Learning Curve: The Surgeon as a Prognostic Factor in Colorectal Cancer Surgery

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Abstract

The individual surgeon is an independent prognostic factor for outcome in colorectal cancer surgery. The surgeon's learning curve is therefore directly related to the patient's outcome. The exact shape of the learning curve, however, is unknown. The present study reviewed supervision, training/teaching, specialization, surgeon's caseload, and hospital's caseload as the five main surgeon- and hospital-related confounding factors for outcome, and examined their influence on the learning curve as well as their interactions and prognostic significance. All five confounding factors were related to outcome. The highest degree of evidence, however, was found for training/teaching (introduction of total mesorectal excision), specialization in colorectal surgery (special interest, board-certification, specialized colorectal cancer units), and the surgeon's caseload. Five surgeon- and hospital-related factors directly influence the surgeon's learning curve and are therefore rightly considered predictors of outcome in colorectal cancer surgery. Improvements in supervision, training/teaching, specialization, the surgeon's caseload, and the hospital's caseload will therefore translate into enhanced patient outcome.

Introduction

The individual surgeon is an independent prognostic factor for outcome in colorectal cancer surgery. The surgeon's learning curve is therefore directly related to the patient's outcome. The learning curve is a two-dimensional representation plotting the number of years of training against the outcome for any given surgical procedure and with respect to any given outcome measurement. For illustrative purposes, a learning curve has been drawn in Fig. 1. On the left-hand side we find the young and inexperienced surgeon in training, who has just graduated from university. Outcome for a patient operated on by this surgeon might be as low as 20%. With increasing years of training and accumulating experience, the young trainee will eventually become an expert surgeon with an outcome reaching almost

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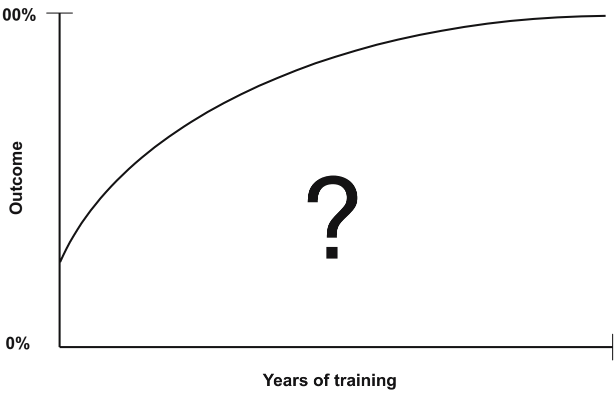

Figure 1. Learning curve

100%. Unfortunately, the exact shape of the learning curve is unknown. All factors changing the shape of the learning curve, however, will alter the patient's outcome.

Several surgeon- and hospital-related characteristics have recently been described as new prognostic factors in colorectal cancer surgery. These new predictors of outcome, in contrast to traditional prognostic factors, which are tumor- and patient-related, can be influenced positively. An improvement of these surgeon- and hospital-related factors leads to enhancement and acceleration of the surgeon's learning curve and therefore to an improvement in the patient's outcome. No attempt will therefore be made to determine the exact shape of the learning curve. The present study will focus on supervision, training/teaching, specialization, surgeon's caseload, and hospital's caseload as the five main surgeon- and hospital-related confounding factors, and will examine their influence on the learning curve as well as their interactions and prognostic significance.

Background

The surgical world was, until recently, quite simple and straightforward. A patient suffering from colorectal cancer would undergo surgery, and the only factors determining the patient's outcome would have been related to either the tumor (e.g., TNM classification, tumor grading), the patient (e.g., age, sex, co-morbidity), or the treatment (e.g., urgency of operation, type of resection, chemo-radiotherapy). The surgeon or surgeon-related factors were not part of the equation.

However, it is a long-standing and common perception of the general public as well as the medical community that there are good and not-so-good surgeons. The first reports on differences in outcome (operative mortality, anastomotic leakage, local recurrence) between individual surgeons for colorectal surgery emerged more than two decades ago (Fielding et al. 1978, 1980; Phillips et al. 1984). In 1991 McArdle and Hole published a prospective study investigating inter-surgeon variability by looking at the outcomes of individual surgeons. Thirteen consultants, none of whom had a special interest in colorectal surgery, operated on 645 patients with colorectal cancer. Outcome differed tremendously between the individual surgeons. The rate of curative resection varied from 40% to 76%, postoperative mortality from 0% to 20%, local recurrence from 0% to 21%, anastomotic leakage from 0% to 25%, and survival at 10 years from 20% to 63%. These important differences in outcome were not entirely explained by differences in patient population (case-mix, e.g., more advanced tumor stage). The existence of a significant inter-surgeon variability was hereby proven.

The individual surgeon was later identified as an independent prognostic factor for the frequency of locoregional recurrence and survival in rectal cancer patients by applying multiple logistic regression analysis adjusting for case mix differences (Hermanek et al. 1995). A great number of publications followed, investigating the prognostic role of the surgeon as well as of surgeon- and hospital-related factors (e.g., board certification, subspecialty training, annual caseload, teaching status).

Most tumor-related, patient-related, and treatment-related predictors of outcome cannot be altered. The majority of surgeon- and hospital-related factors, however, can be influenced positively. Herein lies great promise, since an enhancement of surgeon- and hospital-related factors will lead to a significant improvement in the patient's outcome.

Supervision

It is generally accepted that colorectal cancer surgery performed by young surgeons in training will be less successful and effective than such surgery performed by experienced and well-trained senior surgeons. Supervision of surgeons in training, however, may help to bridge this difference in experience and surgical expertise. Two recent publications address the issue of supervision for colorectal cancer surgery.

The first publication, from Edinburgh, UK, reviewed the results of 245 consecutive patients with colorectal cancer undergoing surgery by either a consultant (a general surgeon with colorectal interest), a supervised surgical trainee, or an independent surgical trainee (Singh and Aitken 1999). A supervised operation was one in which the consultant was scrubbed and actively assisting the surgical trainee. The study did not control for tumor and patient characteristics, and there was a clear patient selection bias which was believed to be inevitable and even desirable, as stated by the authors. Any given operation was therefore allocated to a junior or senior surgical trainee, with or without supervision by a consultant dependent on the accumulated experience of the trainee as well as the expected difficulties of the surgery. There was a comparatively high proportion of supervised operations, as 28.6% of all resections, and 51.1% of those undertaken by trainees, were consultant supervised. This proportion was higher than that reported in the Lothian and Borders Large Bowel Cancer Project (13.9% and 31.5%, respectively) as well as for recent UK colorectal cancer audits (7.6% and 17.4%) (Aitken et al. 1999). The study showed no difference between operations by the consultant, by supervised trainees, and by independent trainees in terms of 30-day mortality (6.5%, 6%, and 4%, respectively), clinical anastomotic leakage rate

(9%, 2%, and 5%), local recurrence rate (2%, 3% and 7%), and adjusted 5-year disease-related survival rate. Therefore it was concluded that, with careful patient selection and patient allocation, properly supervised trainees could resect a high proportion of colorectal cancers without compromising immediate outcome or long-term survival.

The second publication reviewed 194 rectal cancer patients (Tytherleigh et al. 2002). Six consultants operated on 126 patients, and six supervised surgical specialist registrars operated on 68 patients. Supervision always meant that the consultants were scrubbed for the operation and actively assisting. Comparing the outcome between the two groups, there were no differences in postoperative morbidity/mortality, local recurrence rates, or crude survival.

Both publications showed that supervision of surgical trainees significantly improved outcome and effectively compensated for the lack in experience. Taking into consideration the important improvement in outcome by supervision, it is likely that supervision will also improve outcomes of board-certified surgeons. Therefore, it may be desirable that even fully certified surgeons ask for the assistance of a senior specialist surgeon, at least for the critical surgical steps of a difficult operation.

Training/Teaching

The best illustration for the importance of training and teaching was the introduction of the total mesorectal excision (TME) technique for the treatment of rectal cancer, leading to an increase in the rate of sphincter preservation (Lehander Martling et al. 2000) and enhanced preservation of male genital function (Maurer et al. 2001) as well as a decrease in local recurrence and an increase in survival (Arbman et al. 1996; Kapiteijn et al. 2002; Wibe et al. 2003; Lehander Martling et al. 2000). Two Scandinavian studies and one Dutch study have documented the impact of training and teaching on the patient's outcome by the introduction of the TME technique for rectal cancer surgery.

The first study investigated the impact of a surgical training program on the outcomes of rectal cancer patients in the county of Stockholm, Sweden (Lehander Martling et al. 2000). In 1994, the TME concept was introduced and surgeons were trained in workshops through television-based demonstrations, histopathology sessions, and direct operative instruction by senior members of the Colorectal Research Unit from Basingstoke, UK. From 1995 to 1996, a total of 447 patients underwent TME. The outcomes at 2 years were compared with those from the Stockholm I (n=790) and II (n=542) trials investigating the value of preoperative radiotherapy as historical controls. There were no differences in 30-day mortality rate, anastomotic leakage rate, and overall postoperative morbidity, despite a decrease in the proportion of abdominoperineal resections from 55% and 60% (Stockholm I and II trials) to 27% (TME group). The rate of local recurrence at 2 years decreased significantly from 15% and 14% (Stockholm I and II trials) to 6% (TME group), as did the 2-year cancer-related mortality rate (15% and 16% to 9%).

The second publication reported on the introduction of the TME technique in Norway (Wibe et al. 2003). The results of rectal cancer surgery in Norway have been poor. The rate of local recurrence amounted to 28% following treatment with a curative intent. Five-year overall survival was 55% for patients younger than 75 years according to a national audit for the period 1986–1988. In 1994, the Norwegian Rectal Cancer Group was founded. The TME technique was implemented on a national level. All surgeons were taught the TME technique in courses, and pathologists were trained in both macroscopic and microscopic assessment of specimens. A rectal cancer registry was established. A total of 3,432 patients underwent rectal resection with a curative intent from November 1993 until December 1999. Of these, 9% had adjuvant radiotherapy and 2% were given chemotherapy. There was a rapid implementation of the new technique; the percentage of patients undergoing TME increased from 78% in 1994 to 96% in 1998. After 39 months' mean follow-up, the rate of local recurrence was 8%, and 5-year overall survival was 71% for patients younger than 75 years.

The third study described the introduction of the TME technique in the Netherlands by the Dutch Colorectal Cancer Group (Kapiteijn et al. 2002). Surgeons were trained in workshops and symposia. Specially trained instructor-surgeons were used for local teaching and supervision. A large trial investigating short-term preoperative radiotherapy combined with the TME technique for resectable rectal cancer was subsequently initiated (Kapiteijn et al. 2001). The outcome of patients undergoing surgery alone from the TME trial was compared to the outcome of patients from the CRAB (cancer recurrence and blood transfusion) trial. The CRAB trial (1987–1990) included 269 curatively operated patients after conventional rectal surgery, and the TME trial (1996–1999) involved 661 curatively operated patients after TME. The local recurrence rate decreased from 16% (CRAB) to 9% (TME), and the overall 2-year survival increased from 77% (CRAB) to 86% (TME). The type of operation (conventional vs. TME) remained an independent predictor of local recurrence and overall survival after adjustment for tumor and patient characteristics.

Specialization

Three different degrees of specialization in the treatment of colorectal cancer patients can be described: treatment by general surgeons with a special interest in and dedication to colorectal surgery, treatment by colorectal surgeons with subspecialty training and special board certification, and treatment by colorectal surgeons working in specialized colorectal cancer units.

Colorectal Surgery by General Surgeons

General surgeons with a special interest in colorectal surgery tend to perform a different kind of surgery.

Two publications from Glasgow, UK, studied the influence of the surgeon's specialty interest on outcome. The primary study was a pathology investigation reviewing the type of operation performed (Reinbach et al. 1994). Ten surgeons with four different specialty interests treated 116 patients for primary colorectal cancer. Surgeons with an interest in colorectal cancer resected twice as much colon (280 mm vs. 130 mm) and were more likely to perform a multivisceral resection in order to remove adjacent clinically involved organs (15% vs. 0%) for left-sided colon and rectal cancers. Distal resection margins for sigmoid cancers (55 mm vs. 20 mm) and the number of lymph nodes retrieved from the mesentery (13 nodes vs. 7.5 nodes) were significantly greater in the group of surgeons with a special interest in colorectal surgery. The subsequent study examined the long-term outcome depending on the surgeon's specialty interest (Dorrance et al. 2000). Twelve surgeons, with different specialty interests, treated 378 patients for primary colorectal cancer over a 4-year period. There were six surgeons with a vascular or transplant emphasis, four surgeons with a general background, and two surgeons with colorectal subspecialty interest. They operated on 126, 98, and 154 patients, respectively. A significant association between colorectal specialty interest and a reduced local and overall recurrence rate was found. Patients operated on by a surgeon with a general background were 3.42 times more likely to develop a local recurrence than those operated on by a surgeon with a colorectal interest. It is, however, important to notice the difference in the individual caseload for vascular/transplant, general, and colorectal surgery-interested surgeons (21, 24.5, and 77 patients/study period, respectively)—a difference that may have contributed to the differences in outcome. Surgeons with a special interest in and dedication to colorectal surgery seem to be more familiar with the guidelines for colon and rectal cancer surgery, which recently have been critically reviewed and published by the American National Cancer Institute (Nelson et al. 2001). This familiarity translates into a different kind of resection performed, resulting in enhanced radicality in accordance with the principles of surgical oncology (Reinbach et al. 1994), and eventually leads to an improvement in the patient's outcome (Dorrance et al. 2000).

The Royal College of Surgeons of England and the Association of Coloproctology of Great Britain and Ireland published recommended treatment outcomes for colorectal cancer surgery (Royal College of Surgeons and Association of Coloproctology, 1996). These criteria demand an operative mortality of less than 5% for elective surgery, an anastomotic leak rate of less than 8% after anterior resection and less than 4% for other anastomoses, a wound infection rate below 10% after elective surgery, and a local recurrence rate inferior to 10% after curative resection.

Two publications by nonspecialist surgeons reported results in accordance with the above-mentioned recommendations. The first study reviewed patients with colonic and rectal cancer treated by nonspecialist surgeons (Singh et al. 1997). Between 1987 and 1991, four general surgeons, none of whom was a specialist in colorectal surgery, operated on 267 patients and achieved a rate of intraperitoneal sepsis of 1%, a clinical anastomotic dehiscence rate of 3%, and postoperative mortality rates after elective and emergency surgery of 2% and 13%, respectively. The 5-year disease-related survival rates for curative and palliative surgery were 67%

and 9%, respectively. There were no significant differences between the surgeons. The authors concluded that nonspecialist surgeons in a district general hospital could obtain acceptable results. The need for further specialization and centralization was questioned.

The second study originated from a district general hospital before the era of surgical specialization (Saha et al. 2002). A single gastrointestinal surgeon operated on 73 consecutive rectal cancer patients over a 5-year period and reported an operative mortality of 4.1%, an anastomotic leak rate of 6.2%, a wound infection rate of 2.7%, and a pelvic recurrence rate after curative resection of 9.6%. The authors concluded that trained gastrointestinal surgeons could achieve good results with acceptable complication rates outside the setting of a specialist unit.

Both studies reported results in accordance with the recommendations mentioned above. However, it is important to notice that in both studies the surgeons can be considered as high-caseload surgeons. In the first study the individual annual caseload for colonic and rectal cancer amounted to 13.4 patients, and in the second study the individual annual caseload for rectal cancer alone amounted to an impressive 14.6 patients. Whereas the surgeons in both studies considered themselves nonspecialists, it can be assumed that the good results achieved are partly explained by the high-caseload figures.

Board Certification in Colorectal Surgery

Surgery is becoming increasingly complex, and subspecialization is therefore often considered necessary. The American Society of Colon and Rectal Surgeons was founded in 1899. Thus subspecialty training in colorectal surgery and subsequent specialist board certification has a long tradition in the United States. In contrast to the North American situation, subspecialty training in visceral surgery is just being introduced in Switzerland. Table 1 summarizes the major publications that investigated the impact of colorectal subspecialty training on outcome. Specialization in colorectal surgery led to a significant reduction in in-hospital mortality (Rosen et al. 1996; Callahan et al. 2003) and an increase in sphincter preservation (Read et al. 2002). Concerning long-term outcome, specialization led to a significant reduction in the rate of local recurrence (Porter et al. 1998; Read et al. 2002) and an increase in survival (Porter et al. 1998; Read et al. 2002; Bokey et al. 1997). There are compelling data showing that even after adjusting for case mix differences as well as caseload, subspecialty training in colorectal surgery remains an independent prognostic factor for outcome.

Specialized Colorectal Cancer Units

The formation of specialized colorectal cancer units was the next logical step in an attempt to improve the patient's outcome. Two Swedish studies and one Spanish study compared the results for rectal cancer surgery before and after the

Table 1. Specialization in colorectal surgery

Publication	Setting	Surgeons	Outcome measure
Rosen et al. 1996	1986–1994, MC, 2805 P, CRC	1565 P/6 colorectal surgeons, 1240 P/33 other surgeons	↓ In-hospital mortality
Bokey et al. 1997	1971–1994, SC, 709 P, RC	428 P/n colorectal surgeons, 281 P/n other surgeons	↑ Long-term survival
Porter et al. 1998	1983–1990, MC, 683 P, RC	109 P/5 colorectal surgeons, 574 P/47 other surgeons	↓ Local recurrence, ↑ Disease-specific survival
Read et al. 2002	1977–1995, MC, 384 P, RC	251 P/5 colorectal surgeons, 133 P/68 other surgeons	↓ Local recurrence, ↑ disease-free survival, ↑ Sphincter preservation
Callahan et al. 2003	1998–2001, MC, 48582 P, CR	4757 P/61 colorectal surgeons, 43771 P/2590 other surgeons	↓ In-hospital mortality
Smith JAE et al. 2003	1991–1994, MC, 4562 P, CRC	2100 P/12 colorectal surgeons, 2462 P/65 other surgeons	↓ 30-day mortality, ↓ Anastomotic leakage, ↑ Local recurrence-free survival, ↑ Long-term survival

MC, multicenter; SC, single-center; P, patients; RC, rectal cancer; CRC, colorectal cancer; CR, colon resection.
↓ Reduction, decrease in outcome for patients operated on by colorectal surgeons/specialists.
↑ Improvement, increase in outcome for patients operated on by colorectal surgeons/specialists.

formation of a specialized colorectal cancer unit. The common feature of these three publications was that fewer specialized surgeons treated a greater number of patients, which resulted in an increase of both the individual surgeon's caseload as well as the hospital's caseload.

The first study reviewed the results from the county of Västmanland, Sweden (Smedh et al. 2001). Between 1993 and 1996, 133 patients were operated on at four county hospitals. After centralization, 144 patients were operated on at the new colorectal unit in the county central hospital from 1996 to 1999, supervised by a colorectal surgeon. The number of operating surgeons was reduced from 26 to four. There was a significant reduction in the postoperative mortality rate (8% vs. 1%), the total postoperative complication rate (57% vs. 24%), the number of surgical complications (37% vs. 11%), the relaparotomy rate (11% vs. 4%), and the postoperative hospital stay (13 days vs. 9 days).

The second report originated from the Ersta Hospital, Sweden (Machado et al. 2000). During the first period (1990–1992), 18 general surgeons operated on 72 patients with rectal cancer. Substantial changes in the treatment strategy of rectal cancer were implemented (increased use of preoperative radiotherapy, standardized surgical technique, concentration of the surgery to a limited number of colorectal surgeons). Thereafter, 180 patients were treated in the newly created colorectal cancer unit between 1994 and 1996, and two colorectal surgeons treated more than 90% of these patients. This specialization led to a significant decrease in permanent stoma formation (52% vs. 33%) and in the rate of local recurrence (18% vs. 3%). There was no increase in the frequency of postoperative complications, reoperations or pelvic sepsis, although more extensive surgery was used and the anastomotic level decreased from 8 to 4 cm ($p<0.001$). Furthermore, cancer-specific survival at two years increased significantly.

The third study was conducted in Valencia, Spain (Garcia-Granero et al. 2001). During a first period from 1986 to 1991, fourteen general surgeons operated on 94 patients with rectal cancer. Thereafter a Colorectal Surgery Unit was established. During the second period (1992–1995), four specialized surgeons operated on 108 patients. This resulted in a reduction of the abdominoperineal resection rate (25.8% to 16.7%) and an increase in the radical resectability rate (67.7% to 82.4%). Local recurrence after low anterior resection was reduced from 30% to 9%, and cancer-specific 5-year survival increased from 61% to 87%.

Surgeon's Caseload

Surgical expertise is acquired through practice. The more operations a surgeon is able to perform, the better the outcome for the patient. A positive beneficial relationship between a higher individual surgeon's caseload and better outcome is generally assumed.

Two multicenter trials investigated the influence of the surgeon's caseload on survival by studying the outcome of 3217 colorectal cancer patients from Northern Ireland (Kee et al. 1999) and 927 from the UK (Parry et al. 1999). Both trials failed to show any influence of caseload on survival. However, the large majority of publications seem to support a positive caseload–outcome relationship in colorectal cancer surgery.

Table 2 summarizes the major publications that have investigated the influence of the surgeon's caseload on outcome. A higher surgeon's caseload was positively linked to a reduction in the anastomotic leakage rate (Consultants 1995), a reduction of in-hospital mortality (Harmon et al. 1999; Ko et al. 2002; Hannan et al. 2002), a reduction in hospital stay and cost (Harmon et al. 1999), a reduction in the local recurrence rate (Hermanek et al. 1995; Porter et al. 1998; Stocchi et al. 2001; Martling et al. 2002), and an increase in survival (Porter et al. 1998; Martling et al. 2002; Schrag et al. 2002). There is today an impressive body of evidence showing that after adjustment for case mix differences, the surgeon's caseload confidently can be considered an independent prognostic factor for both short- and long-term outcome.

Interaction of Training/Teaching and Surgeon's Caseload

Conventional blunt surgical resection of rectal cancer is linked to a high rate of local recurrence and to an important inter-surgeon variability (McArdle and Hole 1991). It was reasonable to expect that through the introduction of the standardized TME technique, the intersurgeon variability wound be substantially reduced or even eliminated. A recent study from Stockholm, Sweden, reviewed 652 patients with rectal cancer who underwent TME (Martling et al. 2002). All surgeons were trained in the TME technique in workshops. Nevertheless, high-caseload surgeons (>12 operations/year) had a reduced rate of local recurrence (4% vs. 10%) and a reduced rate of rectal cancer death (11% vs. 18%). Intersurgeon variability persisted even after the introduction of the standardized TME technique. Therefore, both training and caseload must be regarded as prognostic factors for outcome, and it is not sufficient to be only a well-trained surgeon—it is necessary to be a well-trained surgeon with a high annual caseload.

Interaction of Specialization and Surgeon's Caseload

Specialization in colorectal surgery and the surgeon's annual caseload have both been shown to positively influence outcome. A Canadian study investigated the interaction between both prognostic factors by reviewing the results of 683 rectal cancer patients (Porter et al. 1998). The risk of local recurrence was increased for those patients operated on by non-colorectal-trained surgeons (hazard ratio 2.49) as well as for patients operated on by low-caseload surgeons (hazard ratio 1.80). Patients operated on by low-caseload and non-colorectal-trained surgeons had an observed hazard ratio for local recurrence of 4.29. This figure correlated closely with the calculated hazard ratio for local recurrence of 4.48 (2.49×1.80). A corresponding calculation was valid for the hazard ratios of survival. Therefore it was concluded that both co-variables were independent prognostic factors for outcome in rectal cancer surgery. For that reason, it is not sufficient to be a good

Table 2. Surgeon's caseload in colorectal surgery

Publication	Setting	Cut-off value for caseload	Outcome measure
Consultants 1995	1990–1992, MC, 260 P, RC	131 P/2 years/5 surgeons, 129 P/2 years/23 surgeons	↓ Anastomotic leakage
Hermanek et al. 1995	1984–1986, MC, 1121 P, RC	6.4 P/year	↓ Local recurrence, ↑ 5-year survival, no effect on 5-year cancer survival and overall survival
Grabham et al. 1996	1991–1994, MC, 603 P, RC	10 P/year	↓ Anastomotic leakage
Porter et al. 1998	1983–1990, MC, 683 P, RC	2.6 P/year	↓ Local recurrence, ↑ Disease-specific survival
Parry et al. 1999	1993, MC, 927 P, CRC	$\leq$ 6, 7–12, 13–18, $\geq$ 19 P/6 months	No effect on sphincter preservation and overall survival
Kee et al. 1999	1990–1994, MC, 3217 P, CRC	$\leq$ 9.7, 9.8–12.7, 12.8–16.1, 16.2–24.9, $\geq$ 25 P/year	No effect on 2-year overall survival
Harmon et al. 1999	1992–1996, MC, 9739 P, CRC	$\leq$ 5, 5–10, $\geq$ 10 P/year	↓ In-hospital mortality, ↓ Hospital stay, ↓ Cost
Stocchi et al. 2001	1979–1992, MC, 673 P, RC	10 P/study period	↓ 5-year local recurrence
Ko et al. 2002	1996, MC, 22408 P, CC	Continuous variable, mean 10.8±7.8 P/year	↓ In-hospital mortality
Hannan et al. 2002	1994–1997, MC, 3711 P, CC	$\leq$ 11, 12–20, 21–34, $\geq$ 35 P/4 years	↓ In-hospital mortality
Martling et al. 2002	1995–1997, MC, 652 P, RC	12 P/year	↓ Local recurrence, ↓ Rectal cancer death, no effect on postoperative mortality and anastomotic leakage
Schrag et al. 2002	1992–1996, MC, 2815 P, RC	1, 2, 3–5, 6–26 P/5 years	↓ 2-year mortality, ↑ Overall survival, no effect on 30-day mortality and sphincter preservation

MC, multicenter; P, patients; RC, rectal cancer; CC, colon cancer; CRC, colorectal cancer.
↓ Reduction, decrease in outcome for patients operated on by high-caseload surgeons.
↑ Improvement, increase in outcome for patients operated on by high-caseload surgeons.

colorectal surgeon—it is necessary to be a good colorectal surgeon performing a large number of colorectal cancer surgeries.

Hospital's Caseload

The outcome for complex surgical procedures is not only dependent on the surgeon's skill and expertise but also on the experience of an interdisciplinary team. Therefore the outcome is considerably influenced by the hospital's caseload. A positive relationship between a higher hospital caseload and an improved outcome has been found for esophagectomy, pancreatic resection, resection for lung cancer, and liver transplantation (Birkmeyer et al. 2002; Bach et al. 2001; Begg et al. 1998; Edwards et al. 1999; Ho and Heslin 2003). However, it can be argued that the outcome in colorectal cancer surgery is largely dependent on the surgeon's skill and less on the hospital's infrastructure (e.g., an experienced interdisciplinary team with gastroenterologists, radiologists, oncologists, anesthesiologists, critical care specialists, specialized nursing professionals). Whereas the surgeon's caseload can confidently be considered an independent prognostic factor for outcome, the impact of the hospital's caseload is somewhat less clear. Table 3 summarizes the major publications that have investigated the influence of the hospital's caseload on outcome. Several studies were unable to find any influence of greater hospital caseload on survival for patients with colorectal cancer (Kee et al. 1999; Parry et al. 1999; Simunovic et al. 2000). Evidence, however, is slowly increasing that the caseload of an individual hospital might be an independent prognostic factor. Investigators found a reduction of in-hospital mortality (Hannan et al. 2002; Schrag et al. 2000; Ko et al. 2002; Marusch et al. 2001b; Hodgson et al. 2003), an increase in sphincter preservation (Simons et al. 1997; Marusch et al. 2001a; Hodgson et al. 2003), an increase in survival (Simons et al. 1997; Schrag et al. 2000; Hodgson et al. 2003), and a borderline nonsignificant reduction in local recurrence (Holm et al. 1997) for hospitals with higher colorectal cancer caseloads.

Interaction of Surgeon's Caseload and Hospital's Caseload

A study from The Johns Hopkins Hospital, Baltimore, Maryland, drew attention to the interaction between the individual surgeon's caseload and the hospital's caseload (Harmon et al. 1999). During a 5-year period, 812 surgeons at 50 hospitals performed 9739 resections for colorectal carcinoma. The annual surgeon's caseload was stratified into low (≤ 5), medium (5–10), and high (>10). Hospitals were stratified into low (<40), medium (40–70), and high (>70) caseload institutions. A higher surgeon's caseload was associated with a significant improvement in all three outcome measurements (in-hospital death, length of stay, cost) after multivariate analysis and adjustment for variations in type of resections performed, cancer stage, patient co-morbidities, urgency of admission, and patient demographics. Interestingly, medium-caseload surgeons achieved excellent outcomes similar to high-caseload surgeons when operating in medium-caseload or high-

Table 3. Hospital's caseload in colorectal surgery

Publication	Setting	Cut-off value for caseload	Outcome measure
Holm et al. 1997	1980–1993, 1399 P, RC	≤ 5, 6–10, ≥ 10 P/year	↓ Local recurrence (borderline significance $p = 0.06$)
Simons et al. 1997	1988–1992, 2006 P, RC	≤ 5, ≥ 5 P/year	↑ Spincter preservation, ↑ Survival
Kee et al. 1999	1990–1994, 3217 P, CRC	≤ 23, 24–32, 33–46, 47–54, ≥ 55 P/year	No effect on 2-year overall survival
Parry et al. 1999	1993, 927 P, CRC	≤ 30, 31–44, 45–55, ≥ 56 P/6 months	No effect on sphincter preservation or overall survival
Khuri et al. 1999	1991–1993, 13310 P, CR	≤ 13, 13–22, 23–30, 31–52 P/year	No effect on 30-day mortality
Schrag et al. 2000	1991–1996, 27986 P, CC	≤ 57, 58–112, 113–165, 166–383 P/6 years	↓ 30-day mortality, ↑ Overall and cancer-specific long-term survival
Simunovic et al. 2000	1990, 1072 P, RC	≤ 11, 12–17, ≥ 18 P/year	No effect on operative mortality and long-term overall survival
Marusch et al. 2001a	1999, 1463 P, RC	≤ 20, 20–40, ≥ 40 P/year	↓ Postoperative morbidity, ↓ Permanent stoma formation, no effect on complications that required reoperation (afterbleeds, burst abdomen, ileus, anastomotic leakage)
Marusch et al. 2001b	1999, 2293 P, CC	≤ 30, 31–60, ≥ 60 P/year	↓ General postoperative complications, no effect on resection rate, intraoperative complications, in-hospital mortality
Ko et al. 2002	1995, 22408 P, CC	Continuous variable, mean 60 ± 41 P/year	↓ In-hospital mortality
Hannan et al. 2002	1994–1997, 3711 P, CC	≤ 83, 84–144, 145–253, ≥ 254 P/4 years	↓ In-hospital mortality
Birkmeyer et al. 2002	1994–1999, 304285 P, CR	≤ 33, 33–56, 57–84, 85–124, ≥ 124 P/year	↓ In-hospital mortality
Hodgson et al. 2003	1994–1997, 7257 P, RC	≤ 7, 7–13, 14–20, ≥ 20 P/year	↓ Permanent colostomy formation, ↓ 30-day mortality, ↑ 2-year survival

P: patients, RC: rectal cancer, CC: colon cancer, CRC: colorectal cancer, CR: colon resection
↓ reduction, decrease in outcome for patients operated on in high-caseload hospitals
↑ improvement, increase in outcome for patients operated on in high-caseload hospitals

caseload hospitals, but not in low-caseload hospitals. The results of low-caseload surgeons improved with increasing hospital caseload but never equaled those of the high-caseload surgeons.

A second study investigated the relative importance of surgeons' and hospitals' caseloads on short- and long-term outcome following rectal cancer resection (Schrag et al. 2000). The outcomes of 2,815 rectal cancer patients were reviewed. Neither hospital-specific nor surgeon-specific caseload was significantly associated with 30-day postoperative mortality or rates of sphincter-sparing surgery. Although an association between hospital caseload and mortality at 2 years was evident, this finding was no longer significant once the surgeon's caseload was controlled for. In contrast, a higher surgeon's caseload was associated with a reduced 2-year mortality, and the surgeon's caseload remained an important predictor of outcome even after adjustment for the hospital's caseload. The surgeon's caseload proved to be superior to the hospital's caseload in predicting long-term survival. The authors concluded that in order to improve outcome following rectal cancer resection, greater emphasis should be placed on understanding surgeon-specific rather than hospital-specific practice patterns.

The Relative Importance of Caseload on Outcome

Relying on the data of the Healthcare Cost and Utilization Program, a large study from the United States reviewed 22,408 patients with colon cancer for in-hospital mortality (Ko et al. 2002). A multivariate logistic regression model was applied, adjusting for more than 30 different independent variables, including demographic factors (e.g., age, gender, race, ethnicity, socio-economic status), burden of morbid and co-morbid disease (prevalence and severity), and provider variables (e.g., hospital size, location, teaching status, surgeon's and hospital's caseload). The baseline probability analysis showed a mortality rate for the baseline colon cancer patient of 12 in 1,000. Being operated on by a high-caseload surgeon or in a high-caseload hospital reduced the mortality to 10 in 1,000 and 11 in 1,000, respectively. However, if this baseline colon cancer patient had coexistent liver disease or required an emergency operation, mortality increased to 44 in 1,000 and 45 in 1,000, respectively. The authors concluded that although both surgeon and hospital caseloads were independent prognostic factors for in-hospital mortality, their relative impact on outcome was rather small as compared to other confounding factors such as co-morbidity and emergency operation.

Defining Caseload Threshold Values

The Leapfrog Group, a consortium of more than 100 large employers in the United States, has set up arbitrary caseload thresholds for hospitals performing coronary artery bypass grafts (500 patients/year), coronary angioplasties (400 patients/year), abdominal aortic aneurysm repairs (30 patients/year), carotid endarterectomies (100 patients/year), and esophagectomies (seven patients/year). These threshold recommendations were recently critically reviewed (Christian et al. 2003). As for colorectal cancer, threshold values have not yet been established, either for the surgeon's or for the hospital's caseload. The vast majority of publications listed in Tables 2 and 3 describe a gradual improvement in outcome with increasing caseload. Caseload thresholds, however, were not defined.

Discussion

The individual surgeon is an independent prognostic factor in colorectal cancer surgery. The surgeon's learning curve is therefore directly related to the patient's outcome. The exact shape of the learning curve is unknown. Several surgeon- and hospital-related factors, however, might positively influence the learning curve and therefore enhance the patient's outcome. A beneficial relationship between supervision, teaching/training, specialization in colorectal surgery, higher surgeon caseload, higher hospital caseload, and improvements in different outcome measurements has been established. The whole issue, which is extremely policy-relevant, has generated huge interest even beyond the medical community. An impressive number of excellent publications have appeared in the most prestigious medical journals. The evidence seems to be overwhelming.

However, several potential shortcomings of the cited publications deserve to be mentioned. The majority of publications included only patients with rectal cancer; some, however, extended their analyses to patients with colon cancer or to patients undergoing colon resection for whatever reason. Most studies were retrospective, and an important number of studies were based on large but rather unsophisticated administrative databases. Elaborate adjustments for differences in case mix by multivariate logistic regression models were not always performed. End-point measurements were often limited to short-term outcome (e.g., in-hospital mortality) or crude survival (e.g., overall survival instead of cancer-specific disease-free survival). The definitions of surgeons with colorectal interest as well as specialist surgeons were not always precise. Cut-off values defining low- and high-caseload surgeons as well as low- and high-caseload hospitals showed an important and somewhat disturbing diversity. Several studies considered only one surgeon- or hospital-related factor without adjustment for the other potential confounding factors (e.g., only hospital's caseload investigated, but not surgeon's caseload or specialization).

Despite these limitations, all five surgeon- and hospital-related confounding factors can today be considered as significant and mostly independent predictors of outcome in colorectal cancer surgery.

The prognosis of colorectal cancer is largely determined by factors related to the tumor (e.g., TNM classification, tumor grading) and the patient (e.g., age, sex, co-morbidity). These factors cannot significantly be influenced. The relative prognostic importance of surgeon- and hospital-related factors might be rather small (Ko et al. 2002). However, these surgeon- and hospital-related characteristics are the only predictors of outcome that can be influenced in a way benefiting the patient.

Policy makers and surgical leaders will have to decide which prognostic factors they would like to promote in order to improve the outcomes of their patients. They may enhance the supervision of trainees and even extend the supervision to board-certified surgeons. They may invest in teaching and training by organizing colorectal cancer workshops, video-conferencing, and expert-surgeon instruction, or by promoting colorectal fellowships at centers of excellence. Furthermore, they may choose to introduce a certain degree of specialization. The establishment of subspecialty training in visceral surgery may be a first step. Some countries may even proceed further and launch colorectal subspecialty training. Eventually, specialized colorectal cancer units may be founded. However, policymakers and surgical leaders won't be able to completely elude the caseload–outcome relationship for the individual surgeon as well as for a specific hospital. since the most convincing evidence so far has been produced for this association. A low surgeon or hospital caseload may be compensated for by intensified supervision or by improved training and teaching. However, most surgeon- and hospital-related factors are, at least on a practical level, interdependent, and neither supervision nor training/teaching nor specialization is possible without an adequate caseload. The caseload–outcome relationship has been discussed in a recent editorial commenting on a publication linking the hospital's caseload to the rate of permanent stoma formation and survival (Hodgson et al. 2003). The authors (Smith TJ et al. 2003) stressed the importance of the caseload–outcome relationship, and wrote that "it is time for us to take our heads out of the colostomy bag, and take some action."

Therefore, the surgeon's learning curve in colorectal cancer can and should be effectively altered and accelerated by promoting improvements in all five surgeon- and hospital-related characteristics.

Conclusion

Five surgeon- and hospital-related factors directly influence the surgeon's learning curve and are therefore rightly considered predictors of outcome in colorectal cancer surgery. Improvements in supervision, training/teaching, specialization, the surgeon's caseload, and the hospital's caseload will therefore translate into enhanced patient outcome.

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