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Surgeons see anatomical structures faster and more accurately compared to novices: Development of a pattern recognition skill assessment platform

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ABSTRACT

Background: This study aimed to identify differences in pattern recognition skill among individuals with varying surgical experience.
Methods: Participants reviewed laparoscopic cholecystectomy videos of various difficulty, and paused them when the cystic duct or artery was identified to outline each structure on the monitor. Time taken to identify each structure, accuracy and work load, which was assessed using the NASA-Task Load Index (TLX), were compared among the three groups.
Results: Ten students, ten residents and eight attendings participated in the study. Attendings identified the cystic duct and artery significantly faster and more accurately than students, and identified the cystic artery faster than residents. The NASA-TLX score of attendings was significantly lower than that of students and residents.
Conclusions: Attendings identified anatomical structures faster, more accurately, and with less effort than students or residents. This platform may be valuable for the assessment and teaching of pattern recognition skill to novice surgeons.
Short summary: Accurate anatomical recognition is paramount to proceeding safely in surgery. The assessment platform used in this study differentiated recognition skill among individuals with varing surgical experience.

Introduction

Accurate identification of anatomic structures during an operation is paramount to proceeding safely in surgery. Poor recognition can lead to inadvertent division of the wrong structures and negatively impact patient safety.[1,2] This "pattern recognition" skill is particularly salient for surgeons who practice laparoscopy, considering that laparoscopic surgery consists of the two-dimensional depiction of three-dimensional anatomy. Indeed, a review of 252 laparoscopic cholecystectomy videos showed that bile duct injuries stemmed principally from misperception and misidentification of the anatomical structures, rather than skill, knowledge, or judgment errors.[1] In addition to understanding basics of anatomy and procedures, surgeons need to carefully observe the operating field, be prepared to encounter structures, recognize slight differences in colors or textures, and quickly find any unusual situations. Studies outside of medicine have demonstrated that expert performers have superior skills in recognizing specific patterns, discriminating between normal and abnormal situations, and anticipating forthcoming events based on their experience.[3–5] Indeed, it has been our clinical observation that attending surgeons typically identify anatomic structures earlier and more accurately than inexperienced trainees. If this issue can be experimentally proven and a platform can be developed to assess this skill in surgery, it may allow educators to develop curricula that help trainees improve pattern recognition skill outside of the operating room. Nevertheless, little work has been done in surgery on this topic. Our aims in this study were, therefore, to objectively assess differences in pattern recognition skill among individuals with variable surgical experience and to describe an assessment platform that could be used for the assessment of such skills.

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We hypothesized that more experienced surgeons would identify anatomical structures (cystic duct and artery) faster and more accurately during a review of laparoscopic cholecystectomy videos compared with less experienced individuals.

Methods

This study was approved by the institutional review board of Indiana University School of Medicine in Indianapolis, Indiana.

To assess pattern recognition skill among experienced and inexperienced surgeons, we elected to focus on laparoscopic cholecystectomy. Our rationale for the choice of this procedure was that it is one of the most commonly performed by general surgeons and surgical trainees and associated with a higher incidence of bile duct injury compared with the open approach.[6] Further, the previously suggested mechanism behind such injuries, that of misperception and misidentification of anatomic structures,[1] makes this procedure a prime target for the assessment of pattern recognition skill.

To select the appropriate videos for this study, investigators reviewed ten laparoscopic cholecystectomy videos performed by the same attending surgeon and selected an easy (video 1) and a difficult (video 2) video. Easy was defined as a gallbladder with minimal inflammation and bleeding where the anatomic structures of interest were straightforward to identify based on investigator consensus, whereas difficult was defined as an inflamed gallbladder with distorted anatomy and less clear tissue planes where the anatomical structures of interest were more difficult to identify. We also included a difficult case video performed by a resident (video 3) to assess whether operating surgeon's skill had an impact on structure recognition. Each of the three identified videos was edited down to a 10-min duration and finished when the cystic duct and artery were cut.

An invitation email was distributed to all medical students, surgical residents and attending surgeons at Indiana University School of Medicine. Participants were asked to complete a brief survey about their demographic data (i.e., age, gender, and years in practice) and the number of laparoscopic cholecystectomy procedures they had performed. To be included attending surgeons had to be regularly performing laparoscopic cholecystectomies in their practice. All participants were provided with information on laparoscopic cholecystectomy using a Microsoft® PowerPoint (Microsoft Corporation, Redmond, WA) presentation that included information on biliary anatomy, steps of the procedure, bile duct injury mechanisms, and criteria and example images of the critical view.[7,8] It was mainly aimed at medical students who had little prior knowledge of biliary anatomy and laparoscopic cholecystectomy but also at junior residents who may not have had observed/performed the procedure recently.

Each participant then watched the three video recordings of laparoscopic cholecystectomy on a computer in the same order from video 1 to 3. Participants were instructed to pause the video when they identified the location of the cystic duct and artery as the dissection proceeded. They were then asked to precisely outline the structures on the monitor using a computer mouse to control a pointer which was pen-shaped and allowed drawing lines on the screen using Bandicam (Bandisoft, Seoul, Korea). Participants were instructed to not include surrounding structures in their outline such as connective tissue, the common bile duct, the right hepatic artery or the duodenum. Rewinding was not permitted for participants.

To assess speed of recognition, we recorded time until the video was stopped. To assess accuracy of recognition, the drawings by each participant were compared with those of an expert (DS), who had performed over 1000 laparoscopic cholecystectomy procedures. The expert followed the same guidelines for drawing the structures on the screen at the same point at which each participant had outlined the structures. For example, if the participant had stopped the video and identified the cystic duct and artery 300 s after video start. The expert was asked to pause the same video at 300 s from start and outline/identify the two structures. The expert was allowed to rewind the video as needed to obtain the best possible view of the structures but was blinded to participant identity and drawn structure outlines to avoid bias. Accuracy was defined as percentage of overlap between participant and expert drawings (Fig. 1) using the following equation:

$$Overlap\ with\ expert\ (\%) = \frac{Overlapping\ area\ (sq\ in)}{Expert\ identified\ area\ (sq\ in)} \times 100$$

Incorrect identification was defined as the non-overlapping area selected by the participant according to the equation:

$$Incorrect\ identification\ (\%) = \frac{Participant\ identified\ area\ (sq\ in) - Overlapping\ area\ (sq\ in)}{Participant\ identified\ area\ (sq\ in)} \times 100$$

These two metrics were chosen since limited overlap or a large area outside of the expert marking can both lead to injuries to important structures and were felt to have both clinical significance.

In addition, participants were asked to rate how confident they were in the identification of each structure using a 5-point Likert scale and to complete a NASA-Task Load Index (TLX) to indicate their work load.[9]

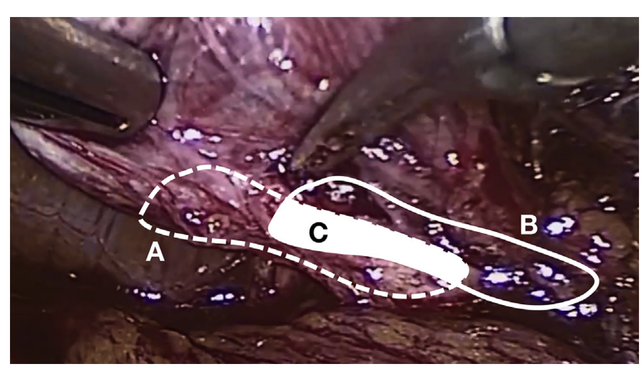

Fig. 1. Method of recognition accuracy and error calculation.
Accuracy was calculated by measuring the expert identified area (A), the participant identified area (B), and the overlapping area (C). Overlap with the expert (%) was defined as (Area A)/(Area B)*100. Incorrect identification (%) was defined as {(Area B)-(Area C)}/(Area B) *100.

Statistical analysis

The numbers of laparoscopic cholecystectomy procedures participants had performed were compared among the three groups using the Kruskal-Wallis test. This test was also used for comparison of time, overlap with expert and incorrect identification on each video among the three groups. Both analyses were followed by non-parametric multiple pairwise comparisons. To compare participant performance across all videos, scores for each video were normalized using the following formula:

$$Z_{video\ X} = \frac{Score - \mu}{\sigma}$$

(Z = individual's normalized score, μ = mean score of all participants, σ = standard deviation of all participants) and normalized scores of the three videos were averaged:

$$Z = \frac{Z_{video\ 1} + Z_{video\ 2} + Z_{video\ 3}}{\sigma}$$

Correlations among normalized scores and the number of laparoscopic cholecystectomy procedures participants had performed were assessed using the Spearman's correlation test.[10]

Data are presented as medians [ranges]. A p-value of less than 0.05 was considered statistically significant with the exception of Bonferroni corrected p-value for pairwise comparison, which was 0.017. JMP® Pro 12 (SAS Institute, Inc., Cary, NC) software was used for data analysis.

Results

Ten medical students (second year [1–4]), ten general surgery residents (postgraduate year 2 [1–3]) and eight attending surgeons (years in practice 6.5 [1–14]) participated in the study. The numbers of laparoscopic cholecystectomy procedures participants had performed were 0 [0-0] for medical students, 15 [0–20] for surgical residents, and 225 [100–700] for attending surgeons ($p < .0001$).

Pattern recognition skill differences were identified among group's overall performance (Fig. 2). Attending surgeons identified the cystic artery faster and more accurately compared with residents and students, and residents faster and more accurately than students. While similar trends were seen for the identification of the cystic duct, these differences did not reach statistical significance. Videos 1 and 3 were better at discriminating among groups (Table 1).

Cystic duct and artery scores were significantly correlated for time (0.71; $p < .001$), overlap with the expert (0.48; $p = .009$), and incorrect identification (0.63; $p < .001$). Significant correlations were also observed between participant confidence and identification scores for several metrics and videos (Table 2). Finally, participants who had performed a larger number of laparoscopic cholecystectomy procedures identified the cystic duct with greater accuracy and the cystic artery within less time, and had larger overlap with the expert assessment than those who had less experience in performing the procedure (Table 3).

The NASA-TLX total score of attending surgeons (17 [11–41])

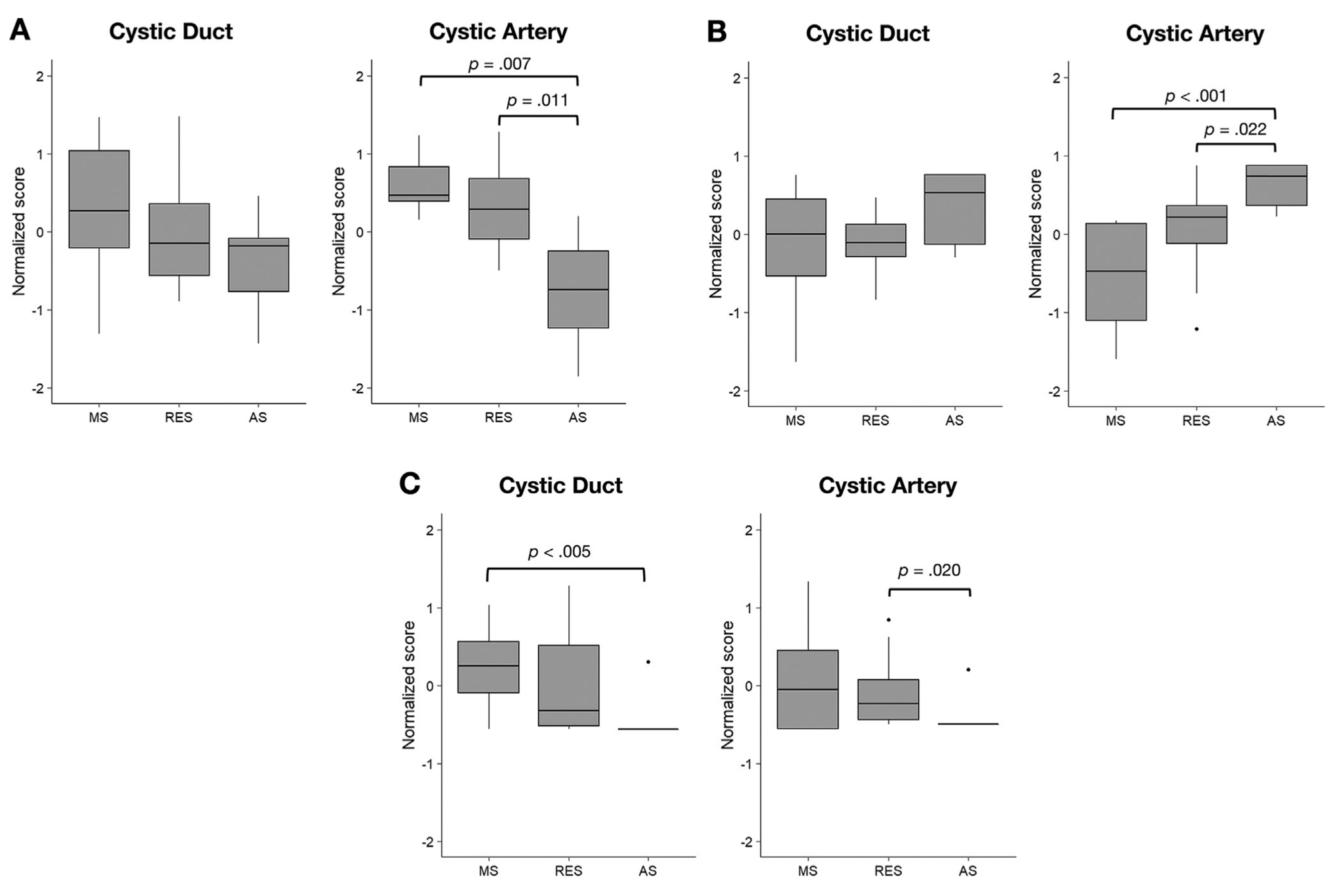

Fig. 2. Pattern recognition skill comparison among groups: (A) Time to recognition, (B) Accuracy of recognition, (C) Recognition error.
The three graphs depict the comparison of normalized scores for identification of the cystic duct and artery among the three groups based on (A) time taken, (B) overlap with expert, and (C) incorrect identification. For graphs A and C, lower scores indicate better performance. For graph B, higher scores indicate better performance.
MS: medical students, RES: surgical residents, AS: attending surgeons.

Table 1
Comparison of pattern recognition skill among the three groups.

	Medical students (N = 10)		Surgical residents (N = 10)		Attending surgeons (N = 8)		*p*-value	
Video 1								
Cystic duct								
Time (sec)	316	[29–406]	177	[18–442]	158	[20–199]	.155	
Overlap with expert (%)	94	[0–100]	92.4	[0–100]	90	[0–100]	.938	
Incorrect identification (%)	51	[0–100]	10	[0–100]	0	[0-0]	.032	
Cystic artery								
Time (sec)	339	[45–444]	284	[168–422]	183	[20–215]	.002	*†
Overlap with expert (%)	100	[0–100]	74.9	[0–100]	100	[38.5–100]	.630	
Incorrect identification (%)	16.5	[0–100]	2.9	[0–100]	0	[0–75.6]	.135	
Video 2								
Cystic duct								
Time (sec)	250	[117–402]	210	[125–355]	205	[103–264]	.211	
Overlap with expert (%)	90.4	[35.7–100]	78	[0–100]	100	[50.5–100]	.033	
Incorrect identification (%)	0.8	[0–37.9]	0	[0–100]	0	[0-0]	.100	
Cystic artery								
Time (sec)	309	[204–402]	304	[257–402]	242	[195–328]	.050	
Overlap with expert (%)	12.6	[0–100]	52.7	[0–100]	100	[41.1–100]	.039	
Incorrect identification (%)	0	[0–100]	0	[0–65.2]	0	[0-0]	.042	
Video 3								
Cystic duct								
Time (sec)	474	[133–537]	477	[202–537]	385	[235–537]	.913	
Overlap with expert (%)	66.8	[0–100]	92.3	[0–100]	100	[0–100]	.369	
Incorrect identification (%)	0	[0–100]	0	[0–100]	0	[0-0]	.262	*
Cystic artery								
Time (sec)	496	[180–496]	488	[392–496]	381	[316–487]	.010	*
Overlap with expert (%)	0	[0–100]	100	[0–100]	100	[100–100]	.001	*
Incorrect identification (%)	0	[0–100]	0	[0–100]	0	[0-0]	.198	

Data are presented as medians [ranges].
* Significant at *p*-value 0.017 (Bornferroni adjusted) for medical students and attending surgeons.
† Significant at *p*-value 0.017 (Bornferroni adjusted) for surgical residents and attending surgeons.

was significantly lower than that of medical students (44 [27–60]; $p = .006$) or surgical residents (45 [19–68]; $p = .007$). Specifically, attending surgeons invested less effort (3 [1–8]) than medical students (11 [5–19]; $p = .004$) or surgical residents (10 [4–13]; $p = .002$). In addition, frustration of attending surgeons (1 [1–5]) was less than medical students (7 [1–15]; $p = .011$). Interestingly, there were no workload differences between residents and medical students.

Table 2
Correlations between scores and confidence level with identification of each structure.

	Correlation coefficient with confidence level in identifying each structure	*p*-value
Video 1		
Cystic duct		
Time	**−0.402**	**.034**
Overlap with expert	−0.261	.181
Incorrect identification	0.030	.879
Cystic artery		
Time	−0.275	.157
Overlap with expert	−0.034	.866
Incorrect identification	−0.059	.767
Video 2		
Cystic duct		
Time	**−0.389**	**.041**
Overlap with expert	−0.104	.599
Incorrect identification	0.009	.965
Cystic artery		
Time	0.008	.966
Overlap with expert	**0.537**	**.003**
Incorrect identification	**−0.677**	**<.001**
Video 3		
Cystic duct		
Time	−0.318	.099
Overlap with expert	0.194	.322
Incorrect identification	0.033	.877
Cystic artery		
Time	**−0.378**	**.047**
Overlap with expert	**0.377**	**.048**
Incorrect identification	−0.164	.490

A *p*-value of less than 0.05 was considered statistically significant (bold).

Table 3
Correlations between the number of laparoscopic cholecystectomy procedures participants had performed and normalized scores.

	Correlation coefficient with number of cases participant had performed	*p*-value
Cystic duct		
Time	−0.162	.410
Overlap with expert	0.239	.222
Incorrect identification	**−0.553**	**.002**
Cystic artery		
Time	**−0.471**	**.012**
Overlap with expert	**0.811**	**<.001**
Incorrect identification	−0.346	.072

A *p*-value of less than 0.05 was considered statistically significant (bold).

Discussion

This study demonstrated the difference in pattern recognition skill among individuals with varying surgical experience and confirmed our hypothesis. As expected, attending surgeons identified anatomical structures faster and more accurately during the review of laparoscopic cholecystectomy videos than junior surgical residents and medical students.

Similar to our findings, Schlachta et al.[11] previously showed that experienced surgeons more accurately recognized the ideal dissection plane than surgical trainees when watching an image of a mesorectal excision. Distinctive from their study, our study used videos to assess recognition skill. Using videos replicates the operation flow and provides a more dynamic platform for the assessment of recognition skills by also allowing for the assessment of recognition speed. In addition, by not relying on a single image for recognition of accuracy, videos provide a more appropriate and realistic approach to the assessment of these skills. Abdelsattar et al.[12] used operating videos of several laparoscopic procedures and demonstrated that staff surgeons obtained higher scores than novices in verbalizing observations (pathology, anatomical planes, type of procedure, and qualitative aspects). Similar to our study, their findings support the notion that anatomical recognition skill is related to surgical experience and expertise as has been demonstrated outside of surgery for sports, hazard analysis and chess.[3–5]

Our findings also clearly demonstrated that the identification of the cystic artery was more discriminating among groups than the identification of the cystic duct. One of the potential reasons explaining this finding may be that more experienced surgeons, who are well aware of the risk and consequences of bile duct injury, may have spent more time before they finalized their decision on the cystic duct compared to the artery. In addition, it may be related to the anatomic position of these two structures with the typically more lateral position of the cystic duct making it easier to identify; in addition, the artery's position within the fat of Calot's triangle and more variable course may make its recognition more challenging and necessitating more experience with the procedure. Indeed, our findings also showed that participants who had performed a larger number of laparoscopic cholecystectomy procedures identified structures faster and more accurately than less experienced participants. In addition, more experienced participants completed the tasks with less work load than other participants, especially less effort and less frustration, which demonstrates that they were more comfortable with the identification of these structures. Further support to this argument comes from the finding that the more confident participants were in their ratings, the faster and more accurately they identified the structures. This further suggests that these skills are developed through increasing experience; the more times the structures have been identified previously, the more confident and easier their identification becomes in the future. Nevertheless, we found a strong correlation between recognition scores for the cystic duct and artery and similar recognition skill differences among groups for both structures, which may indicate that the lack of statistical significance for the cystic duct might be a function of type II error; a higher number of participants in each group might have allowed us to also demonstrate a difference in the recognition of the cystic duct.

We used three videos for pattern recognition skill assessment in order to mimic the variability inherent to clinical practice. While three videos are unlikely to capture every possible clinical scenario, we chose them to include easy and difficult dissection conditions and included expert and resident performed procedures as both factors may affect recognition skill. We indeed found differences in recognition skill discrimination among videos with videos 1 (expert easy) and 3 (resident difficult) being more discriminatory compared to video 2 (expert difficult). The quality of the video recordings was similar which makes this an unlikely factor for this observation. On the other hand, it is possible that video 2 may have been too difficult and the structures may have first become clearly visible only late in the dissection when they were easy to distinguish by experienced surgeons and novices alike. This intriguing finding demonstrates how little we understand about pattern recognition skill and suggests the need for additional studies that will answer the question of how case difficulty affects recognition skills. Our results may have also been influenced by the video review order. Videos were shown to all participants in the same order because the primary aim of this study was to identify differences in pattern recognition skill among the three groups; as a result, we cannot make conclusions about the discriminatory ability of each video.

Given that misidentification of structures can potentially lead to injuries that impact patient outcomes, it is important to expand our knowledge of how these skills are acquired and what training strategies can be used to develop pattern recognition skill outside of the operating room. Our study provides a platform that can be used for the assessment of pattern recognition skill in several different procedures and may allow for the improvement of these skills when implemented in targeted curricula. If these skills can be improved outside of the operating room, it may have profound implications for patient safety. Nevertheless, whether the differences in recognition skill we encountered between more and less experienced surgeons in this study translate into fewer errors in the operating room remains to be demonstrated.

Conclusions

This study demonstrated that more experienced surgeons identified anatomical structures faster, more accurately and with less work load during the review of laparoscopic cholecystectomy videos than less experienced individuals. Our findings focus the attention of surgical educators on a neglected aspect of surgical training, that of recognition of anatomic structures during surgery, and provides an assessment platform to differentiate learners' pattern recognition skill outside of the operating room.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjsurg.2018.10.011.

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