Verification of Proficiency in Basic Skills for PGY-1 Surgical Residents: 10-Year Update

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OBJECTIVE: The American College of Surgeons and the Association of Program Directors in Surgery developed a curriculum in 2001 that involved instructional modules for 11 basic surgical skills and a standardized Verification of Proficiency (VOP) evaluation instrument. Our institution continues to employ a modified version of this curriculum and the purpose of this study was to provide a 10-year update on our VOP evaluation instrument used to assess postgraduate year 1 (PGY-1) residents on surgical skills.

DESIGN: All PGY-1 surgical residents over the past 10 years at our institution have completed the American College of Surgeons/the Association of Program Directors in Surgery-adapted basic surgical skills curriculum and VOP assessment. Retrospective analysis of VOP data for all residents was subjected to statistical analysis for internal validity and level of correlation.

SETTING: Department of Surgery at Southern Illinois University School of Medicine located in Springfield, Illinois.

PARTICIPANTS: All PGY-1 surgical residents (*per year:* 4 general surgery, 3 orthopedic surgery, 2 plastic surgery, 2 urology, 2 ENT, 1 vascular surgery, and 1 neurosurgery) over the past 10 years.

RESULTS: One hundred and thirty five residents underwent VOP evaluation over 10 years; 92 (68%) failed at least 1 module and 40 (30%) failed at least 2 modules. Residents who failed to demonstrate proficiency were mandated to complete remediation and retested until their scores were considered proficient. Performance on checklist items showed moderate internal consistency ($\alpha \geq 0.50$) on 9 of 11 modules. Poor internal consistency ($\alpha < 0.30$) was noted for overall proficiency across all modules. Combined performance on checklist items and economy of time and motion demonstrated significant positive correlation ($p < 0.05$) with overall proficiency in every module.

CONCLUSIONS: The VOP instrument offers an internally valid means of assessing distinct basic skills of PGY-1 residents at basic surgical skills. The instrument provides critical formative and summative feedback on surgical skill performance to trainees. (J Surg Ed 76: e217−e224. Published by Elsevier Inc. on behalf of Association of Program Directors in Surgery.)

KEY WORDS: Postgraduate education, Technical skills, Assessment and performance, Surgical skills curriculum

COMPETENCIES: Practice-Based Learning and Improvement, Medical Knowledge

INTRODUCTION

Technical skills are an essential component in the overall competence of a surgeon.[1,2] Proficiency-based training involves skill development and testing until a trainee is able to demonstrate a predetermined level of ability. The introduction of proficiency-based training to surgical training has been shown to improve patient safety in the operating room and to decrease skill decay over time.[3-5] In 2001, recognizing the need for formal training and assessment of fundamental technical skills, the American College of Surgeons (ACS) and the Association of Program Directors in Surgery (APDS) developed a Phase I curriculum that involved instructional modules for basic surgical skills with a standardized Verification of

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TABLE 1. Southern Illinois University School of Medicine, Basic Surgical Skills Verification of Proficiency Modules

Basic Surgical Skill
Knot tying *(5 modules)*
Surface 1-handed knot tying
Surface 2-handed knot tying
Deep 1-handed knot tying
Deep 2-handed knot tying
Instrument tying
Basic suturing *(3 modules)*
Simple interrupted skin closure
Vertical mattress skin closure
Subcuticular skin closure
Central venous access
Chest tube insertion
Emergency surgical airway

Proficiency (VOP) evaluation instrument. The modules include objectives for performance, guidelines for practice, and instructions for VOP testing. In 2005, the Department of Surgery at Southern Illinois University (SIU) adapted and implemented Phase I of the ACS/APDS curriculum for postgraduate year 1 (PGY-1) residents and developed specific VOP modules for various basic surgical tasks (Table 1). The SIU VOP evaluation instruments contain a checklist of specific performance items and a global rating of overall performance with space for narrative comments (Fig. 1). The specific checklist items are able to provide formative, precise feedback to trainees on areas for improvement while the global rating is used to determine overall proficiency or the need for remediation.

As residency programs transition to competency-based models, trainee advancement is no longer purely a function of time served. This time-variable model of educating surgical residents necessitates a rigorous, reliable, and regular means of assessing proficiency in surgical skills to inform promotion decisions.[6] The VOP evaluation instrument has been used by the Department of Surgery at SIU for over a decade to assess first-year surgical residents as they complete the basic surgical skills curriculum adapted from the ACS/APDS. In 2010, Sanfey et al. published a report on data over a 2-year period describing the reliability of the VOP.[7] This helped identify the significant VOP items that were most predictive of overall proficiency in a given skill, however, with the continued use of the curriculum and VOP instrument, it is prudent to reassess the measurement tool that continues to determine proficiency of our surgical trainees.

This is the first study to explore VOP data that span an entire decade. The SIU Department of Surgery is in a unique position to possess such data, because it is the site where Sanfey et al. piloted and first collected data using the VOP instruments. The 2-year pilot in that initial report represented the first 2 cohorts of our 10-year sample. We analyze the 10-year data as a whole and contrast it with the findings from Sanfey et al. for 2 primary reasons: first, to determine whether the initial findings hold over time, and second, because local context has changed. Most notably, during the pilot analysis by Sanfey et al. the VOP instruments were new to faculty, staff, and residents alike. Today, VOP instruments are familiar to faculty and staff and they have become an accepted and routine tool in resident assessment at SIU.

Skin Suturing Steps			Comments
Runs the suture, placing appropriate bites into dermal layer	Y	N	
Enters the dermal layer directly across from exit site	Y	N	
Avoids penetration of the epidermis	Y	N	
Avoids multiple forcep grasps of skin	Y	N	
Instrument ties with square knots	Y	N	
Approximates skin with appropriate tension	Y	N	

	1	3	5
Economy of Time and Motion	Many unnecessary / disorganized movements	Organized time / motion, some unnecessary movement	Maximum economy of movement and efficiency

Final Rating	Other Summative Comments:
○ Demonstrates proficiency ○ Requires further practice	Evaluator

FIGURE 1. Example of one of the VOP evaluation forms in use at SIU. This form is specific for Subcuticular Skin Closure. All forms have a skill-specific checklist of steps and a global rating for Economy of Time and Motion and an overall proficiency rating.

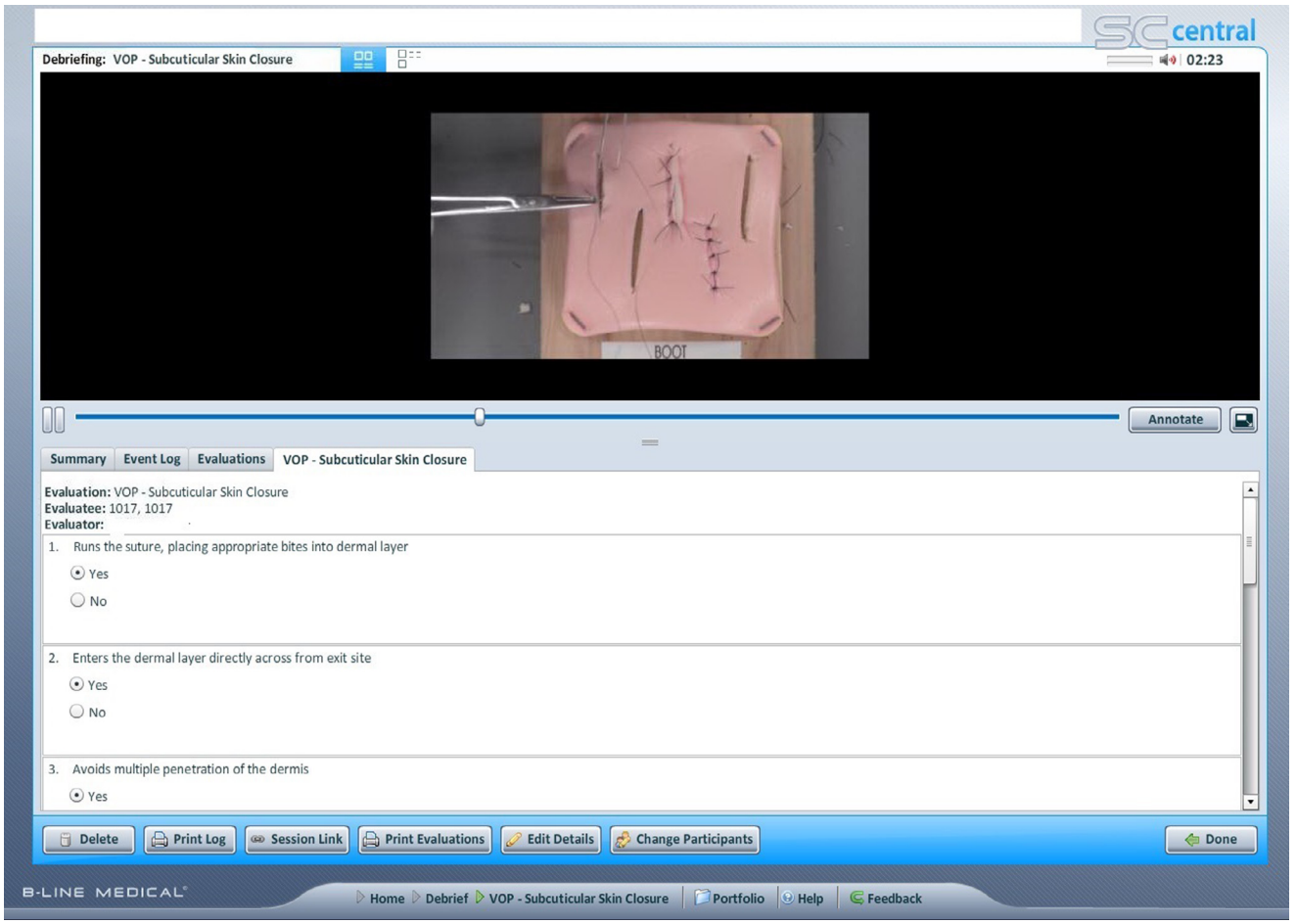

FIGURE 2. B-Line secure portal as viewed by attending surgeons, which allows for simultaneous viewing of the recorded video and scoring of the resident on the VOP evaluation form items.

This basic skills curriculum based on the ACS/APDS structure is still in use today at our institution and is one component of our Surgery Boot Camp. All 15 first-year surgical residents are required to complete the curriculum and demonstrate proficiency in 11 basic surgical skills (Table 1). All surgical skills are taught via modules as described above and residents are encouraged to practice these skills in the lab until they are comfortable with their level of performance. They are then video recorded performing the skill and the recording is de-identified and uploaded to a secure portal (B-Line Medical, Washington, DC) for attending surgeons to view and assess. The attendings are able to watch the video on the secure portal from a remote location at a time of their choosing and assess the resident on the VOP evaluation instrument items (Fig. 2); attendings are blinded to the identity and surgical subspecialty of the resident. All residents are required to demonstrate proficiency in all 11 skills before progressing on to the second year of training. No trainee is prevented from participation in the operating room based on failing a surgical skill, but they are required to remediate a surgical skill VOP module until proficiency is demonstrated.

The purpose of this study was to investigate the existing methods of assessing basic surgical skill at our institution and to provide a data-driven multiyear update on the utility of the VOP evaluation instrument currently used to assess first-year surgical residents.

MATERIALS AND METHODS

All PGY-1 surgical residents at SIU (*per year:* 4 general surgery, 3 orthopedic surgery, 2 plastic surgery, 2 urology, 2 otolaryngology, 1 vascular surgery, and 1 neurosurgery) over the past 10 years have completed the basic surgical skills curriculum and been assessed on those skills using the VOP evaluation instrument. Residents are required to review a relevant module of the ACS/APDS curriculum prior to attending skill sessions. Residents are encouraged to practice a basic surgical skill in the skills lab and then when they are comfortable with their level of

TABLE 2. First-Time Pass and Failure Rates (Overall Proficiency) in 2008 and 2009 as Compared to the Past 10 Years

VOP Module	Pass Rate 2008 (%)	Pass Rate 2009 (%)	Pass Rate 2008-2017 (%)
Chest tube placement	100	100	96
Central line	75	73	83
Emergency surgical airway	83	73	90
Surface 1-handed knot	66	100	75
Surface 2-handed knot	75	100	88
Deep 1-handed knot	58	91	80
Deep 2-handed knot	66	100	90
Instrument tie	92	91	92
Subcuticular	92	100	89
Vertical mattress	100	91	94
Simple interrupted	83	91	98
	Failure rate 2008 (%)	Failure rate 2009 (%)	Failure rate 2008-2017 (%)
Percentage of residents who failed ≥1 VOP	83	45	68
Percentage of residents who failed ≥2 VOPs	75	18	30

performance, they are video recorded. De-identified videos are assessed by attending-level surgeons and scored using the VOP evaluation instruments. VOP data for all residents is routinely collected for the 11 basic surgical skills every year and is available to faculty in the Departments of Surgery and Medical Education. The data was de-identified and statistical analysis included descriptive measures for all the outcomes, grouping variables that will include medians to help identify potential outliers, and internal consistency and correlation as measured by Cronbach's alpha testing and Pearson's correlation coefficient, respectively. Internal consistency is a measure of co-variation within a sample (i.e., a measure of the extent to which all items or scores are measuring the same variable or skill). All reported p values are 2-sided and values of $p < 0.05$ were considered statistically significant. SPSS (Version 20; Chicago, IL) was used to analyze the data. All data analysis was completed at Southern Illinois University School of Medicine. Institutional Review Board exemption was obtained from Springfield Committee for Research Involving Human Subjects.

RESULTS

One hundred and thirty five residents underwent VOP evaluation over 10 years; 92 (68%) failed at least 1 module and 40 (30%) failed at least 2 modules (Table 2). Residents who failed to demonstrate proficiency were mandated to complete remediation under the guidance of a surgical skills coach and retested until their scores were considered proficient; our analysis examines performance on first attempts only. VOP evaluation forms for each module are skill-specific and contain a variable number of checklist items that represent key skill steps; these checklist items are scored as a yes (completed correctly) or no (completely incorrectly). There is also a global rating for economy of time and motion on a scale of 1 to 5 as well as an overall rating of proficiency (yes or no) for each VOP evaluation. The overall proficiency rating is given at the discretion of the rater and is not formally determined by performance on the checklist items.

Average performance on VOP-specific checklist items ranged from 69.2% correct to 98.0% correct. Cronbach's alpha was used to examine the internal consistency of the checklists. Performance on checklist items showed moderate internal consistency ($\alpha \geq 0.50$) on 9 of 11 modules (Table 3).

An overall percent score calculated by combining performance on checklist items and the economy of time and motion item was consistently predictive of overall proficiency rating. The final column of Table 3 shows the Pearson correlation (R) between proficiency rating and the overall percent score ($p < 0.05$ in all instances). Individual checklist items were also evaluated as predictors of overall proficiency rating, replicating the approach taken in the initial study. In almost every instance, individual checklist items were significant predictors of overall proficiency within each module (Table 4). We present these findings in comparison to Sanfey et al. whose pilot analysis included only 2 years of data. Our larger sample allowed us to detect statistical significance in a far larger number of instances.

Overall proficiency across all modules was weakly correlated across all modules ($\alpha < 0.30$), highlighting the idea that proficiency on one surgical skill does not necessarily translate to proficiency on another.

DISCUSSION

The VOP-specific evaluation instrument used at our institution continues to perform effectively as a means of

TABLE 3. Internal Consistency (α), Pearson's Correlation Coefficient (R), and Descriptive Statistics for Verification of Proficiency Modules

	Checklist Items		Economy of Time and Motion			Demonstrates Proficiency	
VOP Module	**N**	**Avg. % Correct**	**Mean**	**SD**	α	**Overall % Score**	**R**
Central Line Catheterization	10	93.1	2.99	0.81	0.72	96.3	0.52
Chest Tube Insertion	9	98.0	3.16	0.84	0.26	96.3	0.42
Emergency Surgical Airway	8	97.1	3.37	0.90	0.59	90.1	0.69
Instrument Knot Tying	5	89.5	3.26	0.76	0.68	91.5	0.57
One-handed Knot Tying-Deep	4	83.7	2.95	0.92	0.72	79.5	0.75
One-handed Knot Tying-Surface	3	81.1	2.95	0.82	0.74	75.2	0.74
Simple Interrupted Suture	6	98.0	3.35	0.80	0.40	97.7	0.59
Subcuticular Skin Closure	6	91.5	3.02	0.88	0.77	89.5	0.76
Two-handed Knot Tying-Deep	4	91.2	3.19	0.76	0.55	89.8	0.53
Two-handed Knot Tying-Surface	3	69.2	3.16	0.82	0.50	88.5	0.43
Vertical Mattress	6	94.7	2.85	0.85	0.58	94.4	0.66
		$\alpha = 0.37$	$\alpha = 0.32$			$\alpha = 0.12$	

assessing the basic surgical skills of PGY-1 surgical residents. Our results support the initial 2-year follow-up study results published by Sanfey et al. and continued use of this evaluation tool is warranted.[7] Only 1 checklist item that was originally found to be a significant predictor of overall proficiency in the original 2-year follow-up study was found not to be statistically significant after 10 years. Conversely, 31 checklist items that were originally not statistically significant were found to be significant predictors of overall proficiency in this study, which helps to identify more critical steps for our learners and gives credibility to those checklist items as critical aspects of their associated surgical skill.

Two of the 11 VOP modules showed high performance rates and low internal consistency, which is not a coincidence. The poor internal consistency in these 2 modules (Simple Interrupted Suture and Chest Tube Insertion) is due to the fact that there was little variation at all in performance — the average percent of items correct on both of these checklists was 98.0%. Without sufficient variation in item performance, there can be little co-variation, which is what Cronbach's alpha is designed to detect. That said, the high performance (as measured by percent completed correctly) on these checklists highlights a possible need to re-write the checklist items. Proficiency at chest tube insertion, we believe, is a skill that varies across residents — but the VOP instrument as constructed does not reflect this reality.

We note that proficiency ratings were weakly related across modules. We believe this is due to the fact that the areas of proficiency measure truly distinct skills. An alternative explanation, as for any weak correlation, is that the ratings are noisy measures that capture random information unrelated to surgical skills. Ultimately, this finding supports the continued inclusion of all 11 basic surgical skills in the VOP curriculum as they likely represent distinct skills valuable to all surgical trainees.

This study was conducted in a surgical skills center that is home to an extensive inventory of surgical equipment and has advanced capabilities for video recording.[12] In this context, the marginal costs of VOP assessments are minimal. The price of simulator models is modest for virtually all of the modules, less than $10 apiece. The lone exception is the model for central line catheterization, a commercial model whose upfront cost was approximately $5000 and whose annual maintenance is approximately $1000; this model has been used to train hundreds of learners since being purchased, which over time brings the approximate cost per learner per year to $25. The total cost per resident for the models across all 11 VOP models is no more than $350. VOP performances are rated by physician faculty, who watch de-identified videos of the simulation modules. We estimate that the average total video time across all modules is approximately 5 minutes, and that faculty need an additional 5 minutes per module to complete each form. Maximum times by module range from 2 to 25 minutes, and total 80 minutes. Ultimately, the average faculty time spent rating videos, per resident, is approximately 110 minutes, with a plausible maximum of 135 minutes.

Over the past 10 years, the Department of Surgery at our institution has continued to expend and several residency programs have added residents or established residency programs (neurosurgery). This influx of new residents is responsible for the varying number of performances of each VOP modules seen in Table 3. No resident who started the curriculum failed to complete it and VOP data for all residents was included in the data set regardless of their future performance or completion of their residency program.

Our study has natural limitations. This was conducted at a single institution — the institution where the VOP instruments were developed and first put into use. However, other institutions use the same VOP instrument as

TABLE 4. Verification of Proficiency Checklist Item Analysis

VOP	Pass Rate	Number of Performances	Items Predictive of Failure to Demonstrate Proficiency on Each Performance	2008-2009 p value	2010-2017 p value
Chest tube insertion	96%	135	Infiltrates local anesthetic at appropriate site	N	<0.001
			Dissects with gentle pressure through muscle. . .	N	<0.05
			Secures chest tube with a suture	N	<0.001
			Economy of Time and Motion	N	<0.001
Central Venous Line	83%	122	Selects appropriate site for venipuncture	<0.001	N
			Simulates injecting local anesthetic into skin at appropriate site	<0.05	0.004
			Needle enters skin at 35-45 degree ankle and directed laterally	N	0.005
			Needle enters at 45 degree angle to floor and aimed at ipsilateral nipple	N	0.007
			Removes syringe while occluding hub of needle	<0.01	0.05
			Inserts J wire into needle, advancing wire without resistance	N	0.01
			Removes introducer needle	<0.04	0.009
			Makes a small incision with an #11 blade	<0.03	<0.001
			Passes dilator through skin over wire and then removes dilator	<0.05	<0.001
			Passes catheter over wire into vessel and removes wire	<0.01	<0.001
			Simulates aspirating blood through catheter	N	0.003
			Secures catheter with suture	N	0.001
			Orders a chest X-ray	N	<0.001
			Economy of Time and Motion	<0.01	<0.001
Emergency Surgical Airway	90%	131	Makes an adequate length incision (longitudinal or transverse)	<0.03	<0.001
			Sharply or bluntly dissects through subcutaneous tissue	<0.003	<0.001
			Maintains control of airway opening	<0.01	<0.001
			Avoids placing tube too far (places tube just past balloon)	N	<0.001
			Time to complete task (in seconds)	N	<0.001
			Economy of Time and Motion	<0.01	<0.001
Subcuticular skin closure	89%	133	Runs the suture, placing appropriate bites into dermal layer	N	<0.001
			Enters the dermal layer directly across from exit site	N	<0.001
			Avoids multiple forceps grasps of skin	N	<0.001
			Instrument ties with square knots	N	<0.001
			Approximates skin with appropriate tension	N	<0.001
			Economy of Time and Motion	N	<0.001
Vertical mattress suture	94%	126	Passes needle perpendicular to skin on both side of skin	<0.05	<0.001
			Avoids multiple forceps grasps of skin	<0.05	0.002
			Approximates skin with appropriate tension	N	<0.001
			Eversion of the skin edges	<0.05	<0.001
			Economy of Time and Motion	N	<0.001
	98%	132		<0.01	<0.001

(continued)

TABLE 4 (*continued*)

VOP	Pass Rate	Number of Performances	Items Predictive of Failure to Demonstrate Proficiency on Each Performance	2008-2009 p value	2010-2017 p value
Simple interrupted skin suture			Passes needle perpendicular to skin on both sides of skin		
			Instrument ties with square knots	<0.01	<0.001
			Approximates skin with appropriate tension	<0.03	<0.001
			Places sutures 0.5-1.0 cm apart	<0.03	<0.001
			Economy of Time and Motion	N	<0.001
Surface 1-handed knot tying	75%	129	Tension maintained on suture throughout performance	N	<0.001
			Smooth transition between knots	<0.02	<0.001
			Hands crossed at appropriate time to create square knot	<0.01	<0.001
			Economy of Time and Motion	N	<0.001
Surface 2-handed knot tying	90%	128	Tension maintained on suture throughout performance	N	0.007
			Smooth transition between knots	N	0.01
			Hands crossed at appropriate time to create square knots	<0.03	<0.001
			Economy of Time and Motion	N	0.002
Deep 1-handed knot tying	90%	128	Tension maintained on suture throughout performance	N	<0.001
			Smooth transition between knots	N	0.03
			Hands crossed at appropriate time to create a square knot	<0.04	0.05
			Traction placed with one hand while knot is slipped down index finger of the other hand	<0.02	<0.001
			Economy of Time and Motion	<0.03	0.04
Instrument tie	92%	130	Tension maintained on suture throughout performance	N	0.02
			Smooth transition between knots	N	<0.001
			Fluid movement with instrument	<0.02	<0.001
			Hands crossed at appropriate time to create square knot	<0.04	<0.001
			Traction placed with one hand while knot is slipped down index finger of the other hand	N	0.03
			Economy of Time and Motion	<0.01	0.001

N = not significant.

part of their basic surgical skills curriculum and future study will look to see whether our results replicate in other settings. VOP assessments are high stakes at our institution as residents must demonstrate proficiency on every module before being permitted to progress to the next level of surgical training. Knowing this, we acknowledge that the VOP instruments may perform differently in low-stakes settings. All attending level surgeons were invited to complete video evaluations for these basic surgical skills, however, not all completed evaluations. Evaluators were randomly assigned de-identified trainee videos to assess without any knowledge of surgical subspecialty.

Prior to sitting for their VOP assessments, every resident in our study was provided with a skill-specific module, which included instructions and objectives for performance, the checklist of items that appears verbatim on the evaluation form, and ample time to practice in a low-stakes environment. Unfortunately, we do not have sufficient data to explore their surgical skills preparation during medical school and therefore stratifying trainees based on prior experience or looking for associations between prior experience and VOP performance was not possible.

Performance on VOP modules has, on average, improved since they were first piloted in 2008. Since the implementation, the surgical skills curriculum and the VOP assessment used at SIU have not changed substantially for the 11 skills that we study. That said, the surgical skills lab has undergone major improvements – the

training space and tools have both been expanded. Despite these environmental changes, we hypothesize that the main cause for improvement is the context of administration (i.e., prerequisite for promotion to PGY-2) and credibility the VOP instrument has developed over time. The introduction of the VOP instrument as a high stakes assessment created a new institutional norm: that residents must become proficient in a defined set of skills. That new norm, we suspect, caused residents to focus heavily on becoming proficient on that set of skills – this sharper focus was one of the primary goals for introducing the VOP modules in the first place.

The VOP modules serve as an objective measure of performance in the surgical skills, which is traditionally otherwise limited to number of cases performed and end-of-rotation evaluations. Surgical residency programs at our institution do employ subspecialty-specific surgical skill assessment tools (e.g., Operative Performance Rating System[8] for general surgery and the ABOS/CORD Surgical Skills assessment form for orthopedic surgery) and surgical residency programs across the country continue to look for ways to increase real-time feedback to surgical trainees on performance.[9-11] However, the VOP modules serve as the only baseline measure of surgical skills that is required, standardized and used to provide formative as well as summative feedback to our surgical residents.

CONCLUSIONS

The VOP instrument offers an internally valid means of assessing the skill of PGY-1 residents at basic surgical skills and serves a critical role as a source of formative and summative feedback to trainees. VOP surgical skill modules currently included in our curriculum demonstrated poor internal consistency (i.e., they likely represent distinct skills) and all warrant continued inclusion. This VOP evaluation instrument measures a baseline level of skill that may be predictive of future performance in residency.

ACKNOWLEDGMENTS

None.

PRIOR PRESENTATIONS

This study was presented as a Quick Shot podium presentation at the Association of Program Directors in Surgery Annual Meeting as part of Surgical Education Week in Chicago, IL on April 25, 2019. Also, a podium presentation of the initial stage of this work was delivered at the 9th Annual Southern Illinois University School of Medicine Teaching & Learning Symposium on April 20, 2018.

REFERENCES

1. Gawande AA. Creating the educated surgeon in the 21st century. *Am J Surg*. 2001;181:551–556.
2. Aggarwal R, Darzi A. Technical skills training in the 21st century. *N Engl J Med*. 2006;355:2695–2696.
3. Ahlberg G, Enochsson L, Gallagher AG, et al. Proficiency-based virtual reality training significantly reduces the error rate for residents during their first 10 laparoscopic cholecystectomies. *Am J Surg*. 2007;193:797–804.
4. Stefanidis D, Acker C, Heniford BT. Proficiency-based laparoscopic simulator training leads to improves operating room skill that is resistant to decay. *Surg Innov*. 2008;15:69–73.
5. Stefanidis D, Korndorffer JR Jr, Markley S, Sierra R, Scott DJ. Proficiency maintenance: impact of ongoing training on laparoscopic skill retention. *J Am Coll Surg*. 2006;202:599–603.
6. Sanfey H, Dunnington GL. Verification of Proficiency: a prerequisite for clinical experience. *Surg Clin N Am*. 2010;90:559–567.
7. Sanfey H, Ketchum J, Bartlett J, et al. Verification of proficiency in basic skills for postgraduate year 1 residents. *Surgery*. 2010;148:759–767.
8. Larson JL, Williams RG, Ketchum J, Boehler ML, Dunnington GL. Feasibility, reliability and validity of an operative performance rating system for evaluating surgery residents. *Surgery*. 2005;138:640–647. discussion 647-9.
9. Kozin ED, Bohnen JD, George BC, et al. Novel mobile app allows for fast and validated intraoperative assessment of otolaryngology residents. *OTO Open*. 2017;1. 2473974X16685705.
10. Wagner JP, Chen DC, Donahue TR, et al. Assessment of resident operative performance using a real-time mobile Web system: preparing for the milestone age. *J Surg Edu*. 2014;71:e41–e46.
11. Bohnen JD, Goerge BC, Willams RG, et al. Procedural Learning and Safety Collaborative (PLSC). The Feasibility of Real-Time Intraoperative Performance Assessment With SIMPL (System for Improving and Measuring Procedural Learning): Early Experience From a Multi-Institutional Trial. *J Surg Edu*. 2016;73:e118–e130.
12. Sanfey H, Ketchum J, Bartlett J, Dunnington G. Education case study: Southern Illinois University. Saltzman PD, editor. Best Practices in Surgical Education: Innovation in Skills Training, Ethicon Endo-Surgery, Inc.; 2010:11.1–11.37.