Survival after hepatic resection: impact of surgeon training on long-term outcome

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Accepted for publication Oct. 9, 2012

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DOI: 10.1503/cjs.023611

Background: Mortality for liver resection has remarkably improved owing to multiple factors. We sought to determine the impact of the various types of fellowship training on patient survival after liver resection.

Methods: Patients who underwent hepatic resection between 1995 and 2004 in either the Calgary or Capital health regions (Edmonton) of Alberta, Canada, were identified using ICD-9 and -10 codes. Primary outcomes included in-hospital mortality and patient survival according to surgeon volume and training type (surgical oncology v. hepatobiliary v. others).

Results: A total of 1033 patients underwent hepatic resection. Surgeon volume was not predictive of either in-hospital mortality (adjusted odds ratio 0.63, 95% confidence interval [CI] 0.32–1.20) or patient survival (unadjusted hazard ratio 1.11, 95% CI 0.82–1.51). Nonsignificance was also demonstrated for a surgeon's type of fellowship training.

Conclusion: The various modes of fellowship training do not appear to influence in-hospital mortality or patient survival after hepatic resection.

Contexte : Le taux de mortalité dans les cas de résection du foie a diminué considérablement à cause de multiples facteurs. Nous avons cherché à déterminer l'effet des divers types de formation au niveau du fellowship sur la survie des patients après une résection du foie.

Méthodes : Les patients qui ont subi une résection hépatique entre 1995 et 2004 dans les régions sanitaires de Calgary ou de la Capitale (Edmonton) de l'Alberta, au Canada, ont été identifiés au moyen des codes CIM-9 et 10. La mortalité à l'hôpital et la survie des patients selon le volume de patients traités par le chirurgien et le type de la formation (oncologie chirurgicale c. hépatobiliaire c. autres) ont constitué les principales mesures de résultats.

Résultats : Au total, 1033 patients ont subi une résection hépatique. Le volume de patients traités par le chirurgien n'était pas un prédicteur de mortalité à l'hôpital (rapport de cotes rajusté, 0,63, intervalle de confiance [IC] à 95 % 0,32–1,20) ni de survie du patient (rapport de risque non rajusté, 1,11, IC à 95 % 0,82–1,51). On a aussi démontré la non importance de la formation au niveau du fellowship selon le type de chirurgien.

Conclusion : Les divers modes de formation au niveau du fellowship ne semblent pas avoir d'effet sur la mortalité à l'hôpital ou la survie des patients après une résection hépatique.

In the late 20th century, mortality for liver resection substantially improved. In a report from 1977,[1] liver resection had an operative mortality of 13%, and that for major resections was more than 20%. Recent studies from high-volume centres have reported operative mortality below 5%.[2–5] Such improvements in outcome have been attributed to general improvements in operative and anesthetic techniques, better patient selection and the emergence of hepatobiliary surgery as a distinct area of specialization.[3]

The association between volume and outcome for liver resection has been well established in the United States.[4,6,7] As a result, a remarkable trend of liver resection regionalization has been observed across North America.[4,8] The effect of provider volume on patient outcome is not as clear in Canada and remains an area of considerable debate.[8,9]

Much recent surgical research has focused on education and the value of different modes of surgical fellowship training. Surgeon training has been correlated with complications, recurrence rates and survival.[10–14] McKay and colleagues[15] previously assessed the effect of surgeon training on outcomes after liver resection and showed that hepatobiliary-trained surgeons had lower complication rates. The present study used the same database but examined a different time period to assess the influence of the different types of subspecialty fellowship training on long-term patient survival after hepatic resection.

Methods

This study was approved by the Conjoint Health Research Ethics Board at the University of Calgary, the Health Research Ethics Board at the University of Alberta and the Research Ethics Board of the Alberta Cancer Board.

Study population and data sources

We included all patients 18 years of age and older who underwent hepatic resection between 1995 and 2004 in either the Calgary or Capital (Edmonton) health regions. In these health regions, all patients admitted to hospital have a record of their visit created in the form of a discharge abstraction. We identified patients in this database using the procedure codes for partial hepatectomy (*International Classification of Diseases*, 9th revision, Clinical Modification [ICD-9-CM], 50.22) and lobectomy (ICD-9-CM 50.3) before April 2002; after April 2002, hepatic resections were identified by the Canadian Classification of Health Interventions and the code 1.0A.87.^^. The Calgary health region serves a population of about 1.2 million people and accounts for 36% of the residents of the province of Alberta,[16,17] whereas the Capital health region serves a population of about 1.1 million people and accounts for 32% of the residents of Alberta.[17,18] Other data abstracted from the database included patient demographic characteristics, comorbidities, urgency of admission, operative indications and postoperative complications. Operative indications were divided into 3 categories: primary hepatic malignancy, secondary hepatic malignancy (metastases to the liver) and other (benign tumours, traumatic injuries, biliary tract malignancy and gallbladder cancer). Surgeons were categorized into groups according to their type of formal subspecialty training, which was determined by the senior surgeon in each region: hepatobiliary, surgical oncology and other (surgeons with other subspecialty training or general surgeons without additional subspecialty training). Hepatobiliary surgeons were defined as those having fulfilled 1 full year of training in hepatobiliary surgery with or without training in liver transplantation. Surgeons who received multidisciplinary training in cancer surgery were categorized into surgical oncology. We defined surgeons as high volume if they performed 5 or more hepatic resections per year; this cutoff

Table 1. Patient characteristics according to health region

	Health region; no. (%)*		
Characteristic	Capital, *n* = 676	Calgary, *n* = 357	*p* value
Age, median (IQR) yr	57 (45–67)	60 (49–70)	0.010
Male sex	360 (53.3)	194 (54.3)	0.74
Type of surgery			
Lobectomy	211 (31.2)	82 (23.0)	0.006
Partial resection	465 (68.8)	275 (77.0)	
Diagnosis type			
Primary	74 (11.0)	42 (11.8)	
Secondary	235 (34.8)	143 (40.1)	0.16
Other	367 (54.3)	172 (48.2)	
Admission details			
Urgent/emergent	134 (19.8)	237 (66.4)	< 0.001
High-volume surgeon	572 (85.1)	223 (62.5)	< 0.001
Training			
Hepatobiliary	520 (77.4)	153 (42.9)	
Surgical oncology	6 (0.9)	136 (38.1)	< 0.001
Others	146 (21.7)	68 (19.1)	
LOS, median (IQR) d	8 (7–13)	9 (8–14)	< 0.001
In-hospital mortality	41 (6.1)	20 (5.6)	0.89
Charlson score			
0	333 (49.3)	147 (41.2)	
1	228 (33.7)	143 (40.1)	0.10
2	79 (11.7)	46 (12.9)	
≥ 3	36 (5.3)	21 (5.9)	
Complications			
Cardiac	27 (4.0)	26 (7.3)	0.023
Myocardial infarction	4 (0.6)	6 (1.7)	0.09
Cardiac arrest	5 (0.7)	10 (2.8)	0.008
Aspiration	51 (7.5)	41 (11.5)	0.034
Hemorrhage	150 (22.2)	81 (22.7)	0.86
Infection	45 (6.7)	34 (9.5)	0.10
Stroke	2 (0.3)	1 (0.3)	0.96
Pulmonary embolus or DVT	9 (1.3)	9 (2.5)	0.16
Acute renal failure	57 (8.4)	40 (11.2)	0.15
Renal	32 (4.7)	13 (3.6)	0.40
Septicemia	29 (4.3)	10 (2.8)	0.23
Surgical misadventures†	127 (18.8)	30 (8.4)	< 0.001
Digestive	66 (9.8)	35 (9.8)	0.98
Biliary	3 (0.4)	1 (0.3)	0.69
Pneumonia	38 (5.6)	16 (4.5)	0.43
Transfusion	0 (0)	3 (0.8)	0.017
Postoperative complications	290 (42.9)	166 (46.5)	0.27

DVT = deep vein thrombosis; IQR = interquartile range; LOS = length of stay.
*Unless otherwise indicated.
†Surgical misadventures as identified using the following *International Classification of Diseases, 9th revision* codes: misadventures to patients during surgical and medical care (E870-E876). It excludes: accidental overdose of drug and wrong drug given in error (E850.0-E858.9); surgical and medical procedures as the cause of abnormal reaction by the patient, without mention of misadventure at the time of procedure (E878.0-E879.9). E870 Accidental cut, puncture, perforation, or hemorrhage during medical care. E871 Foreign object left in body during procedure. E872 Failure of sterile precautions during procedure. E873 Failure in dosage; excludes: accidental overdose of drug, medicinal or biological substance (E850.0-E858.9). E874 Mechanical failure of instrument or apparatus during procedure. E875 Contaminated or infected blood, other fluid, drug, or biological substance; includes: presence of: bacterial pyrogens, endotoxin-producing bacteria, serum hepatitis-producing agent. E876 Other and unspecified misadventures during medical care.

was selected arbitrarily. The median case volume was 0.18 surgeries per year, and the mean was 1.37 cases with a standard deviation of 4.23; quartiles were 0.09 surgeries/year (25%) and 0.55 surgeries/year (75%), range 1–44. We calculated the Charlson comorbidity score for each patient using the original weights described.[19]

Outcomes

Primary outcomes included in-hospital mortality and patient survival. We obtained post–hospital discharge mortality information by abstracting patients' date of death from the Alberta Vital Statistics database for up to and including Jul. 1, 2008. This database only has records of those patients who died in Alberta. All patients who had no further encounters within either the Capital or Calgary health regions were censored in our analysis. Other outcomes included length of stay (LOS) and postoperative complications (Appendix 1, available at cma.ca/cjs).

Statistical analysis

We used descriptive statistics to report characteristics of patients who underwent hepatic resection. Between-group comparisons were made using Fisher exact, χ^2 and Mann–Whitney *U* tests, as appropriate. We used logistic regression models to determine the independent predictors of in-hospital mortality and postoperative complications, and we used multiple linear regression models to assess the impact of study variables on length of stay (LOS) in hospital. Length of stay was logarithmically transformed as a result of their skewed distributions. We performed a univariate screen and included the significant variables in the multivariate models. Survival analysis involved Kaplan–Meier and Cox regression models to assess predictors of survival in our cohort.

Results

Patient characteristics

From 1995 to 2004 inclusive, 676 hepatic resections were performed in the Capital health region and 357 in the Calgary health region, for a total of 1033 hepatic resections (Table 1). These were performed by a total of 67 surgeons in 9 hospitals. The most common indication for resection was the "other" subcategory followed by secondary malignancy. In-hospital mortality was not

Table 2. Predictors of in-hospital mortality

Characteristic	Unadjusted OR (95% CI)	Adjusted OR* (95% CI)	Adjusted OR (95% CI) without postoperative complications in multivariate analysis
Age > 65 yr	1.66 (0.98–2.79)	1.17 (0.63–2.15)	1.40 (0.78–2.53)
Male sex	1.57 (0.92–2.69)	1.11 (0.61–2.01)	1.38 (0.77–2.45)
Type of surgery			
Lobectomy	1.00	1.00	1.00
Partial resection	0.55 (0.32–0.93)	0.58 (0.30–1.13)	0.46 (0.24–0.88)
Diagnosis type			
Primary	1.00	1.00	1.00
Secondary	0.24 (0.11–0.53)	0.55 (0.22–1.34)	0.50 (0.21–1.22)
Other	0.51 (0.26–0.97)	0.92 (0.40–2.09)	0.99 (0.44–2.23)
Admission details			
Urgent/emergent	2.06 (1.23–3.46)	1.52 (0.82–2.83)	1.89 (1.04–3.43)
High-volume surgeon	0.54 (0.31–0.93)	0.42 (0.17–1.05)	0.56 (0.22–1.39)
Training			
Hepatobiliary	1.00	1.00	1.00
Surgical oncology	1.52 (0.73–3.16)	0.51 (0.19–1.40)	0.86 (0.32–2.29)
Others	1.95 (1.08–3.52)	0.59 (0.23–1.53)	0.81 (0.31–2.10)
Charlson score			
0	1.00	1.00	1.00
1	1.74 (0.89–3.38)	1.32 (0.64–2.69)	1.50 (0.75–3.00)
2	3.66 (1.73–7.72)	1.70 (0.68–4.24)	2.09 (0.85–5.16)
≥ 3	6.17 (2.65–14.37)	2.46 (0.88–6.89)	3.07 (1.12–8.40)
Postoperative complications	27.88 (8.68–89.60)	20.18 (6.16–66.09)	—
Moderate, severe liver disease†	6.91 (3.27–14.58)	3.22 (1.30–7.97)	4.28 (1.72–10.65)
Year, ≥ 2000 compared with < 2000‡	0.59 (0.35–0.98)	0.94 (0.51–1.75)	0.84 (0.46–1.54)

CI = confidence interval; OR = odds ratio.
*Adjusted for significant variables in univariate analysis: age, sex, type of surgery, diagnosis, elective admission, surgeon volume and training, Charlson score, severity of liver disease, surgery year and postoperative complications.
†Mortality rate for 2000–2004 (4.8%) compared with 1994–1999 (7.9%); $p = 0.053$.
‡ICD 9/10 codes as per Charlson and colleagues' original definitions.[19]

significantly different between the 2 regions (6.1% v. 5.6%, $p = 0.89$).

In-hospital mortality

The predictive value of each variable on in-hospital mortality is shown in Table 2. Variables that retained significance after multivariate analysis included postoperative complications and the severity of liver disease (adjusted odds ratios 18.97 and 3.20, respectively).

Postoperative complications

Patient sex, type of resection, admission status, surgeon training type, Charlson score and severity of liver disease were all significant in a multivariate analysis (Table 3).

Length of stay

Factors predictive of an increased LOS on multivariate analysis included patient age (> 65), diagnosis ("other"), an urgent/emergent admission status, increasing Charlson score, postoperative complications and severe liver disease. Patients in the "other" subcategory included those with traumatic injury, which is commonly multisystem and perhaps necessitates longer LOS. Neither surgeon volume nor training type had a significant impact on LOS.

Survival analysis

Of the 1033 patients who underwent liver resection, we were able to obtain survival information for 961 (93%). The remaining 72 patients were omitted from the analysis. Overall mortality was 38.8% ($n = 373$) with a median survival of 35.1 months. Of the the patients who died, 14.8% ($n = 55$) died in hospital. Figure 1A represents the Kaplan–Meier survival curve for the entire patient sample. Figure 1B–D shows the Kaplan–Meier curves that describe the results of univariate analysis for surgeon volume status, surgeon training type and postoperative complications. All 3 factors were nonsignificant on univariate analysis. We performed a stratified survival analysis to determine whether there was a difference in survival associated with training and volume according to diagnosis; we did not find a significant difference. Table 4 illustrates the predictive value of all survival factors studied.

Discussion

This study, based on a regional administrative database, describes the factors predictive of LOS, in-hospital mortality, postoperative complications and survival in patients having undergone liver resection between 1995 and 2004.

Table 3. Predictors of postoperative complications

Characteristic	Unadjusted OR (95% CI)	Adjusted OR* (95% CI)
Age > 65 yr	1.56 (1.20–2.02)	1.36 (1.01–1.83)
Male sex	1.70 (1.33–2.19)	1.70 (1.29–2.26)
Type of surgery		
Lobectomy	1.00	1.00
Partial resection	0.59 (0.45–0.77)	0.51 (0.37–0.71)
Diagnosis type		
Primary	1.00	1.00
Secondary	0.39 (0.25–0.59)	0.66 (0.41–1.06)
Other	0.55 (0.37–0.83)	1.04 (0.64–1.70)
Admission details		
Urgent/emergent	2.06 (1.59–2.66)	1.55 (1.14–2.09)
High-volume surgeon	0.62 (0.46–0.83)	1.91 (1.16–3.14)
Training		
Hepatobiliary	1.00	1.00
Surgical oncology	3.34 (2.28–4.88)	4.07 (2.48–6.68)
Other	2.16 (1.58–2.95)	2.37 (1.42–3.98)
Charlson score		
0	1.00	1.00
1	1.58 (1.20–2.08)	1.43 (1.05–1.93)
2	2.83 (1.89–4.24)	1.78 (1.11–2.83)
≥ 3	3.65 (2.04–6.52)	2.12 (1.08–4.15)
Moderate, severe liver disease	5.55 (2.54–12.14)	3.60 (1.53–8.45)
Year, ≥ 2000 compared with < 2000	0.60 (0.47–0.78)	0.69 (0.51–0.94)

CI = confidence interval; OR = odds ratio.
*Adjusted for significant variables in univariate analysis: age, sex, type of surgery, diagnosis, elective admission, surgeon volume and training, Charlson score, severity of liver disease and surgery year.

Table 4. Predictors of patient survival

Characteristic	Unadjusted HR (95% CI)	Adjusted HR* (95% CI)
Age > 65 yr	2.35 (1.84–3.02)	2.04 (1.57–2.64)
Male sex	1.39 (1.08–1.79)	1.09 (0.83–1.42)
Type of surgery		
Lobectomy	1.00	1.00
Partial resection	1.35 (1.02–1.79)	1.28 (0.96–1.70)
Diagnosis type		
Primary	1.00	—
Secondary	1.45 (0.98–2.13)	—
Other	0.80 (0.54–1.18)	—
Admission details		
Urgent/emergent	1.30 (1.01–1.67)	1.14 (0.88–1.47)
High-volume surgeon		—
Training	1.11 (0.82–1.51)	
Hepatobiliary	1.00	—
Surgical oncology	1.36 (0.96–1.93)	—
Other	1.15 (0.86–1.54)	—
Charlson score		
0	1.00	1.00
1	1.50 (1.13–2.02)	1.32 (0.98–1.78)
2	2.44 (1.73–3.45)	1.84 (1.28–2.66)
≥ 3	3.05 (1.83–5.07)	2.13 (1.25–3.63)
Postoperative complications	1.28 (1.00–1.64)	1.07 (0.82–1.39)
Moderate, severe liver disease	0.70 (0.34–1.41)	—

CI = confidence interval; HR = hazard ratio.
*Adjusted for significant variables in univariate analysis: age, sex, type of surgery, elective admission, Charlson score and postoperative complications.

Our findings demonstrate that surgeon volume and training type do not significantly predict patient survival.

Multiple studies have attempted to identify factors predictive of in-hospital mortality after liver resection.[2,3,8] Blumgart and colleagues,[2] in an analysis of 1803 hepatic resections at the Memorial Sloan-Kettering Cancer Center, were able to show that both the number of hepatic segments resected and the volume of operative blood loss strongly predicted perioperative morbidity and mortality. In a previous study by our group, patient age, sex, comorbidity score, operative indication and admission status were highly related to in-hospital mortality after liver resection in Canada.[8] To our knowledge, no study has examined the association between these variables and patient survival years after liver resection.

Our results show that postoperative complications are highly predictive of both LOS and in-hospital mortality. It makes sense that patients who experience more postoperative complications will require a longer LOS and have a higher mortality. This emphasizes the importance of prevention and the early diagnosis of complications during patient care. More difficult to ascertain is the association between complications and later patient survival. In our study, patients with more postoperative complications had a less favourable survival curve, although this did not reach significance. Despite these negative findings, we believe further examination is needed to definitively delineate the effect that in-hospital complications have on long-term survival.

In the United States, high-volume centres have demonstrated consistent superior outcomes for complex surgical procedures.[4,6,7,20,21] We examined hospital volume independently as a continuous variable, dichotomized at 10 and split into quintiles as a post hoc exploratory analysis and also as part of a multivariate analysis in conjunction with surgeon volume; however, we did not find that it was a significant predictor of in-hospital mortality. Surgeon volume was also not a significant predictor of in-hospital mortality in our study, a finding that is consistent with existing Canadian data.[8] Beyond in-hospital mortality, we have found that surgeon volume is not predictive of postoperative complications and patient survival. Indeed, a weakened volume–outcome association for a variety of surgical procedures exists in Canada compared with the United States.[9] This has been attributed to multiple factors, including different models of health care delivery and financing between the 2 countries and to reduced surgeon and hospital heterogeneity in Canada.[8,9] However, we were unable to stratify based on case complexity, as the database did not contain detailed information about the procedure, and it is possible that more difficult cases were referred to subspecialty-trained, higher-volume surgeons.

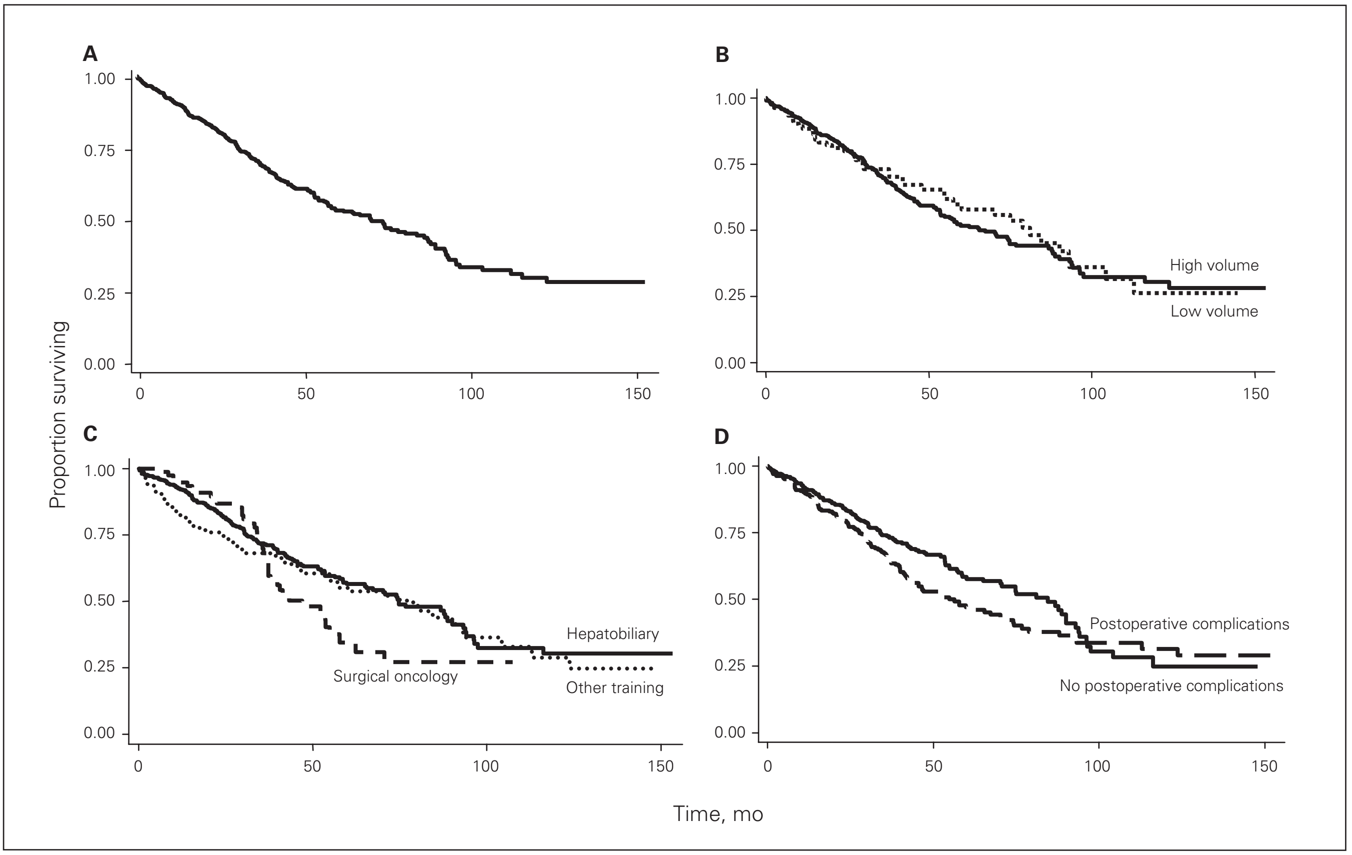

Fig. 1. Kaplan–Meier survival curve for (**A**) entire patient sample (n = 961), (**B**) impact of surgeon volume on patient survival (p = 0.64), (**C**) impact of surgeon training on patient survival (p = 0.20) and (**D**) effect of postoperative complications on patient survival (p = 0.05).

Even though we did not examine hospital volume, it is likely that hospital and surgeon volume are highly correlated. Birkmeyer and colleagues[22] found that the observed variation in outcome between high- and low-volume hospitals could actually be attributed to surgeon volumes, ranging from 100% of the effect for aortic-valve replacement to 24% of the effect for lung resection.

Surgeon training has been linked to improved local recurrence rates and survival for cancer surgery,[10–13] and to complications for both radical prostatectomy[14] and colon resection.[11] Our study, however, failed to demonstrate an association between surgeon training and in-hospital mortality or patient survival. Although training was significant on univariate testing, significance was lost on multivariate testing. Perhaps our study was underpowered to reveal a difference between surgeon training types in these areas. Statistically, it is easier to demonstrate a difference with respect to complications than for mortality indices since the number of complications is higher than the number of patient deaths. Another possible explanation for our findings relates to the learning curve phenomenon. McKay and colleagues[15] suggested that 1 year of intensive training in liver surgery with performance of at least 30 liver resections would be adequate to produce a competent hepatic surgeon. Performing a threshold number of cases necessary for achieving competency has been suggested for a variety of surgical types, including laparoscopic and colorectal surgery.[15,23,24] Perhaps fellowship types differ in terms of exposure and the number of hepatic resections a fellow performs during training. With the implementation of work-hour regulations for residents across North America, exposure to hepatobiliary cases during residency is limited. In the year 2005 in the United States, graduating residents performed an average of 3.9 (± standard deviation [SD] 4) liver resections during their residency, which was clearly not enough cases to feel confident performing liver surgery.[25] It is therefore likely that the greatest difference between surgeons of varying fellowship types would be in their first several years of practice when they are potentially still traversing the learning curve to achieve a threshold number of cases. Finally, perhaps there are no measurable differences in patient mortality outcomes between surgeons of varying training backgrounds, which would indicate that strong homogeneity exists between different fellowship programs across North America.

Limitations

Several limitations of this study should be recognized. First, it is based on administrative data, which do not allow for definitive conclusions to be drawn regarding causation. Further, such data do not allow the researcher to examine the influence of various processes of care, such as preoperative testing and perioperative invasive monitoring, which have been shown to be relevant to surgical patients.[15,22] In addition, we were not able to determine the level of complexity of each procedure. Higher-volume, subspecialty-trained surgeons may have been operating on more complex cases, but we could not factor this into our analysis. Given this capability, we may have had different results. Finally, our study was not able to evaluate other outcomes, such as cancer-free survival; recurrence; and health-related quality of life outcomes, such as postoperative renal dysfunction, that are important indicators of the quality of surgical care.[26] Perhaps differences between surgeon training types would be better elucidated by examining such outcomes.

Although we did not perform a power calculation a priori, we performed a post-hoc power calculation for perioperative mortality, at $\alpha < 0.05$, to detect a mortality difference between 5% and 13% based on mortality reported in the literature. With 795 procedures performed by high-volume surgeons and 234 procedures performed by low-volume surgeons, our study power was determined to be 95%.

Conclusion

This study has examined various factors predictive of long-term patient survival after liver resection. Surgeon training was shown to affect postoperative complication rates, but both training type and a surgeon volume did not appear to influence patient survival.

Competing interests: None declared for R.J. McColl, A.A.M. Shaheen, B. Brar, G. Kaplan, R. Myers and F. Sutherland. E. Dixon is supported through a Population Health Investigator award from the Alberta Heritage Foundation for Medical Research (AHFMR), and a New Investigator award from the Canadian Institute of Health Research. This study was funded through an Establishment Grant from the AHFMR.

Contributors: R.J. McColl, R. Myers, F. Sutherland and E. Dixon designed the study. R.J. McColl, B. Brar and E. Dixon acquired the data. R.J. McColl, A.A.M. Shaheen, G. Kaplan, R. Myers and E. Dixon analyzed the data. R.J. McColl and E. Dixon wrote the article. R.J. McColl, A.A.M. Shaheen, B. Brar, G. Kaplan, R. Myers, F. Sutherland and E. Dixon reviewed the article. All authors approved its publication.

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