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

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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 pancreatectoduodenectomy 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 posterolateral locations) or a left lateral sectionectomy. Anterolateral segments are defined as Couinaud segments II, III, IVb, V and VI. Posterolateral (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 posterolateral 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 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

| Pathway | Grade: 1–2 | Grade: 3 |
|---------|------------|----------|
| **Green pathway: K–G** | | |
| **Postoperative day 0 (evening)** | | |
| Perioperative analgesia | 1. Regional analgesia | 1. Regional analgesia |
| Diet | Noncarbonated clear liquid diet | Ice/sips of water |
| IV fluids | 75 mL/h | 75 mL/h |
| Mobility/function | 1. No nasogastric tube | 1. No nasogastric tube |
| Other medications | 1. Proton pump inhibitor or H2 blocker | 1. Proton pump inhibitor or H2 blocker |
| **Postoperative day 1** | | |
| Perioperative analgesia | Wean dose of PCA/epidural | Discontinue PCA/epidural off. Start oral pain medications. |
| Diet | Gastrointestinal introductory (soft/bland/small portioned) diet | Continue solid food |
| IV fluids | Discontinue IV fluids when PO intake ≥ 600 mL/shift | |
| Mobility/function | Ambulate ≥ 6 times | Ambulate ≥ 10 times |
| Other | | 1) Additional bowel regimen if needed |
| Disposition planning | | 2) Drain bilirubin if drain placed intraoperatively |
| **Postoperative day 2** | | |
| Perioperative analgesia | DiscontinuePCA/epidural off. Start oral pain medications. | |
| Diet | | |
| IV fluids | | |
| Mobility/function | | |
| Disposition planning | | |
| **Postoperative day 3** | | |
| Perioperative analgesia | All oral pain medications | |
| Mobility/function | Ambulate ≥ 12 times | Ambulate ≥ 12 times |
| Other | | 1) Additional bowel regimen if needed |
| Disposition planning | | 2) Drain bilirubin if drain placed intraoperatively |
| **Yellow pathway: K–G grade 3** | | |
| **Postoperative day 0 (evening)** | | |
| Perioperative analgesia | 1. Regional analgesia | 1. Regional analgesia |
| Diet | Noncarbonated clear liquid diet | Ice/sips of water |
| IV fluids | 75 mL/h | 75 mL/h |
| Mobility/function | 1. No nasogastric tube | 1. No nasogastric tube |
| Other medications | 1. Proton pump inhibitor or H2 blocker | 1. Proton pump inhibitor or H2 blocker |
| **Postoperative day 1** | | |
| Perioperative analgesia | Wean dose of PCA/epidural | Wean dose of PCA/epidural |
| Diet | Noncarbonated clear liquid diet | Gastrointestinal introductory (soft/bland/small portioned) diet |
| IV fluids | Discontinue IV fluids when PO intake ≥ 600 mL/shift | Discontinue IV fluids when PO intake ≥ 600 mL/shift |
| Mobility/function | Ambulate ≥ 6 times | Ambulate ≥ 10 times |
| Other | | 1) Additional bowel regimen if needed |
| Disposition planning | | 2) Drain bilirubin if drain placed intraoperatively |
| **Postoperative day 2** | | |
| Perioperative analgesia | Discontinue PCA/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 | Ambulate ≥ 10 times |
| Other | | 1) Additional bowel regimen if needed |
| Disposition planning | | 2) Drain bilirubin if drain placed intraoperatively |
| **Postoperative day 3** | | |
| Perioperative analgesia | All oral pain medications | All oral pain medications |
| Mobility/function | Ambulate ≥ 12 times | Ambulate ≥ 12 times |
| Other | | 1) Additional bowel regimen if needed |
| Disposition planning | | 2) Drain bilirubin if drain placed intraoperatively |
| **Postoperative day 4** | | |
| Mobility/function | Ambulate ≥ 20 times | Ambulate ≥ 20 times |
| Disposition planning | | 1) Additional bowel regimen if needed |
| **Other** | | 2) Drain bilirubin if drain placed intraoperatively |
| **Disposition planning** | | 3) Remove drain if drain bilirubin < 3 × serum bilirubin level |

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

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- Change any remaining IV medications to pills
-戴普通家居衣服
- 确认在休斯敦地区的住宿计划
- 在进食后散步，每天至少10次
- 多喝水以保持水分
- 合理进食

**Day 3**
- 移除引流管（如适用）
- 检查并解释出院指导和疼痛药物停用过程
- 在从医院出院至当地住宿（如来自外地）后，安排在几天内进行随访

此文档总结了我们将为您在医院期间提供的护理，目的是为您提供教育。然而，您的医疗团队可能会根据您的恢复情况对您的个人护理计划做出更改。

** Liver surgery postoperative expectations (yellow pathway)**

**Preoperative clinic visit**
- 详细讨论手术和入院情况
- 签署知情同意书
- 麻醉术前会诊
- 订单必要的测试和与其他团队的会诊
- 预览非阿片类止痛药，以减少术后使用阿片类药物
- 确定在休斯敦地区的停留时间
- 询问与您的手术和术后恢复有关的任何问题
- 安排护理人员帮助出院
- 协调休斯敦地区出院后的跟进计划

**Preoperative holding area**
- 与麻醉科医生会面，最终确定与您的全身麻醉相配的术后止痛方案
- 医生将询问您自上次会诊以来的任何更新
- 通知麻醉科工作人员您有无更新、过去的麻醉问题或特殊要求

**Evening of surgery**
- 术后整晚在术后监测单元进行监测
- 确保使用预定的非阿片类药物和有限的阿片类药物来控制疼痛
- 开始清淡饮食，不喝含气饮料
- 在第一天在帮助下起床并坐在椅子上
- 询问可能的手术引流管和膀胱管

**Day 1 (after surgery)**
- 转至GI手术单元
- 移除膀胱管
- 进一步饮食至清淡饮食
- 开始蛋白饮料
- 排便调节药
- 调整饮食
- 优化疼痛控制
- 回答患者和护理人员的问题
- 涉及其他服务（如：疼痛团队、营养团队、预习惯团队）
- 每日-进行呼吸练习10次/小时
- 走路并增加活动
- 在床时穿下肢循环装置

**Day 2**
- 管理导尿软并自然泻药
- 饮食改为固体食物
- 增加排便常规药
- 开始将IV药物改为片剂

**Day 3**
- 更改所有药物为片剂
- 移除引流管
- 执行抗凝血教育视频并练习抗凝血剂注射
- 收离院指导和疼痛药物停用过程
- 在从医院出院至当地住宿（如来自外地）后，安排在几天内进行随访

**Day 4**
- 饮食回到普通食物
- 使用非处方药
- 吃小餐以避免胀气
- 坐在椅子上吃东西
- 每日-注射抗凝血剂
- 在第二天和之后每天用帮助洗澡
- 讨论饮食问题
- 更新预报
- 走路并每天至少10次
- 吃在适度的
- 喝足够的液体来保持水分
- 确保所有问题都得到解答

**Day 5**
- 完全恢复
- 完全退出
- 完全恢复正常生活

**Day 6**
- 完全恢复
- 完全退出
- 完全恢复正常生活

**Day 7**
- 完全恢复
- 完全退出
- 完全恢复正常生活

**Day 8**
- 完全恢复
- 完全退出
- 完全恢复正常生活

**Day 9**
- 完全恢复
- 完全退出
- 完全恢复正常生活

**Day 10**
- 完全恢复
- 完全退出
- 完全恢复正常生活

**Day 11**
- 完全恢复
- 完全退出
- 完全恢复正常生活

**Day 12**
- 完全恢复
- 完全退出
- 完全恢复正常生活

**Day 13**
- 完全恢复
- 完全退出
- 完全恢复正常生活

**Day 14**
- 完全恢复
- 完全退出
- 完全恢复正常生活

**Day 15**
- 完全恢复
- 完全退出
- 完全恢复正常生活

**Day 16**
- 完全恢复
- 完全退出
- 完全恢复正常生活

**Day 17**
- 完全恢复
- 完全退出
- 完全恢复正常生活

**Day 18**
- 完全恢复
- 完全退出
- 完全恢复正常生活

**Day 19**
- 完全恢复
- 完全退出
- 完全恢复正常生活

**Day 20**
- 完全恢复
- 完全退出
- 完全恢复正常生活

**Day 21**
- 完全恢复
- 完全退出
- 完全恢复正常生活

**Day 22**
- 完全恢复
- 完全退出
- 完全恢复正常生活

**Day 23**
- 完全恢复
- 完全退出
- 完全恢复正常生活

**Day 24**
- 完全恢复
- 完全退出
- 完全恢复正常生活

**Day 25**
- 完全恢复
- 完全退出
- 完全恢复正常生活

**Day 26**
- 完全恢复
- 完全退出
- 完全恢复正常生活

**Day 27**
- 完全恢复
- 完全退出
- 完全恢复正常生活

**Day 28**
- 完全恢复
- 完全退出
- 完全恢复正常生活
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 occurred with 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.

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).

### 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 | 52.5 | .835 |
| Race                     | 16                  | 4.8  | 15  | 9.5  | .915 |
| White                    | 196                 | 72.6 | 157 | 72.4 |        |
| Black                    | 13                  | 4.8  | 12  | 7.5  |        |
| Other race               | 13                  | 4.8  | 8   | 3.7  |        |
| BMI, median kg/m² IQR    | 27.4                | 23.9–31.3 | 27.2 | 24.2–31.1 | .814 |
| BMI ≥ 30 kg/m²           | 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 | 66  | 27.6 |        |
| Metastatic malignancy    | 222                 | 82.2 | 153 | 70.3 |        |
| Receipt of neoadjuvant chemotherapy | 197 | 73.0 | 159 | 73.3 | .939 |
| Receipt of neoadjuvant radiation | 7 | 2.6 | 4 | 1.8 | .792 |

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

| n | PRE %/IQR | POST %/IQR | P |
|---|----------|------------|---|
| 374 | 76.8 | 113 | 23.2 |
| 605 | 51.0–68.6 | 54.8 | 45.7–64.5 | .002 |
| 196 | 52.4 | 73 | 64.6 | .022 |
| 106 | 28.3 | 44 | 38.9 | .033 |
| 5 | 1.3 | 4 | 3.5 | .290 |
| 88 | 77.0 | 87 | 77.0 | .191 |
| 268 | 71.7 | 88 | 77.9 | .848 |
| 9 | 2.4 | 2 | 1.8 | .084 |

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-
RSHP 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 hepatopancreatobiliary 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 RSHPs reduced LOS and decreased variation in care without increasing readmissions after hepatectomy. These generalizable RSHPs 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.
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