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Outcomes of liver surgery: A decade of mandatory nationwide auditing in the Netherlands

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ABSTRACT

Background: In 2013, the nationwide Dutch Hepato Biliary Audit (DHBA) was initiated. The aim of this study was to evaluate changes in indications for and outcomes of liver surgery in the last decade.

Methods: This nationwide study included all patients who underwent liver surgery for four indications, including colorectal liver metastases (CRLM), hepatocellular carcinoma (HCC), and intrahepatic– and perihilar cholangiocarcinoma (iCCA – pCCA) between 2014 and 2022. Trends in postoperative outcomes were evaluated separately for each indication using multilevel multivariable logistic regression analyses.

Results: This study included 8057 procedures for CRLM, 838 for HCC, 290 for iCCA, and 300 for pCCA. Over time, these patients had higher risk profiles (more ASA-III patients and more comorbidities). Adjusted mortality decreased over time for CRLM, HCC and iCCA, respectively aOR 0.83, 95%CI 0.75–0.92, *P < 0.001;* aOR 0.86, 95%CI 0.75–0.99, *P* = *0.045*; aOR 0.40, 95%CI 0.20–0.73, *P < 0.001*. Failure to rescue (FTR) also decreased for these groups, respectively aOR 0.84, 95%CI 0.76–0.93, P = 0.001; aOR 0.81, 95%CI 0.68–0.97, *P* = *0.024;* aOR 0.29, 95%CI 0.08–0.84, *P* = *0.021*). For iCCA severe complications (aOR 0.65 95%CI 0.43–0.99, *P* = *0.043*) also

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decreased. No significant outcome differences were observed in pCCA. The number of centres performing liver resections decreased from 26 to 22 between 2014 and 2022, while median annual volumes did not change (40–49, P = 0.66).

Conclusion: Over time, postoperative mortality and FTR decreased after liver surgery, despite treating higher-risk patients. The DHBA continues its focus on providing feedback and benchmark results to further enhance outcomes.

1. Introduction

Hepatic resection may be indicated for patients with both primary and metastatic liver malignancies. Treatment for liver malignancies is continuously evolving, marked by improvements in surgical technique and local and systemic treatment modalities. Hepatectomy remains a high-risk procedure. A valuable tool to improve the quality of liver surgery care is clinical auditing [1].

Worldwide, only a few nationwide audits on HPB surgery exist [2–4]. In 2013, the Dutch Hepato Biliary Audit (DHBA) was initiated with the objective to monitor and to improve the quality of care for patients with primary and secondary liver cancer [5]. This mandatory audit, in which all hospitals participate, registers all patients who undergo liver resection for colorectal liver metastasis (CRLM) and non-CRLM, benign liver tumours, tumours of hepatocellular origin (HCC), and cholangiocarcinoma [5].

The DHBA systematically collects and assesses data on various aspects of care of all hospitals that perform liver surgery. This data can provide clinicians with feedback on outcomes and clinical practice. Hospital outcomes are compared to the national average score, serving as a reference. To make a more reliable comparison, results are adjusted for non-modifiable patient and tumour characteristics (case-mix) [6]. Hospitals receive insight into their results, presented anonymously with a 95%-interval around the national average for comparison. Ongoing monitoring helps to identify trends and potential issues that require attention. Benchmarking supports to identify areas for improvement. Several studies analysing DHBA data have been published previously [6–16].

The aim of this study was to evaluate changes in nationwide indications for and outcomes of liver surgery since the initiation of the DHBA.

2. Methods

Data for this nationwide study was retrieved from the DHBA. Since 2014, it has been mandatory to register all patients who underwent liver surgery for CRLM and HCC; from 2015 onwards, patients with cholangiocarcinoma were also included. In 2018, the audit became multidisciplinary with the addition of data from intervention radiologists on percutaneous thermal ablation. Registration of thermal ablation procedures was, however, non-obligatory until 2023 [7,17]. The funding, initiation, and dataset of the audit have been previously described [17]. In 2017, data collection was verified. Data completeness showed 97% of all patients were included in the registry [18].

National requirements to perform liver surgery include a minimum of 20 liver resections per centre per year, experienced staff, and access to other local therapies, including thermal ablation [19]. The centralisation of liver surgery is in progress in the Netherlands, which has resulted in a decreased number of hospitals performing liver surgery between 2014 and 2022 [7]. According to Dutch law, no ethical approval or informed consent was needed for this study since collected data was processed anonymously with the goal of quality improvement. The study protocol was reviewed and approved by the Scientific Committee of the DHBA.

2.1. Patients

All consecutive patients who underwent liver resection for CRLM or HCC and registered in the DHBA between January 2014 and December 2022 were included. Also, patients who underwent liver resection for intrahepatic– and perihilar cholangiocarcinoma (iCCA – pCCA) and registered in the DHBA between 2015 and December 2022 were included. Patients with missing data on surgery date or tumour type were excluded.

2.2. Outcomes

The annual number of procedures performed for CRLM, HCC, iCCA, and pCCA were assessed, as well as the number of hospitals that performed these procedures. Outcomes after surgery included data on mortality, overall complications, major complications, post hepatectomy liver failure, bile leakage, failure to rescue (FTR), and postoperative complicated course within a 30-day follow-up period. Outcomes were compared across three equal periods (2014–2016, 2017–2019, and 2020–2022).

Mortality was defined as in hospital mortality or mortality within 30-days after surgery. 90-day mortality is not registered in the DHBA. Major complications were defined as complications graded ≥3a according to the Clavien Dindo classification [20]. Post hepatectomy liver failure and bile leakage were defined according to the International Study Group of Liver Surgery. FTR was defined as the mortality rate among patients with major morbidity [13]. PCC was defined as a complication leading to a prolonged length of hospital stay (>14 days), any (surgical, endoscopic, or radiological) reinterventions, or mortality during the primary admission. Case-mix variables were defined as factors that are non-modifiable patient and tumour characteristics [6].

2.3. Variables

The following patient, tumour and treatment characteristics were extracted from the DHBA, sex, age, body mass index (BMI), Charlson comorbidity index (CCI), American Society of Anaesthesiologist (ASA) grade, diameter of largest liver tumour before any tumour-specific treatment, number of liver tumours, bilobar disease, liver disease, history of liver resection, preoperative MRI, preoperative chemotherapy (defined as neo-adjuvant or induction therapy), combined liver resection with ablation, surgical approach, two-stage liver resection, porta-embolization, major liver resection (major was defined as resection of ≥3 adjacent Couinaud segments) and tumour resection margins.

2.4. Statistical analysis

Separate analyses were performed for CRLM, HCC, iCCA, and pCCA. The number of patients treated per year and the number of patients treated per hospital per year were calculated and compared using descriptive statistics. Patient, tumour, and treatment characteristics were compared between the three time periods using chi-square test for categorical variables and the Kruskal Wallis test for non-normally distributed continuous variables. The impact of time on postoperative outcomes was assessed using multilevel multivariable logistic regression analyses adjusted for patient and tumour characteristics (case-mix factors). A two-level random effect model was utilised to correct for possible clustering within a hospital or unmeasured hospital differences. The relevance of the random effect factor was investigated based on the likelihood ratio and employed when the P value was <0.05. To prevent overfitting of models, for outcomes with <10 events per category, relevant confounders were selected based on their influence to induce a >2.5% change in the odds ratio (OR). Subgroup analyses were performed for trends and outcomes in minor and major liver resections.

Missing items in baseline characteristics were analysed separately if > 5%. Collinearity was determined by a variance inflation factor (VIF). A VIF of >2.5 was considered to indicate multicollinearity. P value < 0.05 was considered statistically significant. All analyses were performed in R version 4.3.1® (R Core Team (2018). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria).

3. Results

In total, 12,132 liver resections were performed in the Netherlands between 2014 and 2022, of which 9485 were included, 2647 procedures were excluded because they underwent liver resection for other indications. Of those, 8057 (85.1%) were for CRLM, 838 (8.8%) for HCC, 290 (3.1%) for iCCA, and 300 (3.2%) for pCCA (Fig. 1). (See Fig. 2)

3.1. Trends in patient characteristics, treatment, and outcomes for colorectal liver metastases

Of patients operated on, an increase in ASA-III scores (16%–30%, *P < 0.001*) was observed over time, and a decline in age (67 IQR (60–73) to 65 IQR (57–74), *P < 0.001*). The median number of CRLM remained stable, and the range increased from 2 (1–3) to 2 (1–4), P = 0.023. The use of preoperative MRI increased (56%–87%, *P < 0.001*). Preoperative chemotherapy was more often administered (30%–35%, *P < 0.001*). The use of laparoscopic liver resections increased (19%–30%, *P < 0.001*). More combined liver resection and ablation were performed (20%–25%, *P < 0.001*). (Table 1).

Unadjusted major complications increased (9.8%–11%, *P = 0.03*), while 30-day postoperative mortality did not change significantly (1.7%–1.0%, *p = 0.074*) over time. Unadjusted FTR decreased from 16% to 13%, P = 0.02. Reinterventions increased from 10% to 13%, *P < 0.001*. Unadjusted overall complications, complicated course, post hepatectomy liver failure and bile leakage remained stable (Table 2). Length of stay decreased with one day, 6 IQR (5–9) versus 5 IQR (3–7), *P < 0.001*.

After case-mix correction, significant reductions were observed in 30-day postoperative mortality (aOR 0.83, 95%CI 0.75–0.92, *P < 0.001*), FTR (aOR 0.84, 95%CI 0.76–0.93, P = 0.001), complicated course (aOR 0.96, 95%CI 0.92–0.99 *P = 0.034*), and liver failure (aOR 0.88 95%CI 0.67–0.94, *P = 0.007*) in which 2014 was the reference year. Other outcomes remained stable over time (Table 3).

3.2. Trends in patient characteristics, treatment, and outcomes for hepatocellular carcinoma

The age of the patients with HCC who underwent resection increased from 66 IQR (57–72) to 72 IQR (63–76), *P < 0.001*. ASA III score (40%–51%, *P < 0.001*) and higher Charlson comorbidity index (28%–55%, *P < 0.001*) were more observed over time (Table 1). The use of laparoscopic liver resections increased (26%–29%, *P < 0.001*). The diameter of the largest tumour did not change significantly from 40 mm IQR (25–60) to 44 IQR (60–66), *P = 0.143*.

Unadjusted major complications did not differ (16%–21%, *P = 0.086*). Unadjusted 30-day mortality did not change significantly (5.8%–2.4%, *P = 0.149*). FTR decreased from 36% to 11%, P = *0.013*. Overall complications, bile leakage, and complicated course remained stable over time (Table 2).

After adjustment for case mix factors, 30-day postoperative mortality (aOR 0.86, 95%CI 0.75–0.99, *P = 0.045*) and FTR (aOR 0.81, 95%CI 0.68–0.97, *P = 0.024*) decreased significantly over time (Table 3).

3.3. Trends in patient characteristics, treatment, and outcomes for cholangiocarcinoma

Patients operated on for iCCA more often had ASA-3 scores over time (25%–44%, *P < 0.001*) and higher Charlson Comorbidity Index >2 (23%–45%, *P = 0.009*). Other patient factors remained stable. The use of laparoscopic liver resection increased (7.7%–16%, P < 0.001). Length of stay decreased by two days. More major liver resections were performed (58%–67%, *P < 0.001*). A decrease was observed in unadjusted 30-day

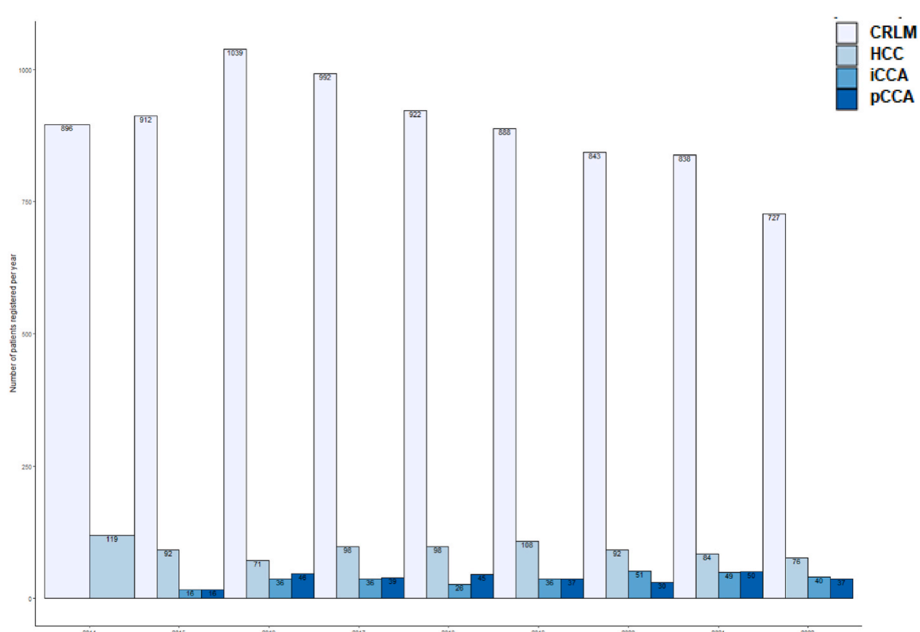

Fig. 1. Number of hepatic resections registered between 2014 and 2022, in the Netherlands for patients diagnosed with colorectal liver metastases (CRLM), hepatocellular carcinoma (HCC), Intrahepatic cholangiocarcinoma (iCCA) and perihilar cholangiocarcinoma (pCCA).

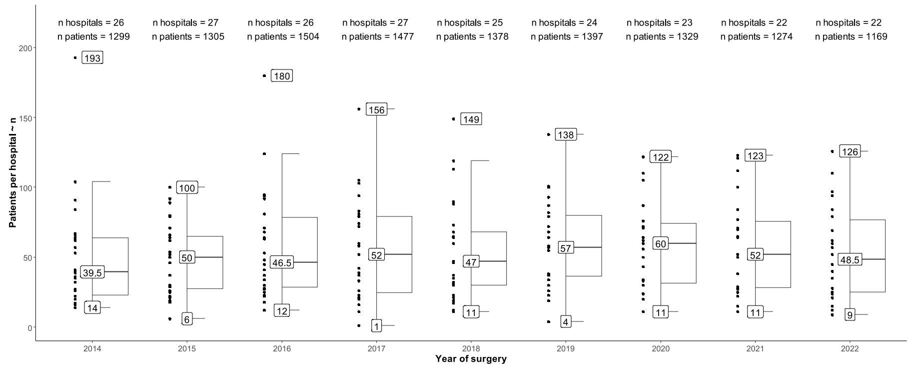

Fig. 2. Annual number of hospitals performing hepatic resections, and the number of resections from 2014 to 2022, in the Netherlands. The boxplots represent the median number of hepatic resections per hospital with the interquartile and total range. Dots represent a single hospital.

mortality (12%–1.4%, $P = 0.012$) and unadjusted FTR (50%–5.4%, $P < 0.001$). Other outcomes remained stable over time. After case-mix correction 30-day mortality (aOR 0.40 95%CI 0.20–0.73 $P < 0.001$), FTR (aOR 0.29 95%CI 0.08–0.84, $P = 0.021$) and severe complications (aOR 0.65 95%CI 0.42–0.99), $P = 0.043$) decreased over time.

Patients operated on for pCCA also had higher ASA and CCI scores over time. Length of stay decreased by two days. The use of open liver resection remained high and stable over time. For pCCA patients, all other outcomes remained stable.

3.4. Trends in total volume, number of hospitals, and hospital volume

Overall, the number of centres performing liver resections decreased from 26 to 22 between 2014 and 2022. The total number of resections decreased from 1299 in 2014 to 1169 in 2022. The median annual volume of liver resections per centre did not increase significantly (from 40 IQR (23–64) to 49 IQR (25–77), P = 0.66). (Fig. 1).

The number of centres performing liver resection for CRLM decreased from 26 to 22 between 2014 and 2022. The total number of resections for CRLM decreased from 896 in 2014 to 725 in 2022, $P < 0.001$. The median annual number of liver resections per centre remained stable (29 IQR (18–47) in 2014 to 31 IQR (18–41) in 2022, P = 0.959). (Sup Fig. S1A).

The number of centres performing liver resection for HCC decreased from 20 to 11 between 2014 and 2022. The median annual number of liver resections for HCC per centre did not statistically significantly increase (from 3 IQR (1–6) to 8 IQR (3–10), P = 0.108). (Sup Fig. S1B).

The number of centres performing liver resection for cholangiocarcinoma decreased from 16 in 2017 to 15 in 2022. The median annual number of liver resections per centre remained stable from 5 (IQR 2–10) to 4 (IQR 2–14), P = 0.78 (Sup Fig. S1C/D).

4. Discussion

This study provides an overview of trends in outcomes, treatment, and patient characteristics during 10 years of nationwide monitoring of liver surgery by the Dutch Hepato Biliary Audit. Mortality and FTR rates decreased significantly, yet reinterventions and major complication rates tended to increase over time. Patients more often had ASA 3 classification and higher comorbidity scores. The use of the preoperative MRI increased, and more patients were operated on using minimally invasive techniques during the years. Length of stay decreased over time. The number of hospitals that performed liver surgery decreased. The number of patients who underwent liver resection for CRLM significantly reduced in the Netherlands.

Studies on trends in short-term surgical outcomes after liver resection for HCC, iCCA, and pCCA are sparse. Due to the heterogeneous patient groups, a fair comparison of postoperative outcomes after liver resections requires consideration of the patient's diagnosis and performance. The findings in this study are concordant with a recent American study, in which similar mortality and major complication rates were observed across various indications of liver surgery between 2014 and 2020 [21]. In contrast, nationwide studies in Germany (between 2010 and 2015) and France (between 2000 and 2017) reported higher mortality rates [22,23].

The present study shows that patients who underwent liver resection had a higher risk profile due to more comorbidities. In addition, patients had more often ASA 3 scores over time, however, this trend could possibly be attributed to the introduction of an updated ASA classification implemented from 2014 onwards [24,25]. In this update, classification remain the same, but the ASA provided examples for every ASA classification as guidance for clinicians [24,25].This resulted in an improvement in the precision of patient categorisation to the different ASA classifications [26].

While observed major complication rates have either remained stable or increased over time in this study, it is noteworthy that FTR and mortality rates have been improved. This can be attributed to several contributing factors including earlier recognition and more effective treatment of complications. The observed higher reintervention rates may indicate a shift towards a more direct and aggressive approach, often involving radiologic drainage, in response to adverse events. This proactive approach lowered the threshold for reinterventions but also resulted in a reduction in mortality [27,28].An example of this could be found in pancreatic surgery in the PORSCH Trial, where a pro-active approach lowered the FTR rate [29]. This could indicate that the quality of peri-operative care in the Netherlands increased.

This study observed an increase in the use of MRI in patients operated on for CRLM. This phenomenon could partly be attributed to the start and results of the CAMINO study in 2019, which was enrolled in 13 hospitals in the Netherlands. This study investigated the added value of MRI to CT in patients with CRLM [30]. MRI led to clinically relevant changes in the surgical planning of 31% of patients with CRLM [31]. Despite an increase in the rate of patients with CRLM who received preoperative chemotherapy, the proportion of patients treated with preoperative chemotherapy remains low when compared with patients from countries outside the Netherlands and Scandinavia; this trend is congruent with current Dutch Guidelines recommending upfront surgery in patients with primarily resectable metastases, as opposed to many other countries [17,32,33].

The present study highlights the adoption of minimally invasive liver surgery for CRLM, HCC, and iCCA. Recent nationwide studies on implementation rates of laparoscopic and robotic liver resections are sparse. In 2015, four European expert centres described an implementation rate of 43% [34]. In addition, a recent NSQIP study described a slightly increasing uptake of laparoscopic liver surgery for patients with CRLM between 2015 and 2019 [35]. The outcomes of Dutch studies

Table 1
Patient and treatment characteristics of patients who underwent hepatic resection between 2014 and 2022 in the Netherlands for different liver malignancies.

Characteristic	CRLM				HCC				iCCA				pCCA			
	2014–2016 N (%)	2017–2019 N (%)	2020–2022 N (%)	P value	2014–2016 N (%)	2017–2019 N (%)	2020–2022 N (%)	P value	2015–2016 N (%)	2017–2019 N (%)	2020–2022 N (%)	P value	2015–2016 N (%)	2017–2019 N (%)	2020–2022 N (%)	P value
	N = 2874	N = 2802	N = 2408		282	304	252		N = 52	N = 98	N = 140		N = 62	N = 121	N = 117	
Sex (Male)	1775 (63)	1807 (65)	1524 (64)	0.349	204 (72)	210 (69)	181 (72)	0.646	29 (56)	47 (48)	70 (50)	0.656	34 (55)	72 (60)	66 (56)	0.806
Age (IQR)	67 (60–73)	67 (59–74)	65 (57–74)	**<0.001**	66 (57, 72)	68 (60, 74)	72 (63, 76)	**<0.001**	66 (54–72)	69 (60–75)	66 (58-, 73)	0.282	66 (56–72)	66 (58–72)	70 (61–74)	0.068
Unknown	3	0	2		1	1	0									
ASA score ≥ 3	469 (16)	693 (25)	724 (30)	**<0.001**	108 (40)	138 (45)	129 (51)	**0.030**	13 (25)	28 (29)	62 (44)	**0.010**	11 (18)	27 (22)	40 (34)	**0.031**
Missing	136 (4.8)	6 (0.2)	4 (0.2)		11	0	1		0 (0)	0 (0)	0 (0)		0 (0)	0 (0)	1 (0.9)	
CCI ≥ 2	679 (24)	780 (28)	603 (25)	**<0.001**	80 (28)	134 (44)	139 (55)	<0.001	12 (23)	31 (32)	63 (45)	**0.009**	14 (23)	39 (32)	35 (30)	0.405
Missing	0 (0)	0 (0)	0 (0)						0 (0)	0 (0)	0 (0)		0 (0)	0 (0)	0 (0)	
BMI	25.6 (23.1, 28.7)	25.8 (23.5, 28.7)	25.9 (23.5, 28.7)	**0.041**	26.3 (23.5, 29.4)	26.5 (23.9, 29.7)	26.3 (23.9, 29.4)	0.667	26.1 (23.3, 28.4)	25.1 (22.5, 27.6)	25.5 (23.0, 29.0)	0.273	23.5 (21.7, 26.1)	25.1 (22.7, 28.1)	24.2 (22.4, 26.4)	**0.016**
Unknown	180	11	48		15	3	4		1	0	2		2	0	0	
Liver disease				**0.004**				0.453				0.155				0.306
Normal	1751 (77)	1841 (76)	1692 (77)		85 (30)	106 (35)	82 (33)		19 (56)	55 (76)	67 (64)		45 (83)	67 (72)	79 (83)	
Steatosis	400 (18)	494 (20)	413 (19)		58 (21)	74 (24)	57 (23)		11 (32)	9 (13)	23 (22)		4 (7.4)	14 (15)	7 (7.4)	
Other	112 (4.9)	75 (3.1)	83 (3.8)		114 (40)	106 (35)	83 (33)		4 (12)	8 (11)	14 (13)		5 (9.3)	12 (13)	9 (9.5)	
Missing	584	392	220		25 (8.9)	18 (5.9)	30 (12)		18	26	36		8	28	22	
History of liver resection	493 (17)	540 (19)	478 (20)	**<0.001**	18 (6.8)	24 (8.1)	19 (7.5)	0.937	4 (7.7)	5 (5.1)	3 (2.1)	0.099	1 (1.6)	1 (0.8)	2 (1.7)	0.766
Missing	92 (3.2)	35 (1.2)	0 (0)		0 (0)	1 (0.3)	0 (0)		0 (0)	2 (2.0)	0 (0)		1 (1.6)	1 (0.8)	0 (0)	
Number of tumours (IQR)	2 (1–3)	2 (1–3)	2 (1–4)	**0.023**					NA	NA	NA		NA	NA	NA	
Missing	141	85	114		19	8	1									
Largest diameter tumour (IQR)	25 (17–38)	25 (17–37)	26 (17–40)	0.202	40 (25, 60)	43 (25, 70)	44 (30, 66)	0.143	55 (38–70)	55 (30–78)	42 (26–64)	0.218	30 (20–35)	28 (20–35)	21 (15–28)	**0.001**
Missing	417	454	200		104	67	35		35	53	41		40	38	45	
Bilobar disease	1523 (53)	841 (30)	901 (37)	**<0.001**	150 (53)	44 (15)	34 (13)	**<0.001**	0 (0)	11 (11)	18 (13)	**<0.001**	0 (0)	18 (15)	27 (23)	**<0.001**
Missing	1078 (38)	168 (6.0)	19 (0.8)		122 (43)	16 (5.3)	0 (0)		49 (94)	11 (11)	0 (0)		60 (97)	9 (7.4)	2 (1.7)	
Pre-op MRI	1505 (56)	1978 (74)	2071 (87)	**<0.001**	195 (73)	229 (77)	206 (82)	0.059	39 (76)	76 (78)	122 (87)	0.11	36 (59)	93 (78)	88 (75)	0.019
Missing	168	140	36		14	7	0		1	1	0		1	2	0	
Preoperative chemotherapy	768 (30)	836 (31)	802 (35)	**0.003**	4 (1.5)	6 (2.0)	0 (0)	0.070	1 (2.8)	2 (2.8)	9 (9.4)	0.163	0 (0)	1 (1.0)	2 (1.9)	0.800
Missing	303	127	90		18	2	3		16	26	44		6	22	9	
Combined with ablation	563 (20)	613 (22)	596 (25)	**<0.001**	14 (5.0)	18 (5.9)	10 (4.0)	0.575	NA	NA	NA		NA	NA	NA	
Surgical approach				**<0.001**				**<0.001**				**<0.001**				0.373
Open	2267 (80)	1847 (66)	1334 (55)		203 (74)	189 (62)	131 (52)		35 (67)	72 (73)	97 (69)		61 (98)	116 (96)	114 (97)	
Laparoscopic	552 (19)	939 (34)	729 (30)		73 (26)	115 (38)	74 (29)		4 (7.7)	10 (10)	23 (16)		0 (0)	2 (1.7)	3 (2.6)	
Robot	NA	NA	344 (14)		0 (0)	0 (0)	47 (19)		NA	NA	20 (14)		NA	NA	0 (0)	
Missing	28 (1.0)	14 (0.5)	1 (<0.1)		6	0	0		13 (25)	16 (16)	0 (0)		1 (1.6)	3 (2.5)	0 (0)	
Two-stage liver resection	NA	205 (7.4)	201 (8.3)	**<0.001**	NA	5 (1.6)	7 (2.8)	0.608	NA	1 (1.1)	2 (1.4)	>0.9	NA	4 (3.4)	5 (4.3)	0.059
Missing	2449	14	0		272	0	0	272	48	11	0		60	3	0	
Porta embolization	NA	105 (3.9)	108 (4.5)	0.177	1 (5.6)	20 (7.0)	14 (5.6)	0.846	7 (16)	11 (11)	14 (10)	0.594	18 (32)	34 (28)	40 (34)	0.597
Missing	2401	78	21		264	18	1		7	2	0		5	0	0	
Major liver resection	601 (21)	629 (22)	463 (19)		86 (30)	113 (37)	78 (31)	0.160	30 (58)	60 (61)	94 (67)	**<0.001**	59 (95)	118 (98)	115 (98)	**0.042**
Resection margin				**<0.001**				**<0.001**				**0.002**				0.338
Tumour-free margin ≥1 mm	2389 (88)	2448 (88)	2033 (85)		256 (93)	279 (92)	215 (85)		36 (92)	71 (86)	92 (71)		44 (73)	90 (76)	80 (69)	
Tumour-free margin <1 mm	303 (11)	307 (11)	352 (15)		16 (5.8)	21 (6.9)	37 (15)		3 (7.7)	11 (13)	38 (29)		15 (25)	24 (20)	35 (30)	
Macroscopic incomplete	25 (0.9)	24 (0.9)	13 (0.5)		3 (1.1)	4 (1.3)	0 (0)		0 (0)	1 (1.2)	0 (0)		1 (1.7)	4 (3.4)	1 (0.9)	
Missing	130	23	10		7	0	0		13	15	10		2	3	1	

Table 2

Outcomes. Postoperative outcomes across three time periods for patients who underwent liver surgery for colorectal liver metastases (CRLM), hepatocellular carcinoma (HCC), intrahepatic – and perihilar cholangiocarcinoma (iCCA and pCCA).

CRLM	2014–2016	2017–2019	2020–2022	P value
	N (%)	N (%)	N (%)	
	N = 2847	N = 2802	N = 2408	
LOS (IQR)	6 (5–9)	6 (4–8)	5 (3–7)	**<0.001**
Missing	154 (5.4)	13 (0.5)	6 (0.2)	
Complications	788 (28)	821 (29)	657 (27)	0.249
Missing	63 (2.1)	15 (0.5)	9 (0.4)	
Severe complications	279 (9.8)	262 (9.4)	276 (11)	**0.032**
30-day or in hospital mortality	46 (1.7)	35 (1.3)	23 (1.0)	0.074
Missing	89 (3.1)	18 (0.6)	4 (0.2)	
Complicated course	390 (14)	353 (13)	312 (13)	0.458
Liver failure	45 (1.6)	36 (1.3)	26 (1.1)	0.219
Missing	98 (3.4)	16 (0.6)	11 (0.5)	
Biliary leakage	77 (2.8)	72 (2.6)	85 (3.5)	0.106
Missing	99 (3.5)	16 (0.6)	11 (0.5)	
Reinterventions	229 (10)	233 (9.8)	249 (13)	**<0.001**
Missing	6 (0.2)	38 (1.4)	0 (0.0)	
Failure to rescue	43 (16)	33 (13)	22 (8.0)	**0.022**
HCC	**N = 282**	**N = 304**	**N = 252**	
LOS (IQR)	7 (5, 11)	6 (4, 9)	6 (4, 8)	**<0.001**
Missing	16 (5.7)	0 (0.0)	1 (0.4)	
Complications	125 (45)	115 (38)	109 (43)	0.157
Missing	6 (2.1)	0 (0.0)	0 (0.0)	
Severe complications	45 (16)	43 (14)	53 (21)	0.086
30-day or in hospital mortality	16 (5.8)	14 (4.6)	6 (2.4)	0.148
Missing	6 (2.1)	0 (0.0)	0 (0.0)	
Complicated course	67 (24)	55 (18)	60 (24)	0.158
Liver failure	13 (4.8	8 (2.6)	5 (2.0)	0.155
Missing	9 (3.2)	0 (0.0)	0 (0.0)	
Biliary leakage	13 (4.8)	13 (4.3)	17 (6.7)	0.397
Missing	10 (3.5)	0 (0.0)	0 (0.0)	
Reinterventions	31 (17)	39 (16)	45 (24)	0.063
Missing	1 (0.4)	0 (0.0)	0 (0.0)	
Failure to rescue	16 (36)	13 (30)	6 (11)	**0.013**
	2015–2016	**2017–2019**	**2020–2022**	**P value**
pCCA	**N = 62**	**N = 121**	**N = 117**	
LOS (IQR)	12 (7–25)	16 (10–27)	15 (8–22)	0.127
Missing	1 (1.6)	2 (1.7)	0 (0.0)	
Complications	54 (89)	97 (80)	101 (86)	0.253
Missing	1 (1.6)	0 (0.0)	0 (0.0)	
Severe complications	29 (47)	62 (51)	68 (58)	0.309
30-day or in hospital mortality	11 (18)	14 (12)	13 (11)	0.374
Missing	0 (0.0)	0 (0.0)	0 (0.0)	
Complicated course	36 (58)	82 (68)	82 (70)	0.253
Liver failure	9 (15)	13 (11)	12 (10)	0.643
Missing	1 (1.6)	0 (0.0)	0 (0.0)	
Biliary leakage	20 (33)	36 (30)	32 (27)	0.748
Missing	1 (1.6)	0 (0.0)	0 (0.0)	
Reinterventions	23 (66)	63 (64)	62 (79)	0.063
Missing	0 (0.0)	0 (0.0)	0 (0.0)	
Failure to rescue	11 (39)	13 (21)	13 (19)	0.089
iCCA	**N = 52**	**N = 98**	**N = 140**	
LOS (IQR)	9 (6–13)	8 (6- 17)	7 (5- 12)	0.055
Missing	2 (3.8)	0 (0.0)	0 (0.0)	
Complications	26 (51)	60 (61)	71 (51)	0.241
Missing	1 (1.9)	0 (0.0)	0 (0.0)	
Severe complications	12 (23)	33 (34)	37 (26)	0.311
30-day or in hospital mortality	6 (12)	5 (5.1)	2 (1.4)	**0.012**
Missing	0 (0.0)	0 (0.0)	0 (0.0)	
Complicated course	17 (33)	42 (43)	41 (29)	0.091
Liver failure	3 (5.9)	9 (9.2)	5 (3.6)	0.194
Missing	1 (1.9)	0 (0.0)	0 (0.0)	
Biliary leakage	10 (20)	16 (16)	22 (16)	0.812
Missing	1 (1.9)	0 (0.0)	0 (0.0)	

Table 2 (*continued*)

CRLM	2014–2016	2017–2019	2020–2022	P value
	N (%)	N (%)	N (%)	
	N = 2847	N = 2802	N = 2408	
Reinterventions	11 (29)	30 (39)	36 (34)	0.522
Missing	0 (0.0)	0 (0.0)	0 (0.0)	
Failure to rescue	6 (50)	5 (15)	2 (5.4)	**0.002**

OS: length of stay. Severe complications were defined as complications grade 3A or higher according to Clavien-Dindo classification. Complicated course was defined as complication after surgery resulting in prolonged hospitalization (>14 days), or reintervention or death because of a complication during the primary admission.

show a safe and efficient application of both laparoscopic and robotic liver resections [36–38].

Despite the increased flexibility in resectability criteria, this study observed a decline in patients who underwent liver resection, primarily seen in patients operated on for CRLM. Furthermore, in this patient group, a decrease in the age of the patients operated on was observed. A possible explanation is the introduction of a colorectal screening program implemented in 2014 with a rollout phase until 2019 [39]. After the introduction of this national screening program, a decrease in overall and advanced-stage colorectal carcinoma was observed [39]. Another explanation could be the use of more parenchymal-sparing techniques, such as percutaneous ablations, in patients with CRLM, which expanded therapeutic options in patients [40,41]. Both reasons could also explain the decrease in age we observed. Possibly more older patients would be counselled for ablation instead of a liver resection and screening is applicable to individuals between 55 years and 75 years old.

This study examined the volume of patients treated per hospital. It was noted that the total number of patients treated has declined since 2018. Furthermore, the number of hospitals performing liver surgery decreased. As a result, the median number did not increase significantly. This trend may be induced by the ongoing centralisation of care in the Netherlands. Centralisation was most profound for patients diagnosed with HCC, yet liver transplantations are exclusively conducted in only three designated centres. Considerable progress in centralisation could be made for patients who underwent liver surgery for cholangiocarcinomas. A recent study with DHBA data did not observe an association between hospital volume and surgical outcomes after liver resection in general [42]. Future studies should evaluate if this ongoing centralisation further improves care quality.

Since 2014, the DHBA has focused on improving the quality of care [17]. Currently, to improve care, the DHBA provides benchmarks that may contribute to enhancing outcomes on local and national levels. Every hospital can access information through an online dashboard. Additionally, outcomes are transparently discussed during national meetings, and best practices and hospital variations are thoroughly reviewed. This is followed by an informative discussion, which serves as the foundation for further improvement in the quality of care. However, more multidisciplinary data could be helpful to reflect the overall quality of care of patients with liver malignancies. These data should include patients undergoing chemotherapy or radiotherapy without surgical intervention. Moreover, information on recurrent disease and primary cancers is required. Efforts are currently being made to combine data from the DHBA with the Dutch Colorectal Cancer audit which provides extra information about the primary disease of the patients registered for CRLM.

Several limitations of this study must be considered since the data was obtained from a nationwide retrospective database. Details, including the decision to perform surgery and detailed information on the location of the liver tumour, were lacking. In the DHBA, only 30-day mortality rates were registered. Previous studies comparing 30-day to 90-day mortality showed a nearly twofold increase in perioperative mortality rates for both CRLM and HCC [43,44]. Furthermore, it is not

Table 3
Multilevel multivariable logistic regression of trends in short term postoperative outcomes after liver surgery between 2014 and 2022 for CRLM and HCC and between 2016 and 2022 for iCCA and pCCA. aOR is adjusted odds ratio per year, reference = 2014.

Outcome	CRLM (N = 8057)				HCC (N = 838)			
		aOR	CI (95%)	P value		aOR	CI (95%)	P value
Complications	**2266**[a]	0.97	0.96–0.98	**<0.001**	**349***	0.99	0.98–1.00	0.32
Severe complications	**817**	1.11	0.98–1.06	0.323	**141**	1.03	0.95–1.13	0.463
30-day mortality	**104**	0.83	0.75–0.92	**<0.001**	**36**	0.86	0.75–0.99	**0.045**
Complicated course	**1055**	0.96	0.92–0.99	**0.034**	**182**	0.97	0.88–1.06	0.120
Liver failure	**107**	0.88	0.67–0.94	**0.007**	**26**	0.85	0.67–1.03	0.189
Bile leakage	**234**	1.08	0.99–1.14	0.068	**43**	1.09	0.94–1.28	0.234
Failure to rescue	**98**	0.84	0.76–0.93	**0.001**	**35**	0.81	0.68–0.97	**0.024**
Outcome	pCCA (N = 300)				iCCA (N = 290)			
		aOR	CI (95%)	p-value		aOR	CI (95%)	p-value
Complications	**239**[a]	0.96	0.67–1.38	0.626	**150**	0.53	0.34–0.79	**0.002**
Severe complications	**150**	1.17	0.92–1.48	0.064	**79**	0.65	0.43–0.99	**0.043**
30-day mortality	**34**	0.73	0.50–1.03	0.078	**11**	0.40	0.20–0.73	**<0.001**
Complicated course	**190**[a]	1.01	0.75–1.36	0.693	**96**	0.56	0.36–0.84	**0.005**
Liver failure	**31**	0.92	0.56–1.50	0.485	**16**	0.81	0.37–1.07	0.078
Bile leakage	**81**	0.78	0.66–1.10	0.482	**46**	0.78	0.51–1.20	0.129
Failure to rescue	**33**	0.67	0.39–1.13	0.61	**11**	0.29	0.08–0.84	**0.021**

[a] Indicate a multilevel model clustered for hospital is used.

possible to determine which factors contributed to observed quality improvement. However, it is likely that this is multifactorial. For example, the introduction of the Enhanced Recovery After Surgery (ERAS) liver protocols and the implementation of prehabilitation programs could also have contributed to the improvement of care [43,44].

In conclusion, during a decade of national auditing by the DHBA postoperative mortality and FTR have improved, and postoperative major complication rates remained stable despite operating on more higher risk patients. The DHBA remains focused on providing feedback and benchmark results to further enhance outcomes in the Netherlands.

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CRediT authorship contribution statement

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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References

[1] Beck N, Van Bommel AC, Eddes EH, Van Leersum NJ, Tollenaar RA, Wouters MW. The Dutch institute for clinical auditing: Achieving Codman's Dream on a Nationwide Basis 2020;271. https://doi.org/10.1097/SLA.0000000000003665.

[2] Lassen K, Nymo LS, Kørner H, Thon K, Grindstein T, Wasmuth HH, et al. The new national registry for gastrointestinal surgery in Norway: NoRGast. Scand J Surg 2018;107:201–7. https://doi.org/10.1177/1457496918766697/ASSET/IMAGES/LARGE/10.1177_1457496918766697-FIG2.JPEG.

[3] Pitt HA, Kilbane M, Strasberg SM, Pawlik TM, Dixon E, Zyromski NJ, et al. ACS-NSQIP has the potential to create an HPB-NSQIP option. HPB 2009;11:405–13. https://doi.org/10.1111/J.1477-2574.2009.00074.X.

[4] Aldrighetti L, Ratti F, Cillo U, Ferrero A, Ettorre GM, Guglielmi A, et al. Diffusion, outcomes and implementation of minimally invasive liver surgery: a snapshot from the I go MILS (Italian group of minimally invasive liver surgery) registry. Updates Surg 2017;69:271–83. https://doi.org/10.1007/S13304-017-0489-X.

[5] van der Werf LR, Kok NFM, Buis CI, Grünhagen DJ, Hoogwater FJH, Swijnenburg RJ, et al. Implementation and first results of a mandatory, nationwide audit on liver surgery. HPB 2019;21:1400–10. https://doi.org/10.1016/j.hpb.2019.02.021.

[6] Elfrink AKE, van Zwet EW, Swijnenburg RJ, den Dulk M, van den Boezem PB, Mieog JSD, et al. Case-mix adjustment to compare nationwide hospital performances after resection of colorectal liver metastases. Eur J Surg Oncol 2020; 47:649–59. https://doi.org/10.1016/j.ejso.2020.10.016.
[7] de Graaff MR, Klaase JM, den Dulk M, Coolsen M, Kuhlman K, Verhoef K, et al. Trends and overall survival after combined liver resection and thermal ablation of colorectal liver metastases: a nationwide population-based propensity score-matched study. Oxford: HPB; 2023. https://doi.org/10.1016/J.HPB.2023.09.012.
[8] de Graaff MR, Klaase JM, van Dam RM, Kuhlmann KFD, Kazemier G, Swijnenburg RJ, et al. Survival of patients with colorectal liver metastases treated with and without preoperative chemotherapy: nationwide propensity score-matched study. Eur J Surg Oncol 2023. https://doi.org/10.1016/J.EJSO.2023.05.007.
[9] de Graaff MR, Klaase JM, de Kleine R, Elfrink AKE, Swijnenburg R-J, M Zonderhuis B, et al. Practice variation and outcomes of minimally invasive minor liver resections in patients with colorectal liver metastases: a population-based study. Surg Endosc 2023;2023:1–15. https://doi.org/10.1007/S00464-023-10010-3.
[10] Elfrink AKEE, Kok NFMM, Swijnenburg R-JJ, den Dulk M, van den Boezem PB, Hartgrink HH, et al. Nationwide oncological networks for resection of colorectal liver metastases in The Netherlands: differences and postoperative outcomes. Eur J Surg Oncol 2022;48:435–48. https://doi.org/10.1016/j.ejso.2021.09.004.
[11] de Graaff MR, Elfrink AKE, Buis CI, Swijnenburg RJ, Erdmann JI, Kazemier G, et al. Defining Textbook Outcome in liver surgery and assessment of hospital variation: a nationwide population-based study. Eur J Surg Oncol 2022. https://doi.org/10.1016/J.EJSO.2022.06.012.
[12] Elfrink AKE, Kok NFM, den Dulk M, Buis CI, Kazemier G, Ijzermans JNM, et al. Short-term postoperative outcomes after liver resection in the elderly patient: a nationwide population-based study. HPB 2021. https://doi.org/10.1016/J.HPB.2021.03.002.
[13] Elfrink AKE, Olthof PB, Swijnenburg RJ, den Dulk M, de Boer MT, Mieog JSD, et al. Factors associated with failure to rescue after liver resection and impact on hospital variation: a nationwide population-based study. HPB 2021. https://doi.org/10.1016/j.hpb.2021.04.020.
[14] Elfrink AKE, Pool M, van der Werf LR, Marra E, Burgmans MC, Meijerink MR, et al. Preoperative imaging for colorectal liver metastases: a nationwide population-based study. BJS Open 2020;4:605–21. https://doi.org/10.1002/bjs5.50291.
[15] Elfrink AKE, Nieuwenhuizen S, van den Tol MP, Burgmans MC, Prevoo W, Coolsen MME, et al. Hospital variation in combined liver resection and thermal ablation for colorectal liver metastases and impact on short-term postoperative outcomes: a nationwide population-based study. HPB 2020. https://doi.org/10.1016/j.hpb.2020.10.003.
[16] Elfrink AKE, Kok NFM, van der Werf LR, Krul MF, Marra E, Wouters MWJM, et al. Population-based study on practice variation regarding preoperative systemic chemotherapy in patients with colorectal liver metastases and impact on short-term outcomes. Eur J Surg Oncol 2020;46:1742–55. https://doi.org/10.1016/j.ejso.2020.03.221.
[17] van der Werf LR, Kok NFM, Buis CI, Grünhagen DJ, Hoogwater FJH, Swijnenburg RJ, et al. Implementation and first results of a mandatory, nationwide audit on liver surgery. HPB 2019;21:1400–10. https://doi.org/10.1016/j.hpb.2019.02.021.
[18] van der Werf LR, Voeten SC, van Loe CMM, Karthaus EG, Wouters MWJM, Prins HA. Data verification of nationwide clinical quality registries. BJS Open 2019;3:857–64. https://doi.org/10.1002/bjs5.50209.
[19] SONCOS. Standardisation of multidisciplinary cancer care in The Netherlands. 2017.
[20] Clavien PA, Barkun J, De Oliveira ML, Vauthey JN, Dindo D, Schulick RD, et al. The clavien-dindo classification of surgical complications: five-year experience. Ann Surg 2009;250:187–96. https://doi.org/10.1097/SLA.0B013E3181B13CA2.
[21] Diggs LP, Fagenson AM, Putatunda V, Lau KN, Grandhi MS, Pitt HA. Intrahepatic cholangiocarcinoma: how do hepatectomy outcomes compare to liver metastases and hepatocellular carcinoma? HPB 2023;0. https://doi.org/10.1016/j.hpb.2023.07.898.
[22] Filmann N, Walter D, Schadde E, Bruns C, Keck T, Lang H, et al. Mortality after liver surgery in Germany. Br J Surg 2019;106:1523–9. https://doi.org/10.1002/BJS.11236.
[23] Hobeika C, Cauchy F, Fuks D, Barbier L, Fabre JM, Boleslawski E, et al. Laparoscopic versus open resection of intrahepatic cholangiocarcinoma: nationwide analysis. Br J Surg 2021;108:419–26. https://doi.org/10.1093/BJS/ZNAA110.
[24] Statement on ASA Physical Status Classification System n.d. https://www.asahq.org/standards-and-practice-parameters/statement-on-asa-physical-status-classification-system (accessed November 27, 2023).
[25] Mayhew D, Mendonca V, Murthy BVS. A review of ASA physical status – historical perspectives and modern developments. Anaesthesia 2019;74:373–9. https://doi.org/10.1111/ANAE.14569.
[26] Hurwitz EE, Simon M, Vinta SR, Zehm CF, Shabot SM, Minhajuddin A, et al. Adding examples to the ASA-physical status classification improves correct assignment to patients. Anesthesiology 2017;126:614–22. https://doi.org/10.1097/ALN.0000000000001541.
[27] Suurmeijer JA, Henry AC, Bonsing BA, Bosscha K, Van Dam RM, Van Eijck CH, et al. Outcome of pancreatic surgery during the first 6 Years of a mandatory audit within the Dutch pancreatic cancer group. Ann Surg 2023;278. https://doi.org/10.1097/SLA.0000000000005628.
[28] Voeten DM, Busweiler LAD, van der Werf LR, Wijnhoven BPL, Verhoeven RHA, van Sandick JW, et al. Outcomes of esophagogastric cancer surgery during eight years of surgical auditing by the Dutch upper gastrointestinal cancer audit (DUCA). Ann Surg 2021;274:866–73. https://doi.org/10.1097/SLA.0000000000005116.
[29] Smits FJ, Henry AC, Besselink MG, Busch OR, van Eijck CH, Arntz M, et al. Algorithm-based care versus usual care for the early recognition and management of complications after pancreatic resection in The Netherlands: an open-label, nationwide, stepped-wedge cluster-randomised trial. Lancet 2022;399:1867–75. https://doi.org/10.1016/S0140-6736(22)00182-9.
[30] Görgec B, Hansen I, Kemmerich G, Syversveen T, Abu Hilal M, Belt EJT, et al. Clinical added value of MRI to CT in patients scheduled for local therapy of colorectal liver metastases (CAMINO): study protocol for an international multicentre prospective diagnostic accuracy study. BMC Cancer 2021;21. https://doi.org/10.1186/S12885-021-08833-1.
[31] Görgec B, Hansen I, Hartgrink HH, Grünhagen D, Kok N, Kuhlmann K, et al. Clinical added value of gadoxetic acid enhanced liver MRI in patients scheduled for local therapy of colorectal liver metastases based on CT imaging (CAMINO). HPB 2023;25:S194. https://doi.org/10.1016/j.hpb.2023.07.015.
[32] MichelleR de Graaff, Klaase JM, van Dam RM, Kuhlmann KFD, Kazemier G, Swijnenburg R-J, et al. Survival of patients with colorectal liver metastases treated with and without preoperative chemotherapy: nationwide propensity score-matched study. Eur J Surg Oncol 2023. https://doi.org/10.1016/J.EJSO.2023.05.007. 0.
[33] Guideline metastatic colorectalcarcinoma (CRC) - Guidelinedatabase n.d. https://richtlijnendatabase.nl/richtlijn/colorectaal_carcinoom_crc/gemetastaseerd_colorectaalcarcinoom_crc.html (accessed October 5, 2022).
[34] Berardi G, Van Cleven S, Fretland ÅA, Barkhatov L, Halls M, Cipriani F, et al. Evolution of laparoscopic liver surgery from innovation to implementation to mastery: perioperative and oncologic outcomes of 2,238 patients from 4 European specialized centers. J Am Coll Surg 2017;225:639–49. https://doi.org/10.1016/J.JAMCOLLSURG.2017.08.006.
[35] Carpenter EL, Thomas KK, Adams AM, Valdera FA, Chick RC, Kemp Bohan PM, et al. Modern trends in minimally invasive versus open hepatectomy for colorectal liver metastasis: an analysis of ACS-NSQIP. Surg Endosc 2023;37:5591–602. https://doi.org/10.1007/S00464-022-09749-Y/FIGURES/2.
[36] Görgec B, Zwart M, Nota CL, Bijlstra OD, Bosscha K, De Boer MT, et al. Implementation and outcome of robotic liver surgery in The Netherlands: a nationwide analysis. Ann Surg 2023;277:E1269–77. https://doi.org/10.1097/SLA.0000000000005600.
[37] van der Poel MJ, Fichtinger RS, Bemelmans M, Bosscha K, Braat AE, de Boer MT, et al. Implementation and outcome of minor and major minimally invasive liver surgery in The Netherlands. HPB 2019;21:1734–43. https://doi.org/10.1016/J.HPB.2019.05.002.
[38] Fichtinger RS, Aldrighetti L, Troisi R, Hilal MA, Sutcliffe R, Besselink M, et al. 384O Laparoscopic versus open hemihepatectomy: the ORANGE II PLUS multicenter randomized controlled trial. Ann Oncol 2021;32:S531. https://doi.org/10.1016/J.ANNONC.2021.08.906.
[39] Breekveldt ECH, Lansdorp-Vogelaar I, Toes-Zoutendijk E, Spaander MCW, van Vuuren AJ, van Kemenade FJ, et al. Colorectal cancer incidence, mortality, tumour characteristics, and treatment before and after introduction of the faecal immunochemical testing-based screening programme in The Netherlands: a population-based study. Lancet Gastroenterol Hepatol 2022;7:60–8. https://doi.org/10.1016/S2468-1253(21)00368-X.
[40] Nieuwenhuizen S, Puijk RS, van den Bemd B, Aldrighetti L, Arntz M, van den Boezem PB, et al. Resectability and ablatability criteria for the treatment of liver only colorectal metastases: multidisciplinary consensus document from the COLLISION trial group. Cancers 2020;12:1–17. https://doi.org/10.3390/CANCERS12071779.
[41] Ruers T, Van Coevorden F, Punt CJA, Pierie JPEN, Borel-Rinkes I, Ledermann JA, et al. Local treatment of unresectable colorectal liver metastases: results of a randomized phase II trial. JNCI Journal of the National Cancer Institute 2017;109. https://doi.org/10.1093/JNCI/DJX015.
[42] Olthof PB, Elfrink AKE, Marra E, Belt EJT, van den Boezem PB, Bosscha K, et al. Volume–outcome relationship of liver surgery: a nationwide analysis. Br J Surg 2020;917:107. https://doi.org/10.1002/BJS.11586.
[43] Mayo SC, Shore AD, Nathan H, Edil BH, Hirose K, Anders RA, et al. Refining the definition of perioperative mortality following hepatectomy using death within 90 days as the standard criterion. HPB 2011;13:473–82. https://doi.org/10.1111/j.1477-2574.2011.00326.x.
[44] Mise Y, Vauthey JN, Zimmitti G, Parker NH, Conrad C, Aloia TA, et al. 90-day postoperative mortality is a legitimate measure of hepatopancreatobiliary surgical quality. Ann Surg 2015;1071:262. https://doi.org/10.1097/SLA.0000000000001048.