A comparison of right posterior sectorectomy with formal right hepatectomy: a dual-institution study

Sarah B. Fisher, Peter J. Kneuertz, Rebecca M. Dodson, Sameer H. Patel, Shishir K. Maithel, Juan M. Sarmiento, Maria C. Russell, Kenneth Cardona, Michael A. Choti, Charles A. Staley III, Timothy M. Pawlik & David A. Kooby

1Department of Surgery, Division of Surgical Oncology, Winship Cancer Institute and 2Department of Surgery, Emory University, Atlanta, GA, USA and 3Department of Surgery, Sidney Kimmel Comprehensive Cancer Center, Johns Hopkins University School of Medicine, Baltimore, MD, USA

Abstract

Objectives: Right posterior sectorectomy (RPS) preserves liver volume but typically requires a longer parenchymal transection distance than does right hepatectomy (RH). This study was conducted to define the advantages of one approach over the other.

Methods: Databases at two institutions were retrospectively reviewed for all patients submitted to RPS or RH between January 2000 and August 2012. Primary outcomes were perioperative complications and 90-day mortality.

Results: Patients undergoing RPS (n = 100) and RH (n = 480), respectively, were similar in demographics, comorbidities, operative indications and Model for End-stage Liver Disease (MELD) mean scores (7.8 in the RPS group and 7.7 in the RH group; P = 0.49). A comparison of the RPS group with the RH group showed no significant differences in mean estimated blood loss (697 ml versus 713 ml; P = 0.900), rate of transfusions (19.2% versus 17.1%; P = 0.720), margin-positive resection (9.2% versus 11.6%; P = 0.70), complications (41.8% versus 42.0%; P = 1.000), bile leak (3.0% versus 4.0%; P = 0.360), or length of stay (7.5 days versus 8.3 days; P = 0.360). Postoperative hepatic insufficiency (defined as a postoperative bilirubin level of >7 mg/dl or significant ascites), occurred less frequently after RPS (1.0% versus 8.5%; P = 0.005). Operation type remained an independent determinant of postoperative hepatic insufficiency after controlling for preoperative risk factors (RH: hazard ratio = 9.628, 95% confidence interval 1.295–71.573; P = 0.027). A total of 28 (4.8%) patients died within 90 days; these included 25 (5.2%) patients in the RH group and three (3.0%) in the RPS group (P = 0.449).

Conclusions: Despite similar blood loss and overall morbidity, RPS is associated with less hepatic insufficiency than RH. Right posterior sectorectomy is parenchyma-sparing and should be strongly considered when it is technically feasible and oncologically sound.

Received 6 March 2013; accepted 5 April 2013

Correspondence

David A. Kooby, 1365C Clifton Road NE, Building C, 2nd Floor, Atlanta, GA 30322, USA. Tel: +1 404 778 3805. Fax: +1 404 778 4255. E-mail: dkooby@emory.edu

Introduction

Improvements in patient selection, surgical technique and perioperative care have led to the increased use of partial hepatectomy for both benign and malignant indications with acceptable morbidity and mortality. Partial hepatectomy is used in the management of patients with primary hepatic tumours and those with limited hepatic metastases with appropriate disease biology. Hepatic resection for metastatic disease is most frequently
performed in patients with colorectal\(^5\)-\(^7\) and neuroendocrine\(^8\) malignancies, but has also been reported in patients with metastases from breast cancer,\(^9,10\) gastrointestinal stromal tumours,\(^11\) ovarian cancer,\(^12\) renal cell carcinoma\(^13\) and other malignancies.\(^4,14\) In the current era of modern chemotherapeutic and targeted molecular agents, patients with metastatic disease who historically would never have been considered appropriate for PH are now potential candidates.\(^6,8,15\) Some may even benefit from repeat hepatectomy in the face of second and third recurrences\(^4,6,16,17\) and thus the preservation of liver parenchyma at the time of first resection is valuable. Over the past three decades enhanced understanding of hepatic anatomy and the use of intraoperative ultrasound have resulted in the increased use of parenchyma-preserving segmental resections,\(^1\) with a subsequent decrease in formal lobar resection in some series.\(^18\) For lesions located in the posterior sector (segments VI and VII), either formal right hepatectomy (RH) or segmentally based right posterior sectorectomy (RPS, also characterized as right posterior sectionectomy\(^19\)) may be performed.

Right posterior sectorectomy preserves functional parenchyma, but requires the same mobilization as RH, often with division of the right hepatic veins,\(^14,19\) and a longer parenchymal transection line than RH (Fig. 1a–c). Isolation of the right posterior pedicle typically requires intraoperative ultrasound guidance (Fig. 2).\(^20\) The advantages and disadvantages of RPS compared with a more traditional RH approach are not well documented. This dual-institution retrospective study was conducted to compare perioperative outcomes in patients undergoing, respectively, RPS and RH.

**Materials and methods**

Hepatobiliary resection databases at two institutions (Emory University, Atlanta, GA, USA and Johns Hopkins University, Baltimore, MD, USA) were queried for all patients aged \(\geq 18\) years and submitted to either RPS or RH between January 2000 and August 2012. Brisbane terminology was used to describe hepatic anatomy.\(^18,21\) According to Brisbane terminology, ‘right posterior pedicle’ typically represents the confluence of right posterior and right posterior inferior pedicles.
sectorectomy’, ‘right posterior sectionectomy’ and ‘right lateral sectionectomy’ are equivalent terms used to describe the anatomic resection of segments VI and VII with ligation of the posterior branch of the right portal pedicle, with or without division of the right hepatic vein(s). ‘Right posterior sectorectomy’ (RPS) will be used throughout this manuscript. Right hepatectomy was defined as the resection of anatomic segments V–VIII with or without caudate lobectomy. Patients who required ligation of the middle hepatic vein were included only if the transection plane paralleled the vein and segment IV was spared. Patients who required extended RH or anatomic resection of adjacent segments that would alter the defining hepatic procedure were excluded. Patients who required additional minor hepatic procedures (i.e. wedge resection, segmentectomy, radiofrequency or microwave ablation) or additional non-hepatic resections (i.e. bowel resection, hernia repair) were included. Adhesiolysis, cholecystectomy and wedge biopsy, when performed in conjunction with either RPS or RH, were not considered as additional procedures. A retrospective chart review was performed for clinicopathologic characteristics, perioperative details, short-term outcomes and perioperative mortality. Smoking history and alcohol abuse were determined from documentation in the admission history and physical or clinic notes of the attending physician. The presence of preoperative ascites was determined from documentation in the admission history and physical or clinic notes of the attending physician. The presence of preoperative ascites was determined by clinical evaluation or the presence of fluid consistent with ascites on cross-sectional imaging. Preoperative laboratory values were determined from laboratory reports within 30 days of surgery; when multiple laboratory findings were available, the values closest to the date of surgery were recorded. Model for End-stage Liver Disease (MELD) scores and Child–Pugh class were calculated accordingly. Postoperative hepatic insufficiency (HI) was defined as postoperative peak bilirubin of >7 mg/dl or the development of postoperative ascites as determined by a postoperative drain output that exceeded 500 ml in a 24-h period or the documentation in the medical record of significant ascites requiring intervention. Complications were graded according to the Clavien–Dindo system of classification; complications of Grades III–V were considered to indicate major morbidity. Perioperative mortality was defined as death within 90 days of surgery or during the same hospitalization. Overall survival was defined as the time elapsed between the date of surgery and the date of last contact or death.

Permission for the study was obtained prior to data collection from the institutional review board at each institution. All data were maintained in a manner compliant with the Health Insurance Portability and Accountability Act of 1996.

Specific technique

Resections were performed under low central venous pressure general anaesthesia, usually with the patient in the Trendelenburg position. Details of the open14,20,22,26,27 and laparoscopic28–30 technique have been thoroughly described elsewhere. For open resections, a vertical upper midline incision or a subcostal incision with or without extension to a vertical midline laparotomy was performed according to the surgeon’s preference. Intraoperative ultrasound was used at the discretion of the operating surgeon to define anatomy and make a staging evaluation. Both RPS and RH required the full mobilization of the right hemiliver. A Pringle manoeuvre was used at the discretion of the surgeon. In most resections, vascular control of the corresponding inflow and outflow structures was obtained prior to parenchymal transection; in RPS temporary occlusion of the right posterior sector pedicle was often used to demarcate the parenchyma. After the anatomy had been established, the hepatic parenchyma was divided using either the traditional clamp-crush technique or one of several energy-assisted devices or staplers. Haemostatic agents were used at the discretion of the surgeon. Postoperatively, patients were admitted to either the intensive care unit or the surgical floor as mandated by their condition.
Statistical analysis
Data were analysed using IBM SPSS Statistics for Windows Version 20.0 (IBM Corp., Armonk, NY, USA). Continuous variables were compared using Student’s t-test. Categorical variables were compared using Pearson’s chi-squared and Fisher’s exact tests, as appropriate. Overall survival analyses were calculated using Kaplan–Meier log-rank survival analysis, and 90-day mortalities were excluded from analysis. A P-value of <0.05 was considered to indicate statistical significance. Univariate and multivariate binary logistic regression analyses were used to evaluate risk factors for postoperative HI. Clinically relevant preoperative factors significant on univariate binary logistic regression analysis to a P-value of <0.1 were included in the multivariate model. In cases of multicollinearity between covariates, the single factor that best encompassed the clinical entity was selected for the model.

Results
Preoperative demographics, comorbidities and operative indications
Patient demographics, comorbidities and pathologic characteristics are shown in Table 1. No patient had encephalopathy. Patients undergoing, respectively, RPS (n = 100) and RH (n = 480) were similar in age, sex, race, comorbidities and American Society of Anesthesiologists (ASA) risk score, and had similar preoperative albumin and bilirubin levels and MELD scores (Table 1). Most patients had a Child–Pugh score of 5 (n = 392, 67.6%) and the majority were classified as Child–Pugh class A. More of the small subset of patients classified as Child–Pugh class B underwent RPS than RH (Table 1). No patients were classified as Child–Pugh class C.

Of the 444 patients who underwent hepatic resection for malignancy, 210 (47.3%) received neoadjuvant chemotherapy. The proportions of patients receiving neoadjuvant chemotherapy did not differ between operative groups (50.0% of the RPS group, 47.0% of the RH group; P = 0.725). In patients who underwent resection for malignancy, the five most common diagnoses were colorectal liver metastases (CLM) (n = 256, 57.7%), hepatocellular carcinoma (n = 65, 14.6%), cholangiocarcinoma (n = 36, 8.1%), metastases from neuroendocrine tumours (n = 24, 5.4%) and breast carcinoma (n = 11, 2.5%). Other diagnoses included metastatic renal cell carcinoma (n = 8, 1.8%), adenocarcinoma not otherwise specified (n = 7, 1.6%), sarcoma (n = 7, 1.6%), gastrointestinal stromal tumours (n = 5, 1.1%), and other less common malignancies (n = 25, 5.6% total, less than 1% each). There were no differences in the frequencies of the five most common histologic diagnoses between patients with malignancy undergoing RPS versus RH (P = 0.254).

In the 136 patients submitted to hepatic resection for benign indications, the most common indication was haemangiomata (n = 31, 22.8%), followed by adenoma (n = 22, 16.2%), focal nodular hyperplasia (n = 17, 12.5%), abscess/infectious process (n = 12, 8.8%), cystic disease (n = 12, 8.8%), cholangitis (n = 8, 5.9%), and haematoma (n = 7, 5.1%). Other indications included angiomyolipoma, arteriovenous malformation, biliary cystadenoma, cirrhotic nodule and hepatolithiasis (<5%).

Operative procedures and perioperative outcomes
Laparoscopic resection was possible in 57 patients (9.8%) and was employed similarly in patients undergoing RPS and RH (Table 2). Amongst patients undergoing RPS, the right hepatic vein was resected in 52 patients (53.6%). Amongst patients undergoing RH, the middle hepatic vein was resected in four patients (0.1%). Additional surgical procedures were required in 110 patients (19.0%), and involved hepatic procedures in 83 (75.5%), extrahepatic procedures in 24 (21.8%), and a combination of both in three (2.7%) patients. The most common additional procedure was hepatic wedge resection or anatomic segmentectomy (n = 36, 6.2% of all patients), followed by intraoperative ablation (n = 28, 4.8%). Bowel resection was performed in 14 patients (2.4%); the incidence of bowel resection did not differ between the RPS and RH groups (4.0% versus 2.1%; P = 0.278). Two patients required distal pancreatectomy in addition to hepatic resection; one underwent RH for metastatic colorectal cancer and required splenectomy, and the other underwent RPS for metastatic pancreatic neuroendocrine carcinoma. Other less frequent operations included abdominal hernia repair, adrenalectomy, hepatic cyst fenestration and nephrectomy (<1%). The frequency of additional surgical procedures did not differ by hepatic resection type (20.0% in the RPS group and 18.8% in the RH group; P = 0.881).

Overall, 242 (41.7%) patients experienced complications and 87 (15.0%) experienced major complications. Reoperation was required in 18 (3.1%) patients. A total of 28 (4.5%) patients died during the 90-day postoperative period. Patients undergoing RPS and RH had similar volumes of operative blood loss, transfusion requirements, margin-positive resection rates, complication rates and hospital lengths of stay (Table 2). Postoperative HI occurred less frequently after RPS (Table 2). Of the 42 patients with HI, 26 (61.9%) had a postoperative bilirubin level of >7 mg/dl and an additional 16 (38.1%) were considered to have HI based solely on the presence of significant ascites. When the definition of HI was narrowed to include only patients with a bilirubin level of >7 mg/dl,23 all patients with HI were found to have undergone RH (n = 26, 4.5% of all patients; P = 0.013). Of the 42 patients with HI, six (1.0% of the entire cohort) progressed to acute postoperative hepatic failure; all had undergone RH (P = 0.596). Perioperative mortality at 60 days and 90 days was higher in patients submitted to RH than in those submitted to RPS, but the difference was not statistically significant (Table 2).

The incidence of HI was higher in patients defined as being in Child–Pugh class B preoperatively (six of 57, 10.5%); all six of these patients met criteria for HI based on hyperbilirubinaemia. Four of the six patients experienced an increase in bilirubin of >10 mg/dl above baseline; only one had a preoperative bilirubin level of >7 mg/dl.

The incidence of HI was higher in patients with malignancy (n = 41, 9.3%) than in those undergoing resection for benign
indications \((n = 4, 2.9\%)\) \((P = 0.016)\). Preoperative factors significantly associated with HI on univariate analysis are shown in Table 3. In comparison with RPS, RH remained an independent risk factor for the development of postoperative HI after controlling for preoperative risk factors in all patients \([\text{hazard ratio (HR)} = 9.628, 95\% \text{ confidence interval (CI)} 1.295–71.573; P = 0.027]\) (Table 3) and in the subset of patients submitted to resection for malignancy \((\text{HR} = 9.662, 95\% \text{ CI} 1.288–72.450; P = 0.027)\) (Table 4).
Longterm outcomes: patients with malignancy
Postoperatively, 30 (30.0%) patients in the RPS group and 164 (34.2%) patients in the RH group received adjuvant chemotherapy \( (P = 0.479) \). Median follow-up in patients with malignancy \( (n = 444) \) was 15.6 months (range: 0.0–150.9 months); 172 (38.7%) patients had died at the time of last follow-up. In patients with CLM (the largest subgroup based on pathology), median follow-up was 17.3 months (range: 0.0–130.5 months); there were no significant differences in length of follow-up between patients submitted to RPS and those submitted to RH (19.6 months versus 28.5 months; \( P = 0.133 \)). Median overall survival was 54.1 months (95% CI 41.5–66.7 months). Overall survival did not differ between patients submitted to RPS and RH, respectively (Fig. 3).

Discussion
The purpose of this study was to compare the perioperative outcomes of two methods of partial hepatectomy for right-sided
pathology: formal RH (segments V–VIII), and RPS (segments VI and VII). For lesions located in the posterior sector, either RPS or formal RH may be performed. The posterior location and relative sizes of segments VI and VII make RPS technically challenging; some surgeons view the lengthy parenchymal resection as a potential cause of morbidity, the risk for which must be weighed against the value of parenchymal preservation. Although others have documented successful series of patients submitted to RPS,\textsuperscript{14,19,31–33} this retrospective analysis is the first to focus on differences in perioperative outcomes between patients undergoing RPS and RH, respectively.

Adequate parenchymal preservation is particularly important in view of the aggressive surgical approach employed today for the treatment of primary liver cancers and hepatic metastases. Advances in chemotherapeutic and targeted agents mean that hepatic resection is pursued frequently in patients who historically would have been considered unresectable. Other patients with favourable disease biology show extended survival with repeat hepatectomy.\textsuperscript{4,6,16} In one of the largest series of major hepatic resections to be reported, Jarnagin et al.\textsuperscript{1} described one or more repeat hepatectomies in 85 of 1568 (5.4%) patients who underwent surgery during 1991–2001. A recent large series (\(n = 2628\)) reported from the MD Anderson Cancer Center (MDACC) cited an increase in the frequency of repeat hepatectomy from 6.1% to 12.2% (\(P = 0.02\)) between 1997 and 2011.\textsuperscript{34} Another series restricted to patients undergoing repeat hepatectomy for CLM (\(n = 246\)) demonstrated that significant proportions of well-selected patients may go on to require third (18.7%) and fourth (3.7%) hepatectomies.\textsuperscript{17} With continued improvements in medical therapy and changes in surgical approaches over time, the rate of re-resection of hepatic metastases can be expected to increase. Because the current study was designed to assess perioperative outcomes, specific long-term data on recurrence and subsequent repeat hepatic resection were unavailable. In theory, patients undergoing RPS, with the resultant preservation of the parenchyma and right portal structures, are more likely to have sufficient functional hepatic volume to allow for aggressive repeat resections when oncologically appropriate. The clinical characteristics, perioperative morbidity and mortality, and oncologic outcomes of patients requiring repeat resection should be

### Table 4 Multivariate analysis of preoperative risk factors for postoperative hepatic insufficiency in patients with malignancy (\(n = 444\))

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Univariate</th>
<th>Multivariate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(P)-value</td>
<td>UNivariate</td>
</tr>
<tr>
<td>Decreased platelets\textsuperscript{a}</td>
<td>0.029</td>
<td>0.029</td>
</tr>
<tr>
<td>Increased total bilirubina\textsuperscript{a}</td>
<td>&lt;0.0001</td>
<td>0.033</td>
</tr>
<tr>
<td>Neoadjuvant chemotherapy</td>
<td>0.050</td>
<td>0.050</td>
</tr>
<tr>
<td>Male sex</td>
<td>0.055</td>
<td>0.055</td>
</tr>
<tr>
<td>Increasing ASA score</td>
<td>0.087</td>
<td>0.087</td>
</tr>
<tr>
<td>Hepatitis C</td>
<td>0.012</td>
<td>0.012</td>
</tr>
<tr>
<td>Increasing MELD score</td>
<td>0.002</td>
<td>0.002</td>
</tr>
<tr>
<td>Perioperative blood transfusion</td>
<td>0.055</td>
<td>0.055</td>
</tr>
<tr>
<td>RH (versus RPS)</td>
<td>0.031</td>
<td>0.031</td>
</tr>
</tbody>
</table>

\(P\)-values in bold indicate statistically significant differences (at \(P < 0.05\)). HR, hazard ratio; 95% CI, 95% confidence interval; ASA, American Society of Anesthesiologists risk score; MELD, Model for End-stage Liver Disease; RH, right hepatectomy; RPS right posterior sectorectomy.

\(a\)Excluded from multivariate model as a result of multicollinearity with MELD score.

Figure 3 Overall survival in patients with colorectal liver metastases undergoing right posterior sectorectomy (RPS) and right hepatectomy (RH), respectively (\(P = 0.642\)). Survival is truncated at 65 months, when the number at risk does not exceed five.
characterized in future studies focused on a single disease type. Regardless, the potential rate of repeat hepatectomy underlines the importance of parenchymal preservation in the initial operation.

Despite the advantage of parenchymal preservation, there are multiple reasons for pursuing RH rather than RPS. The technical difficulty of RPS is greater than that of RH and differences in the surgeon’s level of comfort with the operation and intraoperative ultrasound are potential factors that are difficult to capture in a retrospective study. Other factors that may influence the operative approach and are also not captured in this study include differences in cost and reimbursement between the two procedures (which have unique ICD-9 codes and financial implications). Financial cost should never determine any oncologic procedure, but consideration of costs may be reasonable if two procedures are deemed equivalent in all other aspects. Although the current study suggests that RPS is similar to RH in terms of morbidity, conclusions on the equivalence of the two procedures are limited by the study’s retrospective nature and the lack of data on longterm oncologic outcomes.

A more measurable factor that may cause some to favour RH over RPS refers to increases in operative blood loss and/or bile leak associated with the longer transection distance required in RPS. However, in this study RPS was not associated with significantly different rates of blood loss, transfusion or bile leak. Patients submitted to RPS were similar to those submitted to RH in terms of demographics, preoperative comorbidities and operative indications. Patients submitted to RPS had a significantly lower rate of postoperative HI than those submitted to RH, which is probably attributable to greater parenchymal preservation. The preservation of functional parenchyma is well documented as a predictive factor for decreased morbidity and mortality, both overall and liver-related. Overall, morbidity rates in both operative groups were similar, which suggests that RPS is comparable with RH in appropriately selected patients, and may be advantageous in terms of parenchymal preservation.

The incidence of HI in this study is within the ranges reported previously, but is higher than that cited in a recent large series of major hepatic resections from MDACC (2.6–3.1%). Direct comparisons between institutions of rates of HI are made difficult by variations in extents of resection and definitions of HI. The International Study Group of Liver Surgery defines HI as: ‘...impaired ability of the liver to maintain its synthetic, excretory, and detoxifying functions, which are characterized by an increased international normalized ratio (INR) and concomitant hyperbilirubinaemia.’ Using the INR as a measure for HI has limitations because it is influenced by exogenous vitamin K administration or by the transfusion of clotting factors such as fresh frozen plasma. Postoperative bilirubin of >7 mg/dl has been proposed by others as a simplified and standardized definition and was the strongest predictor of morbidity and mortality (all-cause and liver-related) after major hepatic resection in a multi-institution series of 1059 patients. In the recent MDACC study, HI was defined as postoperative bilirubin >7 mg/dl. The current study used the same definition of hyperbilirubinaemia, but also used the presence of significant ascites as a surrogate criterion for hepatic dysfunction, which accounted for slightly more than one-third of the diagnoses of HI. When HI was defined only by a bilirubin level of >7 mg/dl, its rate in the current study decreased to 4.5% and occurred only in patients who had undergone RH.

Operation type (RH) remained significantly associated with increased risk for HI after other preoperative risk factors were accounted for, including male gender and presence of diabetes mellitus and/or hepatitis C. Another potential contributor to HI that has been less consistently documented is receipt of neoadjuvant therapy. In the current study, neoadjuvant therapy was not significantly associated with HI, which mirrors findings in other studies. It is likely that simple receipt of therapy is not an accurate predictor of chemotherapy-induced liver injury, but given the heterogeneity of chemotherapy regimens utilized within the diverse study population, the accurate quantification of specific regimens and duration of therapy was not possible. The presence of underlying liver disease, such as steatosis, is associated with an increased incidence of complications after major hepatectomy and parenchymal preservation may be particularly beneficial in such patients. In heavily pretreated populations with a high frequency of chemotherapy-induced liver injury and in patients with a higher incidence of underlying liver disease, the parenchymal preservation afforded by RPS may be particularly beneficial.

The present study has several limitations. It was not possible to review preoperative radiographic studies because procedures for storing radiographic studies changed over time at each institution and a large percentage of patients had obtained preoperative radiographic studies at outside facilities. Thus it was not possible to identify patients who underwent RH but would have been suitable candidates for RPS; this represents a major limitation of this retrospective study. However, it is the authors’ opinion that a prospective randomized controlled trial comparing RPS with RH is unlikely to accrue. The study is also limited by its inability to accurately identify the percentage of patients requiring a Pringle manoeuvre or the duration of the manoeuvre, which may have important implications on the development of postoperative HI. Finally, although the present data allow an initial evaluation of longterm survival in patients with CLM, the oncologic non-inferiority of RPS in this heterogeneous group of patients cannot be fully evaluated. Future studies examining longterm outcomes in more homogeneous patient populations matched for tumour size and location are required.

The current, large, dual-institution study demonstrates that patients undergoing RPS and RH, respectively, experience similar rates of blood loss and overall morbidity (including bile leak), but that patients submitted to RPS experience significantly less postoperative HI. Right posterior sectorectomy is parenchyma-sparing and should be considered when it is technically feasible and oncologically sound in patients with disease of the right posterior sector.
Conflicts of interest
None declared.

References


