Nutritional risk screening 2002 and ASA score predict mortality after elective liver resection for malignancy

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Abstract

Introduction: The aim of the study was to evaluate whether Nutritional risk screening 2002 (NRS 2002) at hospital admission may predict postoperative mortality and complications within 90 days after elective liver resection for malignancy.

Material and methods: A retrospective cohort study of a prospective database was performed. Two-hundred and three patients with elective liver resection for malignancy between 9 November 2007 and 27 May 2014 were included. Clinical data, NRS 2002, surgical procedures and histology were recorded. The primary endpoint was 90-day mortality. Complications were registered within 90 days postoperatively according to the Clavien-Dindo classification.

Results: The 90-day mortality was 5.9% and the overall complication rate was 59.1%. Multivariate analysis identified NRS 2002 score ≥ 4 (odds ratio (OR) = 9.24; p = 0.005) and American Society of Anesthesiologists (ASA) score ≥ 3 (OR = 6.20; p = 0.009) as predictors of 90-day mortality. The 90-day mortality was 27.6% (8/29) for patients with both risk factors (NRS 2002 score ≥ 4 and ASA score ≥ 3) vs. 2.3% (4/174) for patients without or with only one risk factor (p < 0.001).

Conclusions: In the present study NRS 2002 score ≥ 4 and ASA score ≥ 3 were predictors of 90-day mortality after elective liver resection for malignancy.

Key words: liver resection, mortality, nutritional risk screening (NRS 2002).

Introduction

Indications for liver resection in malignancy have been extended in the last 20 years [1, 2]. Consequently, there has been an increase in the rate of elderly patients considered for liver resection [3–5] and a higher rate of liver parenchyma alterations caused by preoperative chemotherapy [6, 7], obesity [8] and viral hepatis [9]. Elderly patients with cancer and comorbidities have an increased nutritional risk [10, 11]. There is good evidence that nutritional risk is associated with increased perioperative morbidity and mortality after gastrointestinal surgery [12–14].

Liver resection remains an intervention with considerable morbidity [1–8], and postoperative mortality in the 21st century was reported as being "far from zero" [2] even in expert centers. Halliday *et al.* [15] reported in 1988 an increased mortality and complication rate after hepatobiliary surgery in patients with weight loss > 15% and albumin level < 30 g/dl.

More recently, low preoperative albumin [16] and prealbumin level [17] were confirmed as risk factors for complications [16] and liver insufficiency [17] after liver resection.

The European Society of Parenteral and Enteral Nutrition (ESPEN) recommends Nutritional risk screening 2002 (NRS 2002) for patients undergoing gastrointestinal surgery [18]. NRS 2002 is a reliable and reproducible tool for identifying patients at nutritional risk [19]. It has been studied prospectively in colorectal [14] and abdominal surgery [20] and was able to predict mortality and morbidity after surgery for colorectal cancer [14]. However, outcome data after liver resection are lacking.

Therefore, the aim of the present study was to evaluate the ability of NRS 2002 to predict mortality and complications within 90 days after elective liver resection for malignancy.

Material and methods

In the authors' institution 235 consecutive liver resections were performed between 9 November 2007 and 27 May 2014. Nine patients with emergency liver resection and 23 patients with benign disease were excluded. Therefore 203 elective liver resections for malignancy were included for analysis. Patients who required extrahepatic procedures such as simultaneous colorectal resection or others were included in the study.

The data were retrieved from a prospective liver resection database and retrospectively analysed. The following variables were recorded: age, gender, pathology, TNM stage, histology, preoperative nutritional support and chemotherapy, preoperative laboratory values (hemoglobin, albumin, bilirubin, prothrombin level), preoperative body weight, weight loss, body height, NRS 2002 score, comorbidities, American Society of Anesthesiologists (ASA) score, type of liver resection and associated procedures, length of operation and Pringle clamping time, estimated blood loss, perioperative transfusion, drainage, any postoperative complication and its treatment, postoperative nutritional support, mortality, length of hospital stay and latest news. Patients were followed up for at least 6 months. No patient was lost during follow-up.

All patients gave informed written consent for surgery and data collection. Ethics approval was not required because of the retrospective monocentric study design and local data analysis without data transmission [21].

Preoperative management and nutritional risk screening

Standard preoperative workup included blood analysis, computed tomography scanning or magnetic resonance imaging in all patients. Indocyanine green clearance was performed in patients with liver cirrhosis and in patients undergoing major hepatectomy. Right portal vein embolization [22] or ligation was performed selectively before right (or extended right) hepatectomy if future liver remnant (FLR) < 30%. Contraindications for liver resection were: liver cirrhosis Child-Pugh B or C, insufficient FLR, technical impossibility to obtain complete resection of liver tumors and non-resectable extrahepatic disease. The preoperative NRS 2002 score was calculated for each patient according to Kondrup *et al.* [19]. The baseline level was given by an NRS 2002 score of 2, as all patients had 2 points attributed for the severity of disease. The maximal NRS 2002 score was 6, corresponding to patients undergoing a liver resection (2 points) with severe impaired nutritional status (+ 3 points) and age ≥ 70 years (+1 point). Preoperative nutritional support was provided with oral immunonutrition (Oral-Impact for 7 days) as recommended by the French Society of Digestive Surgery, or occasionally with parenteral nutrition (Nutriflex for 7 days) when oral intake was insufficient [23].

Surgical technique and peri-operative management

After a bilateral subcostal incision, liver parenchyma transection was performed by the clamp crushing technique under intermittent portal triad clamping. Ultrasonography and a bile leakage test were performed routinely. Red blood cell transfusion was given when the hemoglobin level dropped below 8 g/dl and according to hemodynamic tolerance. Antibiotics were given perioperatively according to guidelines [24].

Postoperative management

Postoperatively, patients were monitored in the intensive care unit (ICU) for at least 24 h. An enhanced recovery protocol was not used during the study period. Patients started oral liquids intake the day after the operation and solid food was started at day 2 according to tolerance. Postoperative nutritional support was provided by the parenteral (Nutriflex) or enteral (Fresubin Standard) route in patients unable to eat solid food within 7 days, or with insufficient oral food intake [18, 23]. All patients had thromboprophylaxis with low molecular weight heparin.

Definitions

Major hepatectomy was defined as the resection of three or more liver segments. The Brisbane terminology was used for classification of the type of liver resection [25]. Extrahepatic procedures were defined as partial or total resection of other organs (colon, rectum, stomach, diaphragm, adrenal gland) and biliodigestive anastomosis. Cholecystectomy, liver biopsy and lymph node sampling or dissection were not considered as extrahepatic procedures.

Mortality was defined as death of any cause within 90 days after liver resection [26]. Overall complications were defined as any deviation from an uneventful postoperative course within 90 days after surgery. The diagnosis of an infectious complication was based on clinical, biological and radiological data and included: catheter, surgical site, pulmonary, and urinary infections. Infectious complications were defined according to the criteria established by the Centers for Disease Control and Prevention and the 1991 Consensus Conference [27], and were treated adequately with either antibiotics, percutaneous drainage or surgical revision. Wound infection was classified as surgical site infection. Severity of complications was defined according to the Clavien-Dindo classification [28]. Hospital stay was defined as postoperative hospital stay.

Endpoints

The primary endpoint was 90-day mortality. Secondary endpoints were infectious and overall complications within 90 days.

Statistical analysis

Continuous variables are given as median and range and compared using a Mann-Whitney test. Dichotomous variables are reported as *n* (%) and compared using a Pearson χ^2 or Fisher's exact test, as appropriate. All statistical tests were two-sided and $p < 0.050$ was considered significant. To assess which parameters may have influenced 90-day mortality, uni- and multivariate analysis were performed. Stepwise logistic regression was used for multivariate analysis. All variables with $p < 0.2$ in univariate analysis were included in the multivariate analysis. In multivariate analysis variables with $p \geq 0.1$ were excluded step by step.

Results

Baseline characteristics of the patient population and the indications for liver resection are shown in Table I. Nutritional risk (NRS 2002 ≥ 3 points) [19] was registered in 66.5% (135/203) of patients. The median value of the NRS 2002 score was 3 and was used for quantization in uni- and multivariate analysis. The type of liver resection, simultaneous extrahepatic procedures and intraoperative data are shown in Table II. Median hospital stay after the operation was 10 days (range: 4–90). Postoperatively, patients started oral liquids the day after the operation and solid food at median postoperative day 4 (range: 2–70).

Postoperative mortality

There was no intraoperative death. Eight (3.9%) patients died within 30 days as a result of the following: 4 septic shock (cholangitis, pneumonia, peritonitis caused by an anastomotic fistula after ileostomy closure, unknown origin), 2 liver failures, 1 stroke and 1 cardiac arrest. Four patients died within 90 days after surgery because of the following: tumor progression in two patients with a two-stage or reverse hepatectomy, pneumonia in 1 patient and septic shock caused by endo-

Table I. Baseline characteristics of 203 patients with elective liver resections for malignancy

Parameter	Result
Female gender	55 (27.1%)
Mean age (range) [years]	66.5 (27–89)
Median Charlson Comorbidity Index (range)	6 (2–12)
NRS 2002 score:	
2 points	68 (33.4%)
3 points (= median)	60 (29.5%)
4 points	31 (15.2%)
5 points	31 (15.2%)
6 points	13 (6.4%)
Median body weight (range) [kg]	74 (40–127)
Median body height (range) [m]	1.7 (1.5–1.9)
Median weight loss in % of usual weight	2.7 (0–27)
ASA Score ≥ 3	69 (33.9%)
Albumin level < 35 g/l	24 (11.8%)
Preoperative chemotherapy	68 (33.4%)
Preoperative nutritional support	111 (54.6%)
Postoperative nutritional support	72 (35.4%)
Pathology:	
Colorectal cancer	127 (62.5%)
Cholangiocarcinoma	22 (10.8%)
Hepatocellular carcinoma	42 (20.6%)
Other malignancy	12 (5.9%)
Cirrhosis/fibrosis	34 (16.7%)

ASA – American Society of Anesthesiologists, NRS 2002 – Nutritional risk screening 2002. Continuous variables are reported as median and range. Dichotomous variables are reported as n (%). Other malignancies included: liver sarcoma (n = 2), metastases of endocrine tumors (n = 2), other metastases (n = 8).

Table II. Types of liver resection following the Brisbane terminology [25], extrahepatic procedures and intraoperative data for 203 patients with elective liver resections for malignancy

Type	Result
Major hepatectomy:	61 (31.9%)
Right hepatectomy	33 (18.8%)
Left hepatectomy	20 (9.4%)
Other	8* (3.1%)
Minor hepatectomy:	142 (68.1%)
Extrahepatic procedures:	66 (32.9%)
Colorectal resection	40 (18.3%)
Biliodigestive anastomosis	6 (4.7%)
Other**	20 (9.9%)
Operating time [min]	235 (110–630)
Pringle clamping:	168 (82.7%)
Clamping time [min]	30 (6–82)
Transfusion:	76 (37.4%)
Intra-operatively	59 (29.0%)
Post-operatively	34 (16.7%)
Blood loss [ml]	400 (50–2500)

*Continuous variables are reported as median and range. Dichotomous variables are reported as n (%). *Three patients had two bisegmentectomies (4 resected segments) and 5 patients had trisegmentectomy classifying those resections as major hepatectomy. **Other extrahepatic procedures included: resection and anastomosis of the small intestine (n = 9), partial resection of the right diaphragm (n = 7), distal gastrectomy (n = 1), left pancreatectomy (n = 1) and right adrenalectomy (n = 2).*

carditis with septic cerebral embolism in another patient. The overall 90-day mortality was 5.9% (12/203) and 4.4% (6/137) after liver resection only versus 9.1% (6/66) after liver resection with simultaneous extrahepatic procedures (p = 0.209). Six patients died within 90 days because of postoperative infectious complications, 5 presenting septic shock.

Predictive factors for 90-day mortality

Variables associated with 90-day mortality in univariate analysis were: ASA score ≥ 3, NRS 2002 score ≥ 4, albumin level < 35 g/l, major hepatectomy and transfusion, as shown in Table III. All factors with p < 0.2 in univariate analysis were included in the multivariate analysis. In multivariate logistic regression analysis two independent risk factors were found for 90-day mortality: ASA score ≥ 3 (p = 0.009; odds ratio (OR) = 6.20; 95% confidence interval (CI): 1.56–24.53) and NRS 2002 score ≥ 4 (p = 0.005; OR = 9.24; 95% CI: 1.92–44.39) (Table IV). The numbers of patients alive and deceased within 90 days postoperatively according to the presence of these risk factors are shown in Figure 1. The 90-day mortality was 27.6% (8/29) for patients with both risk factors (NRS 2002 score ≥ 4 and ASA score ≥ 3) vs. 2.3% (4/174) for patients without or with only one risk factor (p < 0.001).

Subgroup analysis of 90-day mortality

In all subgroups 90-day mortality increased for NRS 2002 score ≥ 4. The effect was more pronounced in patients older than 70 years, in major hepatectomy and for extrahepatic procedures (Table V).

Postoperative complications

A total of 212 postoperative complications were registered in 120 (59.1%) patients and were classified according to their severity in the Clavien-Dindo classification (Table V). Procedures under general anaesthesia (Clavien-Dindo IIIb) were performed in 13 (6.4%) patients: surgery in 8 patients because of the following: 1 bile leakage, 1 hemoperitoneum, 1 ischemic colonic perforation, 1 anastomotic leakage after ileostomy closure, 1 ileal perforation caused by adhesiolysis, 1 exploratory laparotomy, 1 endocarditis, 1 pleural empyema; endoscopic procedures in 4 patients (3 biliary stents and 1 hemostatic clip) and interventional radiology in 1 patient (portosystemic shunt). No anastomotic leakage after simultaneous colorectal resection was recorded. Procedures under local anesthesia (Clavien-Dindo IIIa) were performed in 20 (9.8%) patients: percutaneous drainage of abdominal collections in 8 (3.9%) patients, percutaneous drainage of pleural collections in 10 (4.9%) patients, 1 coronarography and 1 pyelostomy.

Nutritional risk measured with the NRS 2002 score was not associated with a higher overall and infectious complication rate. On the other hand, more patients with NRS 2002 score ≥ 4 had septic shock (Table V). Patients with postoperative septic shock had a mortality rate of 41.6% (5/12).

Discussion

In the present study NRS 2002 score ≥ 4 and ASA score ≥ 3 were predictive for 90-day mortality after liver resection in multivariate analysis. The ASA score ≥ 3 has been reported previously to increase the postoperative morbidity [29] and mortality [2, 30] after liver resection. However, the present study is the first to report the impact of nutritional risk screening on mortality after hepatectomy.

In univariate analysis the present study found five risk factors for 90-day mortality: ASA score

Table III. Univariate analysis of risk factors for 90-day mortality in 203 elective liver resections for malignancy

Parameter	Dead (*n* = 12)	Alive (*n* = 191)	*P*-value
Age [years]	77 (55–80)	67 (27–89)	0.186
Female gender	4	51	0.738
Study period:			
First 101 resections	5	96	0.767
Second 102 resections	7	95	
Charlson Comorbidity Index Score > 6	8	73	0.068
ASA Score ≥ 3	9	60	0.003
NRS 2002 ≥ 4	10	65	0.001
Albumin level < 35 g/dl	5	19	0.006
Preoperative chemotherapy	3	64	0.754
Cirrhosis/fibrosis	3	31	0.694
Colorectal liver metastases	5	122	0.135
Hepatocellular carcinoma	4	38	0.275
Cholangiocarcinoma	2	20	0.623
Other malignancy	1	11	1
Major hepatectomy	7	54	0.046
Extrahepatic procedures	6	60	0.209
Duration of surgery [min]	272 (180–360)	230 (110–630)	0.087
Blood loss [ml]	450 (100–1200)	400 (50–2500)	0.865
Transfusion	8	68	0.037

ASA – American Society of Anesthesiologists, NRS 2002 – Nutritional risk screening 2002. Continuous variables are reported as median and range. Dichotomous variables are reported as N. Continuous variables were compared using the Mann-Whitney test. Dichotomous variables were compared using Fisher's exact test. All variables with p < 0.2 in univariate analysis were included in multivariate analysis.

≥ 3, major hepatectomy, perioperative transfusion, NRS score ≥ 4 and albumin level < 35 g/l, confirming the findings of Dokmak *et al.* [2] for the first three variables and the results of Tzeng *et al.* [4] and Aloia *et al.* [16] for transfusion. However, in multivariate analysis only ASA score ≥ 3 and NRS 2002 score ≥ 4 remained significant. This may be due to the rather small study population.

The present study records a 90-day mortality of 5.9% (12/203) after elective surgery for malignancy, which is higher compared to 4.5% (66/1453) recently reported by Dokmak *et al.* [2]. However, the difference is not significant (p = 0.389) in a Pearson χ^2 test. Other studies reported a similar 90-day mortality rate of 5.8% [31] to 10.1% [26] after liver resection. The 90-day mortality rate should be preferred over 30-day mortality, as suggested by Mayo *et al.*, who concluded: "Reporting deaths that occur within a maximum of 30 days of surgery underestimates the mortality associated with hepatic resection. Traditional 30-day definitions of mortality are misleading and surgeons should report all perioperative outcomes that occur within 90 days of hepatic resection" [26].

The 90-day mortality registered in the present study was 4.4% for liver resection only versus 9.1% for liver resection with extrahepatic procedures (p = 0.209). The difference was not significant because of the small number of patients (type II error). Indeed, one third of patients (66/203) had simultaneous extrahepatic procedures, and colorectal resection (n = 40) was the most common. This is in accordance with others institutions: Jarnagin *et al.* [1] and Dokmak *et al.* [2] reported 37% and 27.5% rates of extrahepatic procedures, respectively.

Although the overall complication rate was rather high (59.1%), most were of grade I or II in the Clavien-Dindo classification. The present study failed to register an increased rate of overall and infectious complication for patients with an NRS 2002 score ≥ 4. However, septic shock (the most severe infectious complication) was significantly more frequently registered in patients with an NRS 2002 score ≥ 4 and had a high mortality rate of 41.7% (5/12).

Table IV. Multivariate analysis of risk factors for 90-day mortality in 203 elective liver resections for malignancy

Covariates	Odds ratio	95% CI	*P*-value	
First step of multivariate analysis: inclusion of factors with *p* < 0.2 in univariate analysis (Table III)				
Age [years]	0.99	0.92–1.06	0.990	Excluded
Charlson Comorbidity Index Score > 6	4.38	0.85–22.46	0.076	
ASA Score ≥ 3	4.09	0.87–19.14	0.073	
NRS 2002 ≥ 4	5.20	0.97–27.82	0.053	
Albumin level < 35 g/dl	2.93	0.61–13.87	0.175	Excluded
Colorectal liver metastases	0.20	0.04–0.89	0.035	
Major hepatectomy	3.03	0.68–13.43	0.145	Excluded
Duration of surgery [min]	1.00	0.99–10.1	0.567	Excluded
Transfusion	1.77	0.40–7.80	0.448	Excluded
Second step of multivariate analysis: inclusion of factors with *p* < 0.1 in first step of multivariate analysis				
Charlson Comorbidity Index Score > 6	2.76	0.68–11.16	0.153	Excluded
ASA Score ≥ 3	5.48	1.34–22.37	0.018	
NRS 2002 ≥ 4	7.68	1.54–38.18	0.013	
Colorectal liver metastases	0.32	0.08–1.25	0.103	Excluded
Final step of multivariate analysis				
ASA Score ≥ 3	6.20	1.56–24.53	0.009	
NRS 2002 ≥ 4	9.24	1.92–44.39	0.005	

CI – confidence interval for the odds ratio.

Nutritional risk factors for hepatobiliary surgery were reported by Halliday *et al.* [15] in a study of 32 patients in 1988. In their study weight loss > 15% and albumin level < 30 g/dl were associated with postoperative mortality and morbidity. However, the majority of patients had biliary and bypass procedures and only 6 patients underwent hepatectomy, limiting the conclusion of Halliday *et al.* for liver resection.

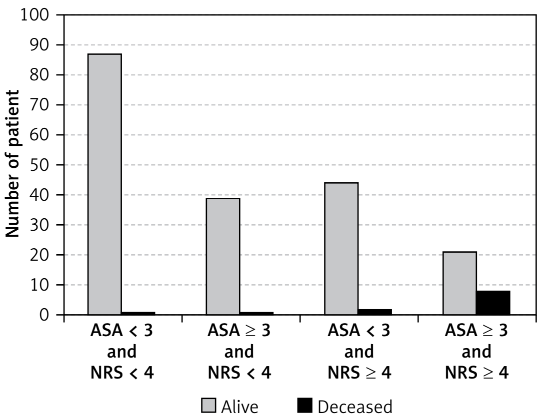

Figure 1. Distribution of patients undergoing 203 liver resections for malignancy according to risk factors for 90-day mortality: NRS 2002 score ≥ 4 and ASA score ≥ 3. The number of patients (alive and deceased at 90 days postoperatively) is given for each group. The 90-day mortality was 1.1% (1/88), 2.5% (1/40), 4.3% (2/46) and 27.6% (8/29), respectively

Nutritional risk screening 2002 was prospectively studied by Schwegler *et al.* [14] in surgery for colorectal cancer. A significantly higher rate of postoperative complications (62% vs. 39.8%, p = 0.004) was registered for patients at nutritional risk (NRS ≥ 3 points). Unlike the present study, complications were not classified according to Clavien-Dindo. Postoperative mortality was not significantly higher in patients with nutritional risk: 7% vs. 1.8% (p = 0.085). However, in their study only in-hospital mortality and complications were registered. The authors concluded "that more morbidity and possibly mortality would have been recorded if the time frame had been longer". Recently NRS 2002 was used by Jie *et al.* [20] in a study of nutritional support in 1085 abdominal surgical patients. In their study a postoperative complication rate of 41.6% (50/120) was reported for patients with an NRS 2002 score ≥ 5, vs. 23.2% (91/392) in patients with an NRS 2002 score of 3 or 4 (p < 0.001). Postoperative 31-day mortality was 1.6% (2/120) in patients with an NRS 2002 score ≥ 5 vs. 0.5% (2/392) in patients with an NRS 2002 score of 3 or 4 (p = 0.235). Although the

Table V. Postoperative complications and mortality within 90 days after 203 elective liver resections for malignancy according to the preoperative value of the Nutritional Risk Screening 2002 Score (NRS)

Parameter	NRS score 2 or 3 (*n* = 128)	NRS score ≥ 4 (*n* = 75)	*P*-value
Number of patients with complications (*n* = 120)	73 (57.0%)	47 (62.6%)	0.462
Number of patients with infectious complications	42 (32.8%)	30 (40.0%)	0.362
Number of patients with septic shock	3 (2.3%)	9 (12%)	0.007
Number of complications (*n* = 212) according to the Clavien-Dindo classification:			
Grade I (*n* = 42)	23 (17.9%)	19 (25.3%)	0.281
Grade II (*n* = 104)	64 (50.0%)	40 (53.3%)	0.665
Grade III (*n* = 33)	21 (16.4%)	12 (16.0%)	1
Grade IV (*n* = 21)	10 (7.8%)	11 (14.7%)	0.152
Grade V, 90-day mortality (*n* = 12)	2 (1.5%)	10 (13.3)	0.001
Subgroup analysis of 90-day mortality:			
Liver resection only (*n* = 137)	2/97 (2.1%)	4/40 (10.0%)	0.060
Extrahepatic procedures (*n* = 66)	0/31 (0%)	6/35 (17.1%)	0.025
Age < 70 years (*n* = 115)	2/81 (2.5%)	3/34 (8.8%)	0.152
Age ≥ 70 years (*n* = 88)	0/47 (0%)	7/41 (17.1%)	0.003
Minor hepatectomy (*n* = 142)	1/94 (1.1%)	4/48 (8.3%)	0.044
Major hepatectomy (*n* = 61)	1/34 (2.9%)	6/27 (22.2%)	0.037

Dichotomous variables are reported as N and were compared using Fisher's exact test. All complications were registered and classified according to the Clavien-Dindo classification [28].

authors included 279 patients with hepatobiliary surgery in their study, no data regarding this specific population was presented.

In a multi-institutional study by Tzeng *et al.* [4], 30-day mortality was registered in 43 of 214 patients ≥ 75 years who had major complications after a liver resection. In their study, the 30-day mortality increased with the number of major complications. However, the impact of nutritional risk on complication and mortality was not studied. To improve surgical outcome Tzeng *et al.* proposed to "limit the extent and complexity of resection procedures for high risk patients".

The high prevalence of nutritional risk (NRS 2002 ≥ 3) observed in the present study and the consequences of nutritional risk for the outcome after surgery explain the clinical interest for nutritional support. However, no consensus on the optimal nutritional support in liver resection has been reached [32, 33]. A Cochrane review by Koretz *et al.* found no impact on postoperative mortality and morbidity for parenteral, enteral or oral nutritional support in surgery for liver disease [33]. In the authors' institution during the study period preoperative nutritional support was mainly provided with oral immunonutrition [23, 34, 35], whereas postoperative nutritional support was mainly provided with parenteral nutrition [36]. The impact of nutritional support on outcome was not analyzed in the present study, as significant covariate imbalances were registered for patients with nutritional support versus those without nutritional support. The authors have reported a propensity score matched case-control analysis of preoperative immunonutrition versus no nutritional support in liver resection, and no benefit of preoperative immunonutrition with regard to postoperative complications could be demonstrated [35]. The impact of nutritional support on outcome should be analyzed in a randomized trial [33, 34, 36].

The major limitation of the present study was its retrospective design. The impact of nutritional risk screening on postoperative mortality and complications after liver resection should be studied in a prospective trial. Furthermore, the number of patients in the present study was rather limited. Therefore, the statistical value of the present analysis should be regarded with caution. In the present study one third of patients had simultaneous extrahepatic procedures which were a confounding factor for complications and mortality. Patients with emergency liver resection and with benign disease were excluded from the present study. However, nutritional risk may also be present in these settings and further studies should be performed.

Clinical implications

What were the consequences of the present study for the surgical practice in the authors' institution? NRS 2002 score ≥ 4 and ASA score ≥ 3 were predictive for increased 90-day mortality after elective liver resection for malignancy. Postoperative mortality was in most cases a consequence of infectious complications. The ASA score cannot be changed, and the impact of perioperative nutritional support to influence postoperative outcome after liver resection remains questionable [32–35]. A careful selection of surgical procedures in patients with nutritional risk and an ASA score ≥ 3 is required to reduce perioperative complications. In the authors' institution, in the light of the present data and following the conclusions of Tzeng *et al.* [4], the "extent and complexity" of liver resection and simultaneous extrahepatic procedures will be limited in patients with an NRS 2002 score ≥ 4 and an ASA score ≥ 3.

In conclusion, in the present study NRS 2002 score ≥ 4 and ASA score ≥ 3 were predictive for 90-day mortality after elective liver resection for malignancy. Further studies are necessary to evaluate the clinical value of nutritional risk screening for liver resection.

Conflict of interest

The authors declare no conflict of interest.

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