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An endoscopic training and assessment model for argon plasma coagulation

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ABSTRACT

Purpose: Argon plasma coagulation (APC) is a standard modality for the treatment of gastrointestinal bleeding. However, there are no metrics to assess technical proficiency. We aimed to determine if a Quick APC Training Test (QAPCTT) can improve performance and assess proficiency with this modality.

Materials and methods: Endoscopy trainees at various levels of training were asked to perform the QAPCTT with an *in vivo* model before and after an APC curriculum with didactic lectures and additional hands-on experience. As trainees performed the test, endoscopic supervisors recorded the time required to complete each task as well as the number of inadvertent mucosal touchdowns. Each partipant was assigned a technical proficiency score by supervising endoscopists.

Results: Fourteen adult gastroenterology fellows participated in the course. 100% of fellows were comfortable with generator settings and APC equipment after the course compared to only 21% ($p < 0.001$) on the pre-test questionnaire. Those deemed technically proficient on the post-course QAPCTT required significantly less time for the task of making a square (100 s *vs.* 215 s; $p = 0.006$) and had significantly fewer inadvertent mucosal touchdowns (5 *vs.* 19; $p = 0.0017$).

Conclusions: Dedicated APC training is required to achieve competence with this modality. A structured curriculum improves knowledge about the technique and hands-on training is important for achieving technical proficiency. The QAPCTT appears improve APC technique and may readily identify trainees in need of additional APC experience to gain proficiency.

1. Introduction

Gastrointestinal (GI) bleeding is one of the leading indications for endoscopy [1]. Argon plasma coagulation (APC) is a widely used modality for the treatment of GI bleeding due to its contact-free method with reliable depth of effect [2,3]. APC is considered a standard technique in the armamentarium of gastrointestinal endoscopy and is commonly used for the treatment of vascular lesions such as arteriovenous malformations (AVMs), gastric antral vascular ectasia (GAVE), and radiation proctitis [4]. In addition, APC is used for ablation of residual neoplastic tissue after polypectomy and tumor debulking. This method allows energy to be transmitted from the electrode to the tissue through ionized argon gas plasma. Fellows in a gastroenterology training program are expected to become proficient with APC. While there are guidelines for minimum numbers of endoscopic procedures that must be performed prior to assessing for technical proficiency, no such guidelines exist for training in APC [5].

Competency with APC not only includes technical proficiency but knowledge of the method, devices, and management of electrosurgical generator settings. Currently, most trainees learn how to use APC through case repetition under direct supervision of a trained endoscopist [6]. Case variation can impact the amount learned from each case and this method is limited by the inconsistent use of the technique by the multiple trainers. Furthermore, the quality of the endoscopic training may be impacted by the stability of the patient in that situation. APC is often performed in an urgent setting for treatment of GI bleeding [7]. The instability of the patient often requires the attending endoscopist to intervene sooner, even if the trainee has been performing well [7]. Although an endoscopist can be technically proficient in a certain procedure, he or she might have difficulty passing on that knowledge. In addition, learning *via* case repetition may improve technical proficiency, but does not ensure competency with indications

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for the procedure and an understanding and management of generator settings.

Simulation training has been demonstrated to improve technical proficiency with other endoscopy techniques. However, there have not been studies that investigate APC training with simulation models or other teaching methods. The primary objective of this study was to determine if a training program in an *in vivo* animal model can improve knowledge and performance of APC. In addition, we aimed to identify metrics that would be predictive of an individual's ability to independently perform APC.

2. Materials and methods

Adult gastroenterology fellows of varying stages of training were enrolled in a one-day training course that included didactic lectures and hands-on APC training in anesthetized pigs. The course was conducted in a mid-year cycle such that fellows in their earliest stage of training had at least 6 months of exposure to endoscopy. Fellows were asked to complete a short survey before and after the course. The survey contained questions regarding the fellow's stage of training, comfort level with APC, number of human cases performed with APC, and their comfort level with electrosurgical generator settings. Individuals were asked to self-report comfort levels based on a scale of 1-5. A self-reported score of 1 indicates that the trainee feels that he or she is capable of independently performing the task without supervision, whereas a score of 5 indicates that the individual is not confident and would rely on a supervising attending physician to perform the task.

A hands-on pre- and post- test was performed, consisting of three separate technical challenges with targeted APC with an *in vivo* pig stomach. As each trainee performed the Quick APC Training Test (QAPCTT), the amount of time needed to complete each task as well as the total number of inadvertent touchdowns, when APC was applied with the probe physically touching mucosa, was recorded. Two separate expert endoscopists independently graded each fellow based on multiple variables including the quality of the APC and the time required to complete each task. Fellows were assigned a score from 1 to 5 (Table 1). A score of 1 indicates the ability to perform APC without supervision and a score of 5 corresponds to inability to perform the majority of the APC procedure and the need for significant additional hands-on experience.

Following the pre-test, a didactic lecture reviewed indications for APC, equipment for the procedure including the types of probes, electrosurgical generator settings, and the technical aspects of the procedure (Supplementary Table). Fellows had an opportunity to perform additional APC as needed. Fellows were then asked to perform a post-test with the same three technical challenges with targeted APC. However, on the post-test, the expert endoscopists were able to provide real-time feedback to the trainee during each task. Two expert endoscopists again independently graded each fellow using the same scale. Immediately following the training session, fellows completed a post-test survey. The pre-test and post-test surveys along with expert evaluations were then analyzed.

Table 1
APC Scoring System.

Score	Narrative Explanation
1	Exemplary, ready for unsupervised practice
2	Satisfactory, does not require hands-on assistance
3	Requires minimal hands-on assistance to complete tasks
4	Requires some hands-on assistance to complete tasks
5	Unable to complete, requires hands-on assistance to complete majority of the tasks

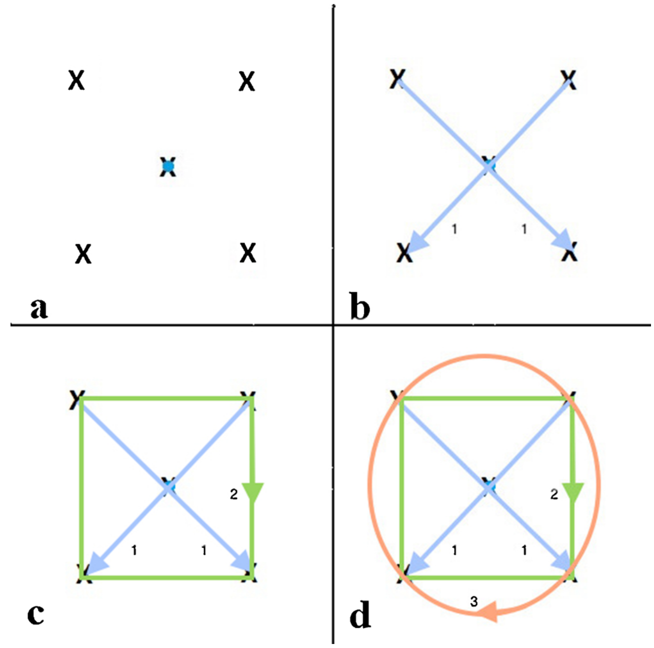

Fig. 1. The Quick APC Training Test is created with five biopsies to create a square with a center mark. For the first test, participants are asked to focally coagulate the center mark (a) followed by an "X" (b). The second test involves creating a square (c). The final test is to create a circle around the square (d).

2.1. Equipment

A GIF-H140 T upper endoscope (Olympus USA, Center Valley, PA, USA) was used for all cases. An ERBE VIO 300 D electrosurgical generator (ERBE USA, Marietta, GA, USA) was used with the following settings: Pulsed APC, 1.2 liters per minute flow, 30 W, Effect 2. A 6.9 French straight fire flexible APC probe (ERBE USA) was used.

2.2. The Quick APC Training Test (QAPCTT)

To create the targeted APC challenges, four endoscopic biopsies were performed by the trainers to create the points of a square, approximately 1.5 cm in length. A fifth biopsy was performed in the center of the square. ***Test 1:*** Fellows were asked to use APC to first coagulate the center dot and then subsequently coagulate an "X" starting at the corners of the square through the center dot using APC. ***Test 2:*** Fellows were asked to perform APC to create a square using the 4 biopsy points as corners. ***Test 3:*** Fellows were asked to use APC to create a circle around the square, making sure that the circle encompassed the four corners of the square (Fig. 1; Video 1 in Supplementary material). Each test was timed independently. As APC is a non-contact modality, the total number of energy activations while in contact with the mucosa (*i.e.* "touchdowns") was recorded. The total number of touchdowns for all three tests was recorded.

2.3. Statistical methods

Data was analyzed using Stata IC version 13.1 (StataCorp, College Station, Texas). Medians and interquartile ranges were determined and recorded. Trainees were analyzed in groups using the following parameters: 1) 10 or less APC procedures performed in humans *vs.* more than 10 prior procedures 2) First year of training *vs.* upper level of training 3) Deemed able to independently perform APC *vs.* requires additional procedures for technical proficiency as determined by the average expert post-test score.

Each grouping was analyzed separately using the Wilcoxon rank-sum test. Individual trainee improvement was analyzed by using each

Table 2
Analysis of subgroups grouped by prior APC procedure experience on the pre-test evaluation.

Variable	10 or less APC procedures performed Median (IQR)	Over 10 APC procedures performed Median (IQR)	P Value
Number of Fellows	8	6	
Comfort	2 (2–3)	2 (2–3)	0.4890
Settings	3 (2–3)	3 (3–3)	0.3311
Draw X (seconds)	185.5 (104.5–222.5)	132.5 (80–145)	0.5186
Draw Square (seconds)	152 (109–182)	112 (105–182)	0.6985
Draw Circle (seconds)	160 (104.5–187)	170 (108–244)	1.0000
Touchdowns	14 (9–21) *[observed 6]*	14 (6–24) *[observed 5]*	0.8551
Expert mean	3 (2.75–3.5)	2.5 (2.5–3)	0.3209

fellow's change in time between the baseline evaluation and the post-course evaluation using the Wilcoxon signed-rank test. Results were considered statistically significant if $p < 0.05$.

2.4. Ethical issues

The training lab was approved by the University of Pennsylvania Institutional Animal Care and Use Committee (IACUC) (protocol number 804333) and approved by the university IRB (protocol number 820691). The study was carried out in accordance with the Animal Research: Reporting of In Vin vivo Experiements (ARRIVE) guidelines.

3. Results

Overall, 14 adult gastroenterology fellows took part in this APC training program. There were 5 first-year GI fellows, 4 second-year, 4 third-year and 1 fourth-year general GI fellow. All fellows completed the course and evaluations. Of the 14 fellows, only 11 had their cumulative total number of touchdowns recorded. Only 3 of 14 fellows (21%) stated they were comfortable in understanding the generator settings on the pre-test *vs.* 100% on the post-test ($p < 0.001$).

3.1. Prior experience analysis

Eight fellows had performed 10 or fewer prior APC procedures while 6 fellows had performed over 10 APC cases (Table 2). Fellows who performed 10 or less prior APC procedures in the past required more time to perform the tasks of drawing an X and square. However, all data points were statistically insignificant.

3.2. Level of training analysis

Of the 14 fellows analyzed, 5 were in their first year of endoscopic training and 9 were in their upper year (Table 3). No statistical differences were noted between the two groups in drawing an X, square or circle. Expert interpretation of the fellows' pre-test skills was significantly different with the upper year fellows receiving a median score of 1 point better than the first-year fellows (2.5 [2.5–3] *vs.* 3.5 [3,4]; $p = 0.0139$). There were no other differences between the two groups with regard to comfort with the technical aspects of APC, adjusting electrosurgical generator settings, and median number of mucosal touchdowns.

3.3. Individual progress

Comparison between an individual's pre-test and post-test evaluation was analyzed (Table 4). On average, comfort level significantly improved from pre-test to post-test with an average improvement of 0.5 (range [0.5–0.5]; $p = 0.0082$), although there were no statistical differences in the time required to perform each task or the number of inadvertent mucosal touchdowns. The average time required to draw an X or a square actually increased on the post-test compared to the pre-test.

Table 3
Analysis of performance on the pre-test evaluation of fellows grouped by year of training.

Variable	First Year Median (IQR)	Upper Year Median (IQR)	P Value
Number of Fellows	5	9	
Comfort	3 (3–3)	2 (2–2)	0.0740
Settings	3 (3–3)	3 (3–3)	0.6157
Draw X (seconds)	161 (120–215)	139 (80–210)	0.4634
Draw Square (seconds)	178 (172–213)	111 (107–132)	0.2053
Draw Circle (seconds)	158 (145–262)	162 (136–190)	0.5485
Touchdowns	16 (8–63) *[observed 3]*	13 (7.5–22.5) *[observed 8]*	0.5403
Expert Mean	**3.5 (3–4)**	**2.5 (2.5–3)**	**0.0139**

Table 4
Comparison of average improvement of fellows between baseline and post course evaluations.

Variable	Within-Subject Median (IQR)	P Value
Comfort Level	0.5 (0.5–0.5)	0.0082
Draw X (seconds)	4.5 (−59–68)	0.3626
Draw Square (seconds)	7 (−14–83)	0.9311
Draw Circle (seconds)	−4 (−44–67)	0.9000
Touchdowns *[11 observed]*	−2 (−11–8)	0.5631

3.4. Technical proficiency

A comparison was made between fellows deemed technically proficient to independently perform APC procedures *versus* fellows in need of additional training as scored by the observing expert endoscopist (Table 5). Those deemed technically proficient with APC received a mean expert score of 2 or better on the hands-on post-test. There were significant differences in post-test scores of fellows that experts deemed capable of performing independent APC procedures *versus* those who needed additional experience with respect to the median time to draw a square (100 s [IQR 97–161] *vs.* 215 s [IQR 169–283]; $p = 0.006$) and overall number of touchdowns (5 [IQR 3–13] *vs.* 19 [18–25]; $p = 0.0017$) There were no other observed differences between the groups. Those deemed unable to perform the test on their own did improve on the time required to draw an X, but did not improve on the time required to draw a square or circle; however, these differences were not statistically significant.

Table 5
Comparison of fellows deemed by experts capable of independently performing APC *versus* those not capable of performing independent APC.

Variable	Can perform test on own Median (IQR)	Cannot perform test on own Median (IQR)	P Value
Number of Fellows	7	7	
Post course hands-on test			
Draw x (seconds)	114 (107–163)	184 (130–236)	0.0842
Draw Square (seconds)	**100 (97–161)**	**215 (169–283)**	**0.0060**
Draw Circle (seconds)	148 (137–200)	225 (145–262)	0.2008
Touchdowns	**5 (3–13)**	**19 (18–25)**	**0.0017**
Difference between hands-on post-test and pre-test			
Draw X (seconds)	38 (−42–74)	−24 (−70–68)	0.4062
Draw Square (seconds)	−4 (−14–27)	70 (−59–99)	0.7012
Draw Circle (seconds)	−35 (−50–38)	0 (−28–106)	0.4062
Touchdowns	−4 (−7 to −1) *[observed 5]*	0.5 (−17–12) *[observed 6]*	0.7150

The bold values indicate statistically significant results (i.e. those with a P value < 0.05).

Table 6
Comparison between mean comfort level of fellow and mean expert analysis of fellows.

Point of Test	Comfort Median (IQR)	Expert Median (IQR)	P value
Before	**2 (2–3)**	**3 (2.5–3.5)**	**0.005**
After	**2 (1–2)**	**2.25 (2–2.5)**	**0.005**
Difference/change	−0.5 (−1–0)	−0.5 (−1–0)	0.655

The bold values indicate statistically significant results (i.e. those with a P value < 0.05).

3.5. Comfort level

Self-perception of ability to perform APC differed significantly from the expert's score. On the pre-test evaluation, the average fellow stated that he/she could perform APC with minimal supervision whereas the experts scored the average fellow as needing some attending assistance to perform APC (2 [2,3] *vs.* 3 [2.5–3.5]; p = 0.005) (Table 6).

The differences in fellows' self-perception and the attending scores on the post-test scores persisted (2 [1,2] *vs.* 2.25 [2–2.5]; p = 0.005). All fellows reported that the course would significantly help with future APC procedures.

4. Discussion

The optimal methods for teaching endoscopic techniques continue to evolve. Typically, fellows learn through observation and case repetition. Recently there have been several studies demonstrating the positive impact of simulation training to supplement a fellow's endoscopic education. An international study published in 2005 used a specific organ preparation machine that simulates upper GI bleeding called the Erlanger Active Simulator for Interventional Endoscopy (EASIE) [7]. On this simulator, fellows were taught and tested on various skills that control GI bleeding [7]. This one-day course showed significant improvements in all endoscopic techniques and these results were reproduced in two separate studies in France and the United States [6,8]. Also in 2013, The Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) developed a new program called the Fundamentals of Endoscopic Surgery (FES) [9,10]. This program entails comprehensive web didactic lessons, written exams and five module skills exam on a virtual reality simulator (GI Mentor II) and demonstrated a significant positive impact on the learning of surgery residents and gastroenterology fellows [10]. With increased emphasis on competency assessment, the FES provides a standardized test for assessing and documenting one's endoscopic knowledge and skillset.

Although these studies have shown promise in general endoscopic procedures, there have not been any studies investigating specific training in APC. Furthermore, in most endoscopic training programs, APC is not taught in a structured format, nor are skills regularly assessed for technical proficiency. APC requires an *in vivo* model to provide the most realistic scenario as certain variables such as the estimation of the tissue effect based on the distance of the probe from the mucosa and the coagulation effect based on generator settings cannot be easily replicated using computer simulation.

Our training program was intended to supplement the traditional model of observation and case repetition. The variable frequency of the need for APC during endoscopic cases as well as the amount of hands-on time leads to considerable variation for trainee exposure to this technique. This course allows for discussion and refinement of technical aspects, including probe location from the desired targeted tissue, duration of energy activation, recognition of adequate tissue effect and avoidance of carbonization (charring), and performance of dynamic (rather than static) APC in a controlled environment.

Competence not only involves technical precision with the APC probe, but also knowledge of the indications for APC, risks of the procedure, and demonstrable knowledge of the equipment and generator settings. Most fellows were knowledgeable of the indications, contraindications, and adverse events associated with the procedure. Many of the fellows, however, were not familiar with how to minimize the risk of adverse events including how to avoid inadvertent submucosal delivery of argon gas, need for intermittent removal of the probe for adequate decompression to reduce the risk of post-procedural pain and perforation, and avoidance of APC when the bowel has not been sufficiently cleansed. In addition, many were not confident in the management of the electrosurgical generator settings. Most rated themselves as somewhat comfortable, meaning they have an idea about the settings, but defer to the attending during live cases. When comparing pre-test comfort level to post-test comfort level, 21% of fellows stated they were comfortable with the generator settings on the pre-test *vs.* 100% on the post-test (3 of 14 fellows *vs.* 14 of 14 fellows; p < 0.0001). Trainees specifically commented on the fact that they have a better understanding of the concept of continuous *versus* pulsed energy delivery and how adjusting these settings results in various tissue effects. Increased comfort level with APC probes and generator settings may impact on future APC performance. Furthermore, standardized training and evaluation of competency may reduce the risk of adverse events associated with APC including bowel gas explosion, perforation, or pain from transmural thermal injury.

Interestingly, when comparing groups based on the year of training or number of prior APC procedures performed, there was no statistical difference in the time required to complete the test nor in the amount of total mucosal touchdowns. However, the expert assessment score was more favorable for upper year fellows (2.5 [2.5–3] *vs.* 3.5 [3,4]; p = 0.0139), which may reflect components of endoscopy and APC technique that were not objectively measured, such as fine tip control or the ability to respond to instruction on the post-test challenge.

When comparing those who were deemed independently able to perform the APC challenge by the experts (a mean expert score of 2 or less) with those who could not, there was a significant difference between the task of drawing a square and the total number of touchdowns. Those who were scored as being able to perform APC on their own completed the challenge in a median of 100 s *vs*. 215 s for those deemed unable to perform independent APC. The challenge of drawing a square appears to be the correct degree of difficulty for discerning those with proper tip control *versus* those who required additional experience as the task of drawing an "X" appears to be too simple and the task of drawing a circle appears too difficult to achieve separation amongst these groups. Similarly, those scored as being able to independently perform APC had 14 less mucosal touchdowns throughout the 3 separate challenges (5 [3–13] *vs*. 19 [18–25]; $p = 0.0017$). The reduction of touchdowns reflects a better ability for fine tip control, appropriate estimation of the distance between the probe and the mucosa, and when to appropriately deliver thermal energy.

Individual comfort level improved significantly with this course. 64% of fellows could perform APC without support from the attending before the course *vs*. 93% afterwards. However, there was a significant difference between the fellow's perception of their performance and expert's perception, with the fellows rating themselves to be better than the attending score. This finding is concerning, and underscores the fact that there needs to be ongoing objective measurement of APC performance and continued guidance on the part of supervising endoscopists to provide feedback.

4.1. Limitations of the study

There were several limitations to our study. Our sample size was small and may be insufficient to fully evaluate multiple variables. Another limitation is the experts were not blinded to the fellow performing the test and were allowed to coach each fellow on the post-test, thereby potentially resulting in bias of the scores. Future studies can involve blinding experts observing procedures from a de-identified monitor or to record videos that can then be de-identified and reviewed. Another limitation is that we do not know the practical application for this course since our results are based on an immediate post-test and not future APC procedures. A test of generator settings and knowledge of indications can also be administered before and after this type of course to determine if traditional education techniques adequately address these topics and validate if this course objectively improves knowledge of these topics.

5. Conclusions

Training in endoscopic procedures for hemostasis is evolving. This study highlights the need for dedicated APC training and skill assessment, which is not routinely offered in most endoscopic training programs. Knowledge of electrosurgical generator settings, APC equipment, and various tissue effects is critical for safe and effective performance of APC. If available, *in vivo* training may enhance traditional training methods. The task of drawing a square and the number of inadvertent mucosal touchdowns may readily identify trainees in need of additional APC experience to gain proficiency. Trainees who participated in this program reported improved confidence with APC equipment, generator settings, and technical proficiency. The added knowledge and confidence along with the hands-on experience may possibly improve future performance or accelerate the learning curve for APC procedures.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.advms.2018.08.012.

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Conflict of interests and financial disclosure

Dr. Vinay Chandrasekhara received consulting royalties from Boston Scientific and has an equity interest in Nevakar Corporation.

Dr. Michael L. Kochman received consulting royalties from Boston Scientific and Dark Canyon labs and holds an equity interest in Merck.

Drs Daniel Rhoades, Pavlos Z. Kaimakliotis, and Sun-Chuan Dai have no conflicts of interest or financial ties to disclose.

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Study Design: Vinay Chandrasekhara, Michael L. Kochman

Data Collection: Vinay Chandrasekhara, Pavlos Z. Kaimakliotis, Daniel Rhoades, Michael L. Kochman

Statistical Analysis: Vinay Chandrasekhara, Daniel Rhoades

Data Interpretation: Vinay Chandrasekhara, Daniel Rhoades, Michael L. Kochman

Manuscript Preparation: Vinay Chandrasekhara, Daniel Rhoades, Pavlos Z. Kaimakliotis, Sun-Chuan Dai, Michael L. Kochman

Literature Search: Vinay Chandrasekhara, Michael L. Kochman

Funds Collection: Michael L. Kochman

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