Effect of sarcopenia on postoperative ICU admission and length of stay after hepatic resection for Klatskin tumour

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<TABLE OF CONTENTS>

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

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Hepatic resection of Klatskin tumours usually requires postoperative intensive care unit (ICU) admission because of its high morbidity and mortality. Identifying surgical patients who will benefit most from ICU admission is important because of scarce resources but remains difficult. Sarcopenia is characterised by the loss of skeletal muscle mass and is associated with poor surgical outcomes. We retrospectively analysed the relationship between preoperative sarcopenia and postoperative ICU admission and length of ICU stay (LOS-I) in patients who underwent hepatic resection for Klatskin tumours. Using preoperative computed tomography scans, the cross-sectional area of the psoas muscle at the level of the third lumbar vertebra was measured and normalised to the patient's height. Using these values, the optimal cut-off for diagnosing sarcopenia was determined using receiver operating characteristic curve analysis for each sex. Of 330 patients, 150 (45.5%) were diagnosed with sarcopenia. Patients with preoperative sarcopenia presented significantly more frequently to the ICU (77.3% vs. 47.9%, $p < 0.001$) and had longer total LOS-I (2.45 vs 0.89 days, $p < 0.001$). Moreover, patients with sarcopenia showed a significantly higher postoperative length of hospital stay, severe complication rate, and in-hospital mortality. Sarcopenia correlated with poor postoperative outcomes, especially with the increased requirement of postoperative ICU admission and prolonged LOS-I after hepatic resection in patients with Klatskin tumours.

Key words : hepatectomy, intensive care units, Klatskin tumour, sarcopenia

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I. INTRODUCTION

Klatskin tumours, also called perihilar cholangiocarcinomas, constitutes 50–70% of all biliary tract malignancies[1]. Klatskin tumours originate from the biliary ductal epithelium and are located between the bifurcation of the cystic duct junction and the second-order intrahepatic bile duct branches[2]. As the tumour progresses, the mass blocks the biliary tract, and patients typically present with cachexia, fatigue, and obstructive jaundice[3,4]. Although complete surgical resection is the only curative treatment for Klatskin tumours, less than half of the cases are resectable[5] In addition, this procedure is technically demanding to achieve a histologically negative margin and has high postoperative morbidity owing to the local anatomy[6,7]. Consequently, the risk of postoperative morbidity and mortality in Klatskin tumours remains high, despite many advances in surgical techniques and perioperative management[8].

Postoperative admission to the intensive care unit (ICU) in high-risk patients is effective for the prevention, early recognition, and management of severe complications, thereby reducing the mortality risk[9,10]. However, routine ICU admission after major surgery is not beneficial to all patients because of increased expenses and limited resources[11,12]. Therefore, it is important to determine the need for ICU admission in high-risk patients, as it can provide more efficient medical resources. However, identifying surgical patients who will benefit the most from intensive care remains difficult, and the identification method is not fully established. Prediction of ICU admission and length of stay has traditionally focused on the presence of comorbidities using scoring systems such as the Acute Physiology and Chronic Health Evaluation (APACHE) II, Simplified Acute Physiology Score, or Surgical Apgar Score[13,14]. To date, patients' nutritional and functional parameters have not been routinely evaluated or considered in the decision-making process[15].

Sarcopenia refers to the loss of skeletal muscle mass and strength associated with wasting and aging[16]. Cancer patients are vulnerable to sarcopenia, as malnutrition, cancer-mediated inflammation, and inactivity may lead to loss of muscle mass and strength[17,18]. Identifying preoperative sarcopenia using computed tomography (CT) analysis is widely accepted because of its practicality[19]. Cross-sectional views of the trunk provide an objective method for estimating body composition, such as muscle mass and intramuscular proportions of adipose tissue in Hounsfield units (HU), and it has many clinical implications in cancer patients[20,21]. Generally, abnormalities in these indices are associated with poor postoperative outcomes. Sarcopenia is reported as an independent risk factor for poor overall survival and disease-free survival[22,23] A negative effect of sarcopenia on short-term outcomes in hepatic resection has been reported[24].

To date, only few studies have investigated the impact of sarcopenia on predicting ICU admission and length of ICU stay (LOS-I) for patients with Klatskin tumours who underwent hepatic resection. We retrospectively analysed the relationship between preoperative sarcopenia and postoperative ICU admission and LOS-I in patients who underwent hepatic resection for Klatskin tumours. We also investigated whether other factors, including body composition and nutritional status, had an impact on postoperative ICU admission and LOS-I. We hypothesised that preoperative sarcopenia is related to poor surgical outcomes, including increased ICU requirements.

II. PATIENTS AND METHODS

1. Study Design

The electronic medical records of patients who underwent elective hepatic resection for Klatskin tumours at Severance Hospital in Seoul, Korea, between November 2005 and June 2022 were retrospectively reviewed. This study was approved by the Internal Review Board of Severance Hospital (approval number: 2022-0870-001). The need for informed consent was waived owing to the retrospective nature of the study. The study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki.

2. Patient characteristics

Patients received the appropriate preoperative treatment, such as endoscopic biliary stenting, percutaneous transhepatic biliary drainage (PTBD), chemotherapy (CTx), and portal vein embolisation (PVE), to augment remnant liver volume if indicated. Hepatic resection included segmental resection, left or right lobectomy, and extended hepatectomy. We collected data including patients' demographics, preoperative clinical characteristics [Body mass index (BMI), CTx, PVE, American Society of Anesthesiologists physical status, Charlson comorbidity index[25]], preoperative laboratory test results [prothrombin time and haemoglobin, albumin, total bilirubin, creatine, aspartate transaminase, alanine transaminase, carbohydrate antigen (CA) 19-9 levels], pathologic data [tumour size, tumour-node-metastasis stage according to the American Joint Committee on Cancer staging manual (8^{th} ed[26]), and bismuth type], and surgical results [negative resection margin (R0 resection), operation time, and intraoperative bleeding amount or packed red blood cell (RBC) transfusion]. We collected data on surgical and oncological outcomes, including postoperative morbidity, mortality, ICU admission, length of hospital stay (LOS-H) and LOS-I, overall survival, and recurrence. Patients who were not directly admitted to the ICU from the operation room but underwent delayed admission or re-admission within 7 days from the surgery date because of an emergent reason, such as complications or re-operation requiring ICU care, were also included. Therefore, the LOS-I was the sum of the total length of ICU stay if admitted within 7 days after surgery. The grade of postoperative morbidity was assigned according to the Clavien–Dindo classification (CDC) within 90 days of surgery or until the discharge date, and severe complications were defined as complications with a CDC ≥ 3[27]. Postoperative mortality was recorded during the same period. To evaluate the preoperative nutritional status of cancer patients, the prognostic nutritional index (PNI), suggested as a clinical predictor of prognosis, was calculated using collected laboratory data[28]. PNI was defined as $10 \times$ serum albumin value (g/dL) + $0.005 \times$ lymphocyte count (/mm^3), with a cut-off value for low PNI of less than 1.39 indicating nutritional impairment. Cancer recurrence and survival were determined from the time of surgery to the time of event or the most recent follow-up date.

3. Radiologic body composition evaluation

Preoperative sarcopenia was evaluated according to the obtained preoperative abdominal and pelvic CT images within 90 days before surgery which were routinely obtained to diagnose and plan treatment. The cross-sectional surface (cm^2) of both psoas muscle areas (PMA) was automatically quantified at the third lumbar (L3) vertebra level using the Aquarius iNtuition Viewer (ver. 4.4.13, TeraRecon Inc., San Mateo, CA, USA) imaging server platform[29]. Using this software, each surface can be automatically quantified using a particular CT attenuation range. Non-contrast-enhanced CT images were used to measure the radiation attenuation density (HU) of the muscle and adipose tissue. Using these values, muscle steatosis was evaluated using intramuscular adipose tissue content (IMAC) by dividing the CT attenuation value of the multifidus muscle (HU) by that of the subcutaneous fat HU[30]. A higher IMAC indicates that skeletal muscles contain a greater amount of adipose tissue and may result in poor prognosis in several cancers[31-33]. Cut-off values for high IMAC (-0.358 for men and -0.229 for women) were defined in a previous study including healthy donors for liver transplantation[34].

The measured PMA was then normalised by patient height squared (cm^2/m^2), which was termed the psoas muscle mass index (PMI). Optimal cut-off points for PMI data in the maximal predictive value for postoperative ICU admission were determined using receiver operating characteristic (ROC) curve analysis. Sarcopenia was determined when the patients' PMI was lower than the sex-specific cut-off. The study population was categorised into two groups: sarcopenia and non-sarcopenia patients, and postoperative short- or long-term outcomes were compared.

4. Statistical analysis

Categorical variables are expressed as frequencies and percentages. Continuous variables are summarised as means with standard deviations (SDs) or medians with interquartile ranges (IQRs). Categorical variables were analysed using the $\chi 2$ or Fisher's exact test, and continuous variables were compared using the independent t-test or Mann–Whitney U test. Spearman's correlation tests were used to assess the relationships between risk factors and continuous outcomes. We set cut-off value for each of abnormal laboratory data, based on our hospital's current criteria. Multivariate analysis was performed to investigate statistically significant risk factors affecting ICU admission (logistic regression) and LOS-I (multivariate linear regression) using variables with p-values < 0.05. Age, sex, and BMI were routinely included in the multivariate analysis to adjust for the variables. Survival estimates were obtained using the Kaplan–Meier survival method, and differences in overall survival (OS) and recurrence-free survival (RFS) between the groups were determined using the log-rank test. All results with p-values < 0.05 were statistically significant. All statistical analyses were performed using IBM SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, NY, USA).

III. RESULTS

1. Study population

A total of 330 patients with pathologically confirmed Klatskin tumours who underwent curative hepatic resection were identified during the study period. Among them, 13 patients were excluded because they underwent hepatic wedge resection (n = 2) or cooperation with other organs (n = 11). Ultimately, 317 patients were included in the analysis. The T stage was unmeasured in three patients owing to post-CTx changes in pathological specimens. The mean age of the study population was 65.6 ± 9.0 years, and 202 men (63.7%) and 115 women (36.3%) were included. The PMI (men: 6.91 vs. women: 3.78 cm^2/m^2, $p < 0.001$) and IMAC (men: -0.44 vs. women: -0.32, $p < 0.001$) showed significant differences between sexes. Among them, 196 patients (61.8%) were provided ICU care within seven postoperative days, and most of them (n = 193/196, 98.4%) were directly transported from the operating theatre to the ICU. During the same period, 11 patients (3.5%) were readmitted to the ICU after being discharged from the ICU to the general ward. Severe complications (CDC ≥ 3) were observed in 125 (39.4%) patients within 90 days of surgery, and 22 patients (6.9%) died owing to postoperative mortality. Table 1 summarises patient characteristics and postoperative outcomes of the study population.

Table 1. Demographic and clinical characteristics of patients with Klatskin tumours who underwent hepatic resection

	All patients (n = 317)	**Male (n = 202)**	**Female (n = 115)**	***p*-value**
Preoperative				
Age (years)	65.6 ± 9.0	65.4 ± 9.0	65.9 ± 8.9	0.652
Body mass index (kg/m²)	23.42 ± 2.69	23.29 ± 2.43	23.62 ± 3.09	0.287
Psoas muscle index (cm²/m²)†	5.78 ± 2.13	6.91 ± 1.72	3.78 ± 1.04	<0.001*
Sarcopenia†	150 (47.3%)	106 (52.5%)	44 (38.3%)	0.015*
Intramuscular adipose tissue content	n = 287 -0.40 ± 0.11	n = 184 -0.44 ± 0.10	n = 103 -0.32 ± 0.09	<0.001*
Prognostic nutritional index	44.86 ± 6.84	44.93 ± 6.81	44.73 ± 6.91	0.798
Postoperative				
Intensive care unit-admission	196 (61.8%)	127 (62.9%)	69 (60.0%)	0.613
Intensive care unit-re-admission‡	11 (3.5%)	7 (3.5%)	4 (3.5%)	1.000
Intensive care unit-delayed admission‡	3 (0.9%)	2 (1.0%)	1 (0.9%)	1.000
Length of stay-intensive care unit (day)	1.6 ± 3.4	1.6 ± 2.9	1.7 ± 4.1	0.886§
Postoperative length of stay- in hospital (day)	24.5 ± 20.2	22.8 ± 14.2	27.4 ± 27.5	0.094§
Clavien-Dindo classification ≥ 3	125 (39.4%)	78 (38.6%)	47 (40.9%)	0.693
In-hospital mortality	22 (6.9%)	16 (7.9%)	5 (4.3%)	0.492

Values are expressed as means ± standard deviations or absolute numbers (percentages). PMI and intramuscular adipose tissue content showed significant differences between the sexes. Sarcopenia which was diagnosed based on sex-specific PMI cut-offs was frequent in men. There was no difference in postoperative short-term outcomes between the two groups.

† The cross-sectional surface (cm^2) of both psoas muscles area was automatically quantified at the third lumbar vertebra level using preoperative abdomen and pelvis computed tomography images. The measured area was then normalized by patients' height squared (cm^2/m^2), which was termed PMI. Sarcopenia was determined when patients' PMI was lower than the sex-specific cut-off values at 6.74 cm^2/m^2 for men and 3.39 cm^2/m^2 for women per receiver operating characteristic curve analysis.

‡ Patients who were not directly admitted to ICU from the operating room, but rather, underwent delayed admission or re-admission to ICU within 7 days from the surgery date.

* $p < 0.05$ in comparison between sexes.

§ Compared by the Mann–Whitney U test.

Abbreviations: ICU, Intensive Care Unit; PMI, Psoas muscle index

2. Association between sarcopenia and postoperative short-term outcomes

The mean ± SD for PMI in men was 6.91 ± 1.72 cm^2/m^2, whereas that in women was 3.78 ± 1.04 cm^2/m^2 ($p < 0.001$). Sex-specific PMI cut-off values for sarcopenia were determined at 6.74 cm^2/m^2 for men [sensitivity = 65.4%, specificity = 69.3%, area under the curve (AUC) = 0.700] and 3.39 cm^2/m^2 for women (sensitivity = 47.8%, specificity = 76.1%, AUC = 0.609) by ROC curve analysis. Using these cut-offs, preoperative sarcopenia was observed in 106 men (52.5%) and 44 women (38.3%). The sarcopenia group had a significant lower BMI (23.0 vs. 23.8 kg/m^2, p = 0.004) and higher preoperative CTx incidence (12.7% vs. 4.8%, p = 0.015) than the non-sarcopenia group. Patients with sarcopenia underwent longer surgeries (550.7 vs. 506.7 min, p = 0.023) with more intraoperative bleeding (1,375 vs. 976 ml, p = 0.006), packed RBC transfusion events (44.7% vs. 28.1%, p = 0.002), and transfusion volumes (427 vs. 210 ml, $p < 0.001$) than those without sarcopenia.

Patients with preoperative sarcopenia presented with significantly more frequent ICU admissions within 1 week after surgery (77.3% vs. 47.9%, $p < 0.001$) and longer total LOS-

I (2.45 vs. 0.89 days, $p < 0.001$) than patients without sarcopenia. Furthermore, the sarcopenia group showed significantly higher postoperative LOS-H (27.8 vs. 21.4 days, $p = 0.006$), severe complication rates (48.0% vs. 31.7%, $p = 0.003$), and in-hospital mortality (11.3% vs. 3.0%, $p = 0.004$) within postoperative 90 days than the non-sarcopenia group. Postoperative re-admission or delayed admission in ICU showed no difference between the two groups. Detailed comparisons of baseline characteristics and short-term outcomes between the sarcopenia and non-sarcopenia groups are presented in Table 2.

Table 2. Association between preoperative sarcopenia and perioperative variables

	Sarcopenia (n =150)	**Non sarcopenia (n = 167)**	***p*-value**
Preoperative			
Male	106 (70.7%)	96 (57.5%)	0.015*
Age (year)	66.5 ± 8.2	64.7 ± 9.5	0.080
Body mass index (kg/m^2)	22.96 ± 2.75	23.83 ± 2.58	0.004*
American Society of Anesthesiologists score	2.4 ± 0.6	2.3 ± 0.6	0.185
Charlson comorbidity index	2.6 ± 1.3	2.5 ± 1.0	0.499
Psoas muscle index†	4.76 ± 1.48	6.69 ± 2.22	<0.001*
Intramuscular adipose tissue content	-0.39 ± 0.10	-0.41 ± 0.12	0.161
Chemotherapy	19 (12.7%)	8 (4.8%)	0.015*
Portal vein embolization	43 (28.7%)	53 (31.7%)	0.553
Laboratory finding			
Haemoglobin (g/dL)	11.8 ± 1.4	12.2 ± 1.6	0.020*
Platelet count (10^3/uL)	293.4 ± 101.7	301.8 ± 107.5	0.481
Prothrombin time (International normalized ratio)	1.04 ± 0.16	1.03 ± 0.11	0.421
Creatine (mg/dL)	0.80 ± 0.35	0.76 ± 0.22	0.343
Albumin (g/dL)	3.5 ± 0.4	3.7 ± 0.5	0.001*
Alanine aminotransferase (IU/L)	41.3 ± 24.6	48.6 ± 44.3	0.077
Aspartate aminotransferase (IU/L)	34.9 ± 27.9	45.1 ± 44.4	0.053
Total bilirubin (mg/dL)	1.54 ± 1.23	1.65 ± 1.98	0.552
Carbohydrate antigen 19-9 (U/mL)	918.7 ± 3118.2	566.9 ± 1743.6	0.739§
Prognostic nutritional index	44.09 ± 6.43	45.55 ± 7.14	0.058
Bismuth type			0.471
1	5 (3.3%)	5 (3.0%)	

2	14 (9.3%)	26 (15.6%)	
3a	64 (42.7%)	72 (43.1%)	
3b	24 (16.0%)	20 (12.0%)	
4	43 (28.7%)	44 (26.3%)	
Intraoperative			
Operation type			0.188
Liver lobectomy	119	118	
Extended hepatectomy	22	37	
Central lobectomy or segment resection	9	12	
Tumour stage (n = 314)	n = 148	n = 166	0.281
T1	17 (11.5%)	14 (8.4%)	
T2	97 (65.5%)	125 (75.3%)	
T3	26 (17.6%)	22 (13.3%)	
T4	8 (5.4%)	5 (3.0%)	
Lymph node metastasis	51 (34.0%)	57 (34.1%)	0.637
Resection margin negative	116 (77.3%)	118 (70.7%)	0.286
Mass size (cm)	2.8 ± 1.4	2.9 ± 1.3	0.576
Operation time (min)	550.7 ± 172.7	506.7 ± 169.7	0.023*
Estimated Blood loss (cc)	1375 ± 1423	976 ± 1119	0.002*§
Packed RBC transfusion	67 (44.7%)	47 (28.1%)	0.002*
Transfusion amount (cc)	427 ± 838	210 ± 577	<0.001§
Postoperative			
Intensive care unit admission	116 (77.3%)	80 (47.9%)	<0.001*
Intensive care unit re-admission‡	8 (5.3%)	3 (1.8%)	0.124
Intensive care unit delay-admission‡	2 (1.3%)	1 (0.6%)	0.605
Length of stay-intensive care unit (days)	2.5 ± 4.5	0.9 ± 1.4	<0.001*§
Length of stay-hospital (days)	27.8 ± 25.4	21.4 ± 13.1	0.006*§
Clavien-Dindo classification ≥ 3	72 (48.0%)	53 (31.7%)	0.003*
In-hospital mortality	17 (11.3%)	5 (3.0%)	0.004*

Sarcopenia group showed significantly lower BMI and serum haemoglobin and albumin levels and a higher preoperative chemotherapy frequency. During surgery, sarcopenia group had longer operation time with more intraoperative bleeding, packed RBC transfusion events, and transfusion amounts. The sarcopenia group was admitted ICU more frequently within 1 week after surgery and stayed longer in ICU and hospital than the non-sarcopenia group. The Clavien-Dindo Classification of Surgical Classifications was used throughout surgery for grading adverse events. The sarcopenia group showed a significant higher severe complication rate and in-hospital mortality within postoperative 90 days.

† The cross-sectional surface (cm^2) of both psoas muscles area was automatically quantified at the third lumbar vertebra level using Aquarius iNtuition Viewer software. The measured area was then normalized by patients' height squared (cm^2/m^2)

‡ Patients who were not directly admitted to ICU from the operation room, but rather, underwent delayed admission or re-admission to ICU within 7 days from the surgery date.

* $p < 0.05$ in comparison with the non-sarcopenia group.

§ Compared by the Mann–Whitney U test.

Abbreviations: BMI, body mass index; ICU, intensive care unit; RBC, red blood cell

Multivariate analysis showed that sarcopenia was significantly associated with postoperative ICU admission [adjusted odds ratio (OR): 2.461, 95% confidence interval (CI): 1.289 – 4.697, p = 0.006] and prolonged LOS-I (B: 0.957, 95% CI: 0.252 – 1.663, p = 0.008). Other factors associated with postoperative ICU admission in the multivariate analysis were serum CA 19-9 levels, operation time, and intraoperative packed RBC transfusion events. Alternatively, BMI, Charlson comorbidity index, T stage 3 or 4, operation time, and intraoperative packed RBC transfusion events were significantly associated with LOS-I in multivariate linear regression (Tables 3 and 4).

Table 3. Multivariate logistic regression analysis for risk factors of postoperative ICU admission

Variable	**OR**	**95% CI**		***p*-value**
		Lower limit	*Upper limit*	
Male	1.109	0.554	2.222	0.770
Age (years)	0.998	0.961	1.037	0.919
Body mass index (kg/m²)	0.964	0.841	1.106	0.604
Sarcopenia	2.461	1.289	4.697	0.006*
Intramuscular adipose tissue content > -0.358 (men), > -0.229 (women)	2.259	0.743	6.873	0.151
Prognostic nutritional index < 40	0.865	0.220	3.394	0.835
American Society of Anesthesiologists score	1.731	0.815	3.675	0.153
Charlson comorbidity index	0.885	0.583	1.342	0.565
Pre-operative chemotherapy	2.214	0.582	8.428	0.244
Haemoglobin < 13.0 (men, g/dL) < 11.4 (women)	1.377	0.703	2.694	0.351
Prothrombin time (international normalized ratio) > 1.12	2.320	0.944	5.700	0.066
Preoperative albumin < 3.3 (g/dL)	2.014	0.481	8.438	0.338
Carbohydrate antigen (CA) 19-9 (U/mL)	1.000	1.000	1.001	0.028*
T stage 3 or 4	1.599	0.637	4.009	0.317
Bismuth type 2	0.682	0.286	1.625	0.388

Packed RBC Transfusion	4.027	1.813	8.945	0.001*
Operation time (min)	1.006	1.003	1.008	0.000*

Twelve perioperative variables showed association with postoperative ICU admission in univariate analysis ($p < 0.05$). In multivariate analysis, sarcopenia, serum CA 19-9 level, operation time, and intraoperative packed RBC transfusion were significantly associated with postoperative ICU admission.
* $p < 0.05$ in comparison with the non-sarcopenia group.
Abbreviations: CI, confidence interval; ICU, intensive care unit; OR, odds radio; RBC, red blood cell

Table 4. Multivariate linear regression analysis for risk factors of postoperative length of ICU stay (days)

Variable	**B**	**95% CI (B)**		**ß**	***p*-value**
		Lower limit	*Upper limit*		
Male	-0.353	-1.062	0.356	-0.050	0.328
Age (years)	0.002	-0.038	0.041	0.004	0.939
Body mass index (kg/m²)	-0.143	-0.277	-0.009	-0.114	0.036*
Sarcopenia	0.957	0.252	1.663	0.142	0.008*
Charlson comorbidity index	0.409	0.084	0.734	0.139	0.014*
Pre-operative chemotherapy	0.946	-0.319	2.210	0.078	0.142
Platelet count < 150 (10³/ uL)	1.643	-0.137	3.423	0.093	0.070
Prothrombin time > 1.12 (international normalized ratio)	0.662	-0.259	1.583	0.072	0.158
Total bilirubin (mg/dL)	0.194	-0.012	0.400	0.096	0.065
T stage 3 or 4	1.507	0.624	2.391	0.176	0.001*
Packed RBC Transfusion	0.953	0.132	1.774	0.136	0.023*
Operation time (min)	0.004	0.001	0.006	0.186	0.001*

Nine variables including sarcopenia showed an association with postoperative length of ICU stay per univariate analysis ($p < 0.05$). Per multivariate analysis, sarcopenia, T stage 3 or 4, operation time, and intraoperative packed RBC transfusion were significantly associated with postoperative total length of ICU stay.
* $p < 0.05$ in compared with the non-sarcopenia group.
Abbreviations: CI, confidence interval; ICU, intensive care unit; RBC, red blood cell

3. Impact of the nutritional status and body composition on short-term outcomes

Non- contrast-enhanced CT images were available for 285 patients, and a high IMAC was observed in 12.0% (n = 38/285) of the patients. A strong linear correlation was noted between PMI and IMAC (correlation coefficient; -0.414, $p < 0.001$), and a high IMAC was more frequent in sarcopenia patients (17.4% vs. 9.4%, $p = 0.046$) than in patients without sarcopenia. Preoperative nutritional assessment via laboratory data revealed that patients with sarcopenia had lower serum haemoglobin and albumin levels than patients without sarcopenia. A low PNI was noted in 74 (23.3%) patients and was significantly more frequent in the sarcopenia group (28.7% vs. 18.6%, $p = 0.034$) than in the non-sarcopenia group. A high IMAC (81.6% vs 58.6%, $p = 0.007$) and low PNI (73.0% vs 58.4%, p = 0. 024) were significantly associated with an increased postoperative ICU admission rate.

4. Survival analysis

In total, the median follow-up duration among the living patients was 44.3 months, and 181 (57.1%) patients experienced recurrence during the study period. The 1-, 3-, and 5-year OS rates of the patients were 84%, 57%, and 44%, respectively, while RFS rates were 74%, 39%, and 25%, respectively (Table 5). The median RFS was 27.8 months in patients with sarcopenia and 20.3 months in patients without sarcopenia, but the difference was not statistically significant ($p = 0.609$). However, sarcopenia patients showed a trend towards a lower OS than non-sarcopenia patients, with borderline significance (median 38.7 vs 57.3 months, $p = 0.075$). In the subgroup analysis, male patients with sarcopenia had significantly lower OS than those without sarcopenia (median 31.8 vs 57.2 months, p = 0.024, Figure 1). Further analysis of patients' IMAC and PNI did not yield significant impacts on RFS and OS, except that patients with a low PNI were associated with lower OS (median 29.7 vs 57.2 months, $p = 0.006$, Figure 2) than patients with a normal PNI.

Table 5. Comparison of overall survival and recurrence-free survival in patients with and without sarcopenia

	Total (n)	Mortality (n)	1-year OS (%)	3-year OS (%)	5-year OS (%)	10-year OS (%)
Sarcopenia	150	74	80.7	50.7	39.5	34.5
Non-sarcopenia	167	59	87.5	62.7	49.3	22.1
Total	317	133	84.0	56.5	44.1	26.4
	Total (n)	**Recurred (n)**	**1-year RFS (%)**	**3-year RFS (%)**	**5-year RFS (%)**	**10-year RFS (%)**
Sarcopenia	150	85	72.7	40.3	23.1	15.3
Non-sarcopenia	167	96	71.1	34.9	26.0	10.2
Total	317	181	73.7	38.5	25.2	13.0

The median follow-up duration among lived patients was 44.3 months during the study period.
Abbreviations: OS, overall survival; RFS, recurrence-free survival

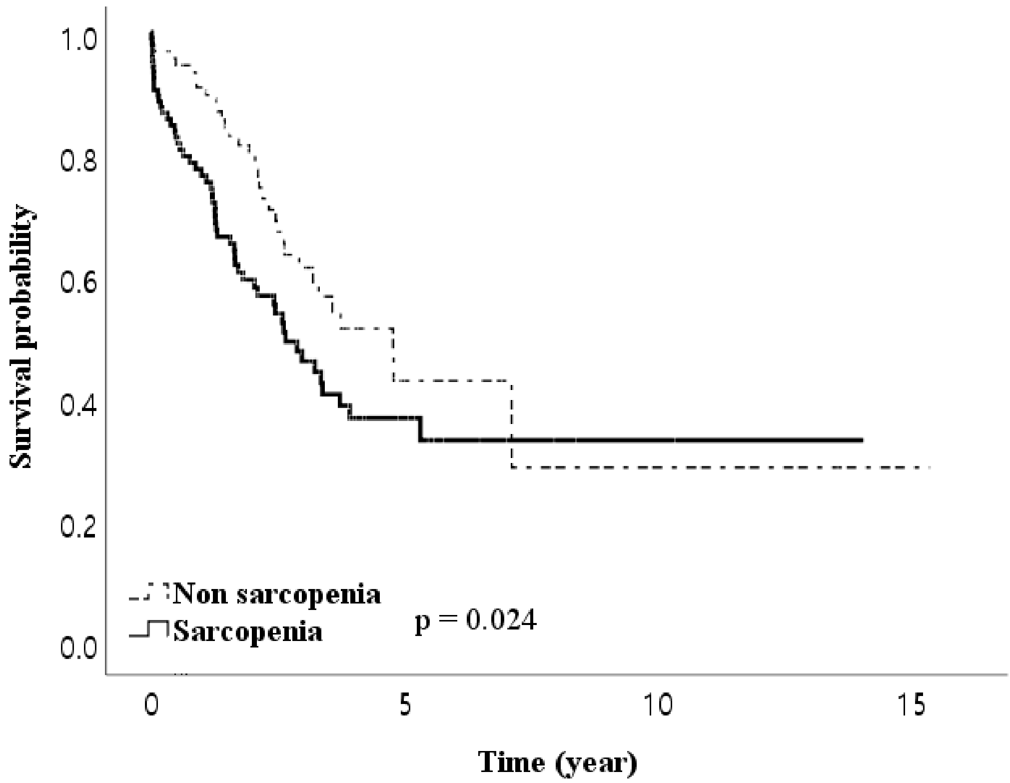

Figure 1. Kaplan–Meier curves for overall survival after hepatic resection of Klatskin tumours for male patients stratified by presence of preoperative sarcopenia. Overall survival for male patients with sarcopenia following surgery of Klatskin tumours was shorter than for those without sarcopenia

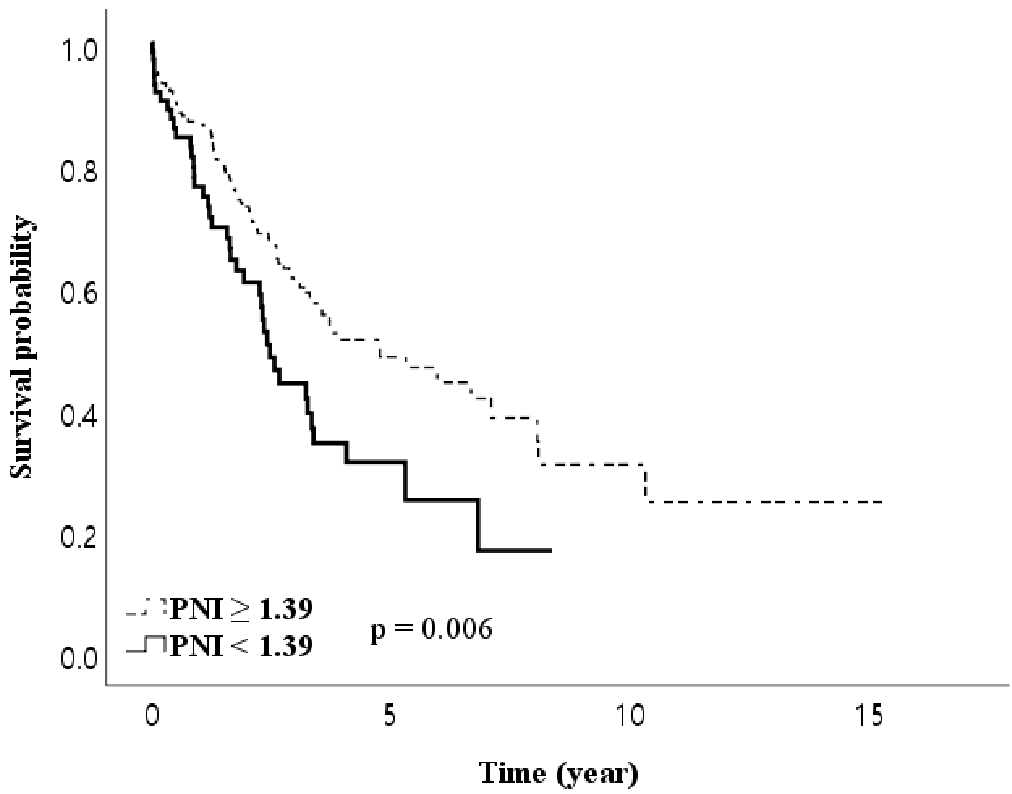

Figure 2. Kaplan–Meier curves for overall survival after hepatic resection of Klatskin tumours stratified by prognostic nutritional index (PNI). Preoperative PNI lower than 1.39 was associated with a shorter overall survival for patients with Klatskin tumours following surgery.

IV. DISCUSSION

We aimed to investigate the clinical impact of sarcopenia on the surgical outcomes of patients who underwent hepatectomy for Klatskin tumours. The results showed that preoperative sarcopenia increased the ICU admission rate and prolonged ICU stay after hepatic resection in patients with Klatskin tumours. Additionally, sarcopenia patients showed significantly higher postoperative severe morbidity and mortality than non-sarcopenia patients. Our study implies that sarcopenia patients present a higher necessity of being admitted to the ICU postoperatively and should be given priority among high-risk patients who underwent major surgeries.

Sarcopenia, a physiological syndrome characterised by a combination of low muscle mass and low muscle function, has been proposed as a factor that increases perioperative risk for adverse clinical outcomes[35]. In particular, frequent obstructive jaundice in patients with Klatskin tumours makes them vulnerable to poor oral intake and decreased activity, which consequently induce sarcopenia[36,37]. In addition, sarcopenia patients underwent preoperative CTx more frequently in this study, which can aggravate sarcopenia through toxicity and malnutrition[38]. Together, high expression of inflammatory cytokines in low skeletal muscle mass and cancer cachexia may induce a pro-inflammatory state and increase the complication risk[39]. Among many previous definitions, the cut-offs for diagnosing sarcopenia for Klatskin tumour differed depending on the studies (range of PMI cut-off for men: 4.77 – 8.60 cm^2/m^2 and for women: 3.38 – 6.04 cm^2/m^2)[40]. These were usually determined by the lowest tertile, lower than the median PMI from the population, or by ROC curve analysis of mortality. We used the normalised PMA which is widely used to diagnose sarcopenia, and the cut-off value was determined by ROC curve analysis by taking the rate of ICU admission as an indicator for predictive validity to determine the optimal cut-off value for each sex (6.74 cm^2/m^2 for men and 3.39 cm^2/m^2 for women). Sarcopenia was present in 47.4% of our population, which is consistent with previous reports stating that sarcopenia was common among patients with Klatskin tumours, occurring in more than 30% of patients[29].

In addition, we analysed other parameters, such as body composition and nutritional status. Sarcopenia patients had a lower BMI and showed decreased serum haemoglobin and albumin levels which correlated with the results of a previous study[41]. Although BMI was negatively correlated with LOS-I per multivariate analysis without multicollinearity in this study, this should be interpreted carefully, as being underweight or obese could affect ICU patients differently[42,43]. On the other hand, BMI was not statistically related to postoperative ICU admission per multivariate logistic regression. Through image analysis, we observed that muscle steatosis determined by a high IMAC was associated with postoperative ICU admission following hepatic resection of Klatskin tumours. This also corresponds with our earlier observations which showed that a poor preoperative nutritional status of patients based on the calculated low PNI increased ICU requirements. Furthermore, a high IMAC and low PNI were more frequent among patients with sarcopenia than among those without sarcopenia, which indicates their poor nutritional status and low muscle density. It can be interpreted that muscle steatosis is generally correlated with overall muscle quality and strength[44]. This result suggests that preoperative sarcopenia is strongly related to muscle steatosis and poor nutritional status with weight loss, indicating increasing requirements for postoperative ICU care. Prior studies have shown the importance of perioperative nutritional support which can accelerate protein synthesis and regeneration to improve patients' outcomes[45,46]. Kamiya et al. (2004) reported that drained bile juice replacement for patients with biliary obstructive cholangiocarcinoma after PTBD is beneficial for intestinal barrier function[47]. In addition, Kaido et al. (2013) assumed that branched-chain amino acids are mainly consumed in skeletal muscle metabolism in cirrhosis patients, and they reported that perioperative nutritional support with a nutrient mixture enriched with branched-chain amino acids significantly increased the OS after living donor liver transplantation in patients with sarcopenia[48].

Our findings also support those of previous studies, as we showed that sarcopenia was associated with increased operation time, intraoperative blood loss, packed RBC transfusion, and poor overall short-term prognosis[29,49]. With lower preoperative serum haemoglobin levels in our results, sarcopenia could increase transfusion requirement owing to patients' relatively smaller blood volume reserve, as they have reduced skeletal muscle and capillary density[50,51]. Moreover, sarcopenia showed poor OS which was consistent with findings of previous studies, while we did not observe any relevance to RFS[40]. It can be interpreted that our cut-off was based on the ROC curve analysis of ICU admission. However, intraoperative transfusion and longer operation time were significantly related to both postoperative ICU admission and LOS-I in multivariate analysis. Poor nutritional status and intraoperative packed RBC transfusion are also associated with poor OS in cholangiocarcinoma[52,53]. In addition, prolonged operation time is a known risk factor for postoperative complications, which can help to interpret our results[54].

To the best of our knowledge, the current study is the first to analyse the impact of preoperative sarcopenia on postoperative ICU care frequency and duration. Postoperative ICU care is beneficial for the management and early detection of severe complications. However, unnecessary postoperative ICU admission only for surveillance is not appropriate considering low cost-effectiveness and increased ICU-related complications, such as infection or delirium[55,56]. These issues have been considered during the COVID-19 pandemic which induced a shortage of critical care beds and staff[57]. Likewise, unpredicted, prolonged ICU stays can negatively affect ICU bed resources and may alter other operational schedules[58]. Therefore, filling surgical requests for ICU preparation should consider objective triage to maximise patient outcomes and medical resources[59]. Although some scoring systems have been developed to aid the preoperative determination of surgical candidates for ICU care, they are insufficient to provide adequate information regarding the risk for an individual patient[13,60]. We suggest that physicians diagnose sarcopenia using preoperative CT images and use it as a parameter in predicting postoperative ICU requirements for patients with Klatskin tumours.

The current study has some limitations. 1) Our data were collected from a single institution, and the study population was limited to East Asians (Koreans). Furthermore, we could not measure other functional parameters of sarcopenia, such as handgrip strength, walking speed, and low physical activity, owing to the retrospective nature of the study. 2) Chronological improvements in surgical techniques and diversity of surgeons were not considered during the long-term study period. 3) Possible differences as a consequence of using different CT scanners and scanning protocols in various periods or hospitals could not be precluded. In the future, multicentre, large, prospective studies may be required to verify this result. Together, skeletal muscle mass and function should be evaluated to diagnose sarcopenia. Further randomised controlled trials should be conducted to investigate whether improving muscle mass and quality before surgery through rehabilitation or nutritional support has the potential to reduce postoperative ICU admission and length of stay[48,61].

V. CONCLUSION

This study showed that sarcopenia was correlated with poor postoperative outcomes, especially with the increased requirement of postoperative ICU admission and prolonged LOS-I after hepatic resection for patients with Klatskin tumours. The evaluation of preoperative sarcopenia could help predict the postoperative outcomes of such patients.

REFERENCES

1. Nakeeb A, Pitt HA, Sohn TA, Coleman J, Abrams RA, Piantadosi S, et al. Cholangiocarcinoma. A spectrum of intrahepatic, perihilar, and distal tumors. Ann Surg 1996;224:463-73; discussion 73-5.
2. Capobianco I, Rolinger J, Nadalin S. Resection for Klatskin tumors: technical complexities and results. Transl Gastroenterol Hepatol 2018;3:69.
3. Jo JH, Chung MJ, Han DH, Park JY, Bang S, Park SW, et al. Best options for preoperative biliary drainage in patients with Klatskin tumors. Surg Endosc 2017;31:422-9.
4. Jarnagin W, Winston C. Hilar cholangiocarcinoma: diagnosis and staging. HPB (Oxford) 2005;7:244-51.
5. Jarnagin WR, Fong Y, DeMatteo RP, Gonen M, Burke EC, Bodniewicz BJ, et al. Staging, resectability, and outcome in 225 patients with hilar cholangiocarcinoma. Ann Surg 2001;234:507-17; discussion 17-9.
6. Nimura Y, Kamiya J, Nagino M, Kanai M, Uesaka K, Kondo S, et al. Aggressive surgical treatment of hilar cholangiocarcinoma. J Hepatobiliary Pancreat Surg 1998;5:52-61.
7. Mizuno T, Ebata T, Nagino M. Advanced hilar cholangiocarcinoma: An aggressive surgical approach for the treatment of advanced hilar cholangiocarcinoma: Perioperative management, extended procedures, and multidisciplinary approaches. Surg Oncol 2020;33:201-6.
8. Lee SH, Choi GH, Han DH, Kim KS, Choi JS, Rho SY. Chronological analysis of surgical and oncological outcomes after the treatment of perihilar cholangiocarcinoma. Ann Hepatobiliary Pancreat Surg 2021;25:62-70.
9. Pearse RM, Holt PJ, Grocott MP. Managing perioperative risk in patients undergoing elective non-cardiac surgery. Bmj 2011;343:d5759.
10. Fahim M, Visser RA, Dijksman LM, Biesma DH, Noordzij PG, Smits AB. Routine postoperative intensive care unit admission after colorectal cancer surgery for the elderly patient reduces postoperative morbidity and mortality. Colorectal Dis 2020;22:408-15.
11. Merath K, Cerullo M, Farooq A, Canner JK, He J, Tsilimigras DI, et al. Routine Intensive Care Unit Admission Following Liver Resection: What Is the Value Proposition? J Gastrointest Surg 2020;24:2491-9.
12. Thevathasan T, Copeland CC, Long DR, Patrocínio MD, Friedrich S, Grabitz SD, et al. The Impact of Postoperative Intensive Care Unit Admission on Postoperative Hospital Length of Stay and Costs: A Prespecified Propensity-Matched Cohort Study. Anesth Analg 2019;129:753-61.
13. Lin YC, Chen YC, Yang CH, Su NY. Surgical Apgar score is strongly associated with postoperative ICU admission. Sci Rep 2021;11:115.
14. Milić M, Goranović T, Holjevac JK. Correlation of APACHE II and SOFA scores

with length of stay in various surgical intensive care units. Coll Antropol 2009;33:831-5.
15. Giani M, Rezoagli E, Grassi A, Porta M, Riva L, Famularo S, et al. Low skeletal muscle index and myosteatosis as predictors of mortality in critically ill surgical patients. Nutrition 2022;101:111687.
16. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, et al. Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. Age Ageing 2010;39:412-23.
17. Wang A, He Z, Cong P, Qu Y, Hu T, Cai Y, et al. Controlling Nutritional Status (CONUT) Score as a New Indicator of Prognosis in Patients With Hilar Cholangiocarcinoma Is Superior to NLR and PNI: A Single-Center Retrospective Study. Front Oncol 2020;10:593452.
18. Fearon K, Strasser F, Anker SD, Bosaeus I, Bruera E, Fainsinger RL, et al. Definition and classification of cancer cachexia: an international consensus. Lancet Oncol 2011;12:489-95.
19. Gomez-Perez SL, Haus JM, Sheean P, Patel B, Mar W, Chaudhry V, et al. Measuring Abdominal Circumference and Skeletal Muscle From a Single Cross-Sectional Computed Tomography Image: A Step-by-Step Guide for Clinicians Using National Institutes of Health ImageJ. JPEN J Parenter Enteral Nutr 2016;40:308-18.
20. Martin L, Birdsell L, Macdonald N, Reiman T, Clandinin MT, McCargar LJ, et al. Cancer cachexia in the age of obesity: skeletal muscle depletion is a powerful prognostic factor, independent of body mass index. J Clin Oncol 2013;31:1539-47.
21. Shen W, Punyanitya M, Wang Z, Gallagher D, St-Onge MP, Albu J, et al. Total body skeletal muscle and adipose tissue volumes: estimation from a single abdominal cross-sectional image. J Appl Physiol (1985) 2004;97:2333-8.
22. Friedman J, Lussiez A, Sullivan J, Wang S, Englesbe M. Implications of sarcopenia in major surgery. Nutr Clin Pract 2015;30:175-9.
23. Jones K, Gordon-Weeks A, Coleman C, Silva M. Radiologically Determined Sarcopenia Predicts Morbidity and Mortality Following Abdominal Surgery: A Systematic Review and Meta-Analysis. World J Surg 2017;41:2266-79.
24. Perisetti A, Goyal H, Yendala R, Chandan S, Tharian B, Thandassery RB. Sarcopenia in hepatocellular carcinoma: Current knowledge and future directions. World J Gastroenterol 2022;28:432-48.
25. Charlson ME, Carrozzino D, Guidi J, Patierno C. Charlson Comorbidity Index: A Critical Review of Clinimetric Properties. Psychother Psychosom 2022;91:8-35.
26. Chun YS, Pawlik TM, Vauthey JN. 8th Edition of the AJCC Cancer Staging Manual: Pancreas and Hepatobiliary Cancers. Ann Surg Oncol 2018;25:845-7.
27. 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.

28. Akgül Ö, Bagante F, Olsen G, Cloyd JM, Weiss M, Merath K, et al. Preoperative prognostic nutritional index predicts survival of patients with intrahepatic cholangiocarcinoma after curative resection. J Surg Oncol 2018;118:422-30.
29. Chakedis J, Spolverato G, Beal EW, Woelfel I, Bagante F, Merath K, et al. Pre-operative Sarcopenia Identifies Patients at Risk for Poor Survival After Resection of Biliary Tract Cancers. J Gastrointest Surg 2018;22:1697-708.
30. Hamaguchi Y, Kaido T, Okumura S, Kobayashi A, Fujimoto Y, Ogawa K, et al. Muscle Steatosis is an Independent Predictor of Postoperative Complications in Patients with Hepatocellular Carcinoma. World J Surg 2016;40:1959-68.
31. Shiozawa T, Kikuchi Y, Wakabayashi T, Matsuo K, Takahashi Y, Tanaka K. Body composition as reflected by intramuscular adipose tissue content may influence short- and long-term outcome following 2-stage liver resection for colorectal liver metastases. Langenbecks Arch Surg 2020;405:757-66.
32. Okumura S, Kaido T, Hamaguchi Y, Kobayashi A, Shirai H, Fujimoto Y, et al. Impact of Skeletal Muscle Mass, Muscle Quality, and Visceral Adiposity on Outcomes Following Resection of Intrahepatic Cholangiocarcinoma. Ann Surg Oncol 2017;24:1037-45.
33. Hamaguchi Y, Kaido T, Okumura S, Kobayashi A, Shirai H, Yao S, et al. Preoperative Visceral Adiposity and Muscularity Predict Poor Outcomes after Hepatectomy for Hepatocellular Carcinoma. Liver Cancer 2019;8:92-109.
34. Hamaguchi Y, Kaido T, Okumura S, Kobayashi A, Shirai H, Yagi S, et al. Impact of Skeletal Muscle Mass Index, Intramuscular Adipose Tissue Content, and Visceral to Subcutaneous Adipose Tissue Area Ratio on Early Mortality of Living Donor Liver Transplantation. Transplantation 2017;101:565-74.
35. Reisinger KW, van Vugt JL, Tegels JJ, Snijders C, Hulsewé KW, Hoofwijk AG, et al. Functional compromise reflected by sarcopenia, frailty, and nutritional depletion predicts adverse postoperative outcome after colorectal cancer surgery. Ann Surg 2015;261:345-52.
36. Zhang JX, Ding Y, Yan HT, Zhou CG, Liu J, Liu S, et al. Skeletal-muscle index predicts survival after percutaneous transhepatic biliary drainage for obstructive jaundice due to perihilar cholangiocarcinoma. Surg Endosc 2021;35:6073-80.
37. Pavlidis ET, Pavlidis TE. Pathophysiological consequences of obstructive jaundice and perioperative management. Hepatobiliary Pancreat Dis Int 2018;17:17-21.
38. Bozzetti F. Chemotherapy-Induced Sarcopenia. Curr Treat Options Oncol 2020;21:7.
39. Scheede-Bergdahl C, Watt HL, Trutschnigg B, Kilgour RD, Haggarty A, Lucar E, et al. Is IL-6 the best pro-inflammatory biomarker of clinical outcomes of cancer cachexia? Clin Nutr 2012;31:85-8.
40. Shin SP, Koh DH. Clinical Impact of Sarcopenia on Cholangiocarcinoma. Life (Basel) 2022;12.
41. Picca A, Coelho-Junior HJ, Calvani R, Marzetti E, Vetrano DL. Biomarkers shared by frailty and sarcopenia in older adults: A systematic review and meta-analysis.

Ageing Res Rev 2022;73:101530.
42. Dennis DM, Bharat C, Paterson T. Prevalence of obesity and the effect on length of mechanical ventilation and length of stay in intensive care patients: A single site observational study. Aust Crit Care 2017;30:145-50.
43. Fujinaga J, Suzuki E, Irie H, Onodera M. Body Mass Index and Ventilator Dependence in Critically Ill Subjects in Japan: A Cohort Study Using a Nationwide Database. Respir Care 2021;66:1433-9.
44. Goodpaster BH, Carlson CL, Visser M, Kelley DE, Scherzinger A, Harris TB, et al. Attenuation of skeletal muscle and strength in the elderly: The Health ABC Study. J Appl Physiol (1985) 2001;90:2157-65.
45. Chaudhary RJ, Higuchi R, Nagino M, Unno M, Ohtsuka M, Endo I, et al. Survey of preoperative management protocol for perihilar cholangiocarcinoma at 10 Japanese high-volume centers with a combined experience of 2,778 cases. J Hepatobiliary Pancreat Sci 2019;26:490-502.
46. Oussoultzoglou E, Jaeck D. Patient preparation before surgery for cholangiocarcinoma. HPB (Oxford) 2008;10:150-3.
47. Kamiya S, Nagino M, Kanazawa H, Komatsu S, Mayumi T, Takagi K, et al. The value of bile replacement during external biliary drainage: an analysis of intestinal permeability, integrity, and microflora. Ann Surg 2004;239:510-7.
48. Kaido T, Ogawa K, Fujimoto Y, Ogura Y, Hata K, Ito T, et al. Impact of sarcopenia on survival in patients undergoing living donor liver transplantation. Am J Transplant 2013;13:1549-56.
49. Yang J, Chen K, Zheng C, Chen K, Lin J, Meng Q, et al. Impact of sarcopenia on outcomes of patients undergoing liver resection for hepatocellular carcinoma. J Cachexia Sarcopenia Muscle 2022.
50. Jones AJ, Campiti VJ, Alwani M, Novinger LJ, Tucker BJ, Bonetto A, et al. Sarcopenia is associated with blood transfusions in head and neck cancer free flap surgery. Laryngoscope Investig Otolaryngol 2021;6:200-10.
51. Prior SJ, Ryan AS, Blumenthal JB, Watson JM, Katzel LI, Goldberg AP. Sarcopenia Is Associated With Lower Skeletal Muscle Capillarization and Exercise Capacity in Older Adults. J Gerontol A Biol Sci Med Sci 2016;71:1096-101.
52. Wang Q, Du T, Lu C. Perioperative blood transfusion and the clinical outcomes of patients undergoing cholangiocarcinoma surgery: a systematic review and meta-analysis. Eur J Gastroenterol Hepatol 2016;28:1233-40.
53. Cui P, Pang Q, Wang Y, Qian Z, Hu X, Wang W, et al. Nutritional prognostic scores in patients with hilar cholangiocarcinoma treated by percutaneous transhepatic biliary stenting combined with 125I seed intracavitary irradiation: A retrospective observational study. Medicine (Baltimore) 2018;97:e11000.
54. Cheng H, Clymer JW, Po-Han Chen B, Sadeghirad B, Ferko NC, Cameron CG, et al. Prolonged operative duration is associated with complications: a systematic review and meta-analysis. J Surg Res 2018;229:134-44.
55. Gilio AE, Stape A, Pereira CR, Cardoso MF, Silva CV, Troster EJ. Risk factors for

nosocomial infections in a critically ill pediatric population: a 25-month prospective cohort study. Infect Control Hosp Epidemiol 2000;21:340-2.
56. Halpern NA, Goldman DA, Tan KS, Pastores SM. Trends in Critical Care Beds and Use Among Population Groups and Medicare and Medicaid Beneficiaries in the United States: 2000-2010. Crit Care Med 2016;44:1490-9.
57. Grasselli G, Pesenti A, Cecconi M. Critical Care Utilization for the COVID-19 Outbreak in Lombardy, Italy: Early Experience and Forecast During an Emergency Response. Jama 2020;323:1545-6.
58. Verburg IW, Atashi A, Eslami S, Holman R, Abu-Hanna A, de Jonge E, et al. Which Models Can I Use to Predict Adult ICU Length of Stay? A Systematic Review. Crit Care Med 2017;45:e222-e31.
59. Sobol JB, Wunsch H. Triage of high-risk surgical patients for intensive care. Crit Care 2011;15:217.
60. Lian C, Wang P, Fu Q, Du X, Wu J, Lian Q, et al. Modified paediatric preoperative risk prediction score to predict postoperative ICU admission in children: a retrospective cohort study. BMJ Open 2020;10:e036008.
61. Tsukagoshi M, Harimoto N, Araki K, Kubo N, Watanabe A, Igarashi T, et al. Impact of preoperative nutritional support and rehabilitation therapy in patients undergoing pancreaticoduodenectomy. Int J Clin Oncol 2021;26:1698-706.

ABSTRACT(IN KOREAN)

클라스킨 종양 환자의 수술 전 근감소증이 간 절제술 후 중환자실 입실 및 재실기간에 미치는 영향

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정 현 엄

클라스킨 종양 환자에 대한 간 절제술은 그 침습성으로 인해 수술 후 합병증 발생과 사망률이 높으므로 수술 후 집중적 감시 및 치료가 필요하다. 그러나 외과계 중환자실은 한정된 자원이므로 환자의 기저 상태 및 수술의 위험도에 따라 병상 배정을 하는 것이 효율적이다. 근감소증은 노화 과정에 동반되는 골격근의 양, 질, 근력의 점진적인 감소로 정의되고 있으며, 여러 연구에서 수술 후 합병증 및 사망률을 증가시키는 것으로 보고되었다. 우리 연구는 클라스킨 종양에 대해 근치적 간 절제술을 받는 환자의 수술 전 근감소증 여부가 중환자실 입실율 및 재실기간을 포함한 수술 후 예후에 유의미한 영향을 끼치는지 후향적으로 확인하였다. 연구 대상군의 수술 전 복부 전산화 단층촬영 영상을 통해 요추 3번 높이에서 허리근의 단면적을 측정하고 신장의 제곱으로 나누어 표준화하였고, 이 값을 수신자 작용 특성 곡선을 이용하여 성별에 따른 절단값을 정하여 근감소증을 정의하고 근감소증 군과 대조군에서 간 절제술 후 예후를 비교하였다. 330명의 환자 중 150명 (45.5%)이 근감소증으로 진단되었고 이들은 수술 후 더 높은 중환자실 입실율 (77.3% vs 47.9%, $p < 0.001$) 및 총 중환자실 재실 기간 (2.45 vs 0.89일, $p < 0.001$)을 보였다. 또한 근감소증 환자들에서 대조군보다 수술 후 병원 재원기간, 합병증 발병, 원내 사망률이 높게 나타났다. 클라스킨 종양 환자의 수술 전 근감소증은 수술 후 나쁜 예후 및 중환자실 이용 증가와 연관이 되어 있으므로 추후 임상에서의 의사결정에 도움을 줄 수 있을 것으로 기대한다.

핵심되는 말 : 간 절제술, 근감소증, 중환자실, 클라스킨 종양