The Pareto Analysis for Establishing Content Criteria in Surgical Training

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INTRODUCTION: Current surgical training is still highly dependent on expensive operating room (OR) experience. Although there have been many attempts to transfer more training to the skills laboratory, little research is focused on which technical behaviors can lead to the highest profit when they are trained outside the OR. The Pareto principle states that in any population that contributes to a common effect, a few account for the bulk of the effect. This principle has been widely used in business management to increase company profits. This study uses the Pareto principle for establishing content criteria for more efficient surgical training.

METHOD: A retrospective study was conducted to assess verbal guidance provided by 9 supervising surgeons to 12 trainees performing 64 laparoscopic cholecystectomies in the OR. The verbal corrections were documented, tallied, and clustered according to the aimed change in novice behavior. The corrections were rank ordered, and a cumulative distribution curve was used to calculate which corrections accounted for 80% of the total number of verbal corrections.

RESULTS: In total, 253 different verbal corrections were uttered 1587 times and were categorized into 40 different clusters of aimed changes in novice behaviors. The 35 highest-ranking verbal corrections (14%) and the 11 highest-ranking clusters (28%) accounted for 80% of the total number of given verbal corrections.

CONCLUSIONS: Following the Pareto principle, we were able to identify the aspects of trainee behavior that account for most corrections given by supervisors during a laparoscopic cholecystectomy on humans. This strategy can be used for the development of new training programs to prepare the trainee in advance for the challenges encountered in the clinical setting in an OR. (J Surg Ed 73:892-901.

KEY WORDS: pareto principle, surgical training, laparoscopic cholecystectomy, content validity

COMPETENCIES: Medical Knowledge, Interpersonal and Communication Skills, Practice-Based Learning and Improvement

INTRODUCTION

In 1887, the Italian economist Vilfredo Pareto observed an exponential relationship between the amount of wealth an inhabitant owned and the rank order of the inhabitant.[1] He discovered that 80% of property is owned by merely 20% of the inhabitants, a pattern which later was popularized in the 1950s by management consultant Joseph M. Juran[2] as the Pareto principle or "80-20 rule". The Pareto principle is best known for its use in increasing business returns by identifying the vital-few causes responsible for the bulk of income within a company and consequently increasing its efficiency by focusing investments on these company facets.[2-5] The Pareto principle has also been observed in many other fields such as literature (the frequency of words in a book), sociology (intensity of wars) and astronomy (intensity of solar flares).[6]

In the surgical profession, the operating room (OR) is the ultimate teaching venue for learning surgical skills. However, learning how to operate costs significant amounts of money and time.[7-9] Bridges and Diamond[9] compared the operative times of cases performed by faculty with those

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performed by residents and calculated that the increased operative times during surgical training cost $47.970 per year per resident. Furthermore, it seems that the exposure of residents to surgical procedures is decreasing because of the implementation of work hours restrictions.[10] These findings underline the need for higher training efficiency in the OR.

Previous studies that have described content criteria for surgical training based their findings mainly on cognitive task analysis, human reliability analysis, or expert opinion.[11-13] A cognitive task analysis consists of the identification of the different cognitive and procedural steps that have to be undertaken to complete a procedure.[11] Information about these steps is obtained through an interview of experts and can be used as a "blueprint" for the development of training tasks for a procedure. Human reliability analysis has been used in high-risk technological advanced industries, such as aviation and nuclear power plant development, but it has recently also been used in laparoscopic surgery as a means for developing surgical training content.[14-16] Human reliability analysis consists of identifying what can go wrong, estimating the probability and consequences of the errors and consequently developing (training) methods to minimize the risk and consequences of these errors. Although cognitive task analysis, human reliability analysis, and expert opinion all provide valuable information for surgical training curriculum development, they do not provide us with a description of the aspects of surgical expertise that require the most time and energy during training in the OR. Meanwhile, the Pareto analysis might provide a valuable tool in the reduction of training duration in the OR by identifying those aspects of surgical skills that require the most resources to instil in trainees. This study attempts to answer the following research questions:

(1) Does the Pareto principle exist in the surgical training of a basic surgical procedure?
(2) What is the content criteria for more efficient surgical training stated by means of the Pareto principle?
(3) How can surgical training in the dry laboratory and in the OR be adapted to these content criteria?

METHODS

This study was a retrospective analysis of operative videos of laparoscopic cholecystectomies recorded for other study purposes. All the videos were recorded in Leeuwarden Medical Centre, a regional high-volume teaching hospital performing >200 laparoscopic cholecystectomies per year.

Data Collection

The laparoscopic cholecystectomy, a frequently performed laparoscopic training procedure, was used for the Pareto analysis. The audio-visual recordings of laparoscopic cholecystectomies performed during 2 prospective studies conducted in our institution were retrospectively reviewed. The first study was conducted by van Det[17] and the second by Kramp.[18] The trainees in these videos had performed 0 to 30 procedures as first surgeon. Because the current research was focused on identifying novice surgical behavior, only videos of trainees that had performed ≤10 laparoscopic cholecystectomies were included.

Surgical Training

In both study periods, each trainee was a resident in surgery and had completed a simulator course in basic laparoscopic skills training on the SIMENDO laparoscopy trainer (Simendo, Rotterdam, The Netherlands) before commencing supervised laparoscopic surgery on patients. Knowledge of the relevant anatomy and procedural steps necessary to complete the procedure was acquired by trainees through the usual sources available online and within our institution (anatomy books, online information, example videos, etc.).

During supervised surgical training in the OR, supervising surgeons aim to find a balance between creating the optimal learning experience and guarding the patient safety during the operation. They therefore guide trainees through the procedure by giving verbal guidance and taking over when necessary while they act as assistant surgeons. The verbal guidance was divided into 2 different categories, verbal instructions and verbal corrections. Verbal instructions were defined as the verbal guidance provided to initiate a certain surgical behavior (e.g., "make an incision from point a to point b"). Verbal corrections are given to reduce potentially unsafe surgical behavioral patterns or to optimize the degree of skillfulness, while a specific surgical behavior is being exhibited by a trainee (e.g., "stay closer to the gallbladder"). Medical declarative knowledge is usually evaluated by the supervising surgeon through a quizzing behavior, by Sutkin et al.[19,20] described as "socratic-like questioning to assess the surgical trainee's knowledge." Although the aim of these questions is primarily to stimulate thinking about a particular aspect of the procedure, the corrections of wrong answers on these questions were also classified as verbal corrections. Furthermore, if a supervising surgeon perceives an operative step as a particularly difficult dissection (e.g., as a consequence of variation in anatomy), or perceives the trainee as incompetent to deal with a certain aspect of the operation, he or she might temporarily take over one or both instruments to guard the flow and safety of the procedure. The exact content of the verbal guidance and reasons for a takeover are based on the supervising surgeon's judgment of the observed situational characteristics of the operation (e.g., time pressure, anatomic variation, and inflammation) and surgical behavior of the trainee.

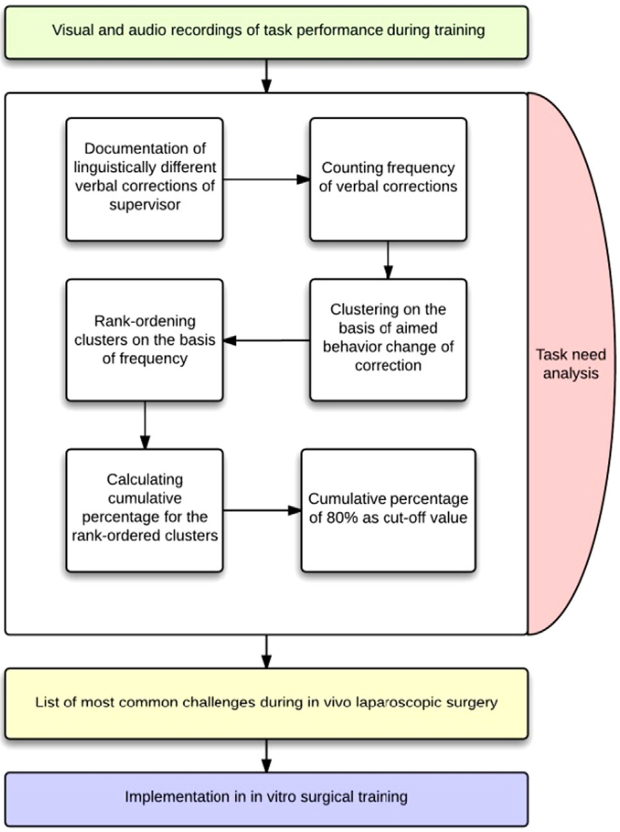

FIGURE 1. Flowchart of study methodology.

Evaluation of the Pareto Principle

To evaluate whether the Pareto principle exists in the verbal corrections during surgical training, the different verbal corrections had to be counted. The data collection method used for counting verbal corrections was based on the sampling methods for observational studies of animal behavior described by Altmann (Fig. 1).[21] The audio of the videos was used to document the content of the verbal corrections given by the supervising surgeon during the operation. The verbal corrections were documented in computerized sheets and were time coded. If the same novice behavior was observed on separate occasions multiple times during a procedure, the number of repetitions of the verbal corrections to correct the behavior was counted. If multiple verbal corrections were given to clarify the primary verbal correction, they were counted as one verbal correction as shown in Figure 2.

Verbal instructions were not counted because they are predominantly used to initiate a behavior in the trainee, e.g. the supervising surgeon instructing the trainee to clip the cystic artery. Verbal instructions therefore provide little information about what is challenging about a specific behavior. For example, in the above described situation of the supervising surgeon instructing the trainee to clip the cystic artery, one of the challenges is the optimal exposure of the artery by exercising traction on the gallbladder in an adequate amount and in the right direction, a skill often not learned in one attempt and thus can be perceived as a challenge. Takeovers were not counted because the exact reason for a takeover is often not made clear by the supervising surgeon. Verbal corrections to adjust the viewing perspective of the camera when the trainee was acting as the assisting surgeon during a takeover were also not counted.

The verbal corrections were clustered according to the corrected behavior. For instance, while using the dissection hook (behavior), a trainee can be corrected to "look for the silver sign," not to burn while applying traction with the hook, not to apply diathermia too close to the instrument tip of the opposite hand, etc. To identify handling of the dissection hook as the behavior that was challenging during these instances, the counts of these corrections were summed in the cluster "use of the dissection hook."

Finally, the different verbal corrections and the clusters of verbal corrections were rank ordered based on the total frequency of the verbal corrections they contained. The Pareto principle was evaluated for the individual verbal corrections and for the clusters of verbal corrections by (1) Plotting the number of verbal corrections as a function of the rank order of the individual verbal corrections, (2) plotting the number of verbal corrections within a cluster as a function of the rank order of the clusters of verbal corrections, and (3) evaluating whether the curves showed a power law distribution with a cumulative distribution curve similar to those observed in other data.[6]

Establishing Content Criteria for Surgical Training by Means of the Pareto Principle

Whole Procedure

A cutoff value of 80% was used in the cumulative distribution curve of the clustered verbal corrections to identify training content that could be used for increasing training efficiency.

Operative Steps

To estimate the highest-ranking corrected novice behaviors per procedural step, the start and end time of the different key steps of the recorded procedures was determined according to a previously published study.[22] The procedural steps include (1) open introduction of the first trocar and accessory trocar placement, (2) opening of the peritoneal envelope, (3) creating critical view of safety, (4) clipping and division of cystic duct and artery, (5) retrograde cholecystectomy, and (6) gallbladder removal and closure.

Observed Perceived Importance

If one surgeon of the included surgeons considers one kind of technical surgical behavior more important than other

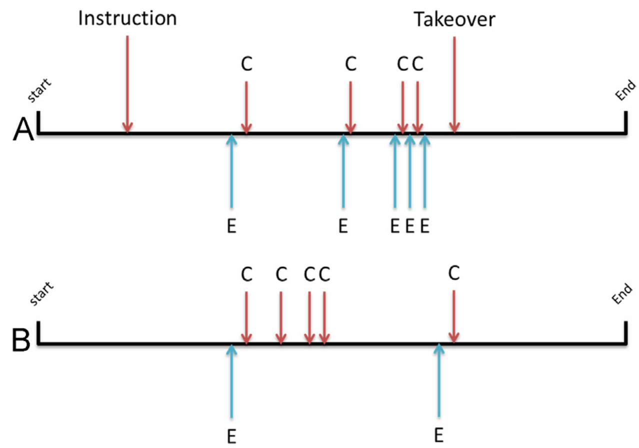

FIGURE 2. Counting of verbal corrections: red = communication from supervising surgeon to trainee, blue = erroneous or unskilled behavior of trainee, C = verbal correction, E = expressed erroneous or unskilled surgical behavior. (A) Instruction is given by supervisor (e.g., dissect gallbladder from liver bed by opening the peritoneum at the right of the gallbladder). The trainee portrays a behavior during the performance of the task that requires an increasing frequency of supervisorial corrections. After 5 times this behavior has been observed, the supervisor takes over to proceed with the operation. Instruction and takeovers are not counted as supervisorial correction, thus $N_{vc} = 4$ in this case. (B) The first verbal correction is not clear enough to correct the trainee. A number of verbal corrections with the intend to clarify the primary correction are given. In this case $N_{vc} = 2$.

surgeons, this could potentially bias the results. To evaluate whether this was the case, the "observed perceived importance" was calculated for each supervising surgeon with:

$$\textit{Observed perceived importance} = N_{vc-SS}/(N_{proc-SS} \times N_{total-SS} \times \Sigma(N_{vc-SS}/(N_{proc-SS} \times N_{total-SS})) \quad (1)$$

where $N_{\text{vc-SS}}$ = the total number of verbal corrections in 1 cluster given by a supervising surgeon, $N_{\text{proc-SS}}$ = total number of procedures wherein the surgeon acted as the supervisor (correction for number of supervised procedures), and $N_{\text{total-SS}}$ = total number of verbal corrections of the supervising surgeon over all clusters (correction for talkativeness). The number of verbal corrections per cluster normalized for number of supervised procedures and talkativeness was divided by the sum of the normalized numbers of verbal correction of all surgeons to obtain a percentage. Because this method is specifically aimed to screen for surgeon-specific bias in the results of a Pareto analysis, no threshold values were available in the literature to guide interpretation. Consequently, we determined threshold values as follows: (1) to minimize sampling error, only surgeons with >10 supervised procedures were included and (2) an absolute difference of 30% between the maximum and minimum observed perceived importance was used as a cutoff value for identifying differences in supervisorial behavior between surgeons in each cluster.

RESULTS

Data Characteristics

A total of 64 procedures performed by 12 trainees and supervised by 9 surgeons were analyzed. The median number of videos wherein a surgeon acted as a supervisor was 4 (range: 1-19.5) (in 1 video, the supervising surgeon had to leave in the middle of a procedure and another one took over supervision). The median number of procedures performed by the trainees in the videos was 4 (range 1-8).

Evaluation of the Pareto Principle

The videos contained 1587 verbal corrections in total. A rank-ordered distribution of the counts of the verbal corrections is shown in Figure 3. Eighty percent of the total number of verbal corrections was caused by 35 of the 253 different corrections (14%).

The verbal corrections were categorized in 40 different clusters of technical behavior (Supplement). Further, 46 times verbal corrections were categorized in more than one cluster. Eighty percent of the total number of verbal corrections within the clusters were caused by the 11 highest-ranking clusters (28%) (Fig. 4).

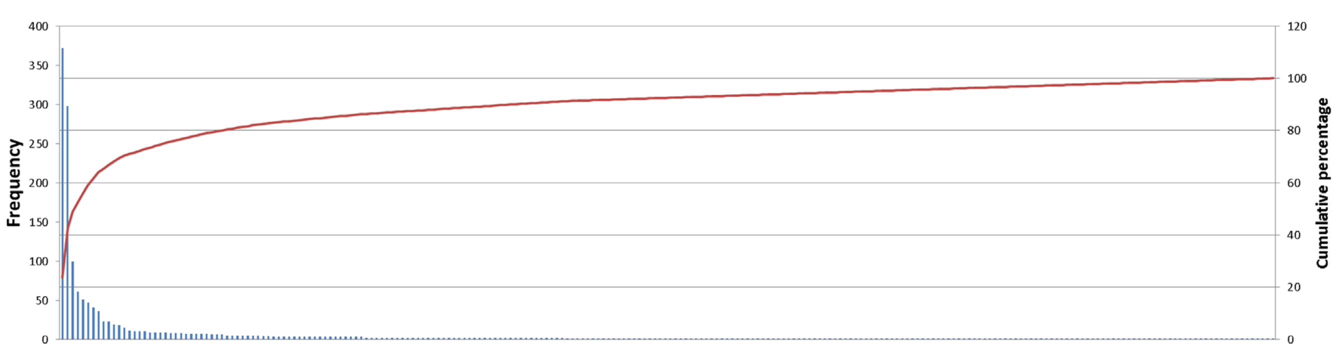

FIGURE 3. Rank-ordered counts (blue) and cumulative distribution curve (red) of the 253 different verbal corrections.

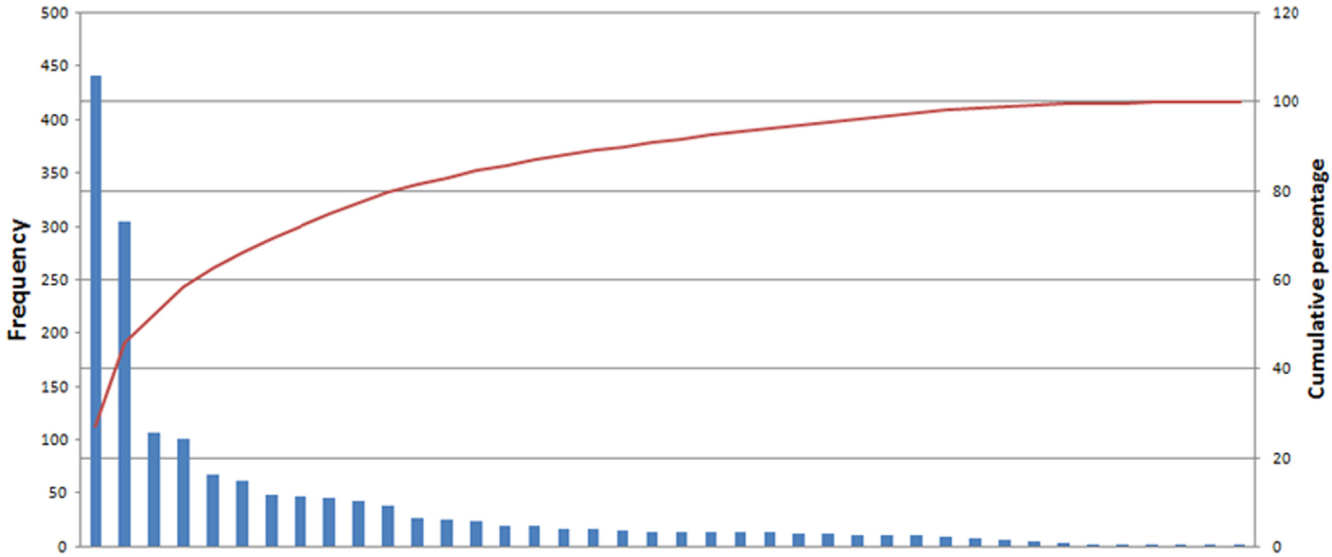

FIGURE 4. Rank-ordered counts (blue) and cumulative distribution curve (red) of the 40 clusters of novice behavior.

Establishing Content Criteria for Surgical Training by Means of the Pareto Principle

Whole procedure

A list of the 11 highest-ranking clusters is shown in Table 1. In the whole procedure, the cluster "tensioning the gallbladder with the appropriate direction and strength" was with the highest number of corrections, accounting for 27.0% of clustered corrections. The cluster "identifying the correct surgical plane" accounted for 18.6% of clustered corrections.

Operative Steps

For the classification of verbal corrections into steps, steps 2 and 3 were merged because the operating team frequently shifted between the substeps of these 2 procedural steps (e.g., opening the peritoneum and performing dissection of Calot's triangle at the left side of the gallbladder before proceeding to the peritoneum at the right side). The percentage of verbal corrections in step 1 was 9.4%, step 2 to 3 was 42.2%, step 4 was 11.4%, step 5 was 32.5%, and step 6 was 4.5%. The clusters of verbal corrections with the highest frequency were about choosing the position and direction of the trocars (66.9%) in step 1, applying left-hand traction on the gallbladder with the appropriate strength and direction in steps 2 to 3, step 4, and step 5 (25.6%, 43.2%, and 34.9%, respectively), and using the endobag in step 6 (38.0%). The second most frequent clusters of verbal corrections were aspects of the incision in step 1 (13.2%), determining the optimal direction of dissection in step 2 to 3 and 5 (21.8% and 28.9%, respectively), the use of the clipping instrument in step 4 (25.7%), and the use of the crocodile clamp in step 6 (23.9%).

Observed Perceived Importance

To evaluate whether one of the supervising surgeons considered one of the clusters as more important or less important than other surgeons, observed perceived importance was calculated for the verbal corrections. In the clusters "staying close to the gallbladder," "staying superficial during dissection," "use of the clipping instrument," "avoiding liver damage," and "positioning of the clip" the differences between surgeons exceeded the threshold of 30% (Table 1).

DISCUSSION

For a job training to be useful, the appropriate training content must be identified through a proper analysis of job requirements. Surgery is a psychomotor and cognitive challenging discipline. Many different sensory motor patterns and cognitive schemata have to be acquired to perform surgery independently in a safe and skillful manner. Intuitively, the available training resources would be distributed among the spectrum of necessary skills to become a competent surgeon. However, if there is a misbalance during training in favor of certain surgical behaviors in the OR, it would be more profitable to prioritize investments in the training of those specific surgical skills. The Pareto principle is a well-established theory in business management and states that the bulk of a common effect is caused by just a few of the causes. It is used to increase business returns by investing company resources in those aspects of business that have the highest revenue. In this study, we evaluated whether the Pareto principle is true for OR training in a basic surgical procedure, the laparoscopic cholecystectomy.

TABLE 1. Overview of clusters of verbal corrections contributing 80% of the total number of corrections given by clinical supervisors and the key steps in which the behaviors were corrected. Step 1: Open introduction of the first trocar and accessory trocar placement, Step 2: opening of the peritoneal envelope, Step 3: creating the CVS, Step 4: clipping and division of cystic duct and artery, Step 5: retrograde cholecystectomy, and Step 6 gallbladder removal and closure. Min. = minimum observed perceived importance, max. = maximum observed perceived importance, diff = difference between minimum and maximum.

Order nr.	Verbal correction	N	$f_{procedure}$	Step 1	Step 2-3	Step 4	Step 5	Step 6	Min.	Max.	Diff
1	Tensioning the gallbladder with the appropriate direction and strength	441	7.11	—	+	+	+	—	24,6	43,6	19,0
2	Identifying the correct surgical plane	304	4.90	—	+	—	+	—	25,0	48,9	23,8
3	Use of the dissection hook	106	1.71	—	+	—	+	—	30,1	38,1	8,0
4	Choosing position and direction of trocar placement	101	1.63	+	—	—	—	—	28,1	43,2	15,1
5	Using the clamp	67	1.08	—	+	—	+	—	19,8	43,9	24,0
6	Staying close to the gallbladder	61	0.98	—	+	—	+	—	19,3	55,3	35,9
7	Staying superficial during dissection	49	0.79	—	+	—	+	—	15,4	61,4	45,9
8	Using the clipping instrument	47	0.76	—	—	+	—	—	17,7	55,5	37,8
9	Avoiding harm to surrounding structures other than the liver	45	0.73	—	+	—	+	—	19,4	48,8	29,4
10	Avoiding liver damage	42	0.68	—	+	—	+	—	18,8	56,3	37,4
11	Positioning of the clip	39	0.63	—	—	+	—	—	18,7	49,9	31,2
All clusters		1633*	26.34								

+ = correction has been addressed in the operative step, - = correction has not been addressed in the operative step.
46 times a verbal correction was categorized in more than one cluster.

Secondly, the verbal guidance expressed by supervising surgeons during training was analyzed with the Pareto analysis to identify training content that could be used to increase the efficiency of training in a basic surgical procedure.

Does the Pareto Principle Exist in the Surgical Training of a Basic Surgical Procedure?

The separate and clustered verbal corrections plots showed a power law distribution with a cumulative distribution curve similar to those observed in other studies.[6] Furthermore, 35 (14%) of the 253 different verbal corrections and 11 (28%) of the 40 clusters of novice behavior accounted for 80% of the corrections given by supervisors, confirming the 80-20 rule. Based on these findings, it seems that the Pareto principle can be demonstrated in the verbal corrections uttered by supervising surgeons during a surgical procedure.

Establishing Content Criteria for Surgical Training by Means of the Pareto Principle

The next step is to develop training methods for the job requirements identified with the Pareto principle. In general, these training methods could consist of all educational resources currently available to trainees such as textbook explanations, educational videos, instructional courses, and dry laboratory training tasks. We have chosen to specifically discuss training tools for the following 5 themes: (1) tissue exposure, (2) surgical dissection plane, (3) instrument handling, (4) insertion of trocars, and (5) use of the endobag.

Tissue Exposure

Applying traction in the appropriate direction and with the appropriate force accounted for 27.0% of clustered corrections expressed by the supervising surgeons in our study. This is in line with an interview of experts about the most common problem areas experienced by novice trainees. These experts identified neglect of the nondominant hand as 1 of the 5 most common difficulties.[13] Although there are a number of tasks on the SIMENDO to train the nondominant hand, our results provide evidence that the content of these tasks do not suffice for adequate training of left-hand coordination during a laparoscopic cholecystectomy. The full procedure simulator LapSIM, almost 20 times as expensive as the SIMENDO,[23] includes the simulator tasks dissection of Calot's triangle and removal of the gallbladder from the liver bed. These are the 2 operative steps in which adequate exposure of the gallbladder with the left hand is essential. Surprisingly, no explicit measures are included to assess whether the trainee adequately exposes the gallbladder through exercising traction in the right strength and direction.[24] Horeman et al. have described a training tool to more comprehensively teach this skill. In their studies, they have demonstrated an improved tissue handling when trainees receive laparoscopic skills training with visual feedback of the size and the direction of the force they exercise through the surgical instruments.[25,26] Therefore, a learning module wherein the right amount of force, defined by the force exerted by experts on real tissue, and direction of traction with the nondominant hand result in the optimal exposure for performance of a task with the dominant hand and could be used to address the issue of adequate tissue exposure in surgical training.

Surgical Dissection Plane

Choosing the direction of dissection showed the second highest frequency of verbal corrections, accounting for 18.6% of the total number of verbal corrections. This behavior is probably technically challenging, because it consists of a complex interaction between the motor task of adequately exposing the tissue and the visual perceptual task of identifying the accurate dissection plane during exposure. Although engineers should pursue incorporating the training of this task in virtual reality (VR) simulator tasks, a VR environment might currently not be the most suitable method for learning this behavior because of the complexity of the tissue that needs to be simulated. There are 2 alternatives (other than the use of cadavers or animals) that could support training in identifying the surgical dissection plane.

A tool to transfer training in identifying the surgical dissection plane to outside the OR could be the recently validated surgical planes perception task developed by Schlachta et al.[27] They developed a task in identifying the accurate dissection plane in colorectal surgery by challenging subjects to draw the plane for dissection on a digital picture and calculating the distance of the line with the average line drawn by certified colorectal surgeons. A significant difference was observed between the variation in line distances among novice trainees compared with the variation among consultant surgeons for a number of the digital pictures. However, more research is currently being conducted to evaluate whether this task can actually be used to train subjects in identifying the right plane for dissection.

A second option includes technical adjustments in the OR environment to support the teaching of this topic to surgical trainees. For instance, in our institution, a trainee had once placed a marking at the middle of the screen. This allowed the supervising surgeon to point out the exact expected route of dissection for the trainee while holding the camera. A clearer visualization of dissection plane can facilitate in proceeding through the dissection a longer distance without verbal guidance than otherwise would be possible, consequently, increasing the autonomy of the trainee. Ideally, the supervising surgeon would be able to switch on a digital pointer built in the laparoscope to show the right path when the trainee loses sight on the optimal plane of dissection.

Instrument Handling

The use of the dissection instruments also accounted for a high number of verbal corrections. Use of the dissection hook was ranked third in the final rank-order of the clusters. Interestingly, in our study, 51 of the 106 corrections (48.1%) in this cluster were given to teach the trainee a specific pattern, namely, a pull-cautery-pull pattern that consists of (1) placing the tissue under tension by pulling, (2) activating the cautery without pulling, (3) deactivate the cautery, and (4) pulling again. This pattern can be measured with measures of psychomotor skills and therefore seems a viable option for inclusion in a VR or video trainer training task. The same holds for going into the tissue parallel to the dissection plane and pulling orthogonal to the dissection plane with the hook, which accounted for 36 of the 106 (34.0%) verbal corrections related to the use of the dissection hook.

Trocar Insertion

Choosing the correct location and direction for insertion of the trocars accounted for 66.9% of the total number of corrections in step 1. Because the use of excessive force was the most commonly cited malpractice in relation to trocar insertion,[28] the development of the first training task dedicated to the practice of trocar insertion was focused on the number of turns needed to insert the trocars and the plunge depth during insertion.[29,30] However, the majority of supervision is actually focused toward getting the trocar in the right location and direction instead of correcting the amount of turns or preventing too deep of a plunge. Although it might be difficult to incorporate trocar insertion in VR simulator training because of the strong dependence on haptic feedback during insertion, the variety of the abdominal wall characteristics and the preference of the surgeon, our results suggest that future educational developments, such as textbook explanations, dedicated courses and educational videos, should preferably also include determining the (patient specific) direction and position for insertion of trocars.

Use of the Endobag

The use of the endobag did not belong to the 11 highest-ranking clusters; nonetheless, corrections for the use of the endobag accounted for 38.0% of the corrections in step 6. Corrections were given during manipulation of the endobag, placing the gallbladder in the endobag and during specimen retrieval to increase the efficiency in the use of the limited intra-abdominal space. The lack of training in these skills could be, in part, related to the high expenses of the endobag (60.33 GBP/92.00 USD).[31] The literature describes the use of 2 practical and inexpensive alternatives for specimen retrieval that can be used for training. (1) Turial and Schier[31] have demonstrated the use of the innermost plastic wrapping of a Redon drain bag (0.20 GBP/0.30 USD, including Redon drain) grasped with a 2-mm needle holder and inserted through a 5-mm trocar as an alternative specimen retrieval system in children and (2) Yao et al.[32] reported the extraction of 2 large gastric phytobezoars with a simple surgical glove (0.46GBP/0.70 USD) as a specimen retrieval system. These alternatives could enable the addition of specimen retrieval training to the already existing training tasks on a video trainer and consequently decrease the energy and time needed to teach the use of the endobag during training in the OR.

Observed Perceived Importance

The difference in the observed perceived importance did not reach the threshold in the highest-ranking clusters, negating the possibility that the professional judgment of a surgeon was overtly focused toward one aspect of surgical behavior and thereby influenced their rank. As the number of verbal corrections per cluster decreased toward the lower ranking clusters, the difference in the observed perceived importance per surgeon reached the threshold in the sixth, seventh, eighth, tenth and eleventh cluster, most likely as a consequence of sampling error.

Limitations

Some limitations should be kept in mind when interpreting the results of this study. Methodological limitations include the retrospective nature of the study, a large dispersion in the number of supervised procedures per surgeon, the videos originating from studies performed in one institution, coding of the audio recordings performed by one author, and the subjectivity of the interpretation of interactions between persons. We also did not attempt to track the time records of the takeovers, which would have allowed a ratio of behavior per time unit calculation instead of per procedure, one of the methods proposed by Altmann[21] to more accurately determine behavior during animal observation. This could have been a more reliable way of documenting supervisorial behavior; however, the number of corrections given per time period the trainee holds the instruments in his hands is also dependent on other factors than the interaction between the professional judgment of the supervising surgeon and the observed skills of the trainee. Time pressure, patient characteristics, and even the mood of the surgeon are all factors that cannot be controlled in a retrospective study and could therefore have been factors that influenced the behavior per time unit.

To evaluate whether surgeon-specific factors have a significant influence on the study results, the observed perceived percentage was calculated. However, this is a novel method that has not been validated previously. Consequently, there is no scientific evidence to support the decision to include only surgeons with a number of supervised procedure >10 and to define a difference of 30% as a cutoff point. Nonetheless, we believe that screening for surgeon-specific factors by calculating an observed perceived percentage should be included in the evaluation of a Pareto analysis as described in this study, as it provides information about the generalizability of the study findings to supervising surgeons in general.

Another important methodological limitation is that this study was focused on 1 procedure. To confirm that this Pareto principle holds for surgical procedures in general and to identify learning points that can be used to increase the training efficiency of the whole scope of surgical procedures, other procedures also have to be analyzed according to the Pareto principle. Furthermore, the data acquisition process in this study was labor intensive, raising the question on how many procedures have to be analyzed to observe an exponential pattern. Particularly in more advanced laparoscopic procedures, an exponential pattern in a rank-ordered list might be hard to identify owing to adjustments in behavior or gains of knowledge during experience in more basic laparoscopic procedures.

Finally, it is important to note that a popular synonym for the Pareto principle "the vital-few and trivial many," does not hold in surgical training, as seldom corrected behaviors are not per se unimportant novice behaviors. The goal of the Pareto analysis is to describe important aspects for increasing training efficiency, not to describe the most important aspects of the procedure itself.

CONCLUSION

The OR is an expensive teaching venue. Health institutions are under pressure to increase patient safety and reduce the financial costs for training in the OR. The Pareto principle states that an observed few causes are responsible for the bulk of a common effect. This principle has been used within varying industries to increase business returns by increasing work process efficiency. In this study, the Pareto principle was evaluated as a tool for the development of training content for more efficient surgical training. The verbal corrections uttered by supervising surgeons in the OR were used to explore surgical behaviors that could be the focus for better OR preparation. We found that most verbal corrections were directed toward a few novice behaviors in the OR. The next step would be to validate the Pareto principle by exploring if adequately addressing the identified behaviors in trainee preparation leads to the expected reduction in resources for health institutions.

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SUPPORTING INFORMATION

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