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The growing discrepancy between resident training in colonic surgery and the rising number of general surgery graduates

Käser, Samuel A ; Rickenbacher, Andreas ; Cabalzar-Wondberg, Daniela ; Schneider, Marcel ; Dietrich, Daniel ; Misselwitz, Benjamin ; Clavien, Pierre-Alain ; Turina, Matthias

Abstract: **PURPOSE** The decrease in resident operative experience due to working-hour directives and sub-specialization within general surgery is the subject of growing debate. This study aims to examine how the numbers of colectomies used for resident training have evolved since the introduction of working-hour directives and to place these results within the context of the number of new general surgeons. **METHODS** Based on the nationwide database of the Swiss association for quality management in surgery, all segmental colectomies performed at 86 centers were analyzed according to the presence or absence of residents and compared to national numbers of surgical graduates. **RESULTS** Of 19,485 segmental colectomies between 2006 and 2015, 36% were used for training purposes. Residents performed 4%, junior staff surgeons 31%, senior staff surgeons 55%, and private surgeons 10%. The percentage performed by residents decreased significantly, while the annual number of graduates increased from 36 to 79. Multivariate analysis identified statutory (non-private) health insurance (OR 7.6, CI 4.6-12.5), right colon resection (OR 3.5, CI 2.5-4.7), tertiary referral center (OR 1.9, CI 1.5-2.6), emergency surgery (OR 1.7, CI 1.3-2.3), and earlier date of surgery (OR 1.1, CI 1.0-1.1) as predictors for resident involvement. **CONCLUSIONS** Only a low and declining percentage of colectomies is used for resident training, despite growing numbers of trainees. These data imply that opportunities to obtain technical proficiency have diminished since the implementation of working-hour directives, indicating the need to better utilize suitable teaching opportunities, to ensure that technical proficiency remains high.

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The Growing Discrepancy Between Resident Training in Colonic Surgery and the Rising Number of General Surgery Graduates

Samuel A. Käser MD¹, Andreas Rickenbacher MD¹, Daniela Cabalzar-Wondberg MD¹, Marcel Schneider MD¹, Daniel Dietrich², Benjamin Misselwitz MD³, Pierre-Alain Clavien PhD¹ and Matthias Turina PhD¹

Department of Surgery, University Hospital Zurich, Rämistrasse 100, CH-8091 Zürich, Switzerland¹

Swiss Group for Clinical Cancer Research (SAKK), Bern²

Department of Gastroenterology, University Hospital Zurich, Rämistrasse 100, CH-8091 Zürich, Switzerland³

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Corresponding author / requests for reprints:

Matthias Turina, MD, PhD

Department of Surgery

University Hospital Zurich

Rämistrasse 100

CH-8091 Zürich, Switzerland

Phone: +41 44 255 94 22

E-mail: matthias.turina@usz.ch

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Abstract

Purpose: The decrease in resident operative experience due to working-hour directives and sub-specialization within general surgery is the subject of growing debate. This study aims to examine how the numbers of colectomies used for resident training have evolved since the introduction of working-hour directives, and to place these results within the context of the number of new general surgeons.

Methods: Based on the nationwide database of the Swiss association for quality management in surgery, all segmental colectomies performed at 86 centers were analyzed according to the presence or absence of residents and compared to national numbers of surgical graduates.

Results: Of 19,485 segmental colectomies between 2006 and 2015, 36% were used for training purposes. Residents performed 4%, junior staff surgeons 31%, senior staff surgeons 55%, and private surgeons 10%. The percentage performed by residents decreased significantly, while the annual number of graduates increased from 36 to 79. Multivariate analysis identified statutory (non-private) health insurance (OR 7.6, CI 4.6–12.5), right colon resection (OR 3.5, CI 2.5–4.7), tertiary referral center (OR 1.9, CI 1.5–2.6), emergency surgery (OR 1.7, CI 1.3–2.3), and earlier date of surgery (OR 1.1, CI 1.0–1.1) as predictors for resident involvement.

Conclusions: Only a low and declining percentage of colectomies is used for resident training, despite growing numbers of trainees. These data imply that opportunities to obtain technical proficiency have diminished since the implementation of working hour directives, indicating the need to better utilize suitable teaching opportunities, to ensure that technical proficiency remains high.

Introduction

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The quality of training in general surgery has been a matter of debate ever since the implementation of working-hour directives and has become more accentuated with the ongoing (sub-) specialization of surgery. Numerous reports document a decline of resident operative experience following the introduction of the 80-hour workweek in the United States [1-3]. Recent studies show a reduction in case volume of up to 50%, especially during the early postgraduate years [2,3]. While the consequences of diminished training on the quality of care provided by newly-certified surgeons are difficult to assess, a reduced level of expertise appears an obvious conclusion. In Europe, fewer data on the quality of surgical education are available due to its politically fragmented system, with diverse training models in individual countries. However, due to an even greater reduction of work hours (48 within the European Union), the effects of a decreased caseload on the skill level of newly board-certified surgeons may be even more pronounced. In Switzerland, a work time restriction of 50 hours per week with at least 11 hours of rest between duty periods was implemented in 2005 [4]. In trying to compensate for this reduction, most hospitals have increased the numbers of residents to cover in-house shifts, resulting in a rise in the numbers of graduates in general surgery.

Adding to the above difficulties, general surgery as a specialty of its own is ever more questioned, as the complexity of its individual components has increased in recent years. Colorectal surgery serves as a good example: its operations were previously considered “bread and butter”, but this perception has changed with advanced laparoscopy and other more refined techniques such as complete mesocolic excision (CME).

With respect to laparoscopic colectomies, the learning curve has been thoroughly studied and is reported as 30 to 60 cases [5-7]. The learning curve for

1 traditional open colectomies, which remain the standard in many rural areas, is less
2 well studied [8,9], even though studies report a positive association between
3 operative experience and outcomes [10-12]. To assure proficiency, national boards
4 have defined a minimum number of colorectal and general surgery procedures, even
5 though these numbers appear surprisingly low in some instances, i.e., 5 colonic
6 resections among a total of 545 operations (open or laparoscopic) in Switzerland [13].
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14 In our current study, we analyze the Swiss nation-wide percentage of routine
15 colonic resections used for training residents and fellows, and contrast these results
16 with the number of newly certified graduates in general surgery, as well as the size of
17 the existing surgical workforce. We limited our analysis to segmental colectomies,
18 excluding total colectomies and rectal resections as fellowship-trained colorectal
19 surgeons increasingly perform these. Given the developments described above, we
20 aimed to test the hypothesis that the number of segmental colectomies performed by
21 residents has declined in the past decade, while the number of newly certified
22 surgeons has increased in parallel.
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39 **Methods**

40 *Source data*

41 The AQC (Swiss association for quality management in surgery;
42 Arbeitsgemeinschaft für Qualitätssicherung in der Chirurgie) maintains a prospective
43 database of in-patient data from public Swiss hospitals. This database was founded
44 in 1995 and contains a total of 1.5 million datasets, making it the largest national
45 database for assessing surgical quality in Switzerland [14]. Residents are defined as
46 any general surgery resident employed by the individual hospital without distinction of
47 postgraduate year. Junior and senior surgical staff is a distinction of house staff
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1 surgeons typical of German-speaking nations. Junior staff equals the “Oberarzt”,
2 whereas senior staff corresponds to the “leitender Oberarzt” or “Leitender Arzt”.
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4 The Swiss medical association publishes the numbers of newly certified
5 medical specialists every year [15]. Both numbers were queried for the time period
6 between 2006 and 2015, to determine changes in the number of teaching operations
7 in relation to corresponding numbers of newly certified surgeons, as well as the total
8 number of registered physicians and board-certified surgeons. The number of
9 permanent Swiss residents was retrieved from the Swiss federal statistics office [16].
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11 *Data extraction*

12 The AQC database was analyzed to generate a sample containing all
13 segmental colonic resections from January 2006 to December 2015. Total
14 colectomies and rectal resections were excluded. Cholecystectomies and
15 appendectomies were sampled for comparison. The percentages of segmental
16 colonic resections performed by residents, junior staff surgeons, senior staff
17 surgeons, and private surgeons were assessed. In Switzerland no specific
18 accreditation is needed to train residents other than board-certification. Operations
19 were labeled as teaching operation when the surgeon performing the operation had a
20 lower hierarchical status than the board-certified surgeon assisting the case, both of
21 which are noted in Swiss operative reports. Mere presence of a resident during an
22 operation did not qualify for the case to be labelled as “teaching operation”. Factors
23 predictive for training were analyzed.
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51 *Data analysis & statistics*

52 Numbers of Swiss residents, doctors, surgeons, surgeries, and graduates from
53 the years 2006 to 2015 were visualized as scatter plots. Spearman’s rho was used to
54 test for trend over time. Proportions of binary characteristics over the years 2006 to
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1 2015 were visualized in frequency tables and modeled by Cochran-Armitage trend
2 tests. Multiple logistic regression was used to model binary outcomes by a pre-
3 defined set of predictors. Poisson-regression was used to compare trends over time
4 in different populations. Odds ratios with 95% confidence intervals were presented.
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6 P-values < 0.05 were considered statistically significant. Analyses were conducted
7 using SAS 9.4 (SAS Institute Inc., Cary, NC. USA) and S-PLUS 8.1 (TIBCO Software,
8 Palo Alto, CA, USA).
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19 **Results**

20 *Demographic changes and development of the medical workforce*

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23 From 2006 to 2015, the permanent resident population of Switzerland grew by
24 10%, to 8.24 million residents ($p < 0.001$). During the same time period, the number of
25 certified physicians rose disproportionately by 23%, to 35,325 ($p < 0.001$). The
26 greatest absolute growth, however, was noted within the surgical workforce, with the
27 number of registered surgeons increasing by 27%, to 1351 — or a surgeon density of
28 164:1 million inhabitants — in 2015 ($p < 0.001$, Figure 1).
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42 *Number of segmental colectomies vs. number of surgical graduates*

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44 From 2006 to 2015, 19,485 segmental colectomies were included in the AQC
45 database. The number of resections per year increased from 1229 to 2181 ($p = 0.02$),
46 while the percentage of teaching operations decreased during the same time period
47 from 35% to 22% ($p < 0.001$, Figure 2). Similarly, the percentage of segmental
48 colectomies performed by residents declined from 4.1% to 4.0 % ($p = 0.0118$,
49 Spearman rho trend analysis, Figure 3). While the absolute number of teaching
50 operations (430 to 479, +11%) as well as the resections by residents (50 to 87,
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1 +74%) increased due to the higher overall numbers of operations, the annual number
2 of surgery graduates showed an even greater, disproportionate increase from 36 to
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4 79 per year (+119%, $p < 0.001$, Figure 3). **This annual number was constant in the**
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6 **previous decade (1996 to 2005) with a mean of 40 newly graduated surgeons**
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8 **per year increasing to a mean of 49 in the decade analyzed in this study (2006**
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10 **to 2015). This corresponds to a relative increase of 23% within a decade.**
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16 *Teaching rates among appendectomies and cholecystectomies*

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19 To contrast the number of segmental colectomies with other resident
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21 operations, data on 52,302 cholecystectomies and 41,975 appendectomies were
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23 obtained. Overall, 21% of all cholecystectomies and 28% all appendectomies were
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25 labeled as “teaching operation”, meaning that a more senior surgeon was assisting a
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27 junior colleague on the case. As observed for segmental colectomy, the teaching rate
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29 in cholecystectomies decreased from 24.3% to 17.6% ($p = 0.0038$), while the teaching
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31 rate in appendectomies showed only a minor, insignificant decrease from 30% to
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33 25.9% ($p = 0.0739$). However, residents performed the majority of all teaching
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35 appendectomies (98%) and cholecystectomies (93%).
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45 *Factors predictive for the use of segmental colectomies as teaching operations*

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47 When looking at teaching rates of segmental colectomies in general, we found
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49 that statutory (non-private) insurance, open resection, right-sided resection,
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51 community hospital (i.e., non tertiary referral center), earlier date of surgery, and
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53 advanced patient age were predictors for a higher likelihood of teaching (Table 1). In
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55 contrast, when analyzing factors predictive only for resident training, a different
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57 picture emerges: for residents, operations in a tertiary referral center, emergency
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1 operations, and lower ASA (American Society of Anesthesiology) scores were
2 predictive of higher teaching rates. Private insurance was, predictably, associated
3 with very low teaching rates, reflecting common practice in German-speaking Europe.
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10 *Level of expertise / seniority of surgeons performing segmental colectomies*

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13 The majority of segmental colectomies were performed by senior staff
14 surgeons (55%), junior staff surgeons (31%), and private surgeons (10%), with
15 residents only performing 4% of segmental colectomies. Less than one third (31%) of
16 segmental resections were labeled as teaching operations. When looking at this
17 fraction, however, the data show that only 15% of these cases involved residents,
18 while 69% were conducted by junior staff surgeons under the supervision of their
19 more experienced colleagues. Interestingly, the rate of segmental colectomies
20 instructed among senior staff surgeons increased from 5% to 20% ($p=0.0051$), while
21 the rate of colectomies involving junior staff surgeons dropped from 74% to 66%
22 ($p=0.0003$), and the rate involving residents dropped from 21% to 13% ($p<0.001$).
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25 Conversely, the rate of colectomies not used for training increased from 65% to 78%
26 from 2006 to 2015 ($p<0.001$). Mainly senior surgeons (64%), junior staff surgeons
27 (24%), and private surgeons (10%) performed these operations. Senior staff
28 surgeons performed more and more of these resections by themselves, without
29 utilizing the case to teach another colleague (2006: 67% to 2015: 71%, $p<0.001$). At
30 the same time, the rate of unsupervised operations performed by junior staff
31 surgeons declined sharply, from 30% to 16% ($p<0.001$).
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Discussion

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2 Our present study shows a striking discrepancy between the percentage of
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4 colonic resections used for resident training and rising numbers of general surgery
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6 graduates in the decade following the introduction of resident work hour restrictions.
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8 The percentage of resections performed by residents was surprisingly low, at 4.1% in
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10 2005, and decreased further during the study period, indicating a significant decline
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12 in the average resident's operative experience. As this reduction in experience may
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14 be specific to the field of colorectal surgery, we queried appendectomies and
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16 cholecystectomies as well, but found a similar trend.
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21 The implementation of working time restrictions is the most obvious
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23 explanation for this decline in resident involvement. Working time restrictions directly
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25 reduce resident operating room time and are thus unfavorable to adequate surgical
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27 training [17,1-3]. To fulfill working time restrictions, most if not all hospitals have
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29 increased the numbers of in-house staff to safeguard call schedules and off-time
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31 physician presence. Indeed, the number of certified surgeons increased by 27% from
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33 2006 to 2015, while the overall population in Switzerland increased by only 10%.
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35 **This increasing need of surgeons was obviously partly fulfilled by certifying**
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37 **more graduates per year in Switzerland (increase by 23% comparing 1996 -**
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39 **2005 to 2006 – 2015).** As a result, supervised training might occur at a later stage or
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41 newly certified surgeons might begin their practice with an inferior surgical skillset,
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43 which might subsequently result in worse clinical outcomes. Indeed, several reports
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45 show a clear association between the level of clinical experience (or status of board
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47 certification) and postoperative outcomes after colectomy including conversion rates,
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49 morbidity, and mortality [10,18]. Our own data indirectly support this notion, as we
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51 could demonstrate a rising percentage of teaching operations among senior staff and
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chief surgeons, indicating a need for training even in late career stages. However, our study did not directly address residents' surgical skills or patient outcomes.

Apart from work-hour restrictions, other obvious reasons for the decrease in resident exposure include the trend towards sub-specialization. Colorectal surgery has since established itself as a distinct specialty, especially in the United States, where the American Board of Surgery began certifying proctologists as early as the 1940s [19]. European nations have been late in recognizing colorectal surgery as a distinct specialty, and even today, specific colorectal fellowship programs are less common.

The trend toward specialization has been justified by the increased complexity of laparoscopic colorectal surgery, with an associated learning curve averaging 30–60 cases [5-7], which exceeds the training capacity of most residency programs. Our data indicate that even experienced surgeons use the opportunity to learn from their peers, as 16% of colectomies were used for teaching experienced surgeons. It may be that the complexity of even segmental colectomies has risen to a level where its use as a teaching operation for residents is no longer justified. We therefore compared our findings to “simple” operations such as appendectomies and cholecystectomies. Our data show that their utilization for teaching opportunities has declined as well, but not to the extent of colon resections, and that the decline was more obvious for cholecystectomies than for appendectomies.

The reduced percentage of training operations may also result from factors other than working time restrictions. European academic medical centers reward or penalize clinical outcomes and academic achievements, both of which are easily measurable. Teaching quality, however, is more difficult to judge and staff physicians

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may be reluctant to invest time in teaching due to their growing clinical, academic or administrative workloads.

In our study, the use of laparoscopy was a negative predictor for teaching (Table 1). Open operations were more likely to be used for training, as were resections of the right (as opposed to the left) colon. Similarly, residents were more likely to be trained on emergency (as opposed to elective) operations. Elective operations are more likely to be performed using minimally-invasive techniques than urgent nighttime resections, which are often performed for obstruction or perforation and do not lend themselves well to the laparoscopic approach. Also, resident participation in complex minimally invasive resections may be deemed hazardous or a risk for increased perioperative morbidity. Several studies, however, have addressed this topic and do not confirm this perception [20-22]. Renwick et al. did not find differences in oncologic outcomes or morbidity/mortality in 344 patients operated on by residents under supervision when compared with 150 patients operated on by a staff surgeon [21]. Similarly, Krishna et al. did not find differences in length of operation, conversion rate, postoperative morbidity or length of stay in patients undergoing colorectal resection by fellows compared to consultants [20].

Robotically-assisted surgery further adds to the dilemma of increased complexity, as this technology has a learning curve of its own, reported at 15-30 cases in surgeons already trained in laparoscopic surgery [7]. The true impact of robot-assisted colorectal surgery on the quality of general surgery training programs, however, remains unclear.

Limitations

The present retrospective study is based on the largest Swiss national surgical quality control database. As not all hospitals in Switzerland report their data to this

1 database, selection bias may exist. Regarding the generalizability of the results our
2 study is restricted to a single country; however, Switzerland as a typical western
3 European nation with trends in surgery and working time restrictions similar to others,
4 appears representative of the status of contemporary surgical education. Thus, it can
5 be assumed that other nations face similar discrepancies between declining resident
6 training and the rising number of surgery program graduates.
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14 **Due to a lack of a clear definition of teaching vs. non-teaching operations,**
15 **residents might have performed single steps of a surgical procedure [23], while**
16 **the whole operation may not have been labeled as a teaching opportunity.**
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22 **Another limitation of this study is that the increasing role of laparoscopy**
23 **courses and surgery simulators in training of surgical residents has not been**
24 **addressed in this study due to lack of data pertaining to this subject.**
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29 30 31 **Conclusion**

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34 Despite segmental colectomies forming an integral part of general surgery
35 training, only a low and declining percentage of these cases is used for resident
36 training. These findings indicate the need to (re)structure general surgery training, to
37 better define the role of sub-specialties in the contemporary landscape. Care should
38 be taken to insure that residents are adequately exposed to routine abdominal
39 procedures, thus enabling them to attain proficiency as newly certified general
40 surgeons.
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54 **Acknowledgements**

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perform this study.

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Figures

Figure 1.

Relative growth of the Swiss population, number of medical doctors, and surgeon workforce

Figure 2

Number of segmental colon resections per year (regression line), overall teaching rates, and resident teaching rates

Figure 3

Percentage of segmental colonic resections performed by residents and the number of new graduates in general surgery between 2006 and 2015

Table 1

Predictors for teaching in patients undergoing segmental colectomies

	Predictor	OR	95% CI	p-value
Entire cohort	Statutory (non-private) insurance status	8.772	6.803 - 11.364	<0.001
	Open resection	1.745	1.416 - 2.146	<0.001
	Community hospital (non tertiary referral center)	1.631	1.381 - 1.927	<0.001
	Right-sided resection	1.340	1.130 - 1.587	<0.001
	Earlier date of surgery	1.181	1.139 - 1.226	<0.001
	Age ^o	1.009	1.003 - 1.015	0.0056
	Lower ASA* class			<i>0.4755</i>
	Body mass index	1.005	0.990 - 1.020	<i>0.5399</i>
	Malignant disease	0.891	0.744 - 1.067	<i>0.2085</i>
	Emergency operation	1.010	0.828 - 1.231	<i>0.9255</i>
	Male gender	1.096	0.928 - 1.293	<i>0.2814</i>
Residents	Statutory (non-private) insurance status	7.634	4.630 - 12.500	<0.001
	Right-sided resection	3.460	2.530 - 4.740	<0.001
	Tertiary referral center	1.944	1.468 - 2.575	<0.001
	Emergency operation	1.684	1.251 - 2.265	<0.001
	Earlier date of surgery	1.072	1.017- 1.130	0.0098
	Age ^o	1.011	1.001 - 1.021	0.0375
	Lower ASA* class			0.0440[†]
	Male gender	0.916	0.699 - 1.199	<i>0.5208</i>
	Body mass index	0.987	0.961 - 1.013	<i>0.3148</i>
	Malignant disease	1.158	0.861- 1.556	<i>0.3326</i>
	Open resection	1.0741	0.761 - 1.515	<i>0.6863</i>

^oAge was analyzed as continuous variable,

*American Society of Anesthesiology class,

[†]: ASA 2 vs 1: OR 1.848, CI 1.201 – 2.849

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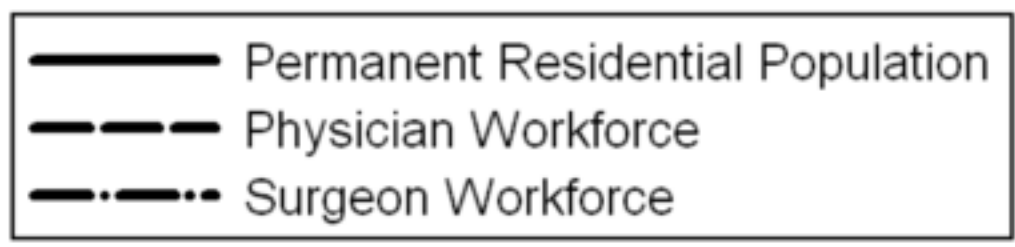
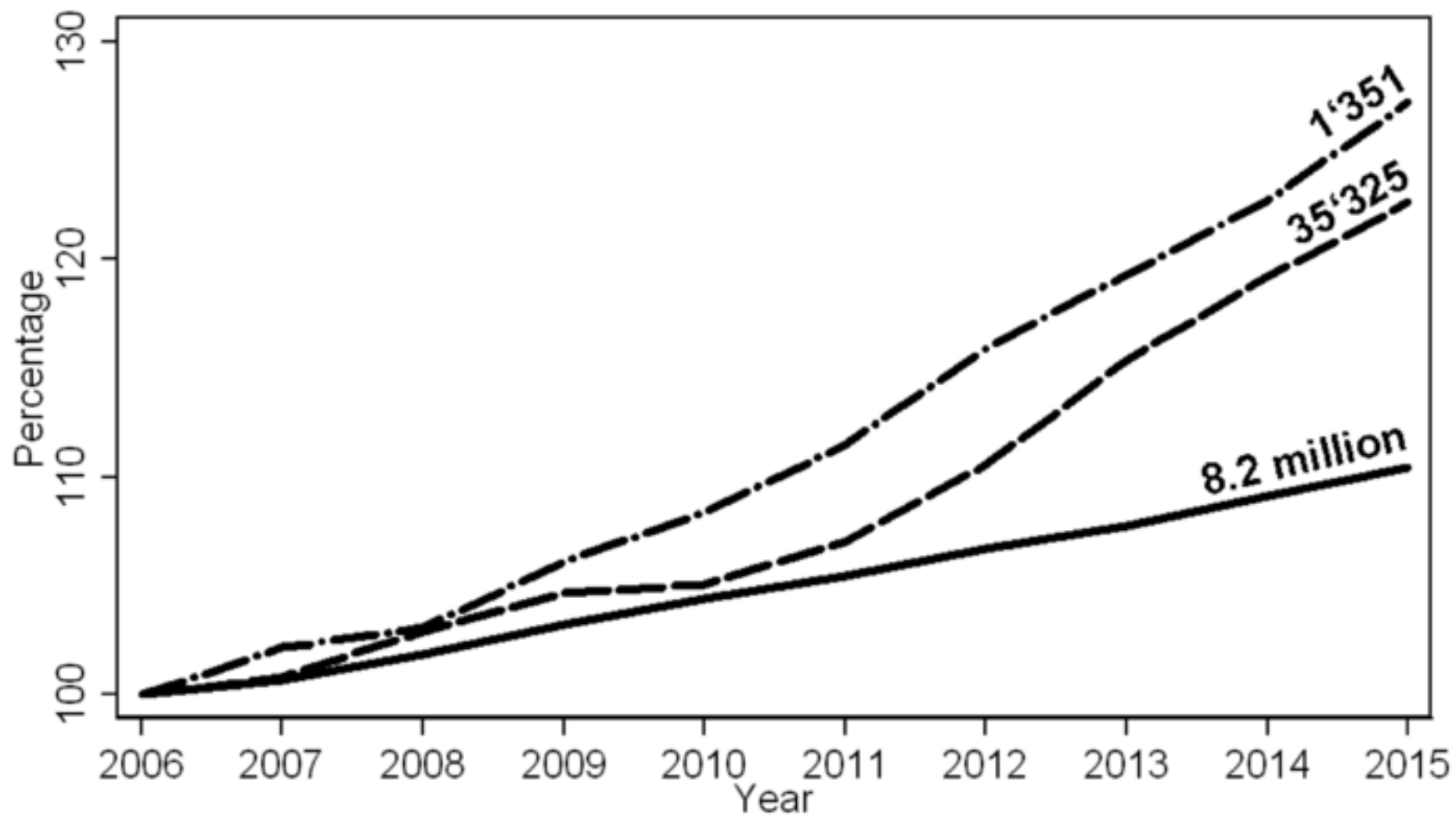
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Figure 1

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Figure 2

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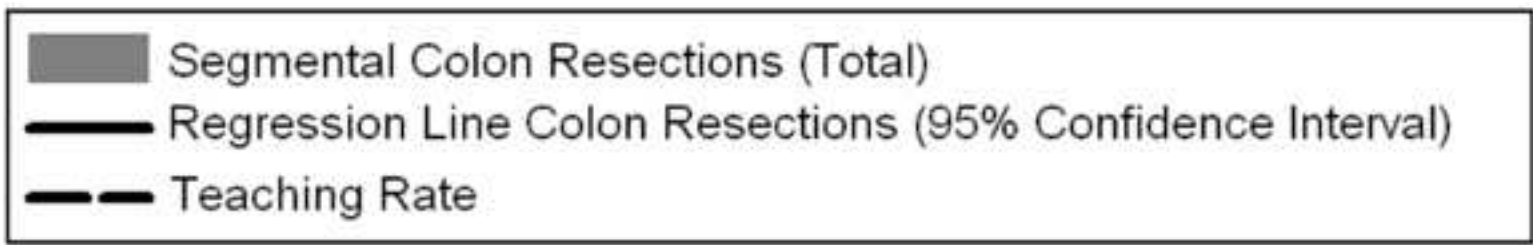
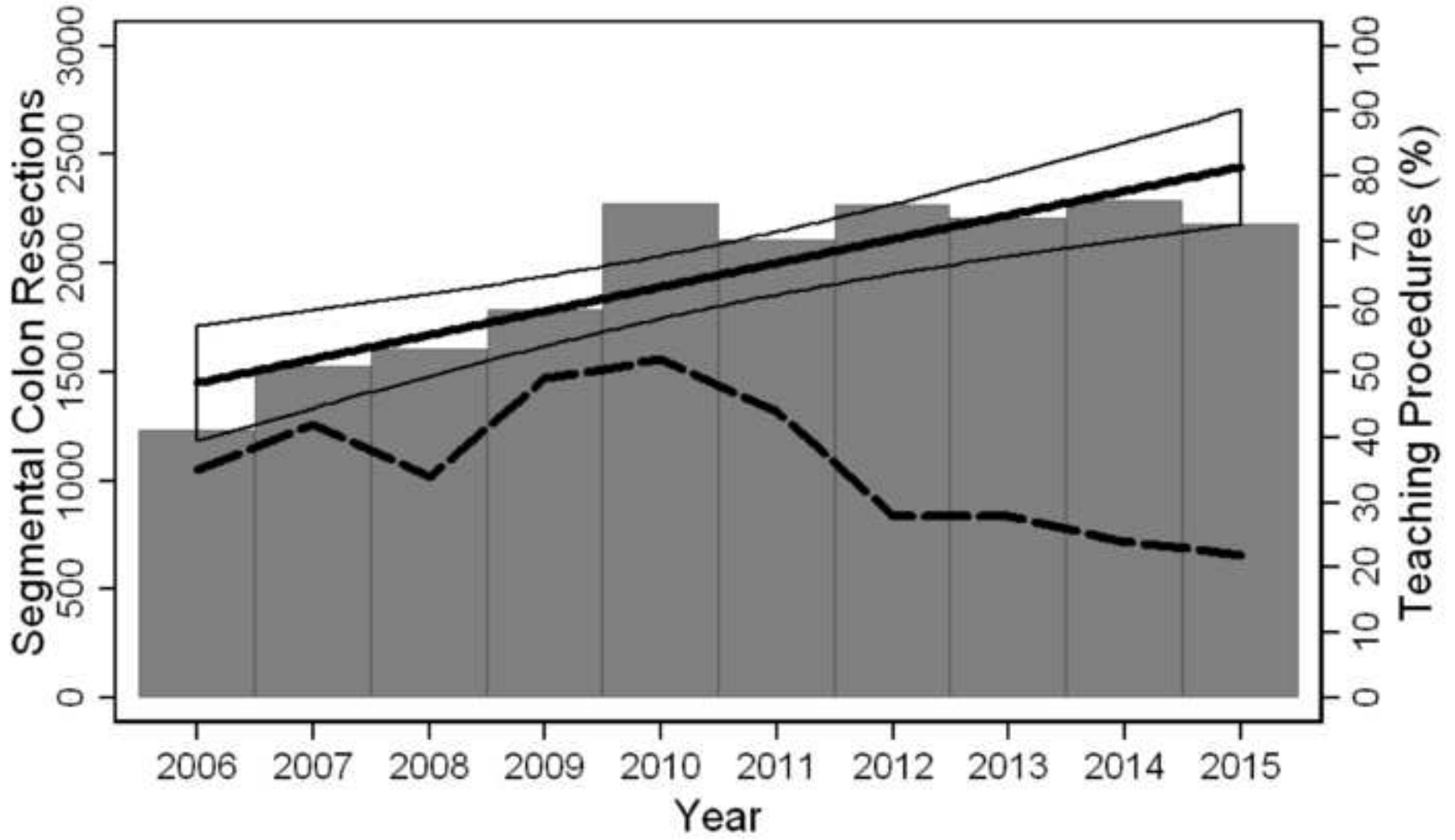
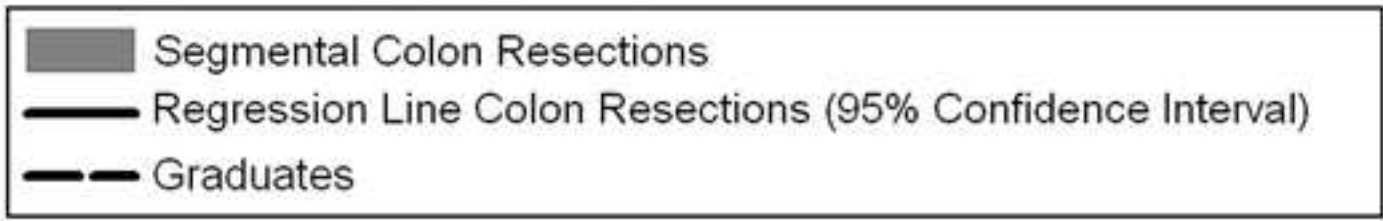
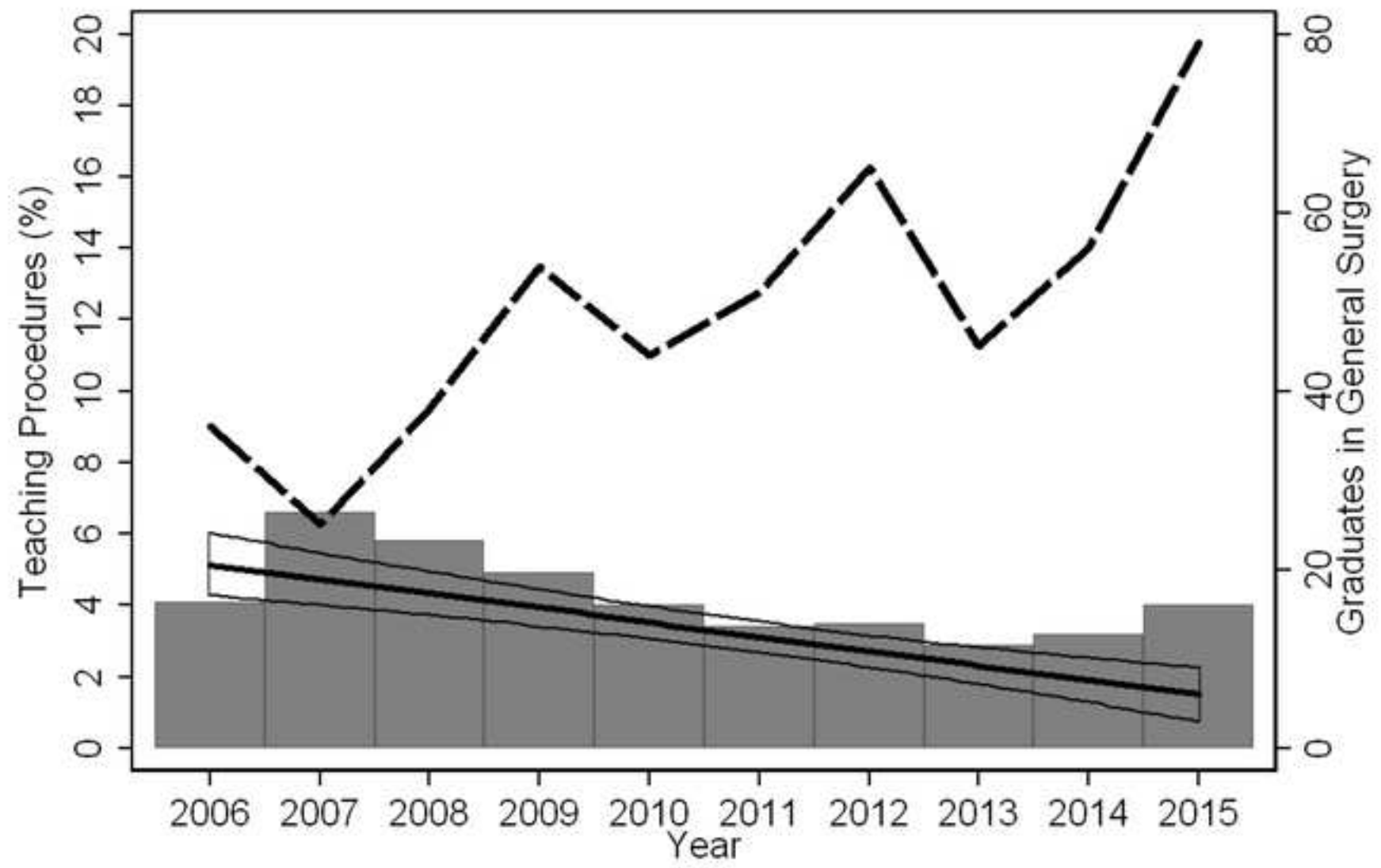


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The Growing Discrepancy Between Resident Training in Colonic Surgery and the Rising Number of General Surgery Graduates

Samuel A. Käser MD¹, Andreas Rickenbacher MD¹, Daniela Cabalzar-Wondberg MD¹,
Marcel Schneider MD¹, Daniel Dietrich², Benjamin Misselwitz MD³, Pierre-Alain Clavien PhD¹
and Matthias Turina PhD¹

Department of Surgery, University Hospital Zurich, Rämistrasse 100, CH-8091 Zürich,
Switzerland¹

Swiss Group for Clinical Cancer Research (SAKK), Bern²

Department of Gastroenterology, University Hospital Zurich, Rämistrasse 100, CH-8091
Zürich, Switzerland³

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Corresponding author / requests for reprints:

Matthias Turina, MD, PhD

Department of Surgery

University Hospital Zurich

Rämistrasse 100

CH-8091 Zürich, Switzerland

Phone: +41 44 255 94 22

E-mail: matthias.turina@usz.ch

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Abstract

Purpose: The decrease in resident operative experience due to working-hour directives and sub-specialization within general surgery is the subject of growing debate. This study aims to examine how the numbers of colectomies used for resident training have evolved since the introduction of working-hour directives, and to place these results within the context of the number of new general surgeons.

Methods: Based on the nationwide database of the Swiss association for quality management in surgery, all segmental colectomies performed at 86 centers were analyzed according to the presence or absence of residents and compared to national numbers of surgical graduates.

Results: Of 19,485 segmental colectomies between 2006 and 2015, 36% were used for training purposes. Residents performed 4%, junior staff surgeons 31%, senior staff surgeons 55%, and private surgeons 10%. The percentage performed by residents decreased significantly, while the annual number of graduates increased from 36 to 79. Multivariate analysis identified statutory (non-private) health insurance (OR 7.6, CI 4.6–12.5), right colon resection (OR 3.5, CI 2.5–4.7), tertiary referral center (OR 1.9, CI 1.5–2.6), emergency surgery (OR 1.7, CI 1.3–2.3), and earlier date of surgery (OR 1.1, CI 1.0–1.1) as predictors for resident involvement.

Conclusions: Only a low and declining percentage of colectomies is used for resident training, despite growing numbers of trainees. These data imply that opportunities to obtain technical proficiency have diminished since the implementation of working hour directives, indicating the need to better utilize suitable teaching opportunities, to ensure that technical proficiency remains high.

Introduction

1
2 The quality of training in general surgery has been a matter of debate ever
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4 since the implementation of working-hour directives and has become more
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6 accentuated with the ongoing (sub-) specialization of surgery. Numerous reports
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8 document a decline of resident operative experience following the introduction of the
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10 80-hour workweek in the United States [1-3]. Recent studies show a reduction in
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12 case volume of up to 50%, especially during the early postgraduate years [2,3]. While
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14 the consequences of diminished training on the quality of care provided by newly-
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16 certified surgeons are difficult to assess, a reduced level of expertise appears an
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18 obvious conclusion. In Europe, fewer data on the quality of surgical education are
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20 available due to its politically fragmented system, with diverse training models in
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22 individual countries. However, due to an even greater reduction of work hours (48
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24 within the European Union), the effects of a decreased caseload on the skill level of
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26 newly board-certified surgeons may be even more pronounced. In Switzerland, a
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28 work time restriction of 50 hours per week with at least 11 hours of rest between duty
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30 periods was implemented in 2005 [4]. In trying to compensate for this reduction, most
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32 hospitals have increased the numbers of residents to cover in-house shifts, resulting
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34 in a rise in the numbers of graduates in general surgery.
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43 Adding to the above difficulties, general surgery as a specialty of its own is
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45 ever more questioned, as the complexity of its individual components has increased
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47 in recent years. Colorectal surgery serves as a good example: its operations were
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49 previously considered “bread and butter”, but this perception has changed with
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51 advanced laparoscopy and other more refined techniques such as complete
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53 mesocolic excision (CME).
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58 With respect to laparoscopic colectomies, the learning curve has been
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60 thoroughly studied and is reported as 30 to 60 cases [5-7]. The learning curve for
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1 traditional open colectomies, which remain the standard in many rural areas, is less
2 well studied [8,9], even though studies report a positive association between
3 operative experience and outcomes [10-12]. To assure proficiency, national boards
4 have defined a minimum number of colorectal and general surgery procedures, even
5 though these numbers appear surprisingly low in some instances, i.e., 5 colonic
6 resections among a total of 545 operations (open or laparoscopic) in Switzerland [13].
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14 In our current study, we analyze the Swiss nation-wide percentage of routine
15 colonic resections used for training residents and fellows, and contrast these results
16 with the number of newly certified graduates in general surgery, as well as the size of
17 the existing surgical workforce. We limited our analysis to segmental colectomies,
18 excluding total colectomies and rectal resections as fellowship-trained colorectal
19 surgeons increasingly perform these. Given the developments described above, we
20 aimed to test the hypothesis that the number of segmental colectomies performed by
21 residents has declined in the past decade, while the number of newly certified
22 surgeons has increased in parallel.
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39 **Methods**

40 *Source data*

41 The AQC (Swiss association for quality management in surgery;
42 Arbeitsgemeinschaft für Qualitätssicherung in der Chirurgie) maintains a prospective
43 database of in-patient data from public Swiss hospitals. This database was founded
44 in 1995 and contains a total of 1.5 million datasets, making it the largest national
45 database for assessing surgical quality in Switzerland [14]. Residents are defined as
46 any general surgery resident employed by the individual hospital without distinction of
47 postgraduate year. Junior and senior surgical staff is a distinction of house staff
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1 surgeons typical of German-speaking nations. Junior staff equals the “Oberarzt”,
2 whereas senior staff corresponds to the “leitender Oberarzt” or “Leitender Arzt”.
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4 The Swiss medical association publishes the numbers of newly certified
5 medical specialists every year [15]. Both numbers were queried for the time period
6 between 2006 and 2015, to determine changes in the number of teaching operations
7 in relation to corresponding numbers of newly certified surgeons, as well as the total
8 number of registered physicians and board-certified surgeons. The number of
9 permanent Swiss residents was retrieved from the Swiss federal statistics office [16].
10

11 *Data extraction*

12 The AQC database was analyzed to generate a sample containing all
13 segmental colonic resections from January 2006 to December 2015. Total
14 colectomies and rectal resections were excluded. Cholecystectomies and
15 appendectomies were sampled for comparison. The percentages of segmental
16 colonic resections performed by residents, junior staff surgeons, senior staff
17 surgeons, and private surgeons were assessed. In Switzerland no specific
18 accreditation is needed to train residents other than board-certification. Operations
19 were labeled as teaching operation when the surgeon performing the operation had a
20 lower hierarchical status than the board-certified surgeon assisting the case, both of
21 which are noted in Swiss operative reports. Mere presence of a resident during an
22 operation did not qualify for the case to be labelled as “teaching operation”. Factors
23 predictive for training were analyzed.
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51 *Data analysis & statistics*

52 Numbers of Swiss residents, doctors, surgeons, surgeries, and graduates from
53 the years 2006 to 2015 were visualized as scatter plots. Spearman’s rho was used to
54 test for trend over time. Proportions of binary characteristics over the years 2006 to
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1 2015 were visualized in frequency tables and modeled by Cochran-Armitage trend
2 tests. Multiple logistic regression was used to model binary outcomes by a pre-
3 defined set of predictors. Poisson-regression was used to compare trends over time
4 in different populations. Odds ratios with 95% confidence intervals were presented.
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6 P-values < 0.05 were considered statistically significant. Analyses were conducted
7 using SAS 9.4 (SAS Institute Inc., Cary, NC. USA) and S-PLUS 8.1 (TIBCO Software,
8 Palo Alto, CA, USA).
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19 **Results**

20 *Demographic changes and development of the medical workforce*

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23 From 2006 to 2015, the permanent resident population of Switzerland grew by
24 10%, to 8.24 million residents ($p < 0.001$). During the same time period, the number of
25 certified physicians rose disproportionately by 23%, to 35,325 ($p < 0.001$). The
26 greatest absolute growth, however, was noted within the surgical workforce, with the
27 number of registered surgeons increasing by 27%, to 1351 — or a surgeon density of
28 164:1 million inhabitants — in 2015 ($p < 0.001$, Figure 1).
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42 *Number of segmental colectomies vs. number of surgical graduates*

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44 From 2006 to 2015, 19,485 segmental colectomies were included in the AQC
45 database. The number of resections per year increased from 1229 to 2181 ($p = 0.02$),
46 while the percentage of teaching operations decreased during the same time period
47 from 35% to 22% ($p < 0.001$, Figure 2). Similarly, the percentage of segmental
48 colectomies performed by residents declined from 4.1% to 4.0 % ($p = 0.0118$,
49 Spearman rho trend analysis, Figure 3). While the absolute number of teaching
50 operations (430 to 479, +11%) as well as the resections by residents (50 to 87,
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1 +74%) increased due to the higher overall numbers of operations, the annual number
2 of surgery graduates showed an even greater, disproportionate increase from 36 to
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4 79 per year (+119%, $p < 0.001$, Figure 3). This annual number was constant in the
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6 previous decade (1996 to 2005) with a mean of 40 newly graduated surgeons per
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8 year increasing to a mean of 49 in the decade analyzed in this study (2006 to 2015).
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10 This corresponds to a relative increase of 23% within a decade.
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16 *Teaching rates among appendectomies and cholecystectomies*

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18 To contrast the number of segmental colectomies with other resident
19 operations, data on 52,302 cholecystectomies and 41,975 appendectomies were
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21 obtained. Overall, 21% of all cholecystectomies and 28% all appendectomies were
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23 labeled as “teaching operation”, meaning that a more senior surgeon was assisting a
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25 junior colleague on the case. As observed for segmental colectomy, the teaching rate
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27 in cholecystectomies decreased from 24.3% to 17.6% ($p = 0.0038$), while the teaching
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29 rate in appendectomies showed only a minor, insignificant decrease from 30% to
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31 25.9% ($p = 0.0739$). However, residents performed the majority of all teaching
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33 appendectomies (98%) and cholecystectomies (93%).
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45 *Factors predictive for the use of segmental colectomies as teaching operations*

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47 When looking at teaching rates of segmental colectomies in general, we found
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49 that statutory (non-private) insurance, open resection, right-sided resection,
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51 community hospital (i.e., non tertiary referral center), earlier date of surgery, and
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53 advanced patient age were predictors for a higher likelihood of teaching (Table 1). In
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55 contrast, when analyzing factors predictive only for resident training, a different
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57 picture emerges: for residents, operations in a tertiary referral center, emergency
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1 operations, and lower ASA (American Society of Anesthesiology) scores were
2 predictive of higher teaching rates. Private insurance was, predictably, associated
3 with very low teaching rates, reflecting common practice in German-speaking Europe.
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11 *Level of expertise / seniority of surgeons performing segmental colectomies*
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13 The majority of segmental colectomies were performed by senior staff
14 surgeons (55%), junior staff surgeons (31%), and private surgeons (10%), with
15 residents only performing 4% of segmental colectomies. Less than one third (31%) of
16 segmental resections were labeled as teaching operations. When looking at this
17 fraction, however, the data show that only 15% of these cases involved residents,
18 while 69% were conducted by junior staff surgeons under the supervision of their
19 more experienced colleagues. Interestingly, the rate of segmental colectomies
20 instructed among senior staff surgeons increased from 5% to 20% ($p=0.0051$), while
21 the rate of colectomies involving junior staff surgeons dropped from 74% to 66%
22 ($p=0.0003$), and the rate involving residents dropped from 21% to 13% ($p<0.001$).
23 Conversely, the rate of colectomies not used for training increased from 65% to 78%
24 from 2006 to 2015 ($p<0.001$). Mainly senior surgeons (64%), junior staff surgeons
25 (24%), and private surgeons (10%) performed these operations. Senior staff
26 surgeons performed more and more of these resections by themselves, without
27 utilizing the case to teach another colleague (2006: 67% to 2015: 71%, $p<0.001$). At
28 the same time, the rate of unsupervised operations performed by junior staff
29 surgeons declined sharply, from 30% to 16% ($p<0.001$).
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Discussion

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2 Our present study shows a striking discrepancy between the percentage of
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4 colonic resections used for resident training and rising numbers of general surgery
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6 graduates in the decade following the introduction of resident work hour restrictions.
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8 The percentage of resections performed by residents was surprisingly low, at 4.1% in
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10 2005, and decreased further during the study period, indicating a significant decline
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12 in the average resident's operative experience. As this reduction in experience may
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14 be specific to the field of colorectal surgery, we queried appendectomies and
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16 cholecystectomies as well, but found a similar trend.
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21 The implementation of working time restrictions is the most obvious
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23 explanation for this decline in resident involvement. Working time restrictions directly
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25 reduce resident operating room time and are thus unfavorable to adequate surgical
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27 training [17,1-3]. To fulfill working time restrictions, most if not all hospitals have
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29 increased the numbers of in-house staff to safeguard call schedules and off-time
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31 physician presence. Indeed, the number of certified surgeons increased by 27% from
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33 2006 to 2015, while the overall population in Switzerland increased by only 10%. This
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35 increasing need of surgeons was obviously partly fulfilled by certifying more
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37 graduates per year in Switzerland (increase by 23% comparing 1996 - 2005 to 2006
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39 – 2015). As a result, supervised training might occur at a later stage or newly certified
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41 surgeons might begin their practice with an inferior surgical skillset, which might
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43 subsequently result in worse clinical outcomes. Indeed, several reports show a clear
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45 association between the level of clinical experience (or status of board certification)
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47 and postoperative outcomes after colectomy including conversion rates, morbidity,
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49 and mortality [10,18]. Our own data indirectly support this notion, as we could
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51 demonstrate a rising percentage of teaching operations among senior staff and chief
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surgeons, indicating a need for training even in late career stages. However, our study did not directly address residents' surgical skills or patient outcomes.

Apart from work-hour restrictions, other obvious reasons for the decrease in resident exposure include the trend towards sub-specialization. Colorectal surgery has since established itself as a distinct specialty, especially in the United States, where the American Board of Surgery began certifying proctologists as early as the 1940s [19]. European nations have been late in recognizing colorectal surgery as a distinct specialty, and even today, specific colorectal fellowship programs are less common.

The trend toward specialization has been justified by the increased complexity of laparoscopic colorectal surgery, with an associated learning curve averaging 30–60 cases [5-7], which exceeds the training capacity of most residency programs. Our data indicate that even experienced surgeons use the opportunity to learn from their peers, as 16% of colectomies were used for teaching experienced surgeons. It may be that the complexity of even segmental colectomies has risen to a level where its use as a teaching operation for residents is no longer justified. We therefore compared our findings to “simple” operations such as appendectomies and cholecystectomies. Our data show that their utilization for teaching opportunities has declined as well, but not to the extent of colon resections, and that the decline was more obvious for cholecystectomies than for appendectomies.

The reduced percentage of training operations may also result from factors other than working time restrictions. European academic medical centers reward or penalize clinical outcomes and academic achievements, both of which are easily measurable. Teaching quality, however, is more difficult to judge and staff physicians

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may be reluctant to invest time in teaching due to their growing clinical, academic or administrative workloads.

In our study, the use of laparoscopy was a negative predictor for teaching (Table 1). Open operations were more likely to be used for training, as were resections of the right (as opposed to the left) colon. Similarly, residents were more likely to be trained on emergency (as opposed to elective) operations. Elective operations are more likely to be performed using minimally-invasive techniques than urgent nighttime resections, which are often performed for obstruction or perforation and do not lend themselves well to the laparoscopic approach. Also, resident participation in complex minimally invasive resections may be deemed hazardous or a risk for increased perioperative morbidity. Several studies, however, have addressed this topic and do not confirm this perception [20-22]. Renwick et al. did not find differences in oncologic outcomes or morbidity/mortality in 344 patients operated on by residents under supervision when compared with 150 patients operated on by a staff surgeon [21]. Similarly, Krishna et al. did not find differences in length of operation, conversion rate, postoperative morbidity or length of stay in patients undergoing colorectal resection by fellows compared to consultants [20].

Robotically-assisted surgery further adds to the dilemma of increased complexity, as this technology has a learning curve of its own, reported at 15-30 cases in surgeons already trained in laparoscopic surgery [7]. The true impact of robot-assisted colorectal surgery on the quality of general surgery training programs, however, remains unclear.

Limitations

The present retrospective study is based on the largest Swiss national surgical quality control database. As not all hospitals in Switzerland report their data to this

1 database, selection bias may exist. Regarding the generalizability of the results our
2 study is restricted to a single country; however, Switzerland as a typical western
3 European nation with trends in surgery and working time restrictions similar to others,
4 appears representative of the status of contemporary surgical education. Thus, it can
5 be assumed that other nations face similar discrepancies between declining resident
6 training and the rising number of surgery program graduates.
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14 Due to a lack of a clear definition of teaching vs. non-teaching operations, residents
15 might have performed single steps of a surgical procedure [23], while the whole
16 operation may not have been labeled as a teaching opportunity.
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22 Another limitation of this study is that the increasing role of laparoscopy
23 courses and surgery simulators in training of surgical residents has not been
24 addressed in this study due to lack of data pertaining to this subject.
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31 **Conclusion**

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34 Despite segmental colectomies forming an integral part of general surgery
35 training, only a low and declining percentage of these cases is used for resident
36 training. These findings indicate the need to (re)structure general surgery training, to
37 better define the role of sub-specialties in the contemporary landscape. Care should
38 be taken to insure that residents are adequately exposed to routine abdominal
39 procedures, thus enabling them to attain proficiency as newly certified general
40 surgeons.
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56 perform this study.
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Figures

Figure 1.

Relative growth of the Swiss population, number of medical doctors, and surgeon workforce

Figure 2

Number of segmental colon resections per year (regression line), overall teaching rates, and resident teaching rates

Figure 3

Percentage of segmental colonic resections performed by residents and the number of new graduates in general surgery between 2006 and 2015

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Table 1

Predictors for teaching in patients undergoing segmental colectomies

	Predictor	OR	95% CI	p-value
Entire cohort	Statutory (non-private) insurance status	8.772	6.803 - 11.364	<0.001
	Open resection	1.745	1.416 - 2.146	<0.001
	Community hospital (non tertiary referral center)	1.631	1.381 - 1.927	<0.001
	Right-sided resection	1.340	1.130 - 1.587	<0.001
	Earlier date of surgery	1.181	1.139 - 1.226	<0.001
	Age ^o	1.009	1.003 - 1.015	0.0056
	Lower ASA* class			0.4755
	Body mass index	1.005	0.990 - 1.020	0.5399
	Malignant disease	0.891	0.744 - 1.067	0.2085
	Emergency operation	1.010	0.828 - 1.231	0.9255
	Male gender	1.096	0.928 - 1.293	0.2814
Residents	Statutory (non-private) insurance status	7.634	4.630 - 12.500	<0.001
	Right-sided resection	3.460	2.530 - 4.740	<0.001
	Tertiary referral center	1.944	1.468 - 2.575	<0.001
	Emergency operation	1.684	1.251 - 2.265	<0.001
	Earlier date of surgery	1.072	1.017- 1.130	0.0098
	Age ^o	1.011	1.001 - 1.021	0.0375
	Lower ASA* class			0.0440[†]
	Male gender	0.916	0.699 - 1.199	0.5208
	Body mass index	0.987	0.961 - 1.013	0.3148
	Malignant disease	1.158	0.861- 1.556	0.3326
	Open resection	1.0741	0.761 - 1.515	0.6863

^oAge was analyzed as continuous variable,

*American Society of Anesthesiology class,

[†]: ASA 2 vs 1: OR 1.848, CI 1.201 – 2.849

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