 h after surgery. However, no statistically significant difference was observed in VAS scores between the two groups at 48 h after surgery.

Comparison of analgesic agent usage

The remifentanil dosage (49.89 ± 12.12 vs 57.84 ± 11.43 mL, $t=-2.475$, $P=0.016$), patient-controlled analgesia frequency (3.83 ± 2.23 vs 5.57 ± 3.52 times, $t=-2.481$, $P=0.015$) and analgesic supplementation frequency (0.57 ± 0.73 vs 1.07 ± 1.02 times, $t=-2.653$, $P=0.010$) in the ERAS group were all lower than those in the traditional group. However, there was no statistically significant difference in sufentanil dosage between the two groups ($t=0.461$, $P=0.670$) (Table 3).

Comparison of inflammatory indicators

Repeated measures analysis of variance was further performed to explore the effects of different management modes on the postoperative PCT, IL-6, CRP and WBC levels in patients. The Shapiro–Wilk test demonstrated an approximate normal distribution of data in each group ($P > 0.05$); Mauchly's spherical hypothesis test revealed an equal variance–covariance matrix in each group ($P > 0.05$), and data were expressed as $x \pm s$. As presented in Table 4, no statistically significant difference was identified in these indicators at baseline between the two groups (all $P > 0.05$), suggesting good comparability between groups. The summary of results is described as follows.

Significant interaction between time*treatment was detected in the postoperative PCT, IL-6, CRP and WBC levels in the two groups of patients ($F_{PCT} = 62.712$, $F_{IL-6} = 51.284$,

Table 4 Comparison of inflammatory indicators

Items	ERAS group ($n = 52$)	Traditional group ($n = 68$)	$F_{interactive}/P_{interactive}$ value	F_{time}/P_{time} value	$F_{treatment}/P_{treatment}$ value
PCT (pg/mL)					
Before surgery[a]	0.19 ± 0.04	0.17 ± 0.05	62.712/0.001	61.364/0.001	45.371/0.001
1d after surgery[b]	2.60 ± 0.46	3.78 ± 0.83			
4d after surgery[b]	2.11 ± 1.17	2.98 ± 1.73			
7d after surgery[b]	1.04 ± 0.56	2.06 ± 0.83			
IL-6 (pg/mL)					
Before surgery[a]	8.18 ± 3.39	7.93 ± 3.74	51.284/0.001	52.475/0.001	43.466/0.001
1d after surgery[b]	128.49 ± 15.17	264.77 ± 18.25			
4d after surgery[b]	87.93 ± 10.33	195.29 ± 12.71			
7d after surgery[b]	33.76 ± 7.54	95.39 ± 10.88			
CRP (mg/L)					
Before surgery[a]	5.48 ± 2.03	5.12 ± 2.85	41.465/0.001	45.564/0.001	51.364/0.001
1d after surgery[b]	40.35 ± 9.78	58.36 ± 13.22			
4d after surgery[b]	67.24 ± 6.44	100.54 ± 10.77			
7d after surgery[b]	32.19 ± 5.35	50.63 ± 8.72			
WBC($\times 10^9$/L)					
Before surgery[a]	5.14 ± 0.84	5.62 ± 1.26	66.467/0.001	61.465/0.001	65.674/0.001
1d after surgery[b]	11.27 ± 2.02	12.86 ± 2.66			
4d after surgery[b]	11.65 ± 1.65	12.53 ± 1.89			
7d after surgery[b]	9.63 ± 0.94	10.81 ± 1.15			

PCT procalcitonin, *IL-6* interleukin-6, *CRP* C-reactive protein, *WBC* white blood cell count, *ERAS* enhanced recovery after surgery, a: without statistically significant difference in inter-group comparison; b: with statistically significant difference in inter-group comparison

$F_{\mathrm{CRP}}=41.465$, $F_{\mathrm{WBC}}=66.467$, all $P<0.001$), indicating that different management modes had different individual effects on postoperative PCT, IL-6, CRP and WBC levels in the two groups of patients at different time points. The levels of PCT, IL-6, CRP and WBC in both groups fluctuated over time ($F_{\mathrm{PCT}}=61.364$, $F_{\mathrm{IL\text{-}6}}=52.475$, $F_{\mathrm{CRP}}=45.564$, $F_{\mathrm{WBC}}=61.465$, all $P<0.001$), suggesting significant changes in these levels over time in both groups. Finally, different management modes demonstrated different effects on the levels of PCT, IL-6, CRP and WBC in the two groups ($F_{\mathrm{PCT}}=45.371$, $F_{\mathrm{IL\text{-}6}}=43.466$, $F_{\mathrm{CRP}}=51.364$, $F_{\mathrm{WBC}}=65.674$, all $P<0.001$). A further comparison of PCT, IL-6, CRP and WBC levels at different time points in the two groups of patients revealed that the levels of PCT, IL-6, CRP and WBC in the ERAS group were all lower than those in the traditional group at the three time points of day 1, 7 and 14 after surgery.

Comparison of postoperative recovery

The anal exhaust time (34.42 ± 8.71 vs 57.72 ± 11.81 h, $t=-7.227$, $P<0.001$), urinary catheter retention time (3.47 ± 0.82 vs 36.72 ± 9.64 h, $t=-19.940$, $P<0.001$), first out-of-bed activity time (19.25 ± 2.33 vs 44.17 ± 10.54 h, $t=-13.950$, $P<0.001$), oral intake time (17.42 ± 3.82 vs 48.33 ± 11.72 d, $t=-15.201$, $P<0.001$) and postoperative length of hospital stay (8.41 ± 2.55 vs 11.61 ± 3.34 d, $t=-7.812$, $P<0.001$) were shorter and the proportion of postoperative complications (9.61% vs 26.47%, $\chi^2=5.403$, $P=0.020$) was lower in the ERAS group than those in the traditional group (Table 5).

Discussion

Hepatectomy is characterised by slow postoperative recovery, high stress response and mortality rate, and numerous postoperative complications. The incidence of complications after liver resection has been reported to range from 15 to 48%, and the average postoperative length of hospital stay is as much as 10 days [13]. Increased preoperative bilirubin, decreased liver reserve function and postoperative liver dysfunction can seriously affect patients' postoperative recovery. The core concept of modern precision liver surgery is to achieve a balance between lesion clearance, liver protection and injury

Table 5 Comparison of postoperative recovery

Items	ERAS group ($n=52$)	Traditional group ($n=68$)	χ^2/t value	P value
Anal exhaust time (h, x ± s))	34.42 ± 8.71	57.72 ± 11.81	− 7.227	< 0.001
Urinary catheter retention time (h, x ± s)	3.47 ± 0.82	36.72 ± 9.64	− 19.940	< 0.001
First out-of-bed activity time (h, x ± s)	19.25 ± 2.33	44.17 ± 10.54	− 13.950	< 0.001
Oral intake time (d, x ± s)	17.42 ± 3.82	48.33 ± 11.72	− 15.201	< 0.001
Postoperative length of stay (d, x ± s)	8.41 ± 2.55	11.61 ± 3.34	− 7.812	< 0.001
Complications (n)				
Incision infection	3	5		
Bile leakage	2	3		
Subphrenic abscess	1	2		
Pulmonary infection	2	5		
Postoperative abdominal distension	3	4		
Total cases	5	18	5.403	0.020

ERAS enhanced recovery after surgery

control [14], laying the foundation for implementing ERAS. The ERAS programme involves the use of a series of evidence-based approaches for optimising perioperative management before, during and after surgery to alleviate or reduce patients' physical and mental stress and promote rapid postoperative recovery. After hepatectomy, the emphasis of ERAS implementation is to strengthen perioperative management, reducing postoperative adverse reactions and alleviating the physical and mental stress as well as complications in patients during the perioperative period.

Surgery and anaesthesia can lead to an increased stress response in patients who have generally been in a state of stress before surgery. The neurohumoral mechanism in vivo may further increase the secretion of endocrine hormones and inflammatory factors (IL-6, cortisol). Glucose is mainly synthesised through three pathways: external intake, glycogenolysis and gluconeogenesis. Under stress, glycogenolysis and gluconeogenesis may be enhanced; insulin, a metabolic hormone that is involved in lowering blood glucose, may exhibit secretion disorder, accompanied by insulin resistance in target cells [15]; and humoral factors, such as NA, IL-6 and cortisol, exhibit increased secretion, raising blood glucose by increasing the secretion of glucagon [16]. All the above-mentioned factors can cause changes in blood glucose levels in patients during the perioperative period. In this study, the blood glucose levels in the ERAS group were lower than those in the traditional group at t1 and t2, indicating that ERAS alleviates postoperative stress in patients and promotes their recovery.

Patients may be more concerned about postoperative pain than the surgery itself. Undoubtedly, a series of pain-induced neurohumoral changes, such as emergency responses triggered by the sympathetic–adrenal–medullary response and stress responses triggered by the activation of the hypothalamic–pituitary–adrenal axis, can impact the surgical recovery of patients. In severe cases, patients may experience stress ulcers and toxaemia. Moreover, persistent pain can seriously affect the early mobilisation of patients and recovery of gastrointestinal function, as well as skeletal muscle tonus and lung compliance, leading to the occurrence of hypoxemia [17]. Common local anaesthetics include bupivacaine and ropivacaine. Ropivacaine is a long-acting aminoamide local anaesthetic with minimal side effects, widely used in various nerve blocks and postoperative analgesia [18]. Research has demonstrated that the use of 0.375% ropivacaine has positive analgesic effects and fewer adverse reactions [19]. Domestic research has also revealed no significant difference in the effectiveness of 0.25% and 0.375% ropivacaine in analgesia for abdominal surgery [20, 21]. However, according to the application guidance of regional anaesthetic agents, these anaesthetics should be administered at a concentration of 0.2–0.5% or 1.5 mg/kg, with a maximum of 210 mg. In this study, the concentration and dosage were reduced as appropriate [22] considering that patients enrolled were older and more sensitive to drugs; thus, 20 mL of 0.25% ropivacaine was selected for analgesia on each side. The results revealed that the VAS scores, intraoperative sufentanil and remifentanil dosage, postoperative analgesic supplementation frequency and patient-controlled analgesia frequency in the ERAS group were all lower than those in the traditional group.

Various injury factors (e.g. anaesthesia, surgical trauma, infection, postoperative pain and anxiety) in hepatectomy can cause the excessive release of pro-inflammatory factors, leading to local and systemic inflammatory reactions [23]. Procalcitonin, the precursor peptide of calcitonin, is extremely low, almost undetectable, in normal human blood. During bacterial infections, however, serum PCT levels significantly increase and continue to remain high or gradually decrease as the infection progresses or is controlled. In addition, CRP is an acute phase reactant with a rapid increase in blood concentration during acute trauma and infection and a rapid decrease during recovery [24]. The combined detection of PCT and CRP can improve the specificity and sensitivity of diagnosis. Furthermore, IL-6 regulates the immune response, acute phase response and haematopoietic function and plays a key role in the anti-infection immune response. During injury and infection, IL-6 in serum has been reported to be significantly elevated. In this study, levels of PCT, IL-6, CRP and WBC in the ERAS group were lower than those in the traditional group, indicating that ERAS can effectively alleviate postoperative inflammatory reactions in patients.

After traditional hemihepatectomy, patients usually start out-of-bed activities after 3 or 4 days because of factors such as incisional pain and surgical impact [25]. This prolonged period in bed may greatly limit thoracic movement, reduce breathing amplitude, affect tissue oxygenation and increase the incidence of lung infections. In addition, it may not be conducive to blood circulation or tissue and cell metabolism, resulting in a potential increase in the incidence of deep vein thrombosis in the lower limbs. When applying ERAS, it is advocated to perform moderate bedside activities with the assistance of family members on postoperative day 1, which could reduce common complications such as lung infection and intestinal obstruction, shorten the time of anal exhaust after surgery, help maintain physiological urination and reduce urinary retention and urinary tract infection. This study also revealed that the ERAS group had significantly superior results to those of the traditional group in terms of anal exhaust time, urinary catheter retention time, first out-of-bed activity time, oral intake time, postoperative length of hospital stay and proportion of postoperative complications.

However, this study has several limitations. First, no unified standard or fixed model exists for ERAS used in hemihepatectomy. As a result, different ERAS measures were adopted in different studies, limiting the comparison of research results. In addition, this study was conducted based on a relatively small sample size that was insufficient to fully indicate the patients' condition. Further improvement is required in future clinical practice to optimise the application of ERAS in hepatectomy to promote patients' postoperative recovery.

Conclusion

The application of ERAS can effectively reduce the perioperative stress response, shorten the postoperative length of hospital stay and lower the overall incidence of postoperative complications in patients with hepatolithiasis while ensuring patient safety, thereby accelerating patients' postoperative recovery. The findings in this study demonstrate that the application of ERAS is relatively safe and effective in the treatment of patients with hepatolithiasis undergoing hepatectomy.

Participants and methods

Study participants

A retrospective comparison analysis was performed on the clinical data of 120 patients with hepatolithiasis undergoing hemihepatectomy who were admitted to the

Department of Hepatobiliary Surgery in our hospital between December 2017 and May 2022 using convenience sampling. According to the perioperative management mode, the enrolled patients were divided into the ERAS group ($n=52$) and traditional group ($n=68$). Inclusion criteria: (1) patients diagnosed with hepatolithiasis through preoperative imaging examination, with no prior history of biliary surgery; (2) patients with generally abnormal cardiopulmonary function after examination, and no surgical contraindications; (3) patients with Child–Pugh class A–B in a preoperative liver function evaluation; (4) patients aged 18–75 years; and (5) patients classified as class I–II by the American Society of Anesthesiologists (ASA). Exclusion criteria: (1) patients with a history of surgery for biliary tract diseases; (2) patients with hepatolithiasis who had a history of combined pancreatic, liver and biliary malignancies, or patients with hepatolithiasis identified as having these malignancies during hospitalisation; (3) patients with a history of genetic diseases (except hypertension and diabetes); and (4) patients with combined active tuberculosis and rheumatic disease, chronic inflammatory disease, chronic organ failure and recent myocardial infarction (< 6 months). This study was approved by the Ethics Committee of our hospital. The research object screening process is shown in Fig. 1.

Methods of study

Preoperative examination

The patients in both groups underwent preoperative chest X-ray, electrocardiogram, echocardiography and routine laboratory blood tests (including liver and kidney function) to evaluate their general condition and cardiopulmonary function. In addition, a preoperative retention rate of indocyanine green at 15 min (ICG 15 min) and postoperative residual liver volume were determined to evaluate liver reserve function combined with the Child–Pugh classification. Patients with Child–Pugh class A can tolerate left hemihepatectomy if the retention rate of ICG 15 min is less than 10%, whereas patients with Child–Pugh class B should be treated with medication and adjusted to class A before undergoing surgery [10]. To clarify the condition, all patients underwent necessary preoperative imaging examinations, including liver and gallbladder ultrasound,

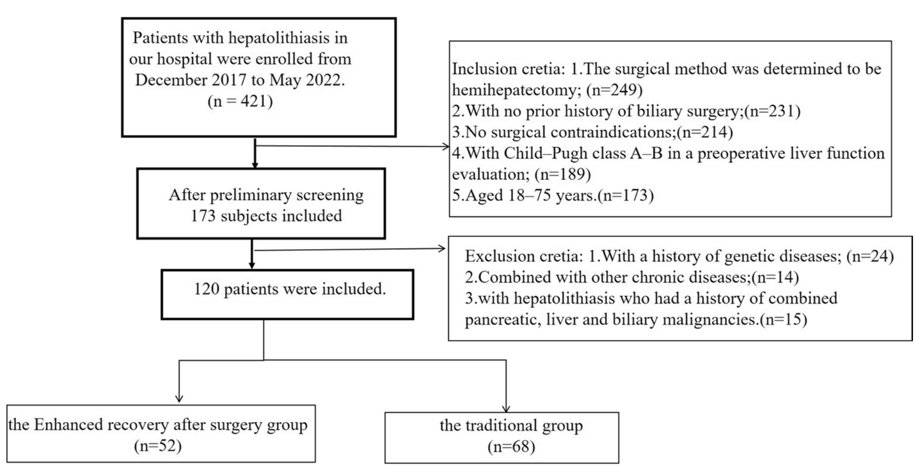

Fig. 1 Research object screening flowchart

computed tomography and magnetic resonance cholangiopancreatography. These assessments aimed to evaluate the location and distribution of stones, the condition of bile duct dilation and the presence of concurrent liver and biliary lesions. If necessary, endoscopic retrograde cholangiopancreatography and/or percutaneous transhepatic cholangiography were conducted to further clarify the condition of the biliary tract.

Surgical procedures

Both groups of patients underwent general anaesthesia after tracheal intubation, and a 4-port laparoscopy was used to establish artificial pneumoperitoneum, with intra-abdominal pressure maintained at 12 mmHg (1 mmHg = 0.133 kPa). To facilitate the intraoperative use of choledochoscopy for stone removal, a puncture was made 3 cm below the xiphoid process and 2 cm to the right, making the puncture port as perpendicular to the common bile duct as possible and maintaining the closest distance. The sites of the remaining puncture port were the same as those of conventional laparoscopic cholecystectomy. The incision length was determined based on preoperative examination and intraoperative observation to block the corresponding vascular system of the diseased liver segment. Haemostasis was performed after disconnecting the diseased liver, with attention paid to the abdominal cavity. With the common bile duct identified, an incision was made into its anterior wall for choledochoscopy to avoid residual stones. Finally, a T-tube was inserted for drainage. When the patient completely returned to normal diet, he could get out of bed in a small range, his liver function index was normal, and the incision healed well, he could return home voluntarily without intravenous infusion.

Perioperative management

Traditional group: Patients in this group received routine perioperative management [11]. Specific strategies included preoperative routine cleaning enema preparation, fasting for 12 h before surgery and routine placement of nasogastric decompression tubes and catheters; traditional general anaesthesia, conventional anaesthetics and abdominal drainage; intraoperative intermittent suture with silk suture during abdominal closure; postoperative use of opioids for pain relief, placement of the T-tube, dual-tube negative pressure on the hepatic cross section and an abdominal drainage tube. Eating and drinking were initiated after intestinal exhaust and out-of-bed activities 3–4 days after surgery. Attention was paid to timely fluid replacement for 1 week.

Enhanced recovery after surgery group: The following improvements were made in this group based on conventional treatment measures combined with ERAS: (1) preoperative rehabilitation education, including disease introduction, potential complications and coping strategies during the perioperative period, alleviation of patient anxiety and patient information on various methods to promote rehabilitation; no intestinal preparation, no fasting 1 day or night before surgery and administration of 0.3 L of 25% glucose solution orally 2–3 h before surgery; (2) traditional intravenous and inhalation general anaesthesia, with short-acting anaesthetics such as remifentanil used as the primary anaesthetic; intraoperative continuous incision with catgut suture, and routine placement of T-tubes and abdominal drainage tubes, without the placement of dual-tube negative pressure on the hepatic cross section; (3) intraoperative monitoring and recording of body temperature, with attention paid to providing patients with warming measures to maintain the temperature at 36℃; intraoperative guidance of the infusion rate and volume control based on goal-directed therapy to no more than 2000 mL; (4) postoperative use of a continuous self-controlled analgesia pump for thoracic epidural analgesia + oral non-steroidal anti-inflammatory and analgesic agents instead of traditional opioids; postoperative routine use of antibiotics, with attention paid to the colour of the wound drainage fluid to prevent postoperative infections; (5) postoperative early removal of abdominal drainage tubes and catheters, early resumption of oral intake, fluid feeding 6 h after surgery and normal diet 3 days later; development of an early mobilisation plan and encouragement of patients to start bedside activities 1 day after surgery, and moderate walking on day 2 after surgery, with the activity level increased daily.

Data collection

Data collected included general data (age, gender, height, weight, Child–Pugh classification, ASA grade, surgical duration); blood glucose levels upon entering the operating room (t0), at the end of surgery (t1) and 2 h after surgery (t2), and visual analogue scale (VAS) scores before surgery and at 6, 12, 24 and 48 h after surgery; intraoperative dosage of sufentanil and remifentanil, analgesic supplementation frequency and patient-controlled analgesia frequency; inflammatory indicators such as procalcitonin (PCT), interleukin-6 (IL-6), C-reactive protein (CRP) and WBC before surgery and on day 1, 4 and 7 after surgery; the time of first postoperative anal exhaust, urinary catheter retention time, first out-of-bed activity time, first oral intake time, postoperative length of hospital stay and incidence of complications.

The VAS score was used to evaluate pre- and post-treatment pain in the two groups, and the score was positively correlated with the degree of pain. The score ranges from 0 (painless) to 10 points (the most painful): ≤ 3 points indicate mild pain, 4–6 points moderate pain and ≥ 7 points severe pain [12].

Complications include incision infection, bile leakage, subphrenic abscess, pulmonary infection and postoperative abdominal distension during postoperative hospitalisation.

Statistical analysis

For statistical processing, SPSS 26.0 (IBM, Armonk, NY, USA) statistical software was used. The Kolmogorov–Smirnov method was used for normality testing. Measurement data that met normality were expressed as mean ± standard deviation ($\overline{x} \pm s$), and the *t*-test was used for inter-group comparison. Repeated measurement data were analysed using repeated measurement analysis of variance, counting data were represented by frequency (n) or rate (%) and inter-group comparisons was made using the χ^2 test. A two-tailed $P < 0.05$ was considered statistically significant.

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Author contributions
Wu XY conceived of the study, and Cao SM participated in its design and data analysis and statistics and Qin SY helped to draft the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
All data generated or analysed during this study are included in this published article.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the Declaration of Helsinki and approved by the ethics committee of Chongzhou People's Hospital.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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References
1. Wu Y, Xu CJ, Xu SF. Advances in risk factors for recurrence of common bile duct stones. Int J Med Sci. 2021;18(4):1067–74. https://doi.org/10.7150/ijms.52974.
2. Pant K, Gradilone SA. Hepatobiliary cancers: progress in diagnosis, pathogenesis, and treatment. Technol Cancer Res Treat. 2022;21:15330338221097204. https://doi.org/10.1177/15330338221097203.
3. Chen X, Wang D, Liang S, et al. Effect of enteral ecoimmunonutrition support for patients undergoing hepatectomy: a meta-analysis of randomized controlled trials. Eur J Clin Nutr. 2022;76(8):1133–41. https://doi.org/10.1038/s41430-022-01073-x.
4. Kehlet H, Wilmore DW. Multimodal strategies to improve surgical outcome. Am J Surg. 2002;183(6):630–41. https://doi.org/10.1016/s0002-9610(02)00866-8.
5. Oremus K, Korolija D, Skegro M, et al. Fast track surgery–enhanced multimodal rehabilitation after surgery. LijecVjesn. 2007;129(8–9):269–75.
6. Gouvas N, Tan E, Windsor A, Xynos E, et al. Fast-track vs standard care in colorectal surgery: a meta-analysis update. Int J Colorectal Dis. 2009;24(10):1119–31. https://doi.org/10.1007/s00384-009-0703-5.
7. Lassen K, Coolsen MM, Slim K, et al. European Society for Clinical Nutrition and Metabolism; International Association for Surgical Metabolism and Nutrition. Guidelines for perioperative care for pancreaticoduodenectomy: Enhanced Recovery After Surgery (ERAS®) Society recommendations. Clin Nutr. 2012;31(6):817–30. https://doi.org/10.1016/j.clnu.2012.08.011.
8. Jia WD, Luo PF. Application of enhanced recovery after surgery in the precision liver surgery. Chin J Dig Surg. 2015;14(1):25–8. https://doi.org/10.3760/cma.j.issn.1673-9752.2015.01.006.
9. Zheng SM, Li H, Zhou XH, et al. Comparison of laparoscopic and open left hemihepatectomy in the treatment of hepatolithiasis. Chin J Hepatobiliary Surg. 2015;21(10):709–11. https://doi.org/10.3760/cma.j.issn.1007-8118.2015.10.019.
10. Dong JH, Zheng SS, Chen XP, et al. Consensus on evaluation of hepatic functional reserve before hepatectomy (2011 edition). Chin J Dig Surg. 2011;10(1):20–5. https://doi.org/10.3760/cma.j.issn.1673-9752.2011.01.006.
11. Professional Committee of Hepatobiliary and Pancreatic Surgery, Chinese Research Hospital Association, Special Committee of Scientific Research Experts of Public Welfare Industry, National Health Commission. Guideline for minimally invasive surgical treatment of hepatolithiasis (2019 edition). Chin J Dig Surg. 2019;18 (5): 407–413.https://doi.org/10.3760/cma.j.issn.1673-9752.2019.05.001.
12. Bodian CA, Freedman G, Hossain S, et al. The visual analog scale for pain: clinical significance in postoperative patients. Anesthesiology. 2001;95(6):1356–61. https://doi.org/10.1097/00000542-200112000-00013.
13. Kaye AD, Urman RD, Cornett EM, et al. Enhanced recovery pathways in orthopedic surgery. J Anaesthesiol Clin Pharmacol. 2019;35(Suppl 1):S35–9. https://doi.org/10.4103/joacp.JOACP_35_18.
14. Dong J, Yang S, Zeng J, et al. Precision in liver surgery. Semin Liver Dis. 2013;33(3):189–203. https://doi.org/10.1055/s-0033-1351781.
15. Akirov A, Shochat T, Dotan I, et al. Glycemic variability and mortality in patients hospitalized in general surgery wards. Surgery. 2019;166(2):184–92. https://doi.org/10.1016/j.surg.2019.02.022.
16. Vedantam D, Poman DS, Motwani L, et al. Stress-induced hyperglycemia: consequences and management. Cureus. 2022;14(7): e26714. https://doi.org/10.7759/cureus.26714.
17. Gerbershagen Hans J, Aduckathil S, van Wijck AJM, et al. Pain intensity on the first day after surgery: a prospective cohort study comparing 179 surgical procedures. Anesthesiology. 2013;118(4):934–44. https://doi.org/10.1097/ALN.0b013e31828866b3.
18. Dai L, Ling X, Qian Y. Effect of ultrasound-guided transversus abdominis plane block combined with patient-controlled intravenous analgesia on postoperative analgesia after laparoscopic cholecystectomy: a double-blind, randomized controlled trial. J Gastrointest Surg. 2022;26(12):2542–50. https://doi.org/10.1007/s11605-022-05450-6.
19. Wang J. Efficacy and pharmacokinetics of transversus abdominis plane block with different concentrations of ropivacaine after cesarean section under general anesthesia. Fujian Med Univ. 2016. https://doi.org/10.7666/d.D01092811.
20. Huang SH. Clinical trial of ultrasound-guided transversus abdominis plane (TAP) block for postoperative analgesia of abdominal surgery. Lanzhou Univ. 2017. https://doi.org/10.7666/d.D01297455.
21. Guo JG, Li HL, Pei QQ, et al. The analgesic efficacy of subcostal transversus abdominis plane block with Mercedes incision. BMC Anesthesiol. 2018;18(1):36. https://doi.org/10.1186/s12871-018-0499-3.
22. Tran DQ, Bravo D, Leurcharusmee P, et al. Transversus abdominis plane block: a narrative review. Anesthesiology. 2019;131(5):1166–90. https://doi.org/10.1097/ALN.0000000000002842.

23. Chinese Society of Liver Cancer, Anti-Cancer Association of China. Multiple disciplinary consensus on the management of excessive inflammatory response in the perioperative period of hepatectomy (2014 edition). Chinese Journal of Digestive Surgery, 2014,13(10):751–755. https://doi.org/10.3760/cma.j.issn.1673-9752.2014.10.001.
24. Wang J, Niu R, Jiang L, et al. The diagnostic values of C-reactive protein and procalcitonin in identifying systemic lupus erythematosus infection and disease activity. Medicine (Baltimore). 2019;98(33): e16798. https://doi.org/10.1097/MD.0000000000016798.
25. Poon RT, Fan ST, Lo CM, et al. Improving survival results after resection of hepatocellular carcinoma: a prospective study of 377 patients over 10 years. Ann Surg. 2001;234(1):63–70. https://doi.org/10.1097/00000658-200107000-00010.

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