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Troubleshooting common endoscopic malfunctions: a study integrating a preoperative checklist and troubleshooting guide into surgical resident training

Jenny Lam[1] · Kevin Grimes[2] · Adnan Mohsin[3] · Shawn Tsuda[3]

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Abstract
Introduction This study assessed the utility of a checklist in troubleshooting endoscopic equipment. Prior studies have demonstrated that performance in simulated tasks translates into completion of similar tasks in the operating room. Checklists have been shown to decrease error and improve patient safety. There is currently limited experience with the use of simulation and checklists to improve troubleshooting of endoscopic equipment. We propose the use of a checklist during a simulated colonoscopy to improve performance during endoscopic troubleshooting.
Methods This study randomized 20 surgical residents (PGY1–3) who were blinded to the purpose of the simulation. Participants were asked to complete two consecutive colonoscopies in a mock endoscopy suite. Prior to each trial, a standard set of equipment malfunctions were created; the equipment was returned to working order if the subjects were unable to successfully troubleshoot the equipment within the first 3 min of the simulation. Between trials, the intervention group was provided a troubleshooting checklist, which they were permitted to utilize during the second trial. The control group had no intervention. Scores were calculated for each task by subtracting time to completion from total time allowed (180 s), with 0 indicating the task was not completed. Groups were compared utilizing unpaired Student's *t*-test with $p < 0.05$ threshold for significance.
Results Average scores were compared for 5 tasks in the first trial and 6 tasks in the second trial. During the first trial, there were no significant differences. However, during the second trial, there was a significant improvement with the checklist for 5/6 tasks.
Conclusion Use of a checklist, with no further intervention, significantly improves the ability of novice endoscopists to identify and remedy common equipment malfunctions. Introduction of a troubleshooting checklist may represent a simple and low-cost way to improve both efficiency and safety in the endoscopy suite.

Keywords Endoscopic troubleshooting · Checklists · Training · Simulation · Endoscopy

Endoscopy is a burgeoning surgical field, evolving rapidly with the advent of laparoscopic simulators and virtual reality trainers. The Accreditation Council for Graduate Medical Education (ACGME) Residency Review Committee (RRC) acknowledges the importance of endoscopic training for surgeons and has increased the number of mandatory endoscopic cases to be completed in residency from 29 to 85, for those completing respective programs in 2009 [1]. In the last decade, there has been a push to integrate simulation into physician training, to enhance technical skills that transfer over into a clinical setting, in a safe, low-stress environment that minimizes patient harm [2, 3]. In 2008, the RRC mandated that all residency programs have skills laboratory curricula for accreditation [4]. In response to this new mandate, the American College of Surgeons and the Association of Program Directors in Surgery (ACS/APDS) created the National Skills

✉ Jenny Lam
JennyLam86@gmail.com

1 Department of Surgery, University of San Diego California, San Diego, CA, USA

2 Department of Surgery, Case Western Reserve University, School of Medicine, Cleveland, OH, USA

3 Department of Surgery, University of Nevada School of Medicine, Las Vegas, NV, USA

Curriculum, so that residency programs could adopt a standardized skills curriculum, which is cost-effective and easily accessible. The curriculum consists of 3 phases (basic surgical skills, advanced procedures, and team-based skills), which comply with the ACGME's six core competencies [5].

The incidence of equipment failure and technical problems during laparoscopic surgery has been previously reported to be high, with most incidences going unnoted in operation reports [6]. In a study comparing technical patient risk in minimally invasive surgery (MIS) versus conventional surgery (CS), the relative risk of having one or more technical problems and two or more problems in MIS compared to CS was 1.7 and 4.1, respectively [7]. These incidences prolong operating times, putting patient safety at risk. Included in the National Skills Curriculum is a laparoscopic troubleshooting team exercise, which includes an equipment failure scenario where there is a loss of visualization. In order to complete the surgical simulation successfully, four mandatory tasks must be completed within the allotted time [8]. In a study establishing the construct and face validity of this exercise, construct validity was not reached for this scenario, as there was no statistically significant performance difference between groups of varying experience. It was reasoned that this might have been due to the simplistic nature of this task [9]. Another study simulated an OR crisis scenario where the surgeon was to troubleshoot problems with placement of a Veress needle. Construct validity of this part of the simulation was also not reached due to lack of significant performance differences between groups as both performed equally well. It was suggested equipment troubleshooting was a "fundamental ability that most surgeons are capable of performing safely" [10]. These findings indicate that residents should be confronted with more difficult equipment issues that commonly occur in surgery, to identify whether expansion of residency skill laboratory curricula to include troubleshooting is warranted. There is also no current literature about the ability of surgeons to troubleshoot equipment problems during endoscopic procedures.

There is also reason to believe that a contributing factor to technical issues is due to inefficient operating room protocol. Implementation of a structured checklist of preparatory measures was shown to reduce incidence of technical issues with laparoscopic equipment [11]. Digital checklist tools, i.e., Pro/cheQ, have been shown to reduce risk-sensitive events (RSE) from happening even in technologically advanced integrated OR systems. The majority of RSE that occurred were due to equipment not being switched on or having the wrong settings, which could have easily solved with a preoperative checklist [12]. Expansion of residency skills training to include exercises that strengthen checklist preoperative measures, as well as stepwise correction during equipment failure scenarios, would improve efficiency in laparoscopic procedures. If it is proven that there is a deficit in surgeons' ability to troubleshoot endoscopic equipment failures, these measures could also improve efficiency in this field.

In this study, we introduce a novel endoscopic troubleshooting simulation that integrates a preoperative checklist and troubleshooting guide. The aim of this study is to develop and validate an alternative surgical learning exercise to improve effectiveness and overall performance of surgeons during endoscopic procedures. We hypothesized that surgical residents are not proficient in endoscopic troubleshooting, but given a short tutorial on how to use a preoperative checklist and troubleshooting guide they will be able to resolve common endoscopic equipment failures.

Materials and methods

Study design

This double-blinded, randomized study was carried out at an academic simulation center. Twenty junior surgical residents participated in the study in July 2012. The residents were randomized into control ($n = 10$) and experimental groups ($n = 10$), but evenly stratified based on postgraduate year (PGY). The checklist and troubleshooting guide used in this study were created using the Olympus Evis Exera CV 160 user manual [13].

The junior residents (PGY1–3) were given a demographic survey, which assessed their PGY as well as how many endoscopies they had previously performed (Table 1). They were also consented to being video captured. The subjects were told that the purpose of the simulation was to finish a simulated colonoscopy as quickly as possible, with a maximum allotted time of 15 min. They were blinded to the fact that the simulation was actually targeting their endoscopic troubleshooting capabilities. They were informed that after the simulation began they were not allowed to ask for help, and when the simulation was finished they were not to discuss the details of the simulation with anyone.

The subjects completed two trials of the 15-min simulation. Trials began with the endoscopic tower misaligned relative to the patient model, in order to assess knowledge of correct patient-equipment orientation. The first trial contained a video error (video umbilical and camera connections were loosened, and video monitor was set to video instead of Y/C) and a light source problem (light source connection was loosened, and filter was turned on). If the subjects did not fix equipment failures within 3 min, the simulation proctor stepped in and informed them that there

Table 1 Participant demographics

Total subjects ($n = 20$)	Resident year	Number of endoscopies performed
Control		
1	PGY1	None
2	PGY1	None
3	PGY3	1–10
4	PGY2	1–10
5	PGY1	None
6	PGY1	None
7	PGY2	1–10
8	PGY2	1–10
9	PGY2	1–10
10	PGY3	11–25
Experimental		
1	PGY2	1–10
2	PGY1	None
3	PGY3	None
4	PGY1	None
5	PGY1	>100
6	PGY2	1–10
7	PGY2	1–10
8	PGY3	11–25
9	PGY1	None
10	PGY2	None

was a problem with the equipment and directed them to step out while it was fixed. They were then instructed to continue the simulated colonoscopy. The control group was given a short break before the second trial, which had the same equipment problems as the first trial in addition to an insufflation failure (insufflator cap was loosened). The intervention group was provided with a 5-min troubleshooting tutorial and instruction on how to use a preoperative checklist and troubleshooting guide, after the first trial (Fig. 1). Each item on the checklist was addressed and manually demonstrated to the subjects. The participants then continued with the second trial, which had identical conditions to the control group.

Scores were calculated for each task by subtracting time to completion from maximum allotted time (180 s), with a score of 0 indicating the task was not completed. Groups were compared utilizing unpaired Student's *t*-test with $p < 0.05$ threshold for statistical significance.

Physical environment and equipment

The simulation was performed in a surgical skills laboratory. The room was set up with an Olympus Evis Exera CV 160 endoscopic tower, abdominal model with colonoscopy enteroscopy simulator, and patient bed. The tower was placed on the left side of the abdominal model, misaligned relative to the conventional placement at the head of the bed. An endoscopic drape was placed over the abdominal model to mimic a real patient environment. A water cup was available to check insufflation. Gloves and lubricant were also provided. The simulation room had video recorders to capture all trials of each subject. A mobile partition was used to separate the subjects from the proctor and prevent subjects' from being disturbed during the simulation.

Performance evaluation

The study subjects were observed during a real-time exercise by a proctor, to determine whether they were able to complete the troubleshooting tasks in the allotted time and reset the simulation parameters as needed. An independent third party, whom was blinded to the demographics and group of the individual subjects, performed the evaluation from video recordings, post-simulation.

Troubleshooting skills were assessed based on if the subject performed tasks on the preoperative checklist before starting the colonoscopy and on the troubleshooting guide after problems were detected. Each item on the task-specific checklist was time stamped relative to starting time. The average time it took to finish each task for each group per trial is reported (Tables 2, 3).

Fig. 1 Surgical safety and troubleshooting checklist

Surgical Safety Checklist for Endoscopy

Patient position	□ Patient positioned correctly
Power sources	□ Connected and linked to all devices
	□ Turned on
Light	□ Turned on (ignition)
Insufflation	□ Confirm insufflation
Suction	□ Confirm suction
Lens Cleaner	□ Trial lens cleaner
Video	□ Check lens clarity
Endoscope	□ Size and type preference

Troubleshooting Checklist for Endoscopy

Insufflation	□ Turned on
	□ Inspect cap
	□ Inspect tubing
Suction	□ Turned on
	□ Inspect and secure suction and wall source connector
	□ Inspect tubing
	□ Check scope cap
	□ Vacuum regulator set to -200 mmHg
Light source	□ Turned on (ignition)
	□ Check connection
	□ Confirm filter is off
	□ Ensure brightness is turned up to maximum
Lens Cleaner	□ Check water volume
	□ Inspect tubing
	□ Inspect scope button
Endoscope	□ Turned on
	□ Inspect power cord
	□ Inspect power button
	□ Check connection
Video monitor	□ Ensure Y/C is selected
	□ Check video umbilical connection
	□ Brightness set to 30
	□ Chroma set to 32
	□ Phase set to 32
	□ Contrast set to 52
Video quality	□ Image source set to scope
	□ RBC are zeroed

Table 2 First trial results

Malfunction	Control (s)	Experimental (s)	*p* value
Preoperative equipment check	27 ± 58	44 ± 72	0.57
Loose endoscope connection	16 ± 32	21 ± 49	0.81
Loose light source connection	20 ± 48	53 ± 61	0.19
Incorrect light source setting	0	14 ± 30	0.18
Incorrect video monitor setting	0	0	1.00

Data are presented as mean ± standard deviation

Table 3 Second trial results

Malfunction	Control (s)	Experimental (s)	p value
Preoperative equipment check	5 ± 15	142 ± 17	<0.0001
Loose endoscope connection	30 ± 61	156 ± 35	<0.0001
Loose light source connection	64 ± 82	134 ± 71	0.058
Incorrect light source setting	4 ± 11	119 ± 66	0.0003
Incorrect video monitor setting	10 ± 30	149 ± 53	<0.0001
Loose insufflation connection	0	85 ± 76	0.00063

Data are presented as mean ± standard deviation

Results

Average scores were compared for 5 tasks in the first trial and 6 tasks in the second trial. The first trial yielded no significant differences between the control and experimental groups in any of the given tasks ($p > 0.05$ for all tasks) (Table 2). During the second trial, there was a significant improvement in the experimental group in 5 out of 6 tasks (Table 3). These tasks included checking the equipment preoperatively ($p < 0.0001$), tightening the loosened endoscope ($p < 0.0001$) and insufflation connection ($p = 0.00063$), and using the correct light source ($p = 0.0003$) and video monitor setting ($p < 0.0001$). There was no statistical difference between the two groups in tightening the light source connection ($p = 0.058$). The experimental group improved in all tasks after being given the tutorial and checklist, which suggests that these tools may improve endoscopic troubleshooting capabilities. There was no consistent evidence that the control group improved after the second trial.

Discussion

Currently there is no set curriculum for teaching endoscopic troubleshooting. Problems are dealt with as they arise, putting patient safety at risk. As we hypothesized, surgical residents are not proficient in troubleshooting endoscopic equipment failures, but after provided with a short tutorial, their performance substantially improved. Being given a second trial to attempt to troubleshoot the simulation's problems without the tutorial, did not improve outcomes. Our study has shown that introducing a preoperative checklist and troubleshooting guide is a quick and effective way to teach surgical residents the basics of endoscopic troubleshooting, so they will have a foundation if problems arise in the future.

Many of the residents in our study were not experienced in performing endoscopies, which could have been an underlying reason why many of them were not competent in endoscopic troubleshooting. However, residents who had performed numerous endoscopies did not show a significant difference in their troubleshooting capabilities. This skill could be lacking because endoscopic troubleshooting is not taught routinely, unless an issue occurs during the residents' training.

We did not test experts in endoscopy on their troubleshooting capabilities to see whether experience in the field is enough to build up this skill, due to the lack of available physicians. If experts were able to perform better or equal to residents' who had gone through our tutorial, it may prove that mastering endoscopy alone is enough to allow surgeons to be proficient in endoscopic troubleshooting. However, mastering endoscopy is a lengthy process and if a short tutorial can get residents to the same skill level in troubleshooting as experts, it is a worthwhile educational tool to consider incorporating into residents' training.

The checklist and guide used in this study were novel and were created using the Olympus Evis Exera CV 160. Although there are some aspects of the checklist that are specific to this particular scope and tower model, the overall troubleshooting concepts for this checklist are universal.

In future research, the subject pool will repeat the endoscopic troubleshooting simulation to observe longitudinal effects on performance. If they are able to complete the simulation successfully, we will have proven the troubleshooting tutorial is effective for long-term purposes and is a valuable asset to surgical resident training.

Compliance with ethical standards

Disclosures Jenny Lam, B.S., Kevin Grimes, M.D., Adnan Mohsin, B.S., and Shawn Tsuda, M.D., F.A.C.S. have no conflicts of interest or financial ties to disclose.

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