



Learning-by-teaching coming into play as a reliable trick for lower GI procedures: a learning curve analysis in 13,210 operative logs including the COVID-19 era

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Abstract

After suspecting a plunge in the operative case logs in our clinic, we wanted to explore the COVID-19 impact on surgical training side of the lower gastrointestinal procedures to raise awareness of the possible cracks in the pillars of general surgery residency. Comparing the coronavirus impact to previous years starting from 2014, we examined the procedures of our residents for their roles in the operating room. We performed interrupted time-series analyses to get a sense of the magnitude and then used a new index to identify the trend of change in operator-to-first assistant rate of experience and searched for signs of learning-by-teaching motives. In total, 13,210 operative logs of residents were included; of procedures, 3483 (41%) were emergency. Both overall resident participations and learning-by-teaching dropped during first 3 months, followed by a rebound. The overall operator-to-first assistant rate of experience was 1.06 before and 0.86 after. Emergency procedures, obstruction, perforation, enterostomy closure, appendix, colon, anus and minimally invasive procedures, and COVID-19 were associated with learning-by-teaching (OR and 95% CI were; 2.20, 1.76–2.75; 0.56, 0.36–0.85; 0.50, 0.38–0.67; 2.29, 1.44–3.63; 11.09, 8.33–14.75; 1.75, 1.32–2.32; 2.56, 2.03–3.22; 0.80, 0.65–0.99 and 1.93, 1.54–2.42, respectively) ($p < 0.05$). The study provided insights into a vastly underrated surgical education subject: learning-by-teaching. The training index introduced here was a valuable learning curve instrument that has the capacity of comparing different training parameters or different residency programs. The surge in learning-by-teaching after the pandemic was interpreted as a reflex, processing the teaching as a training tool.

Keywords COVID-19 · General surgery · Residency · Training techniques

Introduction

Late in the winter of 2019–2020, there was a narrow window contemplating the direction surgical education was headed. The physical context of the pandemic could have altered what we thought were fundamental educational processes in general surgery. Nobody might have foreseen how the story would unfold. Within that narrow window, the Turkish Ministry of Health, the governing body of our hospital, drafted a

circular recommending the postponement of elective cases as much as possible across the country.

At that unpredictable stage, laying the foundations for sustainable training grounds in our department, the weekly schedule of our residents including different shifts switched to a uniform 24-h “coronavirus shift” with the exception of chief residents (CR) who moved on undertaking regular shifts. Most of our meetings were canceled or transferred to online media. Rounds were conducted in smaller groups, and so forth. As the international crisis unfolded on many fronts, unusual fluctuations occurred in the case logs of our general surgery department at Akdeniz University.

In the meantime, the whole world was suffering from confusing early stances contaminated with hampering and low-value information and scientists were searching for an optimal recommendation policy [1]. Despite those rough times, scientific knowledge about coronavirus has advanced quickly and several groups published recommendations for stability

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[2–5]. While all these developments were taking place in the background, we aimed to contribute high-value information to surgical training strategies. With that in mind and taking in consideration the arising question of what was driving the active training strategy differently during the pandemic, we analyzed the 6-year long role of “learning-by-teaching” in lower gastrointestinal surgical procedures (LGSPs) performed in our university residency program.

Methods

All LGSPs with GSR participation at our department, between September 18, 2014 and September 17, 2020 were taken into consideration. Procedures were then categorized as; small intestinal, appendicular, colonic, rectal, perianal and peritoneal/mesenteric procedures. Gluteal and perineal soft tissue excision procedures for diseases including but not limited to hidradenitis suppurativa, pilonidal sinus and Fournier’s gangrene were categorized under perianal procedures. Abdominoperineal and low-anterior resections were categorized under rectal procedures.

Within the 6-year period, there were 32 general surgery residents (GSR) employed in our department. Traditionally, two CRs work at the same time in our department and once every 6 months, one CR completes 12-month service and moves on to the senior resident (SR) position; and general surgery residency lasts at least 5 years in accordance with our national program.

To assess the training factor in depth, procedural data were aggregated into following variables; total GSR participations, operating GSRs, assisting GSRs and teaching GSRs. Learning-by-teaching cases were semi-autonomous LGSPs where the lead assistant was a more experienced resident than the operator and they operated the case under the watchful guidance of an experienced attending.

Comparing the coronavirus impact to previous years starting from the autumn of 2014, we examined the lower gastrointestinal surgical procedures of our residents for their operational assignments and length-of-time spent in surgical training. First, we performed interrupted time-series analyses to get a sense of the magnitude of the impact on overall GSR participations and learning-by-teaching cases.

To identify the trend of change in our residents’ rate of experience (operator to first assistant) in the operating room with increasing length-of-time spent in training, a new surgical training index “O-to-1st index” –rate of area under the frequency distribution curves indicating experience of Operators (the length of time spent by operators in surgical training up until the participation in the case) TO those of FIRST assistants for a specified training period—was introduced and utilized to examine the impact of the pandemic. After

that, we contrasted how COVID-19 related to this index and searched for signs of learning-by-teaching motives.

Statistics

Statistical analysis was performed using the statistical software of Statistical Package for Social Sciences (SPSS) version 23.0 program (IBM, NY, USA). The Kolmogorov–Smirnov test was used to determine the normality, then Student *t* test or Mann–Whitney *U* test was performed according to test assumptions. Parametric data were presented as mean and standard deviation (SD) and non-parametric data were presented as median and interquartile range (IQR). For categorical variables, Pearson’s Chi-square test or Fisher’s exact test was used accordingly. For correlation analysis, Spearman’s Rho was used for correlation analysis of nonparametric data. Logistic regression was used to estimate odds ratios and 95% confidence intervals as well as to control the effects of clinical covariates including COVID-19.

Results

Overall, there were 7684 LGSPs with GSR participation from September 18, 2014 to September 17, 2020. A sum of 13,210 GSR participations were recorded; 2478 (19%) small intestine, 2595 (20%) appendix, 2187 (17%) colon, 677 rectum (5.1%), 2412 (18%) anus and 2861 (22%) mesentery/peritoneal surface procedures. In 5276 LGSPs with GSR participation (69%), the operator was a GSR. Both overall resident participations (Fig. 1) and learning-by-teaching cases (Fig. 2) dropped during first 3 months of COVID-19 impact, followed by a rebound.

Frequency distributions of their length of time spent in surgical training prior to their participation in the cases and the O-to-1st index analysis are depicted in a simple before-and-after chart in Fig. 3. The O-to-1st index for all experience levels were 1.06 before and 0.86 after the impact; the two cumulative trends with increasing experience were not correlated ($p = 0.134$). Surgical experience our residents’ with respect to organ specific procedure groups and admission status (emergency or elective) are analyzed in Table 1. Monthly average number of overall learning-by-teaching LGSPs increased after COVID-19 but observed difference was not statistically significant; median 13.0 (IQR 9.0–17.0) procedures before and 24.0 (IQR 10.0–29.0) procedures after ($p = 0.081$). However, there was a statistically significant increase in overall learning-by-teaching colorectal procedures and in elective colon procedures (Table 2).

Clinical factors associated with a learning-by-teaching motive in the operating room was assessed in a multivariate logistic regression model and COVID-19 impact was found

Fig. 1 Monthly participations of our general surgery residents (GSRs) in lower gastrointestinal surgical procedures; dotted line represents the COVID-19 circular

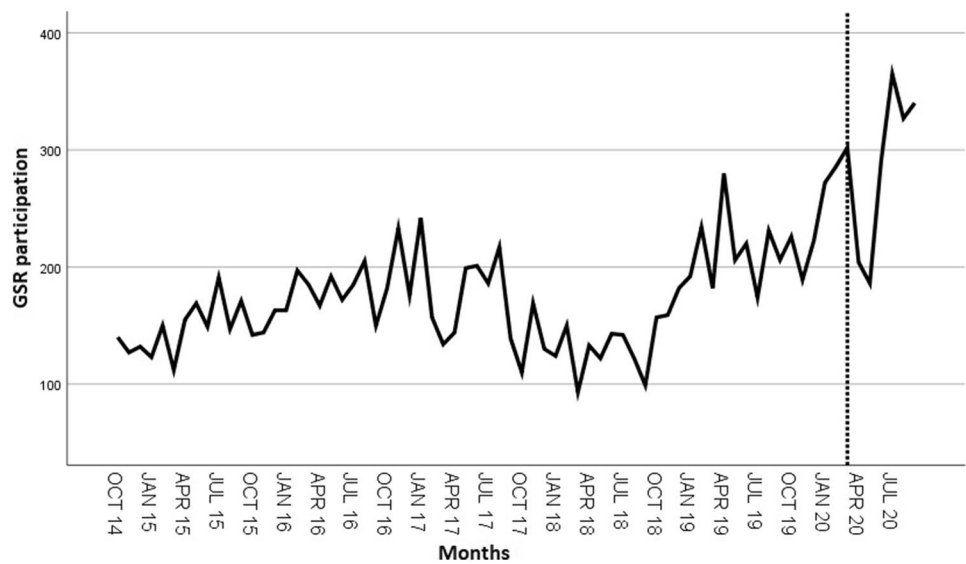
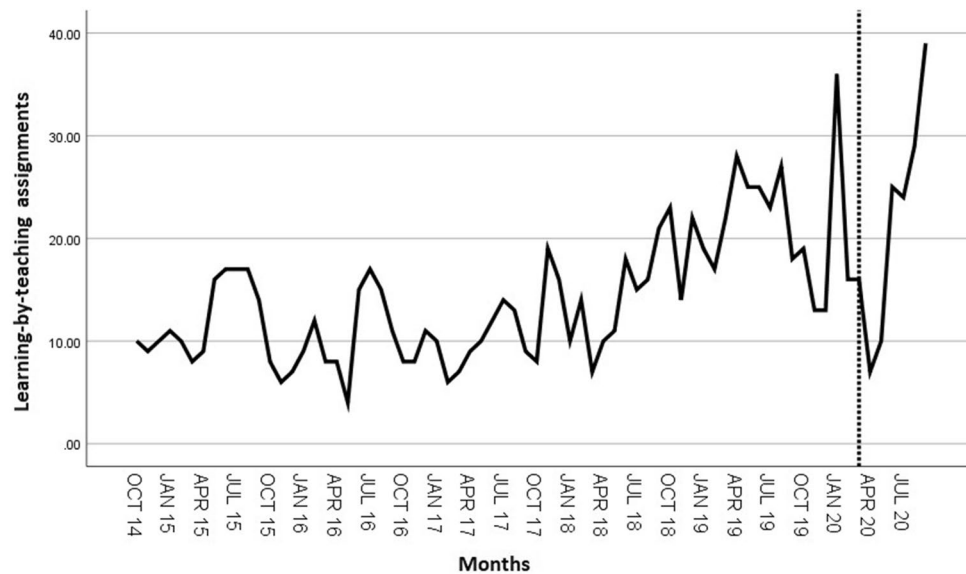


Fig. 2 Monthly numbers of learning-by-teaching assignments of our general surgery residents; dotted line represents the COVID-19 circular



to be an independent predictor of the learning-by-teaching motive (OR 1.93, 95% CI 1.54–2.42 and $p < 0.001$). The strongest positive predictor for the motive was appendix procedures, and the strongest negative predictor was perforations (Table 3).

Discussion

While learning by teaching is a popular pedagogical technique in general, it is a phenomenon that is difficult to study because it is difficult to eliminate variability in the tutor-tutee pairings and learning environments [6]. To the best of our knowledge, there is no study ever published in English medical literature investigating the role of learning-by-teaching

factor on the learning curves of surgical gastrointestinal procedures. With O-to-1st index being a representation of a focused learning curve relying on the operative roles of residents in the theatre, this study is the first of its kind to bring the subject in to the research field. In addition to the historical challenges, we had another unusual source of variability to eliminate; the COVID-19.

Alongside the existing in-house measures for infection prevention/control, surgical departments have been forced to implement a wide range of supplementary protective measures to combat coronavirus [7]. This took priority over many educational practices, even at the expense of breadth in the surgical training [8–10]. Demonstrating the impact quantitatively, in this regard, maintained a straightforward perspective to the intricacy of surgical training. In other words,

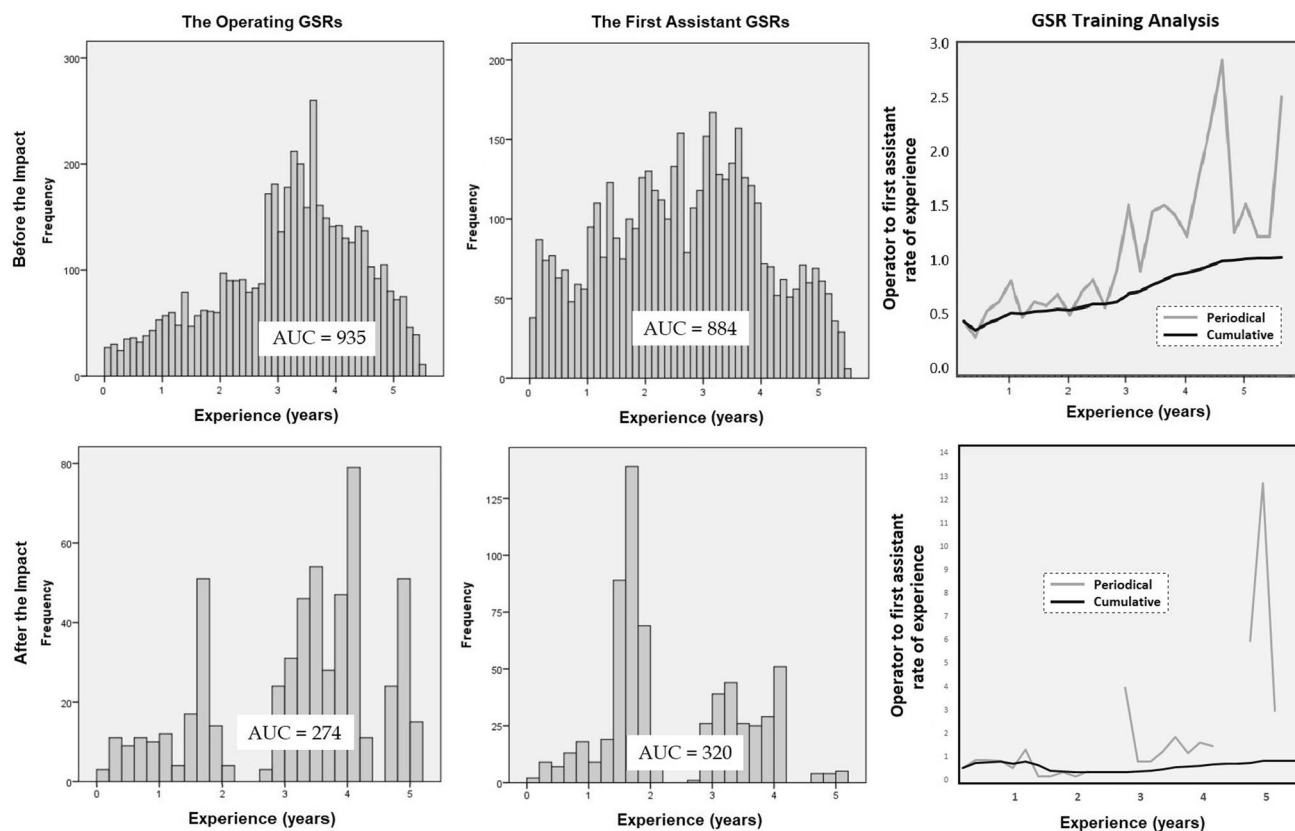


Fig. 3 Frequency distributions of general surgery residents' length of time spent in surgical training prior to their participation in the cases and the O-to-1st index analysis. *GSR* general surgery resident, *AUC* area under the curve

although highly challenging on many levels to interpret, this study attained a certain level of linearity on an event that is characterized by chaos.

At first glance, it is striking that some LGSPs in the coronavirus period were performed by less experienced residents; there was an unusual bumpy beginning in the cumulative O-to-1st index. In the absence of post-graduate year (PGY) 3 residents in our team after the impact, there seemed to be unconventional opportunities, independently of coronavirus, offered to PGY2 residents to leverage the momentum of the team. This effect was more obvious in appendectomies and perianal procedures. Generally in surgical training, laparoscopic appendectomy is performed mostly by PGY3 residents, with PGY2 residents as the second most common operators in laparoscopic appendectomy but the most common operators in open appendectomy [11]. The positive endorsement from our faculty have solidified the role of PGY2 residents in appendectomies in the absence of PGY3 residents. This was a reasonable decision, as the novice residents need to master basic skills of laparoscopic technique before they attempt more complex operations; and laparoscopic appendectomy can foster such skill acquisition

as it is normally regarded as favorable to the initial stage of laparoscopic training [12].

In anal procedures, including emergent perianal abscess drainage, the lack of PGY3 residents was effective in endorsing PGY2 residents to operate. This may be attributed to the abscess drainage procedure being a less complex procedure compared to appendectomy, and it is also likely to be closely related to the tendency of perianal procedures to be left to novice residents. According to an observational study from the United Kingdom, 39% (46/119) incision and drainage procedures for anorectal abscesses are performed by relatively less experienced trainees (specialty training 5 or below) [13]. As with the treatment, the diagnosis of abscesses can also be achieved with a minimal training [14]. Therefore, more junior residents performing perianal procedures in the post-impact period was a consequence of our surgical team's profile. The elective procedures including anorectal fistula repair, were performed by more experienced residents as these interventions include complex techniques and require a higher level of experience than PGY2. Unfortunately, despite all existing anal fistula operations up to date, some cases are very challenging even for experts and

Table 1 Surgical experience of the general surgery residents before and after the circular with respect to specific procedure groups

	Emergency			Elective		
	Before	After	<i>p</i>	Before	After	<i>p</i>
Overall						
Operating GSRs (operator)	3.0 (1.8–4.0)	3.4 (1.5–4.1)	0.142	3.5 (2.9–4.2)	3.5 (3.1–4.1)	0.632
Assisting GSRs (1st assistant)	2.6 (1.5–3.6)	1.7 (1.5–3.0)	< 0.001	2.9 (1.8–3.7)	2.0 (1.6–3.7)	0.808
Teaching GSRs	3.3 (2.5–4.1)	1.8 (1.6–3.4)	< 0.001	4.3 (3.5–4.9)	4.0 (3.3–4.1)	0.075
Small bowel						
Operating GSRs (operator)	3.7 (3.1–4.5)	4.0 (3.3–4.2)	0.785	3.6 (3.1–4.2)	3.7 (3.2–4.1)	0.738
Assisting GSRs (1st assistant)	2.7 (1.7–3.8)	1.8 (1.5–3.1)	0.001	3.1 (1.9–3.8)	1.9 (1.6–3.3)	0.008
Teaching GSRs	4.6 (3.9–5.0)	3.7 (3.3–4.0)	0.133	4.7 (3.6–5.1)	3.9 (3.3–4.1)	0.026
Appendix						
Operating GSRs (operator)	2.2 (1.1–3.4)	1.1 (0.6–2.0)	< 0.001	3.3 (2.6–5.1)	3.5 (3.5–3.5)	1.000
Assisting GSRs (1st assistant)	2.5 (1.4–3.5)	1.7 (1.6–2.9)	0.002	0.2 (0.2–0.2)	4.2 (4.2–4.2)	1.000
Teaching GSRs	3.1 (2.4–3.9)	1.8 (1.6–3.1)	< 0.001	N/A	4.2 (4.2–4.2)	N/A
Colon						
Operating GSRs (operator)	3.7 (3.1–4.4)	3.8 (3.4–4.1)	0.891	3.6 (3.2–4.3)	3.6 (3.3–4.3)	0.197
Assisting GSRs (1st assistant)	2.6 (1.7–3.6)	1.8 (1.6–3.1)	0.017	3.3 (2.2–4.0)	3.2 (1.8–3.8)	0.212
Teaching GSRs	4.5 (3.5–4.7)	3.8 (3.4–3.8)	0.316	4.8 (4.0–5.2)	4.0 (3.8–4.2)	0.001
Rectum						
Operating GSRs (operator)	3.6 (3.2–4.7)	N/A	N/A	3.6 (3.2–4.4)	3.9 (3.5–4.7)	0.067
Assisting GSRs (1st assistant)	3.6 (1.6–4.1)	3.6 (3.4–3.6)	0.841	3.2 (2.4–3.9)	3.1 (1.7–3.8)	0.213
Teaching GSRs	5.2 (5.2–5.2)	N/A	N/A	5.4 (4.9–5.4)	4.0 (4.0–4.1)	0.007
Anus						
Operating GSRs (operator)	2.3 (1.3–3.4)	1.5 (1.2–2.4)	0.036	3.3 (2.3–4.0)	2.9 (1.7–3.9)	0.004
Assisting GSRs (1st assistant)	2.0 (1.1–3.3)	1.5 (1.2–1.7)	0.064	2.5 (1.5–3.6)	1.8 (1.6–3.5)	0.148
Teaching GSRs	3.2 (2.2–3.9)	1.6 (1.5–3.2)	0.053	3.8 (3.0–4.5)	3.4 (1.9–4.1)	0.007

Bold indicates significance (*p* < 0.05)

Median years (interquartile range)

GSR general surgery resident, N/A not applicable, OCR operating chief resident, OSR operating senior resident

Table 2 Impact of COVID-19 pandemic on monthly average number of learning-by-teaching procedures

Site-specific procedures	Emergency			Elective			Overall		
	Before	After	<i>p</i>	Before	After	<i>p</i>	Before	After	<i>p</i>
Small bowel	0.0 (0.0–1.0)	0.5 (0.0–1.2)	0.342	0.0 (0.0–1.0)	1.5 (0.0–4.5)	0.216	0.0 (0.0–2.0)	1.0 (0.0–5.0)	0.093
Appendix	8.0 (6.0–10.0)	7 (5.5–12.8)	0.897	0.0 (0.0–0.0)	0.0 (0.0–0.2)	0.517	8.0 (6.0–10.0)	7.0 (6.0–12.0)	0.681
Colon	0.0 (0.0–0.0)	0.0 (0.0–0.5)	0.882	0.0 (0.0–1.0)	2.5 (0.8–5.2)	0.012	1.0 (0.0–1.0)	2.0 (1.0–5.0)	0.019
Rectum	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.960	0.0 (0.0–0.0)	1.0 (0.0–2.0)	0.093	0.0 (0.0–0.0)	0.0 (0.0–2.0)	0.028
Anus	1.0 (0.0–2.0)	1.0 (0.0–2.0)	0.929	1.0 (0.0–3.0)	2.0 (0.0–8.0)	0.385	2.0 (1.0–4.0)	3.0 (1.0–7.0)	0.176
All LGSPs	10.6 ± 3.9	11.0 ± 4.6	0.828	2.0 (1.0–5.0)	12.5 (2.8–17.0)	0.006	13.0 (9.0–17.0)	24.0 (10.0–29.0)	0.081

Bold indicates significance (*p* < 0.05)

LGSP Lower gastrointestinal surgical procedure

the optimal technique with low recurrence rate and assured safety for the anal sphincter is still lacking [15].

Overall, anorectal procedures required for graduation from a general surgery residency is much lower than other surgical operations such as hernias, biliary stones and intra-abdominal operations [16]. According to the case logs from

the United States, by time of graduation, 30% of GSRs perform ≤ 20 anorectal procedures and many of them don't have even a single case of anorectal fistula procedure [17]. There are clearly additional emerging facets of personal interaction in skill acquisition but the figures are important for setting certain standards. Thus our findings, shed some possible

Table 3 Factors associated with a learning-by-teaching motive in the operating room

	Learning-by-teaching motive in the surgical team roles				
	Bivariate analysis, <i>n</i> (%)			Multivariate analysis	
	Absent	Present	<i>p</i>	Odds ratio (95% CI)	<i>p</i>
	6624 (86)	1060 (14)			
COVID-19 impact			0.002*	1.93 (1.54–2.42)	<0.001*
Before the impact	5993 (87)	926 (13)			
After the impact	631 (82)	134 (18)			
Emergency procedures	2499 (76)	768 (24)	<0.001*	2.20 (1.76–2.75)	<0.001*
GI bleeding	40 (93)	3 (7)	0.194		
GI obstruction	496 (94)	29 (6)	<0.001*	0.56 (0.36–0.85)	0.006*
GI perforation	662 (90)	75 (10)	0.003*	0.50 (0.38–0.67)	<0.001*
Mesenteric ischemia	130 (95)	7 (5)	0.003*		
Volvulus	32 (100)	0 (0)	0.009*		
Trauma	160 (91)	15 (9)	0.043*		
Inflammatory bowel disease	127 (88)	17 (12)	0.485		
Pouch surgery	22 (100)	0 (0)	0.038*		
Jejunostomy/ileostomy surgery					
Creation	493 (96)	20 (4)	<0.001*		
Closure	239 (91)	24 (9)	0.025*	2.29 (1.44–3.63)	<0.001*
Colostomy					
Creation	270 (92)	25 (8)	0.007*		
Closure	75 (90)	8 (10)	0.270		
Site-specific procedures					
Jejunum/ileum	1303 (94)	78 (6)	<0.001*		
Appendix	753 (56)	599 (44)	<0.001*	11.09 (8.33–14.75)	<0.001*
Colon	1070 (93)	84 (7)	<0.001*	1.75 (1.32–2.32)	<0.001*
Rectum	432 (96)	18 (4)	<0.001*		
Anus	1550 (89)	200 (11)	<0.001*	2.56 (2.03–3.22)	<0.001*
Minimally invasive procedures	1235 (72)	482 (28)	<0.001*	0.80 (0.65–0.99)	0.043*

GI gastrointestinal

**p*<0.05

light on the issue and emphasized the current situation and educational need of the residents in the management of perianal diseases. In fact, every effort should be taken to ensure that novice residents have appropriate experience to perform perianal procedures before they are given semi-autonomy.

Operating GSRs in colon and rectum procedures, although not significant, were slightly more experienced residents after the impact. Nevertheless, they were the only procedures where there was a statistically significant increase in learning-by-teaching motive after Covid-19. This was a partial reflection of the increasing use of laparoscopy in colorectal procedures within our 6-year trends; which is in line with the published literature [18, 19]. Despite encouraging upward trends, longer operation times are required, especially during the early learning period for laparoscopic colorectal cancer surgery [20]. As a matter of fact, more experienced residents were endorsed to presumably reduce the duration of these procedures as

part of a measure to reduce the indoor exposure of employees while working under the threat of coronavirus.

In some procedures the teaching residents were less experienced than the autonomously operating residents. We interpreted this as an indication that the attendings actually were processing the concept of a “teaching resident” as a training tool for autonomy itself. In other words, contrary to what is supposed, they had an insight that the ability to teach comes before rather than after autonomy acquisition in surgical training and prepares the teacher to a better autonomy. The fall of the overall O-to-1st index below 1 after the impact might also have emerged as a possible consequence of this insight. This also seemed to be a reflex of attendings to the pandemic, which we think was to speed up the training process, to compensate for the concern that there would be discordant advancements to operator responsibility before learning to actively assist an operating surgeon.

It was clear that the relative merits of learning-by-teaching style were considered by the attendings in LGSPs after COVID-19. However, it is noteworthy to mention that endorsing residents to operate semi-autonomously in a learning-by-teaching style, should take into account the full cycle of the surgical training and the learning curve of a procedure. To make it more fruitful, residents should never leave the track of acting in the best interest of the patient while shadowing the moves of the attending surgeon and they should change back to the traditional roles with the attending taking control of the case when necessary. Moreover, keeping records of learning-by-teaching, despite being under careful guidance of an attending, will serve intrinsically as a benchmark of success for residents mastering surgery; a hint on how they are going to fare in their independent practice as a full autonomous surgeon.

This study has the limitations of being a single center study. The experience distribution of GSRs within the 6-year-long period exhibited substantial heterogeneity due to occasional resignations and resulted in difficulty in objectifying the influence of PGY level. Thus, residents' roles in the teams and service supply oriented inferences were better served as an argument than a PGY level based analysis. In addition, the fact that our center is a tertiary university hospital, that is, the last step in the referral chain of our country, has caused congestion management and capacity allocation for surgical cases to be carried out under more pressure than most institutions providing health services. Therefore, this study is far from representative of surgical training programs in centers where surgical service capacity was radically reduced due to the coronavirus outbreak. A good subject on the future prospects of surgical education can be O-to-1st index oriented studies examining the distribution curves of experience with different slopes in various specific procedures with selective focusing on different training periods.

In conclusion, this new index takes a contextualized look at what is driving the active training strategy of a residency program and provides a roadmap for prioritization to address a certain crisis. It is inherent in the nature of the surgical education that there will always be crises. Sometimes it is a cramped anatomical variation. Sometimes a tool brakes or sometimes, sadly, a GSR resigns; but this time, it was something else; a virus. The surge in learning-by-teaching after the pandemic was a reflex to this virus, processing the teaching as a training tool. It is possible that this was to address a concern of a discordant advancement to operator responsibility.

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Declarations

Conflict of interest The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval This research involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 2013 amendment of Helsinki Declaration. Institutional review board consent at Akdeniz University was obtained (25.11.2020/KA EK-899).

Patient consent Written informed consent was waived because the research could not practicably be carried out without a waiver and after recruitment the data was de-identified and all the analysis used anonymous clinical data.

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