

Abandoning Prophylactic Abdominal Drainage after Hepatic Surgery: 10 Years of No-Drain Policy in an Enhanced Recovery after Surgery Environment

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Keywords

Drain · No-drain · Prophylactic drainage · Abdominal drainage · Liver surgery

Abstract

Background: Routine prophylactic abdominal drainage after hepatic surgery is still being debated, as it may be unnecessary, possibly harmful, and uncomfortable for patients. This study evaluated the safety of a no-drain policy after liver resection within an Enhanced Recovery after Surgery (ERAS) programme. **Methods:** All hepatectomies performed without prophylactic drainage during 2005–2014 were included. Primary end points were resection-surface-related (RSR) morbidity, defined as the presence of postoperative biloma, hemorrhage or abscess, and reinterventions. Secondary end points were length of stay, total postoperative morbidity, the composite end point of liver surgery-specific complications, readmissions, and 90-day mortality. Uni- and multivariate analyses were performed to identify independent risk factors for RSR morbidity. A systematic search was performed to compare the results of this study to literature. **Results:** A total of 538 resections were included in the study. The RSR complication and reintervention rate was 15 and 12%, respectively. Major liver resection (≥ 3 segments)

was an independent risk factor for the development of RSR morbidity (OR 3.01, 95% CI 1.61–5.62; $p = 0.001$) and need for RSR reintervention (OR 3.02, 95% CI 1.59–5.73; $p = 0.001$). **Conclusion:** RSR morbidity, mortality, and reintervention rates after liver surgery without prophylactic drainage in patients, treated within an ERAS programme, were comparable to previously published data. A no-drain policy after partial hepatectomy seems safe and feasible.

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Introduction

In the past decades, the quality of perioperative care for hepatic surgery has improved dramatically due to improvements in surgical technique, risk assessment and perioperative care. Prophylactic intra-abdominal drainage is still routinely applied in many hospitals worldwide. However, prophylactic intra-abdominal drainage may be unnecessary [1], uncomfortable, and even harmful for the patient. As early as 1915, the British surgeon, Major Grey

E.M.W.-L.-H. and V.W. contributed equally to this work. This study has been presented with preliminary results as an oral presentation at the E-AHPBA 2013 congress in Belgrade, Serbia.

Turner, already pointed out the dangers of routine drain use. One hundred years later, the routine use of prophylactic drains in liver surgery is still an on-going debate [2].

Some studies have reported advantages of prophylactic drain placement such as early drainage of bile leaks, preventing subphrenic collection, detecting postoperative hemorrhage, and removing ascites [3–6]. Other studies have indicated that the risks of prophylactic intra-abdominal drains, including drain-related bleeds, ascending intra-abdominal infections by retrograde contamination, and impaired pulmonary function, outweigh the benefits [1, 7, 8]. Furthermore, patients with a drain in place experience more abdominal pain and discomfort, have more difficulties to mobilize, need more nursing care, and this could contribute to a longer admission and increased costs [7].

Currently, if used, drains are usually placed near the transection surface or in the subphrenic space and are often removed on postoperative day 3–5 depending on drain production [7, 9, 10]. Already in 2007, a meta-analysis [11] showed that there were no significant differences in morbidity, mortality, and re-operation rates between patients with or without a prophylactic abdominal drain after uncomplicated elective hepatectomy. Postoperative mortality in patients undergoing liver surgery without a drain ranges between 0 and 3%. Percutaneous or operative reintervention rates in patients without a drain are 0–18% and 0–10%, respectively [1, 4, 7, 8, 12–14], and do not differ from outcomes after placement of an abdominal drain. Patients with a drain have reported mortality, percutaneous reintervention, and re-operation rates of 0–6, 0–36, and 0–6%, respectively [1, 4, 7, 8, 12–14]. The accumulating evidence suggests that routine abdominal drainage after liver resection is unnecessary and the benefit arguable, but it may be indicated in specific patients.

The Enhanced Recovery after Surgery (ERAS) programme has shown a benefit for patient recovery after liver surgery in recent years [15–17]. The programme has been implemented to optimize pre-, peri-, and postoperative care to facilitate a quicker recovery. With the introduction of this programme, the routine use of drains after liver surgery without biliary or vascular reconstruction has been abandoned [15–17].

The aim of this study was to examine the postoperative complication and reintervention rates in patients undergoing liver resection that were treated without prophylactic drains in an ERAS environment, to identify risk factors associated with reinterventions for specific complications, and to compare the results to earlier studies on drainage following liver resection.

Methods

Study Design

All patients undergoing hepatic resection between January 2005 and December 2014 at Maastricht University Medical Centre (MUMC) were included in a prospective database. Patients were retrospectively identified and screened for eligibility in this study. Patients were excluded if a prophylactic abdominal drain was placed, for example, in the case of hepatic resection traumatic lesions, or a bilioenteric anastomosis was created. Primary end points of this study were resection-surface-related (RSR) morbidity and reinterventions for RSR morbidity. RSR morbidity was defined as the presence of bile leakage, intra-abdominal abscess, or/and hemorrhage [18]. Reinterventions for RSR morbidity were considered to be CT- or US-guided percutaneous drainage, re-operation, and endoscopic retrograde cholangiopancreatography with stenting. Data on reinterventions were retrospectively collected from individual patient charts. Secondary end-points were hospital length of stay (LOS), postoperative morbidity, readmission rate, 90-day mortality, and the composite end point of liver surgery-specific complications (CEP). A composite end point consists of 2 or more specific complications that can be regarded as 1 dichotomous end point that occur in 1 patient. The liver surgery-specific CEP consists of ascites, postresectional liver failure, bile leakage, intra-abdominal hemorrhage, intra-abdominal abscess, and/or postoperative mortality [19].

Surgical Techniques

All hepatic resections were performed by 1 of 4 hepatobiliary surgeons (C.H.C.D., R.M.D., S.W.M.O.D., and M.H.B.) or by a senior resident/fellow under the supervision of a hepatobiliary surgeon. Hepatectomies were performed as open or laparoscopic procedures as published previously [20].

For open procedures, a unilateral right subcostal, a bilateral subcostal (right extended to left), J-shaped, or midline incision was used. Intraoperative ultrasound was routinely performed to examine the location of lesions in the liver and the relation to surrounding biliary and vascular structures. Hepatic resection was performed by using a Cavitron Ultrasonic Surgical Aspirator (CUSA; System 200 Macrodissector, Cavitron Surgical Systems, USA) and argon beam coagulation (Force GSU System, Valleylab, USA), with or without Pringle's maneuver, and Ultracision Harmonic ACE (Ethicon Endosurgery, Johnson & Johnson, USA). Central venous pressure was maintained at ≤ 5 cm H₂O during transection to reduce excessive blood loss. During transection, clips and ligatures were used to treat vessels and bile ducts at the resection surface. To avoid postoperative hemorrhage and bile leakage, the resection surface was treated with argon beam coagulation and sealants at the discretion of the surgeon, although the effectiveness has never been proven [18].

For laparoscopic procedures, patients were placed in supine French position. Access to the abdomen was created by an open transumbilical insertion of a 30° laparoscope. Three or 4 additional trocars were inserted. The pressure of the pneumoperitoneum was kept at < 12 mm Hg. Parenchymal transection was performed using the LigaSure 5 mm blunt tip (Covidien, USA), laparoscopic CUSA (Cavitron Surgical Systems, USA), or Harmonic scalpel (Ultracision, Ethicon Endosurgery, Johnson & Johnson, USA). The portal pedicles were stapled using a vascular stapler (Endo GIA Autosuture, Covidien, USA). Resected specimens were placed

in a plastic bag (Endo Catch Autosuture, Covidien, USA) and removed through a separate usually suprapubic muscle sparing incision.

No-Drain Policy

Since the introduction of ERAS in liver surgery in 2005, the MUMC has a no-drain policy; abdominal drains are no longer part of standard management after hepatectomy. The use of prophylactic abdominal drains was limited to a selected group of indications. They were routinely placed after the creation of bilioenteric anastomoses or biliary reconstructions and in the case of traumatic liver lesions. In some cases, placement of a prophylactic abdominal drain could be considered by the surgeon when a high risk of intra-abdominal fluid collection was expected, for example, when performing combined procedures, in the case of intraoperative iatrogenic laceration that required drainage, repeat hepatectomies, excessively large resection surfaces, or central liver resections. Furthermore, all patients were treated within the ERAS programme. Key principles of this programme have been previously described [21]. Patients were closely monitored during hospitalization based on clinical presentation, vital parameters, and standard diagnostic laboratory results. Additional imaging (CT or US) was only performed on clinical findings indicative of postoperative complications. All complications, defined as any deviation from the expected postoperative course <30 days and graded according to the Clavien-Dindo classification system [22], were recorded in the electronic patient record system and in a prospectively maintained research database. Data from the electronic patient record system and the research database were crosschecked for missing data.

Systematic Literature Search

A systematic search was conducted to compare the results of this study with literature following the current recommendations of Preferred Reporting Items for Systematic Reviews and Meta-analysis Approach (PRISMA). Two authors (E.M.W.-L.-H. and V.W.) independently performed the search, study selection, data extraction, and critical appraisal of the studies.

Eligibility Criteria

After review of the abstract, the remaining studies were selected for full text evaluation and inclusion under the following conditions: (1) the subject of the study was a comparison of the routine use of an abdominal drain vs. no-drainage after hepatectomy; (2) the study was not an editorial, systematic review, or meta-analysis; (3) the study compared clinical outcome after abdominal drain vs. no-drainage after hepatectomy; and (4) the study was in the English language.

Study Selection and Quality Appraisal

The search was conducted in Ovid MEDLINE, Embase, and PubMed databases to identify all studies comparing the routine use of an abdominal drain vs. no-drainage after hepatectomy between January 1, 1990, and December 31, 2014. The following search strategy was used: ([["Hepatectomy" [Mesh] OR "liver resection" OR "liver surgery"]]) AND [{"Drainage" [Mesh] OR "drain*"}] NOT [{"preoperative drainage" OR "preoperative biliary drainage"}]. After removal of duplicates, articles were screened by title, abstract, and subsequently full text. In addition, reference lists of all included studies were screened for missed but relevant

studies. The methodological quality and risk of bias of the studies was assessed using the Cochrane Handbook for Systematic Reviews [23]. All included studies were consequently graded by using the Oxford Centre for Evidence-Based Medicine levels of evidence [24]. Furthermore, clinical trial registers were searched for ongoing studies.

Data Collection

Two reviewers (E.M.W.-L.-H. and V.W.) independently extracted data from the selected studies on study design, participant characteristics, mortality, image-guided drainage, re-operation, bile leakage/fistula, infected collections, postoperative bleeding, and wound infection.

Statistical Analysis

Continuous data are described as median (range) and categorical data are presented as percentages. The chi-square/Fisher's exact and Mann-Whitney U tests were used to compare categorical data and continuous data, respectively. Results were considered significant when $p \leq 0.05$. Uni- and multivariate analyses were performed to define specific independent risk factors for RSR reinterventions. Variables included in the univariate analysis: sex, ASA class \geq III, age <65 or \geq 70 years, median BMI, type of liver resection (major, caudate, repeat, central), blood loss >2,000 mL, preoperative chemotherapy, Pringle maneuver, and operating time >240 min. Multivariate analysis was performed with binary logistic regression, and $p \leq 0.10$ was used to select variables from univariate analysis. All statistical analyses were performed using IBM SPSS Statistics for Windows, version 20.0 (IBM Corp., Armonk, NY, USA).

Results

General and Surgical Characteristics

A total of 606 hepatic resections were performed in the study period. All the 66 patients who received a drain were excluded from further analysis. Details of this drain group will be addressed later in this section. Furthermore, 2 patients with missing data were excluded from analysis. A total of 538 patients were analyzed. General and surgical characteristics are shown in Table 1.

Primary Outcome

Seventy-nine (15%) of the 538 patients without a drain developed postoperative RSR complications. Sixty-seven (12%) of these patients required surgical, radiological, or endoscopic reintervention (Table 2).

Of the variables included in the univariate analysis (Tables 3, 4), only age <65 years, major liver resection, blood loss >2,000 mL, Pringle maneuver, operating time >240 min, and preoperative chemotherapy were significantly ($p < 0.1$) associated with the development major RSR morbidity (Clavien-Dindo grade \geq 3a) or the need for postoperative RSR reinterventions.

Table 1. Baseline patient and surgical characteristics

	All patients (n = 538), %
Gender, male	308 (57)
Age, years	64 (55–70)
BMI, kg/m ²	25.6 (22.9–28.5)
ASA physical status	
I	85 (16)
II	339 (63)
≥III	114 (21)
Indications	
Colorectal metastasis	421 (78)
Benign lesions	47 (9)
Other malignancy	29 (5)
HCC	24 (5)
Gall bladder carcinoma	7 (1)
CCC	5 (1)
Other	5 (1)
Preoperative chemotherapy	271 (50)
Resection type	
<1 segment/metastasectomy	213 (40)
Multisegmentectomy	173 (32)
Right hemihepatectomy	74 (14)
Right hemihepatectomy + 1 segment	31 (6)
Left hemihepatectomy	16 (3)
Left hemihepatectomy + 1 segment	2 (0.4)
Right extended hemihepatectomy	12 (2)
Left extended hemihepatectomy	3 (0.6)
Central resection	18 (3)
Caudate lobe resection	25 (5)
Major hepatectomy (≥3 segments)	226 (42)
Repeat hepatectomy	57 (11)
Total operating time, min	200 (150–270)
Intraoperative blood loss, mL	500 (269–1,000)
Pringle	118 (22)

Values in parentheses are percentages, unless indicated otherwise. Numeric data are presented as median (interquartile range). BMI, body mass index; ASA, American Society of Anesthesiologists; HCC, hepatocellular carcinoma; CCC, cholangiocellular carcinoma.

After multivariate analysis, major liver resection was an independent risk factor (OR 3.01, 95% CI 1.61–5.62; $p = 0.001$) for the development of major RSR morbidity and also associated with an increased risk of RSR reinterventions (OR 3.02, 95% CI 1.59–5.73; $p = 0.001$).

Secondary Outcome Measures

The median LOS was 8 days (6–11). Fifty patients (9%) were readmitted within 30 days after surgery (Table 5). Mortality within 90 days after surgery was observed in 15 patients (2.8%). Within this group, 5 patients died from sepsis following an intra-abdominal abscess or biloma,

Table 2. Primary end points

	All patients (n = 538), %
RSR complication rate	79 (15)
All surgery-related complication rate	90 (20)
Bile leakage (RSR)	35 (7)
Hemorrhage (RSR)	9 (2)
Intra-abdominal abscess (RSR)	44 (8)
Ascites	12 (2)
Postoperative liver failure	17 (3)
Pleural effusion	18 (3)
Sepsis	15 (3)
Wound infection	28 (5)
Reintervention rate for RSR complications	67 (12)
Reintervention rate	72 (13)
CT drainage	55 (10)
ERCP with stenting	9 (2)
US drainage	8 (2)
Relaparotomy	11 (2)
Relaparoscopy	1 (0.2)
Thoracotomy	1 (0.2)
Thoracic drainage	8 (2)

Values in parentheses are percentages. Multiple complications or reinterventions per patient were possible. A total of 178 surgery-related complications occurred in 90 patients. A total of 93 reinterventions occurred in 72 patients.

RSR, resection surface-related; ERCP, endoscopic retrograde cholangiopancreatography; US, ultrasound.

3 patients died from multiorgan failure induced by postresectional liver failure, 3 patients died from extensive extra-hepatic metastatic disease and subsequent multiorgan failure, and 4 patients died of an acute cardiac arrest of which one was proven in autopsy to be caused by myocardial infarction.

Prophylactic Abdominal Drain Group

Sixty-six patients received a prophylactic abdominal drain and were excluded from this study. Among them were 25 patients who required a drain after a bilioenteric anastomosis, or another form of biliary reconstruction was created. One patient received a drain after liver surgery for a traumatic lesion. Eight patients obtained a drain because of a difficult repeat hepatectomy. Seven patients received a drain for combined procedures (4 colorectal resections, 2 pancreatic resections, and 1 kidney resection). In 5 patients, a drain was placed after intraoperative iatrogenic lesions of the bile duct, pancreas, or spleen. Central resections and large resection surfaces after surgery were indications for drain placement in 9 patients. Vascular involvement required drain place-

Table 3. Uni- and multivariate analysis of risk factors for significant morbidity (Clavien-Dindo $\geq 3a$) for RSR complications

Variable	Significant morbidity (Clavien-Dindo $\geq 3a$; n = 70)	No significant morbidity (Clavien-Dindo $\geq 3a$; n = 468)	Univariate analysis, p value	Univariate analysis, OR (95% CI)	Multivariate analysis, p value	OR (95% CI)
Male/female	46/24	262/206	0.127	0.664 (0.392–1.123)		
ASA class $\geq III$ (yes/no)	16/54	97/366	0.716	1.118 (0.613–2.039)		
Age, years	66.0 (58–71)	63.7 (54–69)	0.039	1.025 (1.001–1.050)		
<65 (yes/no)	29/41	254/214	0.046	0.596 (0.358–0.992)	0.123	0.629 (0.350–1.133)
≥ 70 (yes/no)	22/48	106/362	0.110	1.565 (0.904–2.710)		
BMI, kg/m ²	25.2 (23–29)	25.6 (23–28)	0.924	0.997 (0.930–1.068)		
Major resection (yes/no)	48/22	178/290	<0.001	3.555 (2.076–6.088)	0.001	3.008 (1.610–5.618)
Caudate lobe resection (yes/no)	2/68	23/445	0.759	0.569 (0.131–2.468)		
Repeat hepatectomy (yes/no)	10/60	47/421	0.285	1.439 (0.716–3.111)		
Central resection (yes/no)	3/67	15/453	0.640	1.352 (0.381–4.795)		
Intraoperative blood loss, mL	818 (463–1,783)	500 (200–1,000)	0.011	1.000 (1.000–1.001)		
Blood loss >2,000 mL (yes/no)	11/48	23/333	0.003	3.318 (1.522–7.235)	0.146	1.933 (0.794–4.704)
Preoperative chemotherapy (yes/no)	40/30	231/233	0.252	1.345 (0.810–2.233)		
Pringle manoeuvre (yes/no)	23/46	95/370	0.017	1.947 (1.125–3.372)	0.163	1.559 (0.835–2.911)
Total operating time, min	240 (181–300)	195 (147–251)	0.008	1.003 (1.001–1.005)		
Operating time >240 min (yes/no)	35/35	149/319	0.003	2.141 (1.289–3.556)	0.110	1.657 (0.893–3.076)

Categorical data are presented as absolute numbers; numeric data are presented as median (interquartile range). RSR, resection- surface-related; ASA, American Society of Anesthesiologists; BMI, body mass index.

Table 4. Uni- and multivariate analysis of risk factors for reinterventions for RSR complications

Variable	Reintervention (n = 67)	No reintervention (n = 471)	Univariate analysis, p value	Univariate analysis, OR (95% CI)	Multivariate analysis, p value	OR (95% CI)
Male/female	44/23	264/207	0.138	0.667 (0.390–1.140)		
ASA class $\geq III$ (yes/no)	16/51	97/369	0.566	1.193 (0.652–2.184)		
Age, years	65.8 (58–71)	63.9 (54–69)	0.069	1.022 (0.998–1.047)		
<65 (yes/no)	27/40	256/215	0.033	0.567 (0.337–0.954)	0.091	0.595 (0.326–1.085)
≥ 70 (yes/no)	21/46	107/364	0.123	1.553 (0.888–2.717)		
BMI, kg/m ²	25.4 (23–29)	25.6 (23–28)	0.821	1.008 (0.940–1.081)		
Major resection (yes/no)	46/21	180/291	<0.001	3.541 (2.046–6.129)	0.001	3.020 (1.592–5.728)
Caudate lobe resection (yes/no)	1/66	24/447	0.219	0.282 (0.038–2.212)		
Repeat hepatectomy (yes/no)	9/58	48/423	0.421	1.367 (0.638–2.933)		
Central resection (yes/no)	3/64	15/456	0.584	1.425 (0.401–5.058)		
Intraoperative blood loss, mL	900 (475–1,766)	500 (200–1,000)	0.011	1.000 (1.000–1.001)		
Blood loss >2,000 mL (yes/no)	10/46	24/335	0.007	3.034 (1.364–6.750)	0.255	1.698 (0.683–4.223)
Preoperative chemotherapy (yes/no)	39/28	232/235	0.193	1.411 (0.840–2.369)		
Pringle manoeuvre (yes/no)	21/45	97/371	0.044	1.785 (1.015–3.138)	0.314	1.392 (0.732–2.648)
Total operating time, min	240 (182–301)	195 (147–251)	0.004	1.003 (1.001–1.005)		
Operating time >240 min (yes/no)	34/33	150/321	0.003	2.205 (1.315–3.696)	0.066	1.804 (0.961–3.387)

Categorical data are presented as absolute numbers. Numeric data are presented as median (interquartile range). RSR, resection- surface-related; ASA, American Society of Anesthesiologists; BMI, body mass index.

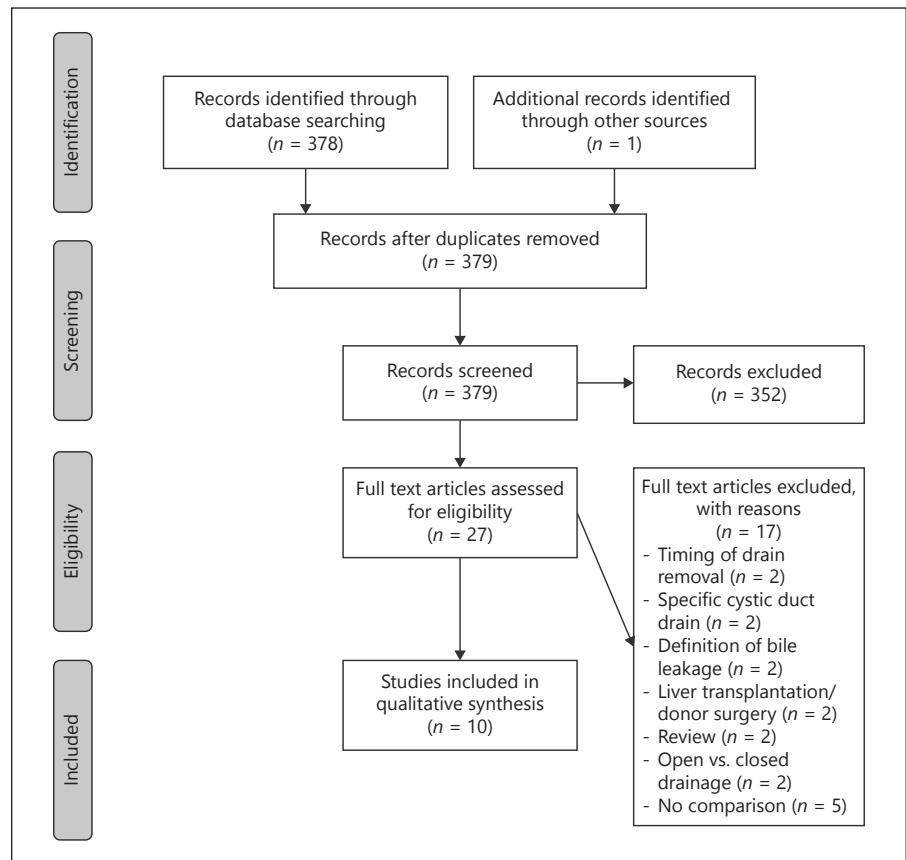


Fig. 1. PRISMA flow diagram of the literature search and inclusion of relevant studies.

Table 5. Secondary outcomes

	All patients (n = 538), %
Readmission rate	50 (9)
Length of stay, days	8 (6–11)
Clavien-Dindo classification	
Grade 1	33 (6)
Grade 2	71 (13)
Grade 3a	55 (10)
Grade 3b	12 (2)
Grade 4	14 (3)
Grade 5 (30-day mortality)	13 (2)
All reported postoperative morbidity	202 (38)
Major morbidity, Clavien-Dindo $\geq 3a$	92 (17)
Major RSR morbidity, Clavien-Dindo $\geq 3a$	70 (13)
Liver surgery-specific CEP	84 (16)
90-Day mortality	15 (2.8)
Liver-related 90-day mortality	13 (2.4)

Values in parentheses are percentages, unless indicated otherwise. Numeric data are presented as median (interquartile range).

RSR, resection-surface-related; CEP, liver surgery-specific composite end point (ascites, postresectional liver failure, bile leakage, intra-abdominal hemorrhage, intra-abdominal abscess, and operative mortality).

ment in 2 patients. Two patients with liver cirrhosis received a prophylactic drain after surgery because of an expected high risk of ascites and subsequent infection. Another 2 patients received a drain in early 2005 because of protocol deviation by the surgeon. Lastly, in 5 patients, an abdominal drain was placed without any specified indication. In this selected drain group, excluded from analysis, morbidity and mortality were high (10.0% mortality, 30.0% RSR morbidity, 37.5% major morbidity, 27.5% reinterventions).

Literature Review

The PRISMA flow diagram of the literature search and inclusion of relevant studies are shown in Figure 1. The search resulted in 27 studies that were assessed for eligibility. Finally, 10 studies, including 5 RCTs and 5 cohort studies (2 prospective and 3 retrospective series), were used to compare the results with those of the present study. The majority of studies included all types of liver resection, except 2 RCTs that only included patients with an underlying liver disease or a hepatocellular carcinoma in cirrhotic livers. Four studies [1, 4, 7, 8] were graded as

level 1b evidence, 1 study [13] was grade level 2b evidence, and the remaining studies [5, 12, 25–27] were cohort studies of grade 4 evidence. No ongoing studies could be identified in clinical trial registers. Table 6 shows a comparison of this study with results from literature.

Discussion

The use of postoperative drains after liver resection is still subject to debate. This study evaluated a no-drain policy, as part of the ERAS programme, in a tertiary referral center during 2005–2014. Implementation of a no-drain policy has resulted in an overall surgical morbidity rate of 20%, RSR complication rate of 15%, and RSR re-intervention rate of 12%.

This implies that 88% of all patients did not require any form of abdominal drainage in the postoperative phase. By not placing a prophylactic drain, they were spared from possible discomfort and harmful drain-related complications. Moreover, in the group of patients that did have an intra-abdominal collection, the majority of them could be treated well with CT- or US-guided drainage and rarely a reoperation was necessary, as is shown in Table 2.

Comparison of results of this study with earlier publications, mainly summarized by Gurusamy et al. [11], confirms the safety and feasibility of the no-drain policy. The 90-day mortality of 2.8% in this study was within the ranges reported in the literature for this type of liver surgery [1, 4, 7, 8, 11, 13, 14]. Reintervention rates of previous studies [1, 4, 7, 8, 11, 13, 14] vary considerably in studies of both drain and no-drain groups. To date, there is no evidence that abandoning prophylactic drainage increases the need for (radiological) reinterventions [11]. The RSR reintervention rate of 12% in this study demonstrates that a no-drain policy does not lead to more reinterventions, higher morbidity, or mortality compared to patients with a drain [1, 4, 5, 7, 8, 12, 13, 27].

Major liver resection is a known risk factor for postoperative complications [12, 13, 28–35]. In this study, it was identified in multivariate analysis as an independent risk factor for RSR-significant morbidity and RSR reinterventions. Other known intraoperative predictive determinants, such as prolonged operating time [12, 13, 28, 31, 33, 35], repeat hepatectomy [35–37], and the use of Pringle maneuver [31, 38], were not confirmed in this cohort. Preoperative risk factors that have been suggested in preceding literature, among which are the presence of significant comorbidities/ASA III–IV [28–30, 32, 39], an abnormal liver function [13, 28, 30], and chemotherapy [40],

were also not confirmed. The fact that major liver resection was found as a risk factor does not mean that a prophylactic drain needs to be placed routinely. It implies that there is a subset of patients in which routine postoperative imaging or an aggressive postoperative imaging strategy needs to be considered. When there is a clinically relevant intra-abdominal collection on ultrasound or CT, a therapeutic radiologically guided drain can then be placed.

The expertise with, and access to, radiological reinterventions may vary substantially between institutions; it has changed over time in hospitals worldwide and it could be an important factor. In centers in which radiological reinterventions are less frequently performed, more collections may be inadequately drained. This could lead to a higher re-operation rate. When compared with patients receiving a drain in other studies, the patients from the present study had a low re-operation rate. This may imply that a no-drain placement policy does not lead to more re-operations. Finally, hospital LOS in other studies was longer [41]. The ERAS programme could explain this faster recovery [21, 42].

This study has several strengths that add to the existing body of evidence of RCTs and a meta-analysis on the studied topic. An important strength of this study is the large cohort size. A total of 538 consecutive patients were treated without a drain after implementation of the no-drain policy. As is demonstrated in Table 6, this no-drain cohort is one of the largest cohorts on the subject. In addition, the group of excluded patients with prophylactic drain placement is well described and provides detailed insight in the selection process. Furthermore, patients with bilioenteric anastomoses were excluded from analysis to enable comparison with previously published studies [7, 8, 13]. Among these patients, leakage rates are high and may confound general results. Another strength of this study is the fact that uni- and multivariate analyses were performed for the identification of risk factors for surface-related morbidity. This can aid in the decision-making process of abandoning the use of drains after liver surgery. Lastly, all patients were prospectively registered and treated within an ERAS programme consisting of standardized care elements. The minimal use of prophylactic drains is an important element in the ERAS programme, and this study advocates a no-drain policy after uncomplicated liver surgery. Drains are thought to affect postoperative mobility and pain control and drains could hamper a swift recovery in uncomplicated cases.

The retrospective analysis of prospectively collected data is a limitation of this study. Although all liver resections in the study period were registered, the final results

Table 6. Results of previous studies (RCTs and cohort studies) comparing the use of abdominal drainage after hepatectomy

Author	Period	Type of surgery	Study type	Evidence level [#]	Risk of bias	Arm	n	Mortality, %	CT or US drain, %	Re-operation, %	Bile leakage/fistula, %	Infected collection, %	Postoperative bleeding, %	Wound infection, %
Belghiti et al. [1]	1990–1991	A	1	1b	Low	D	42	2.4	35.7	2.4	4.8	14.3	4.8	NA
						ND	39	2.6	15.8	2.5	5.1	5.3	2.5	NA
Fong et al. [13]	1992–1994	A	1	2b	Unclear	D	60	3.3	8.3	1.6	5.0	5.0	0	6.6
						ND	60	3.3	18.3	0	5.0	0	0	3.3
Burt et al. [12]	1994–2000	A	3	4	High	D	184	7.1	26.1	NA	NA	16.3	NA	NA
						ND	981	2.0	10.5	NA	NA	3.1	NA	NA
Fuster et al. [4]	1991–1997	B	1	1b	Low	D	20	0	0	0	NA	0	0	0
						ND	20	0	10	5	NA	10	0	15
Liu et al. [7]	1999–2002	C	1	1b	Low	D	52	5.8	3.8	5.8	3.8	3.8	1.9	19.2
						ND	52	1.9	0	1.9	0	0	0	11.5
Aldameh et al. [5]	1999–2002	A	3	4	High	D	126	1.6	1.6	NA	3.2	2.4	NA	6.3
						ND	85	1.2	4.7	NA	3.5	1.2	NA	16.5
Sun et al. [8]	2004–2005	A	1	1b	Low	D	60	0	6.7	1.7	0	3.3	2.0	5.0
						ND	60	1.7	5.0	0	0	0	0	3.3
Lu et al. [27]	2002–2004	A	3	4	High	D	357	0.6	5.6	0.3	1.7	2.0	0.8	3.4
						ND	105	0	3.8	0	0	1.0	1.0	0
Butte et al. [26]	2007–2014	A*	2	4	High	D	87	4.6	8	NA	4.6	NA	NA	NA
						ND	112	0	8	NA	4.5	NA	NA	NA
Brooke-Smith et al. [25]	2010–2011	A	2	4	High	D	603	NA	9.2	NA	11	NA	NA	NA
						ND	345	NA	5.8	NA	1	NA	NA	NA
Present study	2005–2015	A	3	4	High	ND	538	2.8	11.7	2.2	6.5	8.2	1.7	5.2

D, drainage group; ND, non-drainage group; NA, not available; US, ultrasound; hepatic resection: (A) all hepatic resections; (B) all hepatic resections for hepatocellular carcinoma in cirrhotic patients; (C) all hepatic resections in patients with chronic liver disease.

* All patients received mucomyst. In the listed studies, no concomitant operations on other organs or anastomosis were included. Type: (1) randomized controlled trial (RCT); (2) prospective cohort study; (3) retrospective cohort studies.

[#] Level of evidence: according to the Oxford Centre for Evidence-Based Medicine [24].

may have been prone to a form of selection bias, because a small subset of patients was excluded from analysis. This excluded group received an abdominal drain by discretion of the operating surgeon within the studied period. Although no biliary reconstructions were performed in these patients, drains were placed because of major combined procedures, major central liver resections, intraoperative leaks of the bile duct, pancreatic damage, and repeat hepatectomy.

The findings of this cohort study confirm the findings of available RCTs [4, 7, 13] and a Cochrane review [11] that routine drainage after uncomplicated liver resection is not necessary. The results of this study show that a no-drain policy is safe and feasible after liver surgery within an ERAS environment. Placement of a prophylactic drain is unlikely to prevent reinterventions for complications and a no-drain policy seems justified in the majority of patients. At most, placement of a drain allows liver surgeons to detect complications in an earlier phase, but routine placement subjects a large group of patients to potential risks and discomfort. Further studies are still necessary and should focus on specific patient groups with pre-defined risk factors (e.g., underlying liver disease, major resections, biliary reconstructions, intraoperative blood loss, and operating time) or should validate risk factors.

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Conclusion

A selective no-drain policy within an ERAS environment resulted in a rate of postoperative complications, reinterventions, and mortality that is comparable to previously published studies. The routine use of prophylactic abdominal drains after liver surgery therefore seems unnecessary. In patients that undergo a major liver resection, which is an independent risk factor for RSR-related complications, preemptive postoperative imaging can be considered.

In a small group of selected patients known to have a high risk of anastomotic leakage, prophylactic drains still have their place, for example, in the case of biliary reconstruction.

Statement of Ethics

The study was performed in line with GCP guidelines. Due to the retrospective nature of the study, informed consent of the study subjects was not required.

Disclosure Statement

The authors have no conflicts of interest or financial support to disclose.

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