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Original Article

Module-based training enhances residents' operative volume

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ABSTRACT

INTRODUCTION. Efficient workplace-based training in surgery often conflicts with maintaining high-quality patient care. Module-based training has been shown to improve surgical skills, but its impact in clinical settings is less understood. This study compared the operative volume and post-operative complications between module-based and conventionally trained first-year surgical residents.

METHODS. Using business intelligence data, we analysed the number of laparoscopic cholecystectomies (LC) performed by first-year residents in abdominal surgery between 2015 and 2020. Module-based training was defined as performing > 16 LCs in 8-10 weeks. Participants were residents from the Central Denmark Region.

RESULTS. Among 68 residents, 14 (21%) underwent module-based training. Residents with module-based training performed three times as many LCs (40.7 ± 8.1) as those without (13.9 ± 8.7). None of the residents performed more than 50% of the total number of LCs performed in their department per month. The overall incidence of post-operative complications was low, occurring in 2.3% of cases (n = 33), of which 51.5% required reoperation.

CONCLUSIONS. Module-based training enhances residents' operative volume, supporting structured training approaches that ensure consistent education and potentially improve clinical outcomes.

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Tensions between receiving efficient workplace-based training in surgery and providing high-quality patient care are often highlighted in educational literature [1]. Traditionally, apprenticeship and supervision have been a cornerstone through which residents are entrusted with graduated responsibility and increasing autonomy [2]. This model is challenging due to working-hour restrictions, which reduce the time residents have to learn in the operating room (OR). However, no consensus exists regarding the implementation of educational tools in the clinical learning environment, considering the ever-changing nature of surgery [3].

Module-based training and accelerated learning have been described as useful structural tools for accommodating decreasing training opportunities [4]. Module-based learning in surgical education is an instructional approach that structures the curriculum into discrete, self-contained units (modules), each focusing on a specific skill, procedure or competency. This type of training involves performing a specific surgical procedure repeatedly within a specified timeframe. Within this timeframe, the resident is prioritised to perform the specific procedure to ensure continuity in skill acquisition. This approach has been shown to improve and sustain surgical skills compared with traditional training in both simulation settings and clinical

environments [4]. Similarly, motor learning theories prioritise distributed over massed practice, thereby supporting a module-based structure of training [5]. Motor learning theories highlight that the temporal distribution of training is a critical determinant of effective skill acquisition. Evidence suggests that structured programmes incorporating repeated, spaced practice sessions enhance both the mastery and long-term retention of surgical skills.

Interestingly, educational literature highlights the importance of the work environment when residents apply their acquired knowledge and skills in surgery [6]. Additionally, the provision of autonomy and the opportunity to take ownership of clinical work were found to strongly motivate learners [7]. Thus, to achieve proficiency, residents must engage in structured workplace-based learning. However, little is known about how surgical departments organise clinical training for residents.

The present study examined the surgical activities of first-year surgical residents across five hospitals. Aiming to illustrate residents' opportunities to perform surgical activities in the clinical setting, we aimed to visualise the indications of module-based training structures in laparoscopic cholecystectomies (LC) in the Central Denmark Region. In addition, we quantified the post-operative complications of LC performed by the residents. We hypothesised that module-based training would enhance residents' opportunities to perform and achieve operative independence while maintaining high-quality patient care.

METHODS

In this study, we used prospectively collected data on laparoscopic procedures performed by first-year surgical residents in the Central Denmark Region.

Business intelligence portal

In the Central Denmark Region, data from various sources, such as electronic patient records, payrolls and HR administration, are collected into a business intelligence (BI) portal. This portal was developed by the Central Denmark Region using Tableau Software. From the BI, we extracted raw data on surgical activity, 30-day post-operative readmission and reoperation.

Participants and data collection

The Central Denmark Region comprises one university hospital and four regional hospitals with surgical departments. The study participants were all first-year residents in abdominal surgery employed in the Central Denmark Region during 2015-2020. When estimating and comparing surgical activities, we excluded residents with employment periods shorter than 300 days to ensure sufficient exposure to module-based training. Data on readmissions and reoperations were analysed for all operations performed by residents, regardless of length of employment. We included all LC cases in which first-year residents were registered as primary surgeons. We did not include patient data on case complexity.

Module-based training

To investigate the workplace-based education structure for residents across the five hospitals, we applied a framework based on a module-based training curriculum. This approach involves performing a specific surgical procedure multiple times within a defined timeframe. In line with previous studies, we defined module-based training as more than 16 LC procedures performed by the same resident during a ten-week period [3]. Conventional training was defined as LC procedures performed sporadically throughout the resident's one-year rotation. Residents were not formally assigned to a specific training structure by the author group. Instead, we applied the definition from Carlsen et al. [3] to assess whether residents in the included departments followed a

module-based or conventional training pattern. During the residents' one-year rotation, we traced the date of the laparoscopic surgeries to identify patterns aligned with the module-based curriculum. When comparing LC procedure volumes, residents were divided into those who had received module-based and those who had received conventional training.

Data analysis

Data were tested for a Gaussian distribution, and data with a non-normal distribution were normalised by logarithmic transformation. Differences in unpaired data were analysed using a parametric t-test. The results are reported as means with interquartile ranges, with p-values reflecting the differences in surgical activity between the groups. Statistical significance was set at $p < 0.05$.

Trial registration: not relevant.

RESULTS

Table 1 presents the demographic characteristics. Among the 99 residents employed during the study period, 68 (68.7%) had been employed for more than 300 days and were therefore included in the analysis. When analysing surgical activities, we excluded residents with employment periods shorter than 300 days (n = 31), as a short employment period may indicate that the introductory position was concluded earlier than planned. Residents had an average age of 30 years (27-39 years); 40 females (58.8%) and 28 males (41.2%). Overall, the residents performed 1,447 LC, accounting for 15% of the region's total LC in the study period.

TABLE 1 Demographic characteristics of first-year surgical residents, 2015-2020[a].

	Residents			Laparoscopic cholecystectomies, n (%)	
	with 1-yr employment		total		
	n (%)	average (range), yrs	employment, N	total	performed by residents
Hospital					
I	15		21	2,287	551 (24.1)
II	10		19	2,297	190 (8.3)
III	13		14	1,642	287 (17.5.)
IV	18		23	1,869	241 (12.9)
V	12		22	1,518	178 (11.7)
Total	68		99	9,613	1,447 (15)
Gender					
Male	28 (41.2)				
Female	40 (58.8)				
Age		30 (27-39)			

a) When estimating and comparing surgical activities, residents with employment periods shorter than 300 days were excluded (n = 31).

Procedures

Our analysis revealed that the included residents performed 0-58 LC during their one-year position. Among the included residents, 14 (21%) from four departments were identified as having a pattern compatible with module-based laparoscopic training. One department ran the majority of the module-based training programmes (71%). We found a significant difference in the number of LC performed by residents between departments ($p < 0.001$). The mean LC performed by residents engaged in module-based training (40.7 ± 8.1) was three times higher than the mean of residents without module-based training (13.9 ± 8.7) ($p < 0.001$) (**Figure 1**). No significant sex difference was observed in the number of LC performed ($p = 0.477$). We found a significant difference in the number of LC performed between the university hospital and the regional hospitals ($p = 0.002$).

FIGURE 1 Box plot with interquartile ranges illustrating the number of performed laparoscopic cholecystectomies (LC) performed by residents with a full one-year rotation at the five included hospitals in the 2015-2020 period. The horizontal lines in the boxes represent the median values.

Figure 2 illustrates how module-based training was divided among the residents in one department over time. After completing the module-based training, residents continued to perform LC without a scrubbed-in

supervisor, contributing to the department's production. Furthermore, Figure 2 shows that module-based-trained residents did not exceed 50% of the total number of departments' LC. **Figure 3** demonstrates that module-based training within a single procedure does not hinder learning of other procedures.

FIGURE 2 Number of laparoscopic cholecystectomies (LC) performed at one department in a teaching hospital using module-based training. LC are depicted as lines, illustrating the operative volume of residents for this procedure. The columns show the monthly total of LS performed.

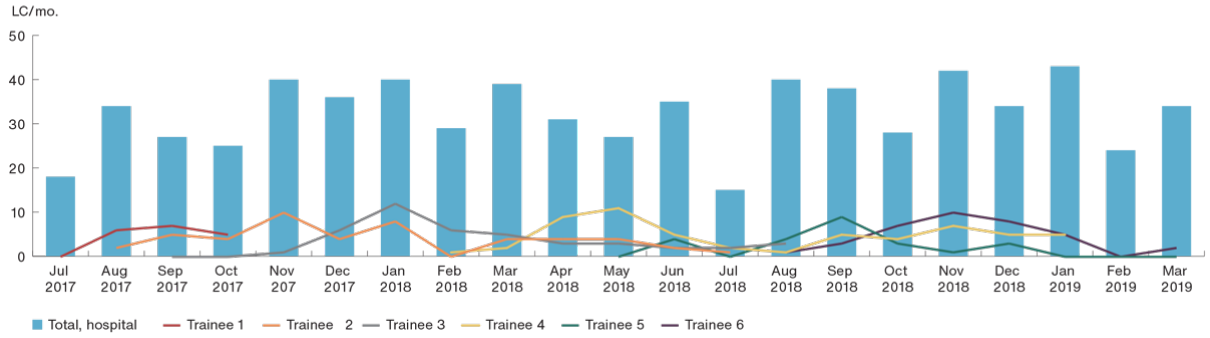
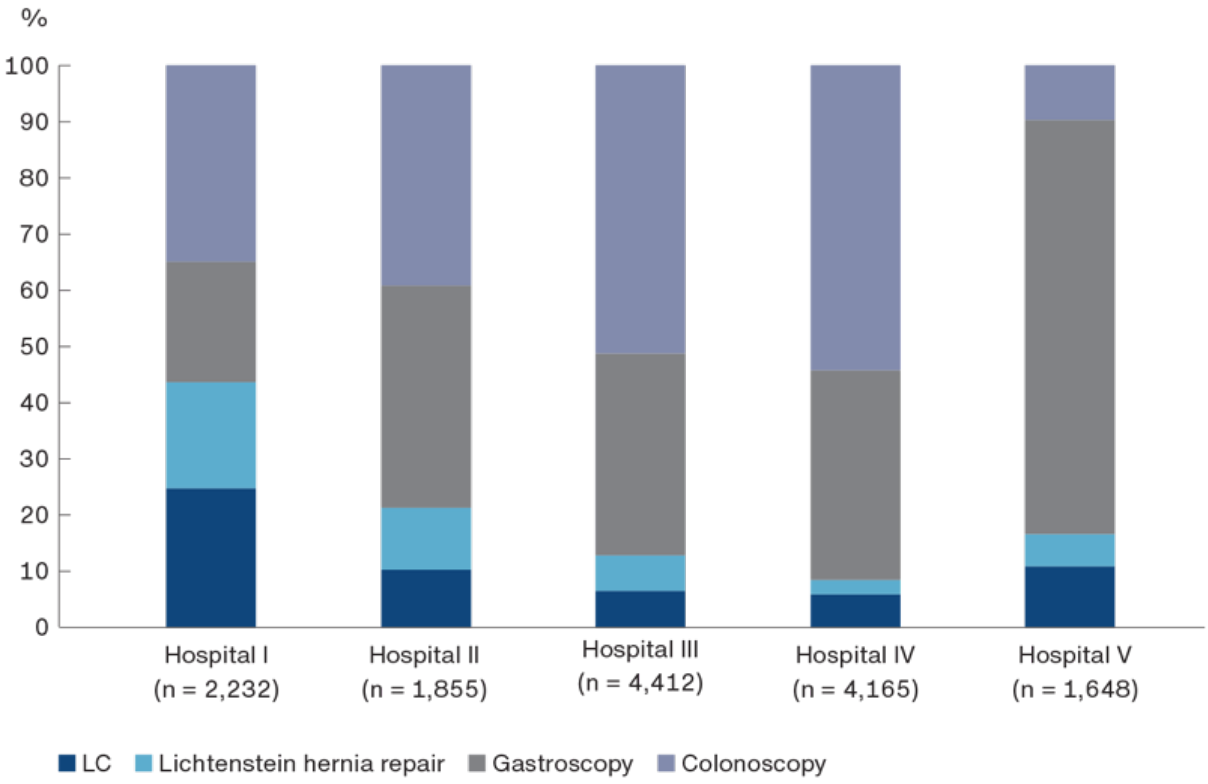


FIGURE 3 Operative distribution. The percentage distribution of the four selected procedures conducted by residents across the five hospitals (with the total number of procedures at each hospital).



LC = laparoscopic cholecystectomy.

Complications

In total, 2.3% (n = 33) of the included patients who underwent LC were readmitted to the hospital 30 days after surgery, and 51.5% of these patients underwent reoperation. Reoperations were performed due to pain (n = 4),

bile duct lesions (n = 2), endoscopic retrograde cholangiopancreatography with stenting and/or papillotomy due to cholangitis (n = 9), and wound infections (n = 2). No statistically significant variation was observed across location, days of employment, sex or type of workplace-based education (module-based versus conventional education).

DISCUSSION

In the present study, we compared the operative volume of module-based-trained first-year surgical residents with that of conventionally trained residents and the incidence of complications and reoperations. We found that 21% of the residents received module-based training. Their operative volume was three times that of residents without such training. While this might seem to be a self-fulfilling prophecy, it indicates that the use of a module-based structured approach ensures that residents are more capable of underpinning department productivity in an autonomous manner. Furthermore, we observed a low rate of post-operative complications and reoperations following LC performed by the residents.

Our analysis revealed that all included departments had a sufficient volume of LC to structure the residents' laparoscopic activities as module-based training. In contrast to traditionally trained residents, module-based residents contributed independently to the department's LC production by the end of their training period. Overall, residents performed 15% of the total LC in the region. At no time did the residents operate more than half of the department's LC, indicating that all surgeons in the department were able to perform a sufficient number of surgeries to sustain their competencies.

Similar to previous studies, we found considerable variation in the number of procedures performed by residents [8, 9]. Variations between different departments may be caused by different organisational factors, the number of residents employed and patient demography. More interestingly, we also observed variations among residents in the same department during the same period, but were unable to determine their cause. However, previous studies have highlighted individual characteristics [10] and environmental elements as probable key determinants of variation in operative volume [11].

We found complication rates below the national and international rates [12]. The low complication rate observed may potentially be attributed to careful patient selection. In workplace-based learning, it is important to match the presumed difficulty of the procedure with the residents' competencies [13] while maintaining a critical perspective on safety [14].

Educational literature shows a strong association between the work environment and the trainee's opportunity to apply newly acquired competencies [6]. Module-based training is one method of structuring, organising and balancing equal operative opportunities between residents; another is to implement an effective system, such as the BI portal or educational portfolios, as described elsewhere [15]. To our knowledge, little is known about the use of data from surgical databases to organise surgical residents' training. With an effective educational database, it is possible to track residents' operative volume and map any inappropriate distribution of operations. The absolute number of hours in the OR and how they are spent are crucial [16]. Hence, an immense amount of literature has examined surgical learning outside the OR through simulation-based training, which has repeatedly been shown to enhance surgical learning [17]. Within simulation-based training, a variety of learning objectives are present [18], leaving a gap between the simulation centre and the OR. Module-based training can serve as a bridge between hours of simulation-based training and workplace-based learning.

While module-based training offers considerable structural advantages in surgical education, its generalisability depends on factors such as procedure type, individual learning needs, number of residents in the departments versus number of procedures, and institutional characteristics. High-volume cases like LC lend themselves well

to module-based training. Unfortunately, only a few of the departments in this study offered module-based training, and it is unclear how these departments tracked their residents' surgical activity.

Strengths and limitations

According to Kirkpatrick's model for evaluating educational interventions, Level 4 focuses on assessing the impact on clinical outcomes. A key strength of this study is the use of comprehensive registry data, which provides a sufficiently large sample to facilitate evaluation at this level. A limitation of the study is that the validity of the BI portal was not assessed before the study. Thus, the data might be subject to information bias. However, data from electronic patient journals, and thereby, the BI portal, serve as legal documents. Therefore, we expected the primary surgeon's registration to be accurate. Moreover, the data are not registered by the surgeons themselves but by administrative personnel. Another limitation is the lack of assessment of case complexity in this study. It was not feasible to assess this; however, the fact that all residents employed at a full one-year period across five hospitals with comparable patient demographics were included may partially compensate for this. The fact that most of the module-based training was delivered within a single department was a limitation too, which may limit the transferability and generalisability of the findings.

CONCLUSIONS

Module-based training is a change in the work environment that improves residents' opportunities to practice relevant procedures, including surgery. Our study showed that only a few surgical departments used module-based training. However, surgical residents in these departments performed more LC than their colleagues. Module-based training may facilitate coherent learner trajectories and enhance workplace-based learning by ensuring a structured training approach for all residents.

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