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Original article

Risk-stratified posthepatectomy pathways based upon the Kawaguchi–Gayet complexity classification and impact on length of stay☆,☆☆,☆☆☆

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ABSTRACT

Background: The Kawaguchi–Gayet classification is a validated system to stratify open liver resections by complexity and postoperative complications. We hypothesized that Kawaguchi–Gayet classification could be used to create and implement risk-stratified posthepatectomy pathways to reduce length of stay and variation in care.

Methods: Clinicopathologic data from hepatectomy patients (1/2017–6/2020) were abstracted from a prospective database. All open hepatectomies were assigned to groups based on 2 levels of Kawaguchi–Gayet classification, and corresponding risk-stratified posthepatectomy pathways were created to decrease length of stay by 1 day compared to patients who were historically treated without a pathway: low–intermediate risk (open Kawaguchi–Gayet I/II) and high risk (open Kawaguchi–Gayet III). Outcomes were compared between periods before ("PRE"; 1/1/2017–9/30/2019) and after ("POST"; 10/1/2019–6/30/2020) implementation.

Results: Among 487 open hepatectomies (PRE: 374, POST: 113), 55.0% (n = 268) were low–intermediate risk and 45.0% (n = 219) were high risk. Major complications were similar PRE/POST: low–intermediate risk (PRE: 7.8%, POST: 9.4%, P = .681) and high risk (PRE: 18.9%, POST 10.0%, P = 0.139). Risk-stratified posthepatectomy pathway implementation reduced median length of stay for both low–intermediate risk (4 to 3.5 days, P = .009) and high risk (5 to 4 days, P = 0.022) patients. Risk-stratified posthepatectomy pathways decreased length of stay variation, reflected in mean and standard deviation for all patients (PRE 5.5 ± 7.5 vs POST 4.4 ± 2.8 days). There was no difference in 90-day readmission rates between PRE (12.6%) and POST (8.8%) periods (P = .278).

Conclusion: The creation and implementation of risk-stratified posthepatectomy pathways reduced length of stay without increasing readmissions after hepatectomy. These generalizable risk-stratified posthepatectomy pathways preoperatively stratify patients a priori into pathways for individualized preoperative discussions on realistic postoperative complications and length of stay expectations.

INTRODUCTION

Safety and quality of liver surgery have improved greatly despite its inherent risk and complexity [1,2]. Enhanced recovery protocols have played a significant role in standardizing perioperative care resulting in decreased length of stay (LOS), complications, and opioid use and improved patient function [3–5]. Taking surgical complexity (beyond major versus minor hepatectomy) into account may further refine enhanced recovery pathways by allowing for more effective stratification of risk and thus more specific and effective patient education and engagement.

Recently, an evolution from the traditional minor/major hepatectomy [6] nomenclature to a more detailed grading system for hepatectomy complexity that goes beyond anatomic landmarks alone was proposed [7–9]. The Kawaguchi–Gayet (K–G) classification is one system for hepatectomy that was initially created to classify laparoscopic hepatectomy based on metrics of technical complexity including complication index, operative time, and estimated blood loss [10,11].

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Recently, this new grading system was validated for open liver resection for postoperative morbidity [12]. Many enhanced recovery programs have yet to be personalized via a priori stratification based on surgical complexity. We have created, implemented, validated, and twice revised preoperatively determined risk-stratified pancreatectomy clinical pathways, resulting in median LOS reduction from 12 to 6 days in high-risk and 10 to 5 days in low-risk pancreatoduodenectomy patients from 2016 to 2020 [13–15]. The foundation of this success was preoperative patient education on expected outcomes stratified by risks associated with their anticipated risk of postoperative pancreatic fistula. Further improvements were facilitated through ongoing yearly validation analyses and active revisions to the pathways.

Within this context, the objective of this study was to use the modified K–G classification to stratify patients for the creation of distinct posthepatectomy care pathways. We hypothesized that these risk-stratified posthepatectomy pathways (RSPHPs) would reduce median LOS by 1 day and reduce variations in care. We then sought to validate our new pathways in a postimplementation cohort.

PATIENTS AND METHODS

Patients and Practice. A prospectively maintained hepatobiliary surgical quality improvement database was queried retrospectively to identify a continuous set of patients from 1/1/2017 to 06/30/2020 treated at The University of Texas MD Anderson Cancer Center. Data verification and entry was performed by 2 specialty advanced practice providers (EMA and WLD) who reviewed the electronic medical record along with review of standardized discharge summaries containing real-time data points and complication information biweekly up to 90 postoperative days with 1 faculty (CDT). Pre-, intra-, and postoperative clinicopathologic patient data were collected from this prospectively maintained database. The data set represented a contemporary cohort of hepatectomy patients before and after initiation of our enhanced recovery protocols (started September 2019). The Institutional Review Board at the University of Texas MD Anderson Cancer Center approved this study (PA19-0424).

Outcomes. The primary outcome was LOS, whereas secondary outcomes included postoperative complications. Readmissions were hospital admissions. Emergency department or observation unit visits did not qualify as readmission. In our practice, postoperative patients are seen in the outpatient clinic for early follow-up within 2–3 business days of discharge to make outpatient adjustments to their early recovery to prevent need for readmission. Postoperative hepatic insufficiency was defined as a peak serum bilirubin level greater than 7 mg/dL [16,17]. Drains were placed at the discretion of the surgeon but were avoided when an air leak test was negative [18]. Liver-specific complications included ascites, abscess, fluid collection, bile leak/biloma, and hepatic insufficiency. Complications were graded using the Modified Accordion Grading System, and postoperative major complication was defined as Modified Accordion Grading System of 3 or higher [19].

Modified Kawaguchi–Gayet Classification and Complexity of Hepatectomy. The previously described modified 3-level K–G classification [10–12,20] was used to grade complexity of open hepatectomy: grades I "low," II "intermediate," and III "high." Grade I liver resections constituted a wedge resection (anterolateral or posterosuperior locations) or a left lateral sectionectomy. Anterolateral segments are defined as Couinaud segments II, III, IVb, V and VI. Posterosuperior (PS) segments are defined as Couinaud segments I, IVa, VII, and VIII.

Grade II was defined as an anterolateral monosegmentectomy or a left hepatectomy. Grade III resections were inclusive of a posterosuperior monosegmentectomy, right posterior sectionectomy, right hepatectomy, central hepatectomy, and extended left/right hepatectomy. In line with other studies [7,11,21], nonanatomic "wedge" resection was defined as resection of less than 1 Couinaud segment for removal of tumor <3 cm in diameter, and segmentectomy included resection of less than 1 Couinaud segment of a tumor ≥3 cm in diameter or anatomical removal of 1 Couinaud segment. When 2 or more areas of the liver were resected, the higher grade was applied to this patient. All hepatectomies performed in conjunction with another procedure (eg, hernia repair or bowel resection) as well as all minimally invasive hepatectomies were excluded from this initial study. Based on previously validated multi-institutional experiences [10–12], all remaining open hepatectomies were classified into 1 of 2 categories: low–intermediate risk (K–G I–II) and high risk (K–G III).

Creation and Implementation of Risk-Stratified Posthepatectomy Pathways (RSPHPs). After review of practice patterns with faculty, advanced practice providers, and fellows, the first iteration of our posthepatectomy pathways was created by stratifying patients by K–G complexity. As the K–G classification has a refined 3-tiered characterization of complexity as described above, we believed that this would more succinctly stratify care within RSPHPs compared to traditional major/minor classifications. Elements of postoperative care were identified and accelerated within the created RSPHPs with the putative goal of decreasing LOS by 1 hospital day. Although 100% consensus across all elements was not realistic in the first iteration, basic tenets of enhanced recovery included the following: early and aggressive ambulation, universal bowel regimens with or without use of promotility agents, low intravenous fluid rates (initially 75 mL/h postoperatively and 50 mL/h postoperatively 8 hours later) with saline lock when 600 mL oral intake was documented (Table 1) [22]. Liver-specific goals were based on previously identified obstacles to patient recovery and early discharge, as well as evidence from our group's efforts with pancreatectomy care pathways that early enteral nutrition after major gastrointestinal operations is feasible [13–15]. These included requiring solid food on day 1 for low–intermediate-risk patients and on day 2 for high-risk patients, limiting peak opioid use by standardizing intravenous patient-controlled anesthesia settings, weaning opioids through required nonopioid bundles, and earlier intravenous-to-oral opioid medication use (linked to sooner diets) to promote the progress of low–intermediate-risk patients who were previously treated similarly to high-risk counterparts.

RSPHPs were created for low–intermediate (K–G I–II) and high-risk (K–G III) hepatectomies (Table 1, Fig. 1). For nomenclature simplicity across providers and for printing patient handouts, pathways were color-coded as green (low–intermediate) and yellow (high complexity). Following implementation in September 2019, patients were assigned to RSPHPs preoperatively, and pathway details were provided to patients as education on expectations of care (Table 2). Pathway details were originally shared on cloud documents for care team members and trainees until November 2019, when they were institutionally approved as official electronic order sets.

Pathway Validation and Statistical Analysis. Preimplementation outcomes were compared to postimplementation outcomes (September 2019 to June 2020) by aggregate and by complexity classification. Continuous variables were reported as medians with interquartile ranges (IQRs) and compared using the nonparametric Mann–Whitney *U* test. Nonparametric categorical data were compared utilizing a χ^2 or Fisher exact test. Some LOS data were presented as mean ± standard deviation (SD) to reflect the changes in variation of LOS and to incorporate the impact of outliers. To further analyze LOS, a Poisson regression model was used for the univariate linear regression model. Statistical analyses were performed using SPSS Statistics 26 (IBM, Armonk, NY) and SAS Enterprise Guide 7.15 (SAS Inc, Cary, NC). All tests were 2-sided.

RESULTS

Patient Demographics. Overall, 487 consecutive patients undergoing open hepatectomy alone were included. The median age was 59 years

Table 1
Risk-stratified posthepatectomy pathways daily order set

Green pathway: K–G: grades 1–2	
Postoperative day 0 (evening)	Orders
Perioperative analgesia	1. Regional analgesia
	2. Optional low-dose PCA
	3. Nonopioid pain modulators
Diet	Noncarbonated clear liquid diet
IV fluids	75 mL/h
Mobility/function	1. No nasogastric tube
	2. Out of bed
Other medications	1. Proton pump inhibitor or H2 blocker
	2. Stool softener
	3. Home medication reconciliation (no ACE inhibitor or ARB)
Postoperative day 1	
Perioperative analgesia	Wean dose of PCA/epidural
Diet	Gastrointestinal introductory (soft/bland/small portioned) diet
IV fluids	Discontinue IV fluids when PO intake ≥600 mL/shift
Mobility/function	1. Ambulate ≥6 times
	2. Remove Foley
Other	Consider tamsulosin in men >50 years of age if blood pressure allows
Postoperative day 2	
Perioperative analgesia	Discontinue PCA/wean epidural off. Start oral pain medications.
Diet	Continue solid food
IV fluids	Hospital fluid balance <2 L. Diuresis with furosemide if needed.
Mobility/function	Ambulate ≥10 times
Disposition planning	Enoxaparin education
Postoperative day 3	
Perioperative analgesia	All oral pain medications
Mobility/function	Ambulate ≥12 times
Other	1) Additional bowel regimen if needed
	2) Drain bilirubin if drain placed intraoperatively
	3) Remove drain if drain bilirubin <3× serum bilirubin level
Disposition planning	1) 28 d prophylactic dose enoxaparin
	2) Discharge in PM
	3) Follow-up phone call in 24–72 h
	4) Short-term follow-up in clinic
Yellow pathway: K–G grade 3	
Postoperative day 0 (evening)	Orders
Perioperative analgesia	1. Regional analgesia
	2. Optional low-dose PCA
	3. Nonopioid pain modulators
Diet	Ice/sips of water
IV fluids	75 mL/h
Mobility/function	1. No nasogastric tube
	2. Out of bed
Other medications	1. Proton pump inhibitor or H2 blocker
	2. Stool softener
	3. Home medication reconciliation (no ACE inhibitor or ARB)
Postoperative day 1	
Perioperative analgesia	Wean dose of PCA/epidural
Diet	Noncarbonated clear liquid diet
IV fluids	Discontinue IV fluids when PO intake ≥600 mL/shift
Mobility/function	1. Ambulate ≥6 times
	2. Remove Foley
Other	Consider tamsulosin in men >50 years of age if blood pressure allows
Postoperative day 2	
Perioperative analgesia	Discontinue PCA/wean epidural off. Start oral pain medications.
Diet	Gastrointestinal introductory (soft/bland/small portioned) diet
IV fluids	Hospital fluid balance <2 L. Diuresis with furosemide if needed.
Mobility/function	Ambulate ≥10 times
Disposition planning	Enoxaparin education
Postoperative day 3	
Perioperative analgesia	All oral pain medications
Mobility/function	Ambulate ≥12 times
Other	1) Additional bowel regimen if needed
	2) Drain bilirubin if drain placed intraoperatively
	3) Remove drain if drain bilirubin <3× serum bilirubin level
Postoperative day 4	
Mobility/function	Ambulate ≥20 times
Disposition planning	1) 28 d prophylactic dose enoxaparin
	2) Discharge in PM
	3) Follow-up phone call in 24–72 h
	4) Short-term follow-up in clinic

ARB, angiotensin receptor blocker; ACE, angiotensin-converting enzyme; *IV, intravenous; PCA*, patient-controlled analgesia; *PO*, per os.

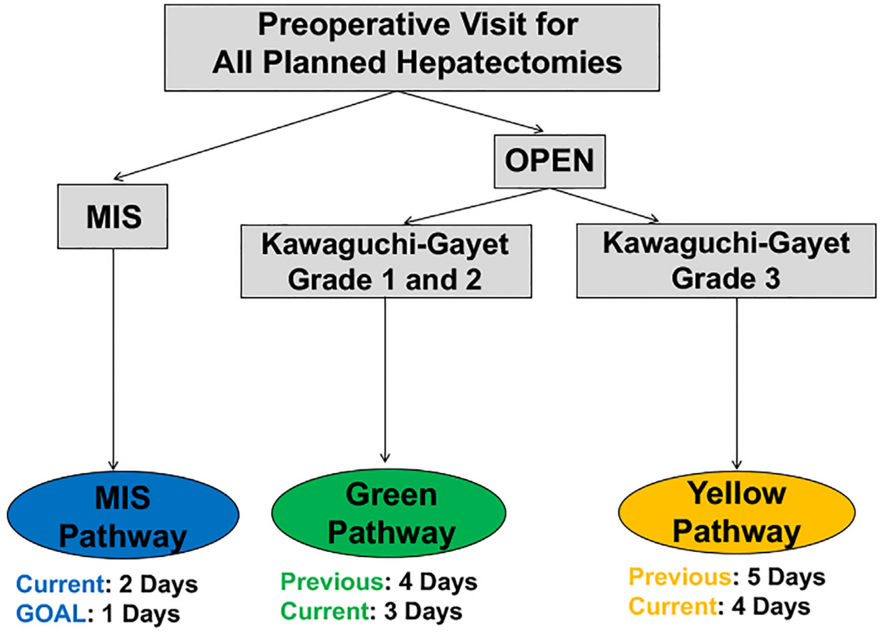

Fig 1. Enhanced recovery pathways are designated a priori in clinic for hepatectomy based on a novel risk stratification system based on the K–G complexity classification.

Table 2
Patient education and expectation forms provided a priori in clinic based on anticipated complexity of hepatectomy via the green (K–G grades 1–2) and yellow (K–G grade 3) pathway

Liver surgery postoperative expectations (green pathway)		
	Anticipated treatment plan	*Your role and responsibilities*
Preoperative clinic visit	-Review details of surgery and hospitalization -Review and sign consents -Anesthesia pre-surgery clinic -Order necessary tests and consultations with other teams -Review medication and diet plans -Preview nonopioid bundle for reducing opioid use after surgery -Determine approximate length of stay in Houston area	-Ask any and all questions relating to your operation and postoperative recovery -Arrange caregivers to help following discharge -Coordinate plans for Houston-area stay following discharge
Preoperative holding area	-Meet with anesthesia providers to finalize postoperative pain regimen that will go with your general anesthesia -A member of the surgical team will ask you for any updates since your last clinic visit	-Notify anesthesia staff of any concerns, past problems with anesthesia, or special requirements
Evening of surgery	-Monitor overnight in the postsurgery monitoring unit -Ensure adequate pain control using scheduled nonopioid medications and limited opioids as needed -Begin clear liquid diet, no carbonated beverages	-Get out of bed to chair with assistance that first day -Ask any questions regarding possible surgical drain and bladder tubes
Daily	-Draw blood for routine tests -Adjust medications as needed -Optimize pain management medication bundle -Answer questions from both patient and caregivers -Involve other services as needed (pain team, nutrition team, prehab)	-Walk with assistance and increase activity as tolerated -Wear sequential compression devices (SCDs) while in bed to prevent blood clots -Perform breathing exercises 10×/h while awake
Day 1 (after surgery)	-Transfer to the GI surgery units -Remove the bladder tube -Advance diet to solid food -Add Protein drinks 4×/d to diet -Administer stool softeners and natural laxatives	-Walk frequently with assistance (minimum 6×/d) -Eat small meals to avoid bloating -Sit in chair while eating
Day 2	-Review any new medications and send prescriptions to the outpatient pharmacy for pick up	-Watch anticoagulation education video and practice blood thinner injections

	-Change any remaining IV medications to pills	-Wear regular house clothes -Confirm lodging plan in Houston area -Walk after eating and a minimum of 10×/d -Drink enough fluids to stay hydrated -Eat in moderation
Day 3	-Remove drain if applicable -Review discharge instructions and pain medication weaning process -Discharge from hospital to local lodging (if from out of town) with follow-up visit within a few days	-Ensure all questions are answered

This document summarizes the care that we anticipate you will receive in the hospital, and it is provided for your education. However, your health care team may make changes to your personal care plan based on your recovery.

Liver surgery postoperative expectations (yellow pathway)

	Anticipated treatment plan	*Your role and responsibilities*
Preoperative clinic visit	-Review details of surgery and hospitalization -Review and sign consents -Anesthesia pre-surgery clinic -Order necessary tests and consultations with other teams -Review medication and diet plans -Preview nonopioid bundle for reducing opioid use after surgery -Determine approximate length of stay in Houston area	-Ask any and all questions relating to your operation and postoperative recovery -Arrange caregivers to help following discharge -Coordinate plans for Houston-area stay following discharge
Preoperative holding area	-Meet with anesthesia providers to finalize choice postoperative pain regimen that will go with your general anesthesia -A member of the surgical team will ask you for any updates since your last clinic visit	-Notify anesthesia staff of any concerns, past problems with anesthesia, or special requirements
Evening of surgery	-Monitor overnight in the postsurgery monitoring unit -Ensure adequate pain control using scheduled nonopioid medications and limited opioids as needed -Begin clear liquid diet, no carbonated beverages	-Get out of bed to chair with assistance that first day -Ask any questions regarding possible surgical drain and bladder tubes
Daily	-Draw blood for routine tests -Adjust medications as needed -Optimize pain control -Answer questions from both patient and caregivers -Involve other services as needed (pain team, nutrition team, prehab)	-Walk with assistance and increase activity as tolerated -Wear sequential compression devices (SCDs) while in bed to prevent blood clots -Perform breathing exercises 10×/h while awake
Day 1 (after surgery)	-Transfer to the GI surgery units -Remove the bladder tube -Advance diet to clear liquid diet, no carbonated beverages -Add Protein drinks 4×/d to diet -Administer stool softeners and natural laxatives	-Walk frequently with assistance (minimum 6×/d) -Eat small meals to avoid bloating -Sit in chair while eating
Day 2	-Advance diet to solid food -Increase bowel regimen medications -Begin to change IV medications to pills	-Shower with assistance today and each following day -Discuss dietary concerns with dietitian and receive dietary education -Walk frequently with assistance (minimum 10×/d)
Day 3	-Change all medications to pills -Remove drain if appropriate	-Arrange Houston-area lodging in anticipation of discharge -Walk immediately after eating and a minimum of 12×/d -Eat in moderation - Watch anticoagulation education video and practice blood thinner injections
Day 4	-Review discharge instructions and pain medication weaning process -Discharge from hospital to local lodging (if from out of town) with follow-up visit within a few days	-Ensure all questions are answered -Eat in moderation, drink enough liquids to stay hydrated

(IQR, 50–68 years), 55% were male, and median body mass index was 27.3 kg/m^2 (IQR 24.1–31.2 kg/m^2). Hepatectomy was performed almost universally for cancer diagnoses (103 [21.1%] primary malignant and 375 [77.0%] metastatic tumors). Additional clinicodemographic features are displayed in Table 3.

Operative Characteristics and Outcomes. Distribution of traditional extent of resection included: 67.1% ($n = 327$) partial, 4.9% (24) left, 11.3% (55) right, and 16.6% (81) extended hepatectomies. With the 3-level K–G classification, this was distributed to 35.7% (174) grade I, 19.7% (96) grade II, and 44.6% (217) grade III. Therefore, complexity of hepatectomy was distributed into 55.4% low–intermediate and 44.6% high complexity.

Overall median operative time was 300 minutes (IQR 230–385.25). Median operative time correlated with increasing complexity (low–intermediate: 261 min, IQR 195–338; high: 349 min, IQR 281–430; $+P < .001$). Complications were experienced by 48.3% (235) patients and major complications by 11.7% (57). Major complications occurred more frequently with complex hepatectomies (low–intermediate: 8.1% [22], high: 16.1% [35], $P = .006$). Readmissions were required in 11.7% (57) patients (low–intermediate: 7.4% [20], high: 17.1% [37]). Overall, postoperative hepatic insufficiency occurred in 1.0% (5) of patients, and there was no 90-day mortality.

Table 3
Demographics and clinical features between low–intermediate- and high-risk hepatectomy

Clinical characteristics	*Low to intermediate*	*%*	*High*	*%*	P
n	270	55.4	217	44.6	
Preoperative					
Age, median IQR	58.8	49.9–68.9	59.2	51–67.0	.726
Sex, male	148	54.8	121	55.8	.835
Race					.915
White	196	72.6	157	72.4	
Black	13	4.8	12	5.5	
Asian	17	6.3	17	7.8	
Other race	13	4.8	8	3.7	
BMI, median kg/m^2 IQR	27.4	23.9–31.3	27.2	24.2–31.1	.814
BMI ≥ 30 kg/m^2	83	30.7	67	30.9	.974
Any comorbidities	191	70.7	156	71.9	.781
Comorbidities ≥3	51	18.9	40	18.4	.898
Tumor type					.007
Benign disease	4	1.5	5	2.3	
Primary hepatic malignancy	43	15.9	60	27.6	
Metastatic malignancy	222	82.2	153	70.5	
Receipt of neoadjuvant chemotherapy	197	73.0	159	73.3	.939
Receipt of neoadjuvant radiation	7	2.6	4	1.8	.792
Intraoperative					
Operative time, median min IQR	261	194.5–338	349	280.5–430	<.001
Epidural	147	54.4	131	60.4	.375
Drain	29	10.7	69	31.8	<.001
Grade 1	174	64.4	0	0.0	
Grade 2	96	35.6	0	0.0	
Grade 3	0	0.0	217	100.0	
Postoperative					
Any complication	103	38.1	132	60.8	<.001
Major complications	22	8.1	35	16.1	.006
Neurologic	3	1.1	6	2.8	.178
Pulmonary	14	5.2	18	8.3	.169
Cardiac	12	4.4	17	7.8	.116
Renal	8	3.0	30	13.8	<.001
Gastrointestinal	22	8.1	24	11.1	.275
Endocrine	4	1.5	5	2.3	.503
Liver	24	8.9	46	21.2	<.001
Wound	39	14.4	56	25.8	.002
Hematology	8	3.0	17	7.8	.015
Other	39	14.4	40	18.4	.235
Readmission	20	7.4	37	17.1	.001
LOS median (d) IQR	4	3–5	5	4–6	<.001

BMI, body mass index.

Impact of RSPHP Implementation on LOS. Characteristics of patients who underwent hepatectomy pre- versus post-RSPHP implementation can be found in Table 4. There were no differences in the rate of major complications between the PRE and POST periods (PRE: 47 [12.6%], POST: 10 [8.8%], $P = .281$), as there was no change in our surgical techniques. There was no difference in 90-day readmission rates between PRE (12.6%) and POST (8.8%) periods ($P = .278$). Overall (PRE + POST) median LOS was associated with complexity (low–intermediate: 4 days, IQR 3–5; high: 5 days, IQR 4–6; $P < .001$). Implementation of RSPHPs decreased the median LOS by 1 hospital day in the high-complexity patients (PRE: 5 days, IQR 4–6; POST: 4 days, IQR 4–5; $P = .022$) and by 0.5 days in the low–intermediate-complexity (PRE: 4 days IQR 3–5; POST: 3.5 days, IQR 3–4; $P = .009$) cohorts in the POST implementation period. There was a statistically significant difference between PRE and POST RSPHP periods in both the low–intermediate- ($P < .001$) and high-complexity ($P = .029$) cohorts on univariate linear regression. Reflecting the impact of outliers, the mean reduction of LOS and reduced SD of LOS were observed in the POST period (PRE: 5.5 days, SD 7.5; POST: 4.4 days, SD 2.8). This reduction in total hospital days and variance in care (reflected by SD) was seen in both pathways: low–intermediate (PRE: 5.5 days, SD 9.6; POST: 4.0 days, SD 2.8) and high complexity (PRE: 5.7 days, SD 3.5; POST: 4.8 days, SD 2.7; Fig 2).

DISCUSSION

The creation and implementation of preoperatively assigned RSPHPs based upon K–G complexity classification resulted in a decrease in median and mean LOS (as well as IQR and SD) following hepatectomy. Higher complexity of hepatectomy was associated with a difference in expected median LOS of 4 days (low–intermediate) and 5 days (high complexity). Similarly, postoperative outcomes such as complication and readmission rates were higher in the high-complexity patients, highlighting the need for unique care pathways. The implementation of the RSPHPs reduced the median LOS by 1 day in the high-complexity patients and by half a day in the low–intermediate-complexity patients. Perhaps more reflective of their impact, the RSPHPs reduced IQR and SD for both low- and high-risk patients in their respective pathways when comparing cohorts pre- and post-

Table 4
Clinical features between before and after the implementation of the risk-stratified post hepatectomy pathways

	PRE	*%/IQR*	*POST*	*%/IQR*	P
n	374	76.8	113	23.2	
Median age	60.5	51.0–68.6	54.8	45.7–64.5	.002
Sex, male	196	52.4	73	64.6	.022
BMI ≥30	106	28.3	44	38.9	.033
Tumor type					.290
Benign	5	1.3	4	3.5	
Primary	81	21.7	22	19.5	
Metastatic	288	77.0	87	77.0	
Receipt of neoadjuvant chemotherapy	268	71.7	88	77.9	.191
Receipt of neoadjuvant radiation therapy	9	2.4	2	1.8	.848
Median operative time (min)	294	223.5–383.5	321	243.5–390	.203
Drain	82	21.9	16	14.2	.071
Epidural	234	62.9	44	38.9	<.001
Low–intermediate K–G	168	44.9	49	43.4	.77
Transfusions	20	5.3	5	4.4	.697
Any complications	183	48.9	46	40.7	.125
Major complications	47	12.6	10	8.8	.281
Liver-related complications	55	14.7	15	13.3	.704
Length of stay, median	4	3–5	4	3–5	.001
90-d readmission	47	12.6	10	8.8	.278

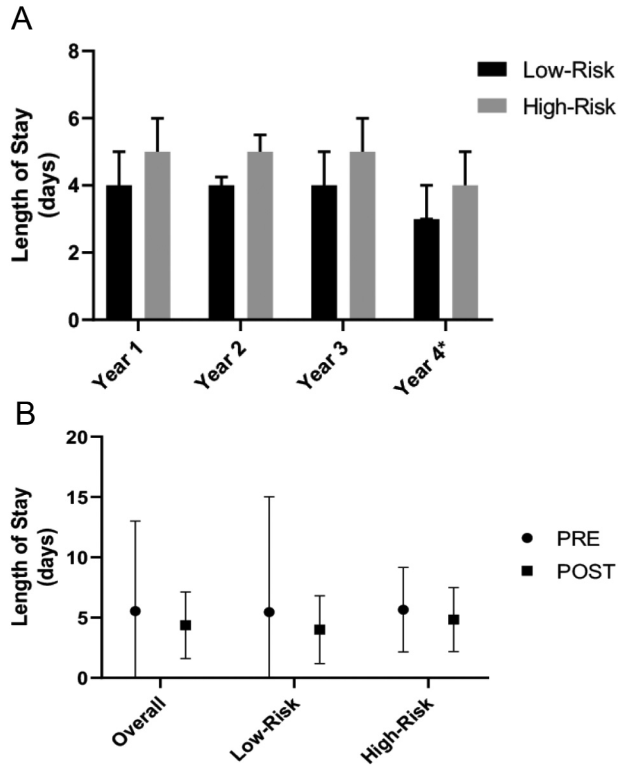

Fig 2. A, Median length of stay across years in the study for low- and high-risk RSPHP patients. Error bars denote interquartile range. *RSPHPs implemented in year 4. B, Mean length of stay according to RSPHP classification in PRE and POST study periods. Error bars denote standard deviation.

RSPHP implementation. These data reinforce the utility of using a complexity scale to group patients a priori to prospectively align their care plans and to counsel realistic expectations in the preoperative clinic.

Currently, enhanced recovery pathways are an advantageous contemporary perioperative care model for hepatectomy patients with benefits that include reduced LOS, decreased morbidity, decreased opioid use, and earlier recovery to baseline [3–5,23,24]. However, enhanced recovery pathways are often singular for all patients regardless of operative complexity. Moreover, many enhanced recovery pathways are aimed at reducing postoperative complications or tailored to risk for procedure-specific major complications. Because rates of liver insufficiency and failure are low in our cohort, we constructed pathways based upon anticipated complications according to operative complexity previously validated in open and laparoscopic surgery. This is the first study to individualize enhanced recovery pathways based upon *preoperatively assigned* risk and hepatectomy complexity with the validated (and modern) K–G classification. Further, the study presented here reports the feasibility and resultant reduction in LOS and variation of care following our first iteration of these posthepatectomy pathways, and further studies on refinement of these pathways, as well as adherence to individual elements, are near-term goals.

This study demonstrated that the K–G complexity classification helped refine the traditional one-size-fits-all enhanced recovery program for hepatectomy patients, which is subject to individual bias. Furthermore, traditional minor/major and segment-based hepatectomy classifications do not consistently stratify patients effectively by expected postoperative outcomes, wherein more complex "partial" parenchymal sparing hepatectomies (eg, posterior sectionectomy instead of a right hepatectomy) benefit the patient but are more technically demanding intraoperatively than traditionally classified [10,21,25–27]. The original K–G classification provided a practical system to associate the technical demands of a wide range (in complexity) of laparoscopic hepatectomies with outcomes, allowing for a safe guide that appropriately selects cases depending on the level of a surgeon's experience (trainee, junior faculty, senior faculty). The K–G classification was further applied to open hepatectomy and validated via a multinational effort at 2 high-volume centers, which is why we chose this classification system to create our new postoperative care pathways [12]. Anecdotally, the creation of risk stratified pathways improved our hepatobiliary group's consensus on electronic order sets and preoperatively stated LOS goals.

We have reported prior enhanced recovery efforts from our institution for hepato-pancreato-biliary surgery patient care and demonstrated continued iterative changes to these within a learning health care system model [13–15,24]. Specifically, a traditional enhanced recovery pathway was suggested within our group and resulted in a reduction in LOS after implementation within one surgeon's practice [24]. However, this pathway was not universally adopted and not standardized across patients, resulting in great variation in care (and stress on advanced practice providers and surgical trainees in daily care) and therefore providing the impetus for further pathway development. Here, the application of the K–G classification of hepatectomy to stratify patients into cohorts by anticipated LOS resulted in not only reduced unnecessary hospital days but decreased variation in care. This decrease in variation of care was associated with reduction in both IQR and SD (the latter accounting for outliers) in both low–intermediate- and high-risk hepatectomies. Although adhering to the core principles of enhanced recovery protocols [23], our preoperatively assigned pathways focus on basic pragmatic questions of every patient: the expected LOS and complication risk. These pathways provide a guide to communicate expectations among surgical team members (especially in handoff situations), patients and families, and inpatient providers.

There are several potential limitations to the current prospective cohort study. First, this is a single-institution analysis that inherently comes with selection bias because our patient population may not reflect that of other hospitals. Moreover, the complication rates of this analysis reflect the practice of a single group of hepatobiliary surgical oncologists. Our risk-stratified posthepatectomy pathways currently do not include minimally invasive hepatectomies, which are the subject of ongoing efforts within our group. Another limitation is the lack of standardization of regional anesthesia as patients receive either thoracic epidural anesthesia or regional anesthetic blocks, which may influence individual pathway elements and overall LOS. However, we are currently conducting a randomized clinical trial evaluating thoracic epidural anesthesia versus transversus abdominus plane blocks with the primary end point of LOS following hepatectomy to further refine our pathways (NCT03214510). Finally, although cost data were not presented here, we believe that the subsequent reduction in LOS reduces cost from a payer and institutional perspective, as well as by conserving resources. Despite these limitations, we believe that the results of this study are pragmatic, are generalizable, and could be replicated within any practice.

In conclusion, using the modified K-G complexity classification, the creation and implementation of RSPHPs reduced LOS and decreased variation in care without increasing readmissions after hepatectomy. These generalizable RSPHPs preoperatively stratify patients a priori into pathways for individualized preoperative discussions on realistic postoperative complications and LOS expectations.

This document summarizes the care that we anticipate you will receive in the hospital, and it is provided for your education. However, your health care team may make changes to your personal care plan based on your recovery.

Author Contribution

Bradford J. Kim, MD, MHS: Participated in research design, writing of the paper, performance of the research, contributed new reagents or analytic tools, participated in data analysis.

Elsa M. Arvide, MS, PA-C: Participated in research design, writing of the paper, performance of the research, contributed new reagents or analytic tools, participated in data analysis.

Cameron Gaskill, MD, MPH: Participated in research design, performance of the research, writing of the paper, participated in data analysis.

Allison N. Martin, MD, MPH: Participated in research design, performance of the research, writing of the paper, participated in data analysis.

Yoshikuni Kawaguchi, MD, PhD: Participated in research design, writing of the paper, participated in data analysis.

Yi-Ju Chiang, MSPH: Participated in research design, writing of the paper, participated in data analysis.

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Teresa Lee, MSN, FNP-C: Participated in writing of the paper, participated in data analysis.

Hop S. Tran Cao, MD: Participated in writing of the paper, participated in data analysis.

Yun Shin Chun, MD: Participated in writing of the paper, participated in data analysis.

Matthew H.G. Katz, MD: Participated in writing of the paper, participated in data analysis.

Jean Nicolas Vauthey, MD: Participated in writing of the paper, participated in data analysis.

Ching-Wei D. Tzeng, MD: Participated in research design, writing of the paper, performance of the research, contributed new reagents or analytic tools, participated in data analysis.

Timothy E. Newhook, MD: Participated in research design, writing of the paper, performance of the research, contributed new reagents or analytic tools, participated in data analysis.

Conflict of Interest

The authors have nothing to disclose for conflicts of interest.

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Ethics Approval

The Institutional Review Board at the University of Texas MD Anderson Cancer Center approved this study (PA19-0424).

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