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Safety of nighttime elective hepatectomy for hepatocellular carcinoma patients: a retrospective study

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Purpose: This study aimed to investigate whether nighttime elective surgery influenced the short-term outcomes and prognosis of hepatocellular carcinoma (HCC) patients.
Methods: The 1,339 HCC patients who underwent hepatectomy were divided into the daytime surgery group (8 a.m.–6 p.m., n = 1,105) and the nighttime surgery group (after 6 p.m., n = 234) based on the start time of surgery. The 1:2 propensity score matching (PSM) analysis was used to control confounding factors. The short-term outcomes of HCC patients in the 2 groups were compared before and after PSM. Factors associated with major complications (Clavien-Dindo grade, ≥III) and textbook oncologic outcomes (TOO) were separately identified by multivariable logistic regression based on variables screened via least absolute shrinkage and selection operator (LASSO). The Kaplan-Meier method was used to analyze overall survival (OS) and recurrence-free survival (RFS).
Results: TOO was achieved after surgery in 897 HCC patients. HCC patients in the nighttime surgery group had a higher body mass index (P = 0.010). After 1:2 PSM, the baseline characteristics of patients between the 2 groups were similar. Short-term outcomes in HCC patients were comparable both before and after PSM (all Ps > 0.05), as were TOO in the 2 groups before (P = 0.673) and after PSM (P = 0.333). In our LASSO-logistic regression, nighttime surgery was not an independent factor associated with major complications or TOO. Both groups also had similar OS (P = 0.950) and RFS (P = 0.740) after PSM.
Conclusion: Our study revealed the safety of nighttime elective hepatectomy for HCC patients.
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Key Words: Hepatocellular carcinoma, Hepatectomy, Safety

INTRODUCTION

In general, nighttime surgery at medical centers is usually performed for emergency patients. The safety of nighttime emergency surgery has always been a concern because of the potential impact that sleep deprivation and fatigue may have on the performance of surgeons who perform nocturnal emergency surgery [1]. It is worth noting, however, that in high-volume medical centers, surgeons often perform nighttime surgery as an elective procedure to improve medical efficiency [2]. Although elective nighttime surgery avoids the sleep deprivation factor for surgeons compared to emergency nighttime surgery, long working hours can still cause surgeon fatigue (including physical fatigue, mental fatigue, and decision fatigue), which may be risk factors in surgery [2-5]. Moreover, shift changes of medical staff in most medical centers usually take place at night, and the shortage of medical staff and lapse in handoffs may result in surgeons being unable to adequately respond to intraoperative emergencies [4,6]. It can be reasonably assumed that these factors may adversely affect the outcome of

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nighttime elective surgery. According to the findings of a study conducted in Colorado and Utah, at least 44,000 Americans die annually as a result of medical errors [7]. Additionally, a study based on surgical errors in 3 teaching hospitals revealed that 33% of medical errors occurred due to fatigue or excess workload [8]. Therefore, the safety of nighttime elective surgery is a question worth considering. However, the relevant research conclusions are somewhat controversial at present. According to a study based on the clinical data of 10,246 cases, patients who received nonemergency general and vascular surgery procedures at night did not seem to have an increased risk of postoperative morbidity or death [9]; though some studies came to the opposite conclusion [10,11].

Hepatectomy is essential for HCC patients to achieve long-term survival [12], yet it is also one of the most dangerous and challenging procedures [13,14]. Patients always request that their surgery be performed during the day, believing that the surgeon will be more vigilant and precise. Our surgeons, however, believe that they can perform the procedure perfectly at any time. Unfortunately, the relationship between nighttime elective hepatectomy and the short-term outcomes and prognosis of HCC patients has not been studied. Furthermore, traditional surgery quality is generally measured by a single metric, such as morbidity, mortality, and readmission rate, but a single metric does not accurately reflect the multidimensional character of the surgical process. Textbook oncologic outcome (TOO), as a composite measure, has been evaluated in a variety of surgical domains, demonstrating that it is a realistic and effective metric for evaluating the quality of surgery [15]. Thus, our study, based on clinical data from a high-volume medical center, sought to explore the relationship between nighttime elective surgery and short-term outcomes and prognosis of HCC patients, and TOO was also our variable of interest. Our study may provide a solution to alleviate the anxiety of HCC patients and rationalize healthcare resource allocation.

METHODS

This research, which adhered to the World Medical Association's Declaration of Helsinki, was sanctioned by the West China Hospital of Sichuan University's Ethics Committee for Biomedical Research (No. 2023-313). Written informed consent was waived due to its retrospective nature..

Patients

HCC patients (n = 1,497) who underwent elective hepatectomy for the first time at our medical center from May 2014 to July 2019 were retrospectively enrolled in this study. Surgeons with more than 10 years of surgical experience performed all elective hepatectomy procedures. Exclusion criteria were as follows: (1) combined with other tumors; (2) Child-Pugh B; (3) combined other surgeries (e.g., splenectomy, biliary intestinal anastomosis); and (4) lack of important baseline information. Eventually, 1,399 patients were enrolled for analysis in our research (Fig. 1).

All patients' clinicopathological characteristics, imaging information, intraoperative information, and laboratory tests were retrospectively collected from the hospital information system. The same criteria for preoperative preparation for all patients: (1) for patients without gastrointestinal dysfunction, it is recommended to drink clear liquids until 2–3 hours before surgery and no solid food at least 6 hours before surgery; (2)

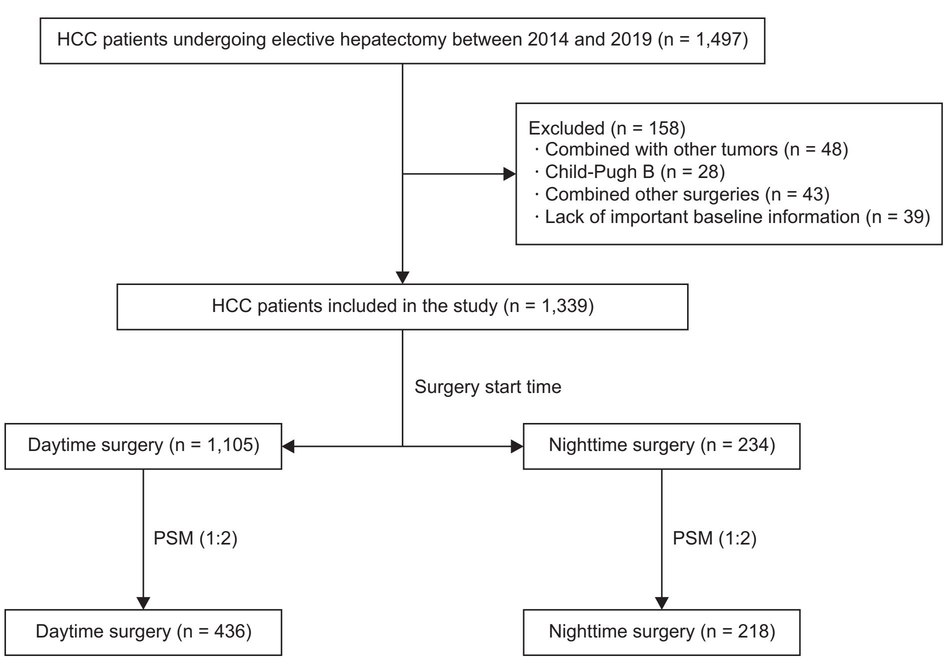

Fig. 1. Flow chart for inclusion of hepatocellular carcinoma (HCC) patients who underwent hepatectomy.

to control central venous pressure, fluid intake is usually <5 mL/kg in the 8 hours before surgery; (3) prophylactic use of antimicrobials, if the duration of surgery is more than 3 hours or more than twice the half-life of the drug used, if the duration of surgery is more than 3 hours or more than twice the half-life of the drug used, or if the bleeding volume of an adult is more than 1,500 mL, one additional dose should be given intraoperatively. The skin incision was the beginning of the procedure. Elective hepatectomy started between 8 a.m. and 6 p.m. were defined as daytime surgery, whereas those started after 6 p.m. were defined as nighttime surgery. A 1:2 propensity score matching (PSM) analysis was used to balance the confounding factors of patients between the 2 groups (Fig. 1).

Postoperative short-term outcomes included length of stay, postoperative complications, unplanned reoperation, transfer to intensive care unit (ICU), perioperative death, 90-day readmission, 90-day mortality, and TOO. Complications that occurred in the hospital or within 30 days after surgery were classified as postoperative complications. Postoperative complications were graded based on the Clavien-Dindo (CD) classification [16]. Overall survival (OS) was measured from surgery to death or final follow-up. Recurrences were defined as the emergence of a lesion with characteristic HCC radiological features as verified by ultrasonography, CT, or MRI. Recurrence-free survival (RFS) was measured from surgery to recurrence, death, or last follow-up. We followed up with all patients included in our study by outpatient department or telephone.

Postoperative short-term outcomes

TOO was defined as microscopically negative (R0) surgical margins, no return to the operating room, no major complications (CD grade, ≥III), no extended hospital stay (length of stay [LOS], ≤75th percentile), no 90-day readmission, and no 90-day mortality [17]. Liver failure was diagnosed according to the 50–50 criteria [18]. Fever was defined as an increase in body temperature requiring pharmacological intervention. Hydrothorax was identified using chest radiography and/or CT scan. Biliary leakage was defined as a total bilirubin concentration of at least 3 times the serum concentration in the abdominal drainage fluid on the 3rd postoperative day, or biliary peritonitis requiring interventional treatment [19]. Peritoneal effusion was defined as drainage of more than 200 mL per day or diagnosed by imaging. Postoperative hemorrhage was defined as a postoperative drop in hemoglobin greater than 3 g/dL, and/or requiring surgical or interventional interventions. Surgical site infection was defined as infections occurring in incisions, deep organs, and cavities. A change in chest radiography, positive sputum cultures, and positive CT scan findings, along with fever and leukocytosis, were used to define pulmonary infection. Perioperative death was defined as death during hospitalization. Complications with a CD grade of ≥III were categorized as major complications.

Propensity score matching analysis

To balance the baseline characteristics and reduce the impact of potential confounders, a 1:2 PSM was utilized. Matching was carried out using a caliper of 0.02 and propensity scores to equalize all recipient factors (standardized mean difference, <0.2). Age, sex, body mass index (BMI), HBV-DNA, intraoperative blooding, major hepatectomy, operation duration, Barcelona Clinic Liver Cancer (BCLC) stage, Milan criteria, single tumor, satellite nodules, microvascular invasion, and portal vein tumor thrombosis were used as covariables for PSM.

Statistical analysis

Means ± standard deviation or median and interquartile range (IQR) was used to describe continuous variables. The Student t-test or Mann-Whitney U-test was used to compare continuous variables between the 2 groups. Categorical variables were presented as numbers and percentages. Categorical variables between the 2 groups were compared by using the chi-square tests or Fisher exact tests. Factors associated with major complications (CD grade, ≥III) and TOO were separately identified by multivariable logistic regression based on variables screened via least absolute shrinkage and selection operator (LASSO). The Kaplan-Meier survival analysis was performed to assess OS and RFS. All data analyses in this study were performed using R software ver. 4.2.1 (The R Foundation). A P-value of <0.05 was considered to be statistically significant.

RESULTS

Patient characteristics

The 1,339 HCC patients who underwent hepatectomy were divided into the daytime surgery group (n = 1,105) and the nighttime surgery group (n = 234) based on the start time of surgery. The average age of patients in the total cohort was 53.3 years, and 1,132 patients were male. HCC patients in the nighttime surgery group had a higher BMI (P = 0.010) than those in the daytime surgery group. The other variables between the 2 groups were similar (all Ps > 0.05). After 1:2 PSM, HCC patients in the daytime surgery group (n = 436) and the nighttime surgery group (n = 218) had similar baseline characteristics (all Ps > 0.05) (Table 1).

Postoperative short-term outcomes and independent factors associated with major complications and textbook oncologic outcomes

When comparing the specific complications (including liver failure, fever, hydrothorax, biliary leak, ascites, hemorrhage, surgical site infection, pulmonary infection, nausea and

Table 1. Baseline characteristics for HCC patients who underwent hepatectomy before and after PSM

Characteristic	Entire cohort (n = 1,339)			PSM cohort (n = 654)		
	Daytime surgery group	Nighttime surgery group	P-value	Daytime surgery group	Nighttime surgery group	P-value
No. of patients	1,105	234		436	218	
Age (yr)	53.3 ± 11.5	53.3 ± 11.1	0.970	53.5 ± 11.1	53.3 ± 11.0	0.838
Male sex	938 (84.9)	194 (82.9)	0.446	365 (83.7)	180 (82.6)	0.824
Body mass index (kg/m^2)	23.1 ± 3.0	23.7 ± 3.2	0.010	23.3 ± 3.0	23.4 ± 3.0	0.638
Smoke	583 (52.8)	120 (51.3)	0.681	233 (53.4)	111 (50.9)	0.542
Alcohol	440 (39.8)	93 (39.7)	0.983	190 (43.6)	85 (39.0)	0.263
Hypertension	179 (16.2)	36 (15.4)	0.758	77 (17.7)	33 (15.1)	0.416
Diabetes mellitus	87 (7.9)	17 (7.3)	0.752	40 (9.2)	16 (7.3)	0.429
HBV-related HCC	1076 (97.4)	224 (95.7)	0.173	423 (97.0)	208 (95.4)	0.293
HBV-DNA, >×10^3 IU/mL	405 (36.7)	71 (30.3)	0.067	128 (29.4)	67 (30.7)	0.717
ALBI grade[a] I/II	869/236	192/42	0.243	341/95	179/39	0.244
Erythrocyte (×10^{12}/L)	4.7 ± 0.6	4.7 ± 0.5	0.333	4.7 ± 0.6	4.7 ± 0.6	0.502
Hemoglobin (g/L)	142.9 ± 18.5	144.9 ± 16.6	0.121	143.0 ± 19.0	144.0 ± 17.0	0.285
Platelet (×10^9/L)	130 (93–179)	134 (99–186)	0.438	129 (94–180)	131 (97–183)	0.765
NLR	2.1 (1.6–2.9)	2.0 (1.6–2.8)	0.981	2.0 (1.5–2.8)	2.0 (1.6–2.8)	0.484
PLR	86.8 (62.5–122.3)	86.1 (62.8–120.6)	0.797	86.0 (60.9–124.2)	85.4 (62.7–119.9)	0.926
Total bilirubin (μmol/L)	13.8 (10.6–17.9)	13.2 (10.4–17.7)	0.319	13.7 (10.6–17.8)	13.2 (10.4–17.7)	0.473
Albumin (g/dL)	42.4 ± 4.1	42.5 ± 3.5	0.464	42.3 ± 4.2	42.6 ± 3.5	0.356
INR	1.0 (0.9–1.1)	1.0 (0.9–1.1)	0.643	1.0 (0.9–1.1)	1.0 (0.9–1.1)	0.747
α-FP, >200 ng/mL	500 (45.2)	96 (41.0)	0.238	194 (44.5)	87 (39.9)	0.264
BCLC 0/A/B/C	78/852/57/118	15/175/18/26	0.475	34/324/32/46	15/167/14/22	0.926
Milan criteria[b]	538 (48.7)	107 (45.7)	0.410	199 (45.6)	103 (47.2)	0.698
Tumor size (cm)	4.9 (3.0–7.9)	5.0 (3.0–7.1)	0.379	5.2 (2.9–7.7)	4.8 (3.0–7.0)	0.536
Single tumor	1,013 (91.7)	206 (88.0)	0.077	389 (89.2)	194 (89.0)	0.929
Operation time (min)	206 ± 60	199 ± 62	0.112	201 ± 57	199 ± 62	0.639
Laparoscope	217 (19.6)	50 (21.4)	0.547	94 (21.6)	49 (22.5)	0.789
Anatomical hepatectomy[c]	408 (36.9)	80 (34.2)	0.430	146 (33.5)	75 (34.4)	0.815
Major hepatectomy[d]	266 (24.1)	64 (27.4)	0.290	112 (25.7)	54 (17.1)	0.799
Intraoperative bleeding (mL)	200 (100–400)	275 (120–400)	0.242	200 (100–400)	200 (100–400)	0.251
Intraoperative blood transfusion	49 (4.4)	15 (6.4)	0.198	20 (4.6)	9 (4.1)	0.788
Low differentiation	498 (45.1)	97 (41.5)	0.312	198 (45.4)	91 (41.7)	0.373
Capsular invasion	587 (53.1)	128 (54.7)	0.660	241 (55.3)	119 (54.6)	0.266
Microvascular invasion	331 (30.0)	67 (28.6)	0.688	124 (28.4)	60 (27.5)	0.806
Satellite nodules	121 (11.0)	18 (7.7)	0.138	31 (7.1)	17 (7.8)	0.750
Cirrhosis	487 (44.1)	102 (43.6)	0.893	197 (45.2)	97 (44.5)	0.868
PVTT	103 (9.3)	21 (9.0)	0.868	39 (8.9)	19 (8.7)	0.923
Positive surgical margin	10 (0.9)	1 (0.4)	0.701	4 (0.9)	0 (0)	0.307

Values are presented as number only, mean ± standard deviation, number (%), or median (interquartile range).
HCC, hepatocellular carcinoma; ALBI, albumin-bilirubin; NLR, neutrophil-to-lymphocyte ratio; PLR, platelet-to-lymphocyte ratio; INR, international normalized ratio; BCLC, Barcelona Clinic Liver Cancer staging system (early stage, BCLC 0/A; advanced stage, BCLC B/C); PVTT, portal vein tumor thrombosis.
[a]ALBI grades were classified into 3 levels (grades I, II, III of ≤–2.60, <–2.60 to ≤–1.39, and >–1.39) based on the ALBI score; ALBI score = (log10 bilirubin [in μmol/L] × 0.66) + (albumin [in g/L] × –0.085).
[b]Milan criteria were defined as up to 3 HCC nodules, the largest <3 cm in diameter or a single HCC nodule up to 5 cm in diameter.
[c]Anatomical hepatectomy was defined as the resection of the tumor together with the hepatic segment or subsegment, which includes tumor-bearing portal tributaries as well as a major branch of the portal vein and hepatic artery [18].
[d]Major hepatectomy was defined as the resection of more than 3 contiguous Couinaud segments [19].

vomiting, and others) of the 2 groups before PSM, we found that there was no difference (all Ps > 0.05). Patients in the 2 groups also had similar LOS (P = 0.241) and extended LOS (P = 0.956). Notably, patients in the nighttime surgery group seemed to be more likely to experience major complications (daytime surgery group *vs.* nighttime surgery group, 4.1% *vs.* 6.4%), but there was no statistical difference (P = 0.116). Moreover, the rate of unplanned reoperation, ICU, perioperative death, 90-day

Table 2. Postoperative short-term outcomes and TOO of the patients before and after PSM

Variable	Entire cohort (n = 1,339)			PSM cohort (n = 654)		
	Daytime surgery group (n = 1,105)	Nighttime surgery group (n = 234)	P-value	Daytime surgery group (n = 436)	Nighttime surgery group (n = 218)	P-value
LOS	10 (8–12)	9.5 (8–12)	0.241	10 (8–12)	9 (7–12)	0.766
Extended LOS	272 (24.6)	58 (24.8)	0.956	87 (20.0)	53 (24.3)	0.200
Liver failure	10 (0.9)	4 (1.7)	0.272	5 (1.1)	4 (1.8)	0.476
Fever	203 (18.4)	46 (19.7)	0.646	71 (16.3)	42 (19.3)	0.342
Hydrothorax	26 (2.4)	8 (3.4)	0.346	9 (2.1)	8 (3.7)	0.244
Biliary leakage	79 (7.1)	18 (7.7)	0.771	29 (6.7)	14 (6.4)	0.911
Peritoneal effusion	9 (0.8)	2 (0.9)	0.951	2 (0.5)	1 (0.5)	>0.999
Hemorrhage	51 (4.6)	12 (5.1)	0.736	19 (4.4)	9 (4.1)	0.891
Surgical site infection	30 (2.7)	3 (1.3)	0.199	14 (3.2)	2 (0.9)	0.105
Pulmonary infection	6 (0.5)	1 (0.4)	0.824	1 (0.2)	0 (0)	>0.999
Nausea and vomiting	65 (5.9)	9 (3.8)	0.216	25 (5.7)	8 (3.7)	0.256
Others	61 (5.5)	11 (4.7)	0.614	24 (5.5)	10 (3.7)	0.618
Unplanned reoperation	2 (0.2)	1 (0.4)	0.438	1 (0.2)	1 (0.5)	>0.999
Transfer to ICU	5 (0.5)	1 (0.4)	0.958	2 (0.5)	1 (0.5)	>0.999
Perioperative death	1 (0.1)	0 (0)	>0.999	1 (0.2)	0 (0)	>0.999
Major complications	45 (4.1)	15 (6.4)	0.116	13 (3.0)	13 (6.0)	0.066
90-Day readmission	89 (8.1)	20 (8.5)	0.802	34 (7.8)	15 (6.9)	0.674
90-Day mortality	25 (2.3)	9 (3.8)	0.162	11 (2.5)	9 (4.1)	0.261
TOO	734 (67.2)	154 (65.8)	0.673	312 (71.6)	148 (67.9)	0.333

TOO, textbook oncologic outcomes; PSM, propensity score matching; LOS, length of stay; ICU, intensive care unit.

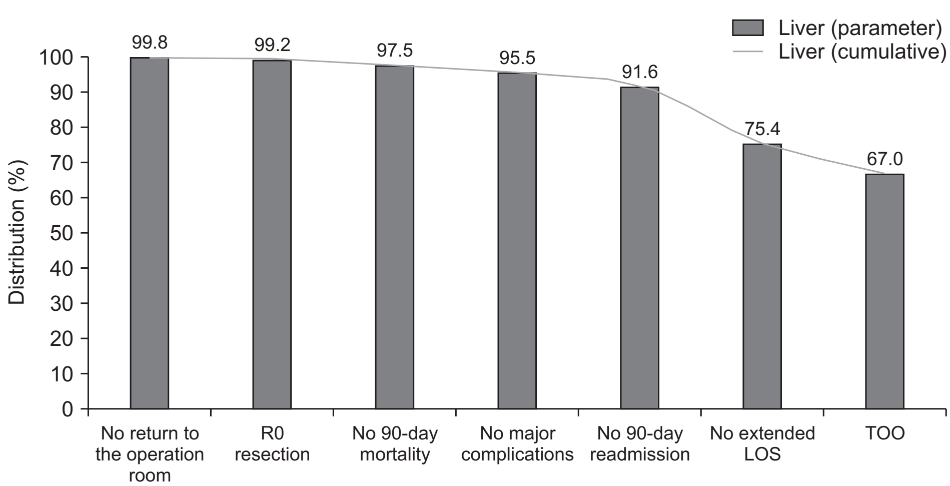

Fig. 2. Textbook oncologic outcomes (TOO) distribution stratified by the specific parameters among patients undergoing hepatectomy for hepatocellular carcinoma. LOS, length of stay.

readmission, and 90-day mortality was also similar (all Ps > 0.05) (Table 2). In the entire cohort, 897 HCC patients achieved TOO after surgery. Fig. 2 shows the TOO distribution stratified by the specific factors among patients receiving hepatectomy for HCC, and we found no difference in TOO between the 2 groups (P = 0.673) (Table 2). After PSM, patients in the 2 matched groups still had similar short-term outcomes (all Ps > 0.05) (Table 2). We further compared specific major complications in the PSM cohort, and there was still no statistical significance (Supplementary Table 1).

The independent factors associated with major complications based on LASSO-logistic regression (Fig. 3A, B) are shown in Table 3. HCC Patients with intraoperative blood transfusion (odds ratio [OR], 2.63; 95% confidence interval [CI], 1.05–6.63; P = 0.040), operation time more than 180 minutes (OR, 2.39; 95% CI, 1.21–4.67; P = 0.012) and diabetes mellitus (OR, 2.55; 95% CI, 1.26–5.18; P = 0.009) had higher odds of experiencing major complications after surgery. Table 4 shows independent factors associated with TOO, in this LASSO-logistic model for TOO (Fig. 3C, D), HCC patients with intraoperative blooding more than 1,000 mL (OR, 0.41; 95% CI, 0.19–0.87; P = 0.020), major hepatectomy (OR, 0.67; 95% CI, 0.50–0.90; P = 0.008), operation

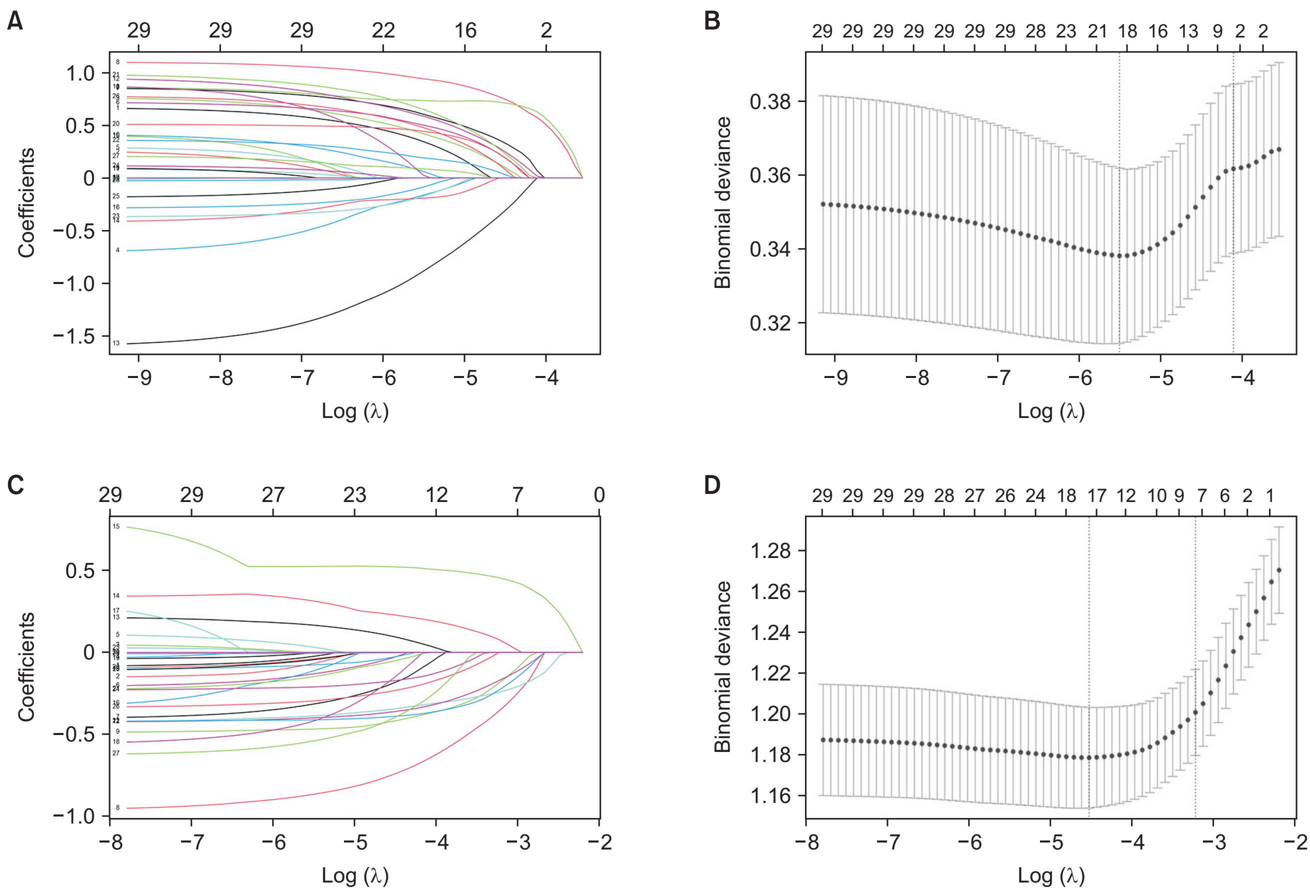

Fig. 3. Screening of variables based on the least absolute shrinkage and selection operator (LASSO) regression. (A) The variation characteristics of the coefficient of variables of major complication. (B) Identification of the optimal penalization coefficient λ in the LASSO model of major complications. (C) The variation characteristics of the coefficient of variables of textbook oncologic outcomes (TOO). (D) Identification of the optimal penalization coefficient λ in the LASSO model of TOO. Variables included operation start time (daytime surgery/nighttime surgery), sex, age, smoke, alcohol, hypertension, diabetes mellitus, intraoperative bleeding, intraoperative blood transfusion, anatomical hepatectomy, major hepatectomy, operation time, laparoscope, Barcelona Clinic Liver Cancer stage, Milan criteria, single tumor, tumor size, HBV-related hepatocellular carcinoma, HBV-DNA, erythrocyte, hemoglobin, albumin-bilirubin grade, international normalized ratio, body mass index, α-FP, total bilirubin, albumin, neutrophil-to-lymphocyte ratio, and platelet-to-lymphocyte ratio.

Table 3. Multivariable logistic analysis of factors with major complication based on LASSO regression

Variable	OR (95% CI)	P-value
Intraoperative blood transfusion		
No	Reference	
Yes	2.63 (1.05–6.63)	0.040
Diabetes mellitus		
No	Reference	
Yes	2.55 (1.26–5.18)	0.009
Operation time, >180 min		
No	Reference	
Yes	2.39 (1.21–4.67)	0.012
Intraoperative bleeding, >1,000 mL		
No	Reference	
Yes	2.51 (0.91–6.91)	0.075

LASSO, least absolute shrinkage and selection operator; OR, odds ratio; CI, confidence interval.

time more than 180 minutes (OR, 0.65; 95% CI, 0.50–0.86; P = 0.002), advanced stage (BCLC stage B/C: OR, 0.71; 95% CI, 0.51–0.99; P = 0.046), and albumin-bilirubin grade II (OR, 0.57; 95% CI, 0.43–0.76; P < 0.001) had lower odds of achieving TOO after surgery. Patients who did not meet the Milan criteria (OR, 0.55; 95% CI, 0.42–0.73; P < 0.001) also had lower odds of achieving TOO.

Survival outcomes

In the matched cohort, the median follow-up period was 45.5 months. In the daytime and nighttime surgery groups, 167 and 83 cases of death were recorded, respectively; 229 and 119 patients in each group suffered recurrence, respectively. The 5-year OS and the 5-year RFS were 60.5% and 45.0% in the daytime surgery group and 59.7% and 41.4% in the nighttime surgery group, respectively. During the follow-up period, patients in the 2 matched groups had similar OS (P = 0.950, Fig. 4A) and RFS (P = 0.740, Fig. 4B).

DISCUSSION

As is known to all, ensuring patient safety is the most important principle in medical practice, but a previous study reported that 33% of medical errors were attributed to fatigue and an overload of medical staff [8]. Thus, it is worth exploring whether it is reasonable for surgeons to continue nighttime elective surgery after high-intensity work during the daytime. Hepatectomy is one of the most difficult and risky procedures. In the present study, we investigated the potential impact of nighttime elective hepatectomy on short-term outcomes and prognosis in HCC patients, and this study demonstrated that nighttime elective hepatectomy had no impact on postoperative short-term outcomes of HCC patients. Moreover, nighttime elective hepatectomy did not affect OS and RFS of HCC patients.

Our study investigated the potential effect of nighttime elective hepatectomy on postoperative short-term outcomes in HCC patients before and after PSM, and we found that HCC patients after surgery in the 2 groups had similar short-term outcomes. Notably, our study first reported nighttime elective hepatectomy did not decrease the odds of achieving TOO, which demonstrated that surgeons may complete the surgery with high quality even at nighttime after high-intensity work during the daytime. Several studies based on high-volume hospital data reported similar results [9,20,21]. Several mechanisms may contribute to explaining our results. First, although long working hours may undoubtedly cause fatigue in surgeons, which in turn will affect their performance in surgery [22,23], in our research, all surgeries were conducted by surgeons with more than 10 years of surgical experience; and the cumulative work experience may counteract the decline in surgical performance resulting from fatigue. Second, our medical center is a large teaching hospital with sufficient medical resources, which enable us to guarantee the quality of care of patients even at night. Moreover, our medical center has a strict handover system to avoid handover errors that can have adverse results in surgery [24]. In addition, operating room nurses and anesthesiologists are divided into

Table 4. Multivariable logistic analysis of factors with TOO based on LASSO regression

Variable	OR (95% CI)	P-value
Intraoperative bleeding, >1,000 mL		
Yes	0.41 (0.19–0.87)	0.020
No	Reference	
Major hepatectomy		
Yes	0.67 (0.50–0.90)	0.008
No	Reference	
Operation time, >180 min		
Yes	0.65 (0.50–0.86)	0.002
No	Reference	
BCLC		
Advanced stage	0.71 (0.51–0.99)	0.046
Early stage	Reference	
Milan criteria		
Yes	Reference	
No	0.55 (0.42–0.73)	<0.001
ALBI grade		
I	Reference	
II	0.57 (0.43–0.76)	<0.001
Intraoperative blood transfusion		
Yes	0.54 (0.29–1.02)	0.058
No	Reference	

TOO, textbook oncologic outcomes; LASSO, least absolute shrinkage and selection operator; OR, odds ratio; CI, confidence interval; BCLC, Barcelona Clinic Liver Cancer staging system; ALBI, albumin-bilirubin.

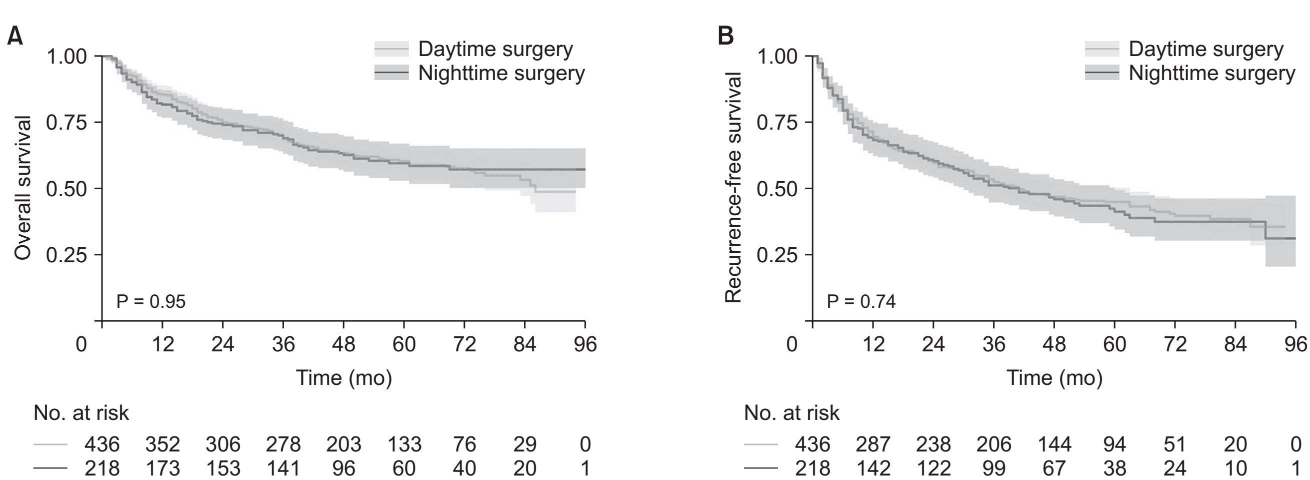

Fig. 4. The Kaplan-Meier curve of patients with hepatocellular carcinoma who underwent hepatectomy in the matched 2 groups. (A) Overall survival after propensity score matching (PSM). (B) Recurrence-free survival after PSM

subspecialties, and they are proficient in the knowledge of relevant specialties and can cooperate with the surgeon to deal with sudden situations during surgery. Third, surgeons can use the fragmentation time to adjust their state. Relatively simple operation steps such as open abdomen, closed abdomen, or free liver are usually performed by experienced assistants, and the chief surgeon generally completes the complex and difficult steps of the surgery, which allows the surgeon to have more rest time between surgeries. Moreover, hepatectomy has its own uniqueness, we usually need to repeatedly block and open hepatic vascular inflow during the surgical process to complete the hepatectomy. During the period of opening hepatic vascular inflow, the chief surgeon will not perform the complex operation steps. Thus, the surgeon may get a short intraoperative break to relieve fatigue [3]. However, previous studies also reported that nighttime elective surgery was associated with poor surgical outcomes. Fatigue, shift changes, and inadequate nighttime medical resources were the main causes of adverse surgical outcomes in relevant studies [4,10,25]. The medical resources, management system, and surgical experience of surgeons are different at different levels of medical centers. Thus, outcomes regarding the safety of nighttime elective surgery may be different in different medical centers. In a word, our study demonstrated the safety of nighttime elective hepatectomy for HCC patients in a high-volume medical center.

Our study also demonstrated that nighttime elective hepatectomy did not affect the OS and RFS of HCC patients. Similar results had been found in colon and endometrial cancer [26,27]. In our study, patient demographic characteristics, tumor characteristics, and surgical modality were similar between the daytime surgery group and the nighttime surgery group, and it was worth noting that there was no difference in incisal margin, intraoperative bleeding, and intraoperative blood transfusion between the 2 groups. Previous studies reported that TOO was associated with improved RFS and OS [28,29]. In our study, patients in the 2 groups had similar TOO before and after PSM. Thus, the OS and RFS were similar between the 2 groups, which implied that experienced surgeons could overcome the negative effects of fatigue by self-regulation to ensure good oncological outcomes during nighttime elective hepatectomy [30].

The conclusions of our study regarding the safety of elective hepatectomy for HCC patients were positive. However, it is also worth noting that long-time intensive work may do harm to the health of medical workers. Thus, the allocation of health care resources needs to be further rationalized to ensure the efficiency of health care while reducing the pressure on medical workers.

There were some limitations in our research. First, there was an unavoidable selection bias due to the retrospective nature of our study. Studies with a higher level of evidence are needed to validate our conclusions. Second, nighttime surgery was defined according to local time characteristics; thus, different time definitions may have different results. Third, this study only included HCC patients who underwent hepatectomy for analysis. Patients requiring hepatectomy for other reasons (e.g., hepatolithiasis, liver metastases) were not analyzed. Thus, our conclusions have certain limitations.

In conclusion, this study demonstrated that nighttime elective hepatectomy was safe for HCC patients. In high-volume hospitals, surgeons can perform nighttime elective hepatectomy to improve medical efficiency; and for these patients, it is unnecessary to be concerned about the order of operations. Further research is needed to demonstrate whether our conclusions can be generalized.

SUPPLEMENTARY MATERIALS

Supplementary Table 1 can be found via https://doi.org/10.4174/astr.2024.106.2.68.

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Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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