Surgical teaching does not increase the risk of intraoperative adverse events

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Abstract

Introduction Training and teaching are cornerstones in developing surgical skills. The present study aimed to compare intraoperative outcomes of colonic resections among fellows, consultants, and supervised trainees.

Methods Data of consecutive colonic resections including demographics, surgical details, and intraoperative outcomes were recorded in a prospectively maintained institutional database. All procedures were standardized and divided in three groups according to the main surgeons experience (fellow or consultant) and whether the procedure was taught. After weighting by inverse treatment probability, intraoperative adverse events including reactive conversion, blood loss, and operating time were compared between these three groups.

Results Six hundred sixty-four colectomies were analyzed between January 2014 and October 2017. Among them, 289 (43.5%) were taught. After weighted propensity score analysis, there was no difference between the three groups (fellow taken as reference), for intraoperative adverse event rate (odd ratio (OR) consultant 1.448 (IQR 0.728–2.878), $p = 0.282$; OR teaching 0.689 (IQR 0.295–1.609), $p = 0.381$), operating time (beta coefficient 0.76 (− 21.91–23.42), $p = 0.947$; beta coefficient − 10.79 (− 28.34–6.75), $p = 0.919$), conversion rates (OR 0.748 (0.329–1.515), $p = 0.412$; OR 1.025 (0.537–1.954), $p = 0.940$), preemptive conversion (OR 1.994 (0.198–20.032), $p = 0.552$; OR 0.659 (0.145–2.991), $p = 0.583$), intraoperative blood loss (beta coefficient 21.19 (− 25.87–68.25), $p = 0.368$; beta coefficient − 12.34 (− 56.13–31.44), $p = 0.573$), intraoperative transfusion (OR 1.962 (0.813–4.735), $p = 0.127$; OR 0.670 (0.260–1.727), $p = 0.397$), and rates of unusual bleeding (OR 1.273 (0.698–2.321), $p = 0.422$; OR 0.572 (0.290–1.126), $p = 0.099$). Time to preemptive conversion was shorter when procedures were performed by consultants (beta coefficient − 25.51 (− 47.71 to − 3.31), $p = 0.025$), while no difference was found for the teaching group (beta coefficient 4.48 (− 30.95–40.62), $p = 0.788$).

Conclusion Within a standardized teaching environment, colonic resections were safely performed regardless of the surgical setting in the present cohort. Teaching does not increase intraoperative adverse events.

Keywords Teaching · Surgery · Outcomes · Complications · Adverse event

Basile Pache and Fabian Grass contributed equally to this work.

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Introduction

Teaching is a cornerstone in developing surgical skills. The traditional adage: “see one, do one, teach one” raised questions about patients’ safety and was therefore studied regarding postoperative complications [1]. Interestingly, experience of the surgeon was associated with postoperative surgical but not with intraoperative complications [2]. Further, it was demonstrated that postoperative surgical complications were rather the result of non-technical factors [3]. A structured and standardized teaching environment with step-by-step definition of surgical procedure allowing trainees to constantly achieve surgical milestones has been repeatedly associated with non-adverse postoperative outcomes [4–6]. However, less is known about the influence of teaching on intraoperative

adverse events that are directly related to technical skills and surgical experience.

The aim of the present study was therefore to analyze the impact of teaching on intraoperative outcomes.

Methods

Patients and procedures

All consecutive patients undergoing colonic resections between January 2014 and October 2017 at the tertiary academic center of Lausanne University Hospital (CHUV) were included. Surgeries were grouped as open and laparoscopic colectomies (right-sided including transverse colectomies, left-sided and total) and Hartmann reversals in an elective or emergency setting.

This study was approved by the Institutional Review Board (Commission cantonale d'éthique de la recherche sur l'être humain CER-VD, # 2017-01971). The study was conducted according to the STROBE criteria and registered under www.researchregistry.com (UIN research registry # 38444).

Demographic and surgical characteristics were prospectively assessed by the main operating surgeon in an a priori designed dedicated database; accuracy of data entry was cross-checked monthly by the consultant surgeons (DH and MH). These items are displayed in Tables 1 and 2, respectively. Indications for surgery (diagnosis) were either diverticulitis, colon cancer, or inflammatory bowel disease (IBD). The group “colectomies within other procedure” contains colectomies which were performed as additional secondary procedure within surgeries for other primary indications or pathologies (mainly major debulking surgeries (i.e., for peritoneal metastasis or sarcoma), or benign indications (i.e., endometriosis, polyps)). Remaining procedures which could not be assigned to either diagnosis were denominated “other indications.” Excluded were rectum procedures, total proctocolectomies and ileo-anal pouch, and stoma procedures (i.e., loop ileostomy closures as main operation). Immunosuppression was defined as ongoing immunosuppressive treatment (i.e., steroids) by the time of surgery. Emergency procedures were procedures performed during non-planned admission. Wound contamination class was assessed by the main surgeon based on four categories (I-

Table 1 Baseline characteristics

Number of patients (%)	Fellow 190 (28.6)	Consultant 185 (27.9)	Teaching 289 (43.5)	<i>p</i> -value
Gender				
Female (%)	82 (43.2)	90 (48.7)	125 (43.3)	
Male (%)	108 (56.8)	95 (51.3)	164 (56.8)	0.451
Age (yrs)(median)	70 (IQR 58-79)	66 (IQR 51-74)	69 (IQR 56-78)	0.005
Age category				
70 or younger	96 (50.5)	118 (63.8)	157 (54.3)	
Older than 70	94 (49.5)	67 (36.2)	132 (45.7)	0.028
BMI [kg/m²] (median)	26 (IQR 22-31)	25 (IQR 21-29)	25 (IQR 22-28)	0.291
BMI lower than 18.5 (%)	12 (8.5)	9 (6.2)	20 (8.1)	0.715
BMI greater than 25 (%)	79 (56.0)	72 (49.3)	132 (53.4)	0.513
ASA category				
1-2 (%)	64(39.3)	111 (70.3)	141 (52.2)	
3-5 (%)	99 (60.7)	47 (29.7)	129 (47.8)	<0.001
Diagnosis				
Colon cancer (%)	53 (28.2)	63 (34.4)	133 (46.5)	
Crohn's disease (%)	4 (2.1)	11 (6.0)	24 (8.4)	
Diverticulitis (%)	98 (52.1)	42 (23.0)	89 (31.1)	
Other (%)	15 (8.0)	16 (8.7)	20 (7.0)	
Colectomy within other procedure (%)	18 (9.6)	51 (27.9)	20 (7.0)	<0.001
Charlson >3 (%)	51 (26.8)	25 (13.5)	55 (19)	0.005
Malignancy	58 (34.5)	71 (47.3)	139 (51.3)	0.002
Immunosuppression	20 (10.5)	16 (8.7)	43 (14.9)	0.098
Previous surgeries	93 (49.2)	108 (59.0)	164 (56.8)	0.129

BMI – Body Mass Index, ASA – American Society of Anaesthesiologists, Charlson – Charlson comorbidity score. Significant values are indicated in bold characters

Table 2 Surgical details

Number of patients (%)	Fellow 190 (28.6)	Consultant 185 (27.9)	Teaching 289 (43.5)	<i>p</i> - <i>value</i>
Procedure				
Left	75 (39.7)	74 (40.0)	139 (48.1)	
Right	78 (41.3)	73 (39.5)	104 (36.0)	
Total	11 (5.8)	4 (2.2)	9 (3.1)	
Hartmann reversal	16 (8.5)	12 (6.5)	18 (6.2)	
Other	9 (8.5)	22 (11.9)	19 (6.6)	0.057
Emergency	109 (57.7)	40 (22.4)	77 (27.1)	<0.001
Wound Contamination class				
2 or less	135 (71.1)	150 (81.1)	251 (87.2)	
3 or more	55 (28.9)	35 (18.9)	37 (12.8)	<0.001
Additional small bowel resection	14 (7.4)	12 (6.5)	11 (3.8)	0.205
Minimally invasive approach	99 (52.7)	113 (62.1)	196 (68.3)	0.003
Protective ostomy	6 (3.2)	20 (10.8)	14 (4.8)	0.004
Adhesiolysis	59 (32.1)	74 (40.9)	99 (34.5)	0.186
Bowel anastomosis	123 (64.7)	157 (84.9)	253 (87.5)	<0.001
Anastomosis				
Hand sewn	23 (18.7)	28 (17.8)	43 (17.0)	0.918

Significant values are indicated in bold characters

clean, II-clean contaminated, III-contaminated, IV-infectious) [7]. Main surgeon was the surgeon actually performing the operation.

All patients were treated within a comprehensive enhanced recovery after surgery (ERAS) pathway, which has been implemented in Lausanne in 2011 for elective and in 2012 for emergency colectomies [8, 9].

Patient's outcomes were adjusted for malignancy, laparoscopy, and emergency, as they were the most relevant clinical confounding factors. Converted patients were analyzed in the laparoscopic group in an intention-to-treat analysis.

Surgeons and surgical setting

Fellows were surgeons with completed general surgical training (board certified surgeons). Surgeries assigned to the group fellows were procedures that were independently performed by fellows without supervision by a consultant. Consultants (DH, MH, and ND) were three board certified colorectal surgeons by the Swiss Society for Visceral Surgery and EBSQ Coloproctology (DH and MH). All procedures are standardized by the consultants [10, 11]. Teaching procedures were defined as procedures performed at least to a degree of 75% by fellows with direct, continuous, and close (face-to-face) supervision by one of the consultants. If less than 75% teaching occurred, the procedure was assigned to the group consultant. If an operation was taught or not was upon discretion of the consultant and labeled directly at the end of the intervention by the fellow. As a general rule, procedures

were taught in the setting of this academic institution unless considered not suitable by the consultant in the first place. Reasons not to teach an operation were insurance status (patients with private insurance operated by consultant according to Swiss policies) and consultants' appraisal of expected difficulty.

Of note, in the present institution, fellows are on-call and present on site over the entire year, working in 12-h shifts. Emergency procedures during night shifts are thus performed by fellows, either alone or in presence of the on-call consultant if needed. For particularly unstable or critical patients, a two-stage strategy has been defined (damage control by the fellow, second look at 36–48 h in presence of a consultant [12–14]). This strategy was chosen based on pre-defined hemodynamic criteria (severe lactic acidosis, vasopressors for inotropic management), independently of the time of surgery or availability of a consultant. Sub-group analysis was performed for procedures performed during night-time (6 pm–6 am).

Outcomes/study endpoints

The primary endpoint was the rate of intraoperative adverse events, defined as any deviation from the ideal intraoperative course, given the indication for surgery and the interventions conform to current guidelines [15]. They were assessed immediately after the surgical procedure in the above-described database by the operating surgeon.

Secondary endpoints regrouped conversion rate, bleeding complications, operating time, or any other adverse events

such as organ lesions or wound contamination. All endpoints were labeled intraoperative outcomes.

Conversion to open approach was further studied in two ways: First, time to conversion was measured. Secondly, type of conversion was assessed; whereas pre-emptive conversion was defined as conversion before an adverse event occurred, contrarily to reactive conversion as a consequence of an adverse event. Bleeding was studied in two ways; unusual bleeding—defined as abnormally important blood loss considering the usual amount of blood loss for the respective procedure (estimated at the main surgeons' discretion) and need of intraoperative transfusion. Operating duration was the time between incision and completed skin closure.

Statistical analysis

All statistical analyses were carried out using the Stata Software (v. 14.2, StataCorp, College Station, TX, USA).

Categorical data were summarized as raw frequencies and relative percentages. Differences in categorical distribution between independent groups were assessed using the Chi-squared test, or Fisher's exact test in case of low sample size. Continuous data were summarized as median, interquartile range (IQR), and range. Differences in medians between independent groups were assessed using the Kruskal-Wallis test.

Multinomial logistic regression was used to derive the probabilities for each patient of being assigned to each of the three surgical settings (fellow, consultant, or teaching) according to the following covariates: malignancy, laparoscopy, and emergency indication. The probability for each patient of being assigned to his actual surgical setting was then used in an inverse treatment probability weighting (IPTW) analysis.

Weighted logistic regression was used to assess the effect of surgical setting on binary outcomes, and results were reported as odds ratio (OR) and 95% confidence intervals. For continuous outcomes, weighted linear regression was used, and results were reported as beta coefficients and 95% confidence intervals. In each case, the fellow group was set as reference.

All statistical tests were two-sided and a level of 0.05 was used to indicate statistical significance.

Results

The study cohort consisted of 664 colectomies, allocated to the three groups: fellow, consultant, and teaching. There were respectively 190 (28.6%), 185 (27.9%), and 289 (43.5%) procedures in each group. Regarding patient's demographic details displayed in Table 1, there were no statistical differences regarding gender, age, and body mass index (BMI). No differences were found either for immunosuppressive status or previous surgeries. The three groups differed regarding age (p value = 0.005), ASA category (p value < 0.001), diagnostic categories (p value < 0.001), Charlson Comorbidity Index (CCI) (p value = 0.005), and malignancy (p value < 0.002).

Surgical details are depicted in Table 2. The three groups differed regarding emergency indication (p value < 0.001), wound contamination class (p value < 0.001), minimally invasive approach (p value < 0.003), protective ostomy (p value < 0.004), and realization of a bowel anastomosis (p value < 0.001).

Figure 1 illustrates the distribution of covariates that were used to derive probabilities of treatment among the three groups, before and after weighting. Homogenous distribution regarding the three covariates after matching was achieved.

Fig. 1 The distribution of covariates that were used to derive probabilities of treatment among the three groups, before and after weighting

Intraoperative binary and linear outcomes are illustrated in Fig. 2a, b, respectively. Detailed numbers are available as online appendix (Table S1 and Table S2). None of the outcomes differed significantly.

Intraoperative adverse events

Intraoperative adverse events occurred in 8% of cases in the fellow group, 15% in the consultant group and in 10% of teaching procedures (p value 0.098). Observed adverse events ($n = 67$) were small or large bowel transmural lesions in 51 patients (7.6% of all surgeries), serosa lesions in 6 patients (0.9%), urinary tract lesions in 6 patients (0.9%), and technical issues (i.e., stapler dysfunction) in 4 procedures (0.6%).

Fig. 2 a, b Intraoperative binary and linear outcomes

Fellow group is reference

Fellow group is reference

After weighting, intraoperative adverse event rates did not differ between the three groups (fellow taken as reference, OR for consultant 1.448 (0.728–2.878), p value = 0.282; OR for teaching 0.689 (0.295–1.609, p value = 0.381).

Conversion

Overall conversion rate was 26% in the fellow group, 17% in the consultant group, and 20% in teaching procedures (p value 0.280). After weighting, conversion rates did not significantly differ between the three groups (OR 0.748 (0.329–1.515), p value = 0.412; OR 1.025 (0.537–1.954), p value = 0.940).

Conversion was pre-emptive in 79% in the fellow group, 84% in the consultant and 87% in teaching procedures (p value 0.737). Pre-emptive conversion rates after weighting

were not statistically significant (OR 1.994 (0.198–20.032), p value = 0.552; OR 0.659 (0.145–2.991), p value = 0.583).

Median time to conversion was 25 min (IQR (min) 15–65) in the fellow group, 30 min (IQR (min) 10–60) in the consultant group, and 41 min (IQR (min) 18–90) (p value 0.288) in teaching procedures. After weighting, time to preemptive conversion was shorter when procedures were performed by consultants (beta coefficient -25.51 (-47.71 – 3.31), p value = 0.025), while no difference was found for the teaching group (beta coefficient 4.48 (-30.95 – 40.62), p value = 0.788).

Bleeding

Median estimated intraoperative blood loss (EBL) was 50 ml (IQR 20–100) in the fellow group, 100 ml (IQR 20–200) in the consultant group, and 50 ml (IQR 20–100) in teaching procedures (p value 0.404). After weighting, no difference was found between the three groups (beta coefficient 21.19 (-25.87 – 68.25), p value = 0.368; beta coefficient -12.34 (-56.13 – 31.44), p value = 0.573).

Intraoperative need for transfusion was 7% in the fellow group, 9% in the consultant group, and 5% in teaching procedures (p value 0.226). Rates after weighting did not differ among the three groups (OR 1.962 (0.813–4.735), p value = 0.127; OR 0.670 (0.260–1.727), p value = 0.397). Of note, overall rate of intraoperative transfusion was 10% in emergency and 3% in elective cases ($p < 0.001$), and these rates did not differ significantly either among the three study groups.

Unusual bleeding was 12% in the fellow group, 18% in the consultant group, and 17% in teaching procedures (p value 0.226). Rates of unusual bleeding after weighting did not differ in the three groups (OR 1.273 (0.698–2.321), p value = 0.422; OR 0.572 (0.290–1.126), p value = 0.099).

Operating time

Median operating time was 152 min (IQR (min) 106–190) in the fellow group, 169 min (IQR (min) 109–262) in the consultant group, and 176 min (IQR (min) 129–223) (p value < 0.001) in teaching procedures. After matching, operating time did not differ in the three groups (beta coefficient 0.76 (-21.91 – 23.42), p value = 0.947; beta coefficient -10.79 (-28.34 – 6.75), p value = 0.919).

Operations at night-time (6 pm–6 am)

In total, 79 procedures (12%) were performed between 6 pm and 6 am (28 (35%) between 6 pm and 10 pm, 34 (43%) between 10 pm and 2 am, and 17 (22%) between 2 am and 6 am. The majority of patients underwent surgery for diverticulitis (64 patients, 81%), while 13 patients (16%) and 2 patients (3%) were operated for colon cancer and IBD,

respectively. During these times, 64 procedures (81%) were performed by fellows, 6 (8%) by consultants (4 diverticulitis and 2 cancer cases), and 9 (10%) were teaching procedures (7 diverticulitis and both IBD cases).

Discussion

Among 664 colectomies analyzed in this study, intraoperative adverse event did not differ significantly when comparing the three study groups: fellows, consultants, and taught trainees, after adjustment of the three groups. Further, bleeding, operating time, and conversion rates were similar regardless of the setting. The structured and standardized teaching environment in the present institution might account for these encouraging outcomes.

Surgery, among all disciplines of medicine, had ever since its early beginnings placed a strong emphasis on practical training [16]. With the fast evolution of technologies in recent years requiring a continuous adaption of practice and evidence of benefits within high-volume centers [17, 18], the surgeon is under constant pressure to perform well on one hand, and cope with his duty of teaching on the other hand. As expected, intraoperative adverse event have a negative impact on postoperative course [19], highlighting the importance of well-structured and meticulous teaching. Academic institutions carry the burden of education, with economic and political imperatives that might not provide the ideal external preconditions for young trainees' needs [20–22].

The influence of teaching on postoperative outcomes has been previously studied in cancer patients, either for minimally invasive or open surgery [23, 24]. Although some studies showed that surgical adverse event were more likely to occur during early years of practice [25], a study from Borowski et al. showed no negative impact of teaching on surgical outcomes, with no differences in anastomotic leak rates or operative mortality. A study from Montroni et al. including 139 patients comparing outcomes between surgeries performed either by resident or by attending showed no differences in oncological accuracy (equal number of node count), respectively 21% vs. 25% morbidity and 3.5 vs. 5.8% mortality rate according to P-POSSUM. Length of surgery was equivalent in the two groups (159 min) [5, 6]. Other outcomes than intraoperative technical adverse event have been studied, with no harm described in teaching settings [4]. The present study focused on intraoperative adverse events to assess the safety of surgical teaching, since postoperative outcomes are influenced by numerous patient- and disease-related factors and compliance to perioperative care pathways and thus not specific enough [3].

As a common conclusion, all mentioned studies emphasize the need of appropriate teaching conditions. The present institution provides a standardized teaching environment. First, only three board-certified senior consultants are in charge of

concerted training. Every part of the procedure, starting with patients' installation through use of surgical instruments and surgical technique, was standardized through hands-on and written guidelines [10, 11]. Further, ERAS guidelines by itself help through standardized pre- and perioperative care [26, 27]. This standardized technique might provide useful guidance for less experienced surgeons to acquire surgical skills and to gain independency and safety even in stressful situations, i.e., management of challenging procedures during night shifts [28–31]. The present results of equal intraoperative outcomes might thus be mainly the result of standardization and structured surgical education [32–34].

Pre-emptive conversion was performed earlier during the procedure by consultants, probably as a result of surgical experience.

The present study included elective and emergency cases likewise, limiting thus selection bias (all comers). This unselected approach was responsible for the observed differences among the three study groups regarding patient demographics and disease presentation at time of surgery (Tables 1 and 2). In consequence, statistical adjustment was performed regarding emergency procedures (preferably performed by unsupervised fellows), minimally invasive approach (to account for learning curve [35–37] and advanced skills of consultants), and malignant indications (mainly performed in presence of consultants). The only significant difference in analyzed outcomes was the shorter time to conversion in the consultant group, pointing out superiority of strategic thinking in more experienced surgeons.

Limitations

There are some limitations to this study that need to be addressed. The retrospective setting could lead to selection and recall bias. This drawback was faced by regular, prospective cross-checking of data by consultant surgeons. Several definitions in this study were subjective, starting with the definition of teaching. Even though a national cut-off of 75% was set (according to the definition of the Swiss Visceral surgery society), evaluation of when 75% threshold was reached remains subjective. However, the decision whether an operation was taught or not was done by the trainee, reflecting his/her satisfaction of the teaching process (or not). Challenging situations or particularly difficult steps of the procedure might have been managed preferably by consultants, which might be source of inherent bias for every study on surgical teaching. Further reasons for a consultant to take over the operation were unexpected difficulties due to anatomical or technical reasons or time issues, situations which however could hardly be summarized since unique for each procedure. Other subjective assessment concerned bleeding. Also, cross-checked with anesthesiologists and based on actually observed estimated blood loss, it was finally recorded by surgeons, which could lead to erroneous measurements. Emergency surgeries at night

have been mainly performed by fellows since on-site 24/7. This obvious bias was faced by statistical adjusting of the three groups for emergencies, surgical approach, and presence of malignancy (Fig. 1). Encouraging results of the present study might thus emphasize acquisition of sufficient skills and independency to manage these stressful situations as a result of standardized teaching. This study focused solely on intraoperative outcomes. Differences in postoperative adverse event among the three groups were not assessed, and thus, the present results cannot be extrapolated to postoperative outcomes. However, the standardized approach with only three different expert surgeons over the entire study period made the assessment of intraoperative complications particularly interesting. Finally, items related to surgical expertise including management of stressful situations, surgical strategy, and technical aspects were not compared between fellows and consultants in the setting of this study.

Conclusion

The present study displayed no differences in intraoperative adverse events when comparing fellows, consultants, and taught trainees. A structured and standardized teaching environment allowed less experienced surgeons to safely perform colonic resections, even without the presence of an experienced senior surgeon. Hence, surgical teaching should be promoted for the sake of surgical quality.

Compliance with ethical standards

This study was approved by the Institutional Review Board (Commission cantonale d'éthique de la recherche sur l'être humain CER-VD, # 2017-01971). The study was conducted according to the STROBE criteria and registered under www.researchregistry.com (UIN research registry # 38444).

Conflict of interest The authors declare that they have no conflict of interest.

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