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Laparoscopic Warm-up Exercises Improve Performance of Senior-Level Trainees During Laparoscopic Renal Surgery

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Abstract

Background and Purpose: Surgery is a high-stakes "performance." Yet, unlike athletes or musicians, surgeons do not engage in routine "warm-up" exercises before "performing" in the operating room. We study the impact of a preoperative warm-up exercise routine (POWER) on surgeon performance during laparoscopic surgery.
Materials and Methods: Serving as their own controls, each subject performed two pairs of laparoscopic cases, each pair consisting of one case with POWER (+POWER) and one without (–POWER). Subjects were randomly assigned to +POWER or −POWER for the initial case of each pairing, and all cases were performed ≥1 week apart. POWER consisted of completing an electrocautery skill task on a virtual reality simulator and 15 minutes of laparoscopic suturing and knot tying in a pelvic box trainer. For each case, cognitive, psychomotor, and technical performance data were collected during two different tasks: mobilization of the colon (MC) and intracorporeal suturing and knot tying (iSKT). Statistical analysis was performed using SYSTAT v11.0.
Results: A total of 28 study cases (14+POWER, 14−POWER) were performed by seven different subjects. Cognitive and psychomotor performance (attention, distraction, workload, spatial reasoning, movement smoothness, posture stability) were found to be significantly better in the +POWER group ($P \leq 0.05$) and technical performance, as scored by two blinded laparoscopic experts, was found to be better in the +POWER group for MC ($P=0.04$) but not iSKT ($P=0.92$). Technical scores demonstrated excellent reliability using our assessment tool (Cronbach $\propto = 0.88$). Subject performance during POWER was also found to correlate with intraoperative performance scores.
Conclusions: Urologic trainees who perform a POWER approximately 1 hour before laparoscopic renal surgery demonstrate improved cognitive, psychomotor, and technical performance.

Introduction

"PRACTICE MAKES PERFECT" is an age-old idiom that transcends across many different disciplines. The concept of doing something more frequently to make oneself better is well accepted by "performers," such as musicians, athletes, artists, and even military personnel, all of who engage in deliberate practice. In addition to deliberate practice, these performers engage in routine "warm-up" exercises before their "performance."

Preperformance warm-up often consists of both mental and physical exercises. Studies have demonstrated that mental practice can significantly improve performance among not only athletes but surgeons as well.[1–4] Whether intentional or not, the vast majority of surgeons engage in some form of mental warm-up—reviewing preoperative imaging, discussing surgical technique, recalling and analyzing experiences with similar procedures in the past.

Despite adequate mental preparation, unlike other performers, surgeons do not routinely engage in technical warm-up exercises before surgery. This might be considered equivalent to a professional athlete going into a game completely cold or an opera singer going on stage without any vocal warm-up whatsoever. With the ultimate goal of delivering optimized care to patients, it follows then that high-stakes skills-based performers such as surgeons, should practice or warm up before surgery to improve surgical performance and patient outcomes.

The notion of warm-up before surgery is a relatively new area of study. The theory proposed by Ericsson[5] on the development of expertise, however, has provided a solid conceptual framework from which to base such studies.

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Although common sense would suggest that a preoperative warm-up exercise routine (POWER) would improve intraoperative performance, little has been published to confirm this concept. Moreover, despite common sense, the vast majority of surgeons do not engage in a technical POWER before surgery.

The aim of our study is to elucidate the impact of a POWER on surgeon performance during clinical laparoscopic renal surgery, particularly with respect to intraoperative cognitive, psychomotor, and technical performance.

Materials and Methods

After obtaining Institutional Review Board approval, urology trainees from our institution were recruited for the study. Serving as their own controls, each subject was scheduled to perform two pairings of laparoscopic renal surgery cases (four total cases each), with each pairing consisting of one case performed after a POWER (+POWER) and one case without (–POWER). Subjects were randomized as to the sequence of cases for each pairing (ie, +POWER followed by −POWER, or vice versa), and all cases were separated in time by at least 1 week. All subjects were evaluated on two specific laparoscopic tasks during surgery: Mobilization of the colon (MC) along the line of Toldt performed at the start of each case and intracorporeal suturing and knot tying (iSKT) to reapproximate the line of Toldt performed at the end of each case. All laparoscopic renal surgery cases performed at our institution, including radical nephrectomy, partial nephrectomy, dismembered pyeloplasty, and renal cyst decortication, were considered for inclusion as study cases. All complex cases (ie, redo operations, aberrant anatomy) were excluded. To ensure patient safety, all subjects were supervised by an attending surgeon with prerogative to take over the case at any time.

Each subject performed the MC task using standard laparoscopic instruments, and the components of the task were standardized; start was considered the initiation of incising the line of Toldt and the end was the complete mobilization of the colon off the kidney and the Gerota fascia. The laparoscopic iSKT task was also standardized for each subject; using two standard laparoscopic needle drivers and an 8-inch 2-0 polyglactin suture on a SH needle, subjects placed a figure-eight stitch to reapproximate the colon to the cut edge of the line of Toldt, followed by the performance of three intracorporeal knot ties.

All subjects completed a demographic and postencounter questionnaire at the start and end of each case, respectively. Subjects were mandated by protocol to refrain from participating in any laparoscopic renal surgery cases within 1 week of a study case.

POWER consisted of completing an electrocautery simulation task (Skill Task #8) on the LAP Mentor™ virtual reality (VR) surgical simulator (Simbionix Ltd, Lod, Israel), shown to have good construct validity,[6] and 15 minutes of laparoscopic suturing and knot tying using a basic laparoscopic pelvic box trainer (3-Dmed, Franklin, Ohio). Performance scores during the POWER were recorded for correlation with intraoperative assessments.

During the performance of MC and iSKT, cognitive, psychomotor, and technical performance data were captured for analysis. Cognitive and psychomotor information was captured in the form of seven-lead electroencephalography (EEG) monitoring, pupillary eye tracking, as well as hand motion, instrument motion, and postural video recordings. A commercially available EEG cap (B-Alert device, Advanced Brain Monitoring, Inc, Carlsbad, CA) was used to determine attention, distraction/drowsiness, and mental workload scores based on intraoperative EEG tracings. Changes in pupillary diameter, eye movements, and blink rates were monitored to measure levels of cognitive effort and spatial reasoning using a patented brain-based metric called the Index of Cognitive Activity© (ICA) (Eye Tracking, Inc, San Diego, CA). Video footage of the subject's posture as well as hand and instrument motions was recorded to provide psychomotor performance scores. Deidentified video footage of the surgical procedure was also captured and scored at a later date by two blinded, laparoscopic expert urologists using a previously validated operative assessment tool[7] that had been modified for laparoscopic renal surgery. The modified assessment device was used independently by each of the expert scorers to obtain technical performance scores (Appendix 1). Because this modified assessment tool was not formally validated, reliability scores were calculated for the device based on the results of this study.

Data were analyzed using methods appropriate for a matched pair design. Differences between +POWER and −POWER cases were tested using the McNemar test for symmetry for categorical variables and matched pair t tests for continuous variables. Global technical scores were compared using repeated measures analysis of variance methods. Grouping variables were added to analysis of variance models to adjust for the effects of training and order.

Results

A total of seven subjects were included in the study: Two junior residents (postgraduate year [PGY]3), two senior residents (PGY5), and three fellows from the department of urology at the University of California, Irvine. Each subject served as his/her own control, performing 2+POWER and 2−POWER cases for a total of 14 cases in each arm of the study.

There were no significant differences between groups with respect to demographic data (Table 1). In regard to the clinical setting in which cases were performed, there were no differences between the +POWER and −POWER groups with respect to cases performed by sleep-deprived subjects (<6 h sleep in last 24 h), cases performed after a previous surgical case the same day, interval of time since last laparoscopic renal surgery, and the level of difficulty of the cases as assessed by the attending surgeon at the completion of the procedure (Table 2).

Table 1. Subject Demographics

Subject	*Level of training*	*Sex*	*Dominant hand*	*# of laparoscopic renal cases as primary surgeon*
1	PGY3	M	R	0–5
2	PGY3	M	Ambid	0–5
3	PGY5	F	R	10–20
4	PGY5	M	R	5–10
5	Fellow	M	R	>20
6	Fellow	M	R	>20
7	Fellow	M	R	>20

PGY = postgraduate year.

Table 2. Group Comparison

		Warm		Cold		
		N	*%*	*N*	*%*	*p-value*
Gender	Male	12	85.7	12	85.7	1.00
	Female	2	14.3	2	14.3	
Handedness	Right	12	85.7	12	85.7	1.00
	Ambidextrous	2	14.3	2	14.3	
Level of Training	R3	4	28.6	4	28.6	1.00
	R5	4	28.6	4	28.6	
	Fellow	6	42.8	6	42.8	
Lap Renal Cases (Experience)	0–5	3	21.4	4	28.6	0.70
	5–20	5	35.7	3	21.4	
	<20	6	42.9	7	50.0	
Interval since last Lap Renal Case	<2 wks	5	35.7	7	50.0	0.61
	2–4 wks	5	35.7	5	35.7	
	>4 wks	4	28.6	2	14.3	
Sleep Deprivation	No	4	28.6	4	28.6	1.00
	Yes	10	71.4	10	71.4	
Prior OR Cases	No	12	85.7	8	57.1	0.10
	Yes	2	14.3	6	42.9	
Difficulty Level of Cases	Easier than avg.	1	7.1	3	21.4	0.41
	Average	12	85.7	9	64.3	
	Difficult	1	7.1	2	14.3	

Lap = laparoscopic; OR = operative.

Because of technical difficulties, pupillary eye tracking data were available for only 6 of the 7 subjects, and technical performance data were available for 26 of the 28 cases, 13 in each group. All other cognitive and psychomotor data were available for all 14 cases in both the +POWER and −POWER arms of the study.

When comparing the two study groups, the +POWER group had higher mean hand movement smoothness scores (0.73 *vs* 0.46, $P<0.03$), tool movement smoothness scores (0.73 *vs* 0.58, $P<0.05$), and posture stability scores (0.54 *vs* 0.34, $P<0.05$) when compared with the −POWER group (Fig. 1). Based on EEG data, the +POWER group had better mean attention scores (0.8 *vs* 0.64, $P<0.02$), distraction scores (0.34 *vs* 0.52, $P<0.001$), and mental workload scores (0.68 *vs* 0.87, $P<0.02$) when compared with the −POWER group (Fig. 2).

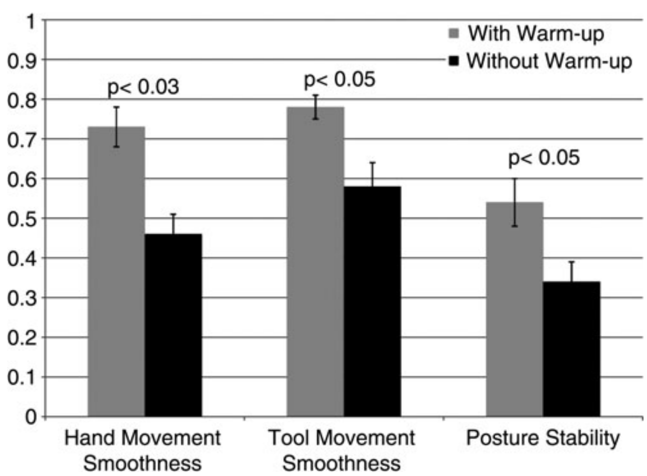

FIG. 1. Psychomotor performance.

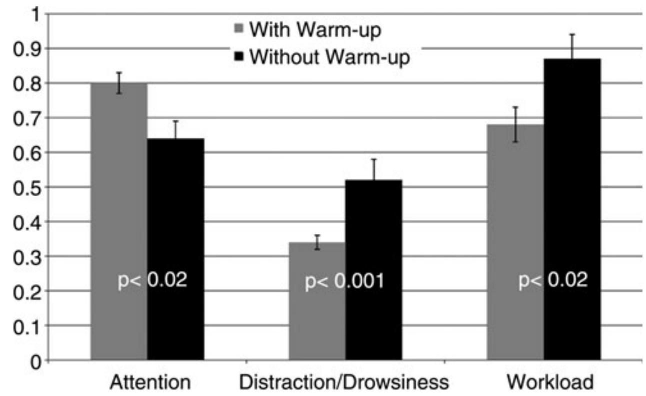

FIG. 2. Cognitive performance.

With respect to spatial reasoning, using mean ICA scores, the +POWER group was found to have significantly lower cognitive workload scores than the −POWER group ($P=0.03$). In addition, when five separate eye tracking variables were included in a linear discrimination analysis to create a classifier, we were able to discern +POWER cases from −POWER cases with a mean area under curve of 0.832 on standard receiver operating characteristic curves for each surgeon (Fig. 3).

With respect to technical performance, there were no differences between groups in the mean time to complete MC (26.6±12.0 min *vs* 29.4±10.1 min, $P=0.40$) or iSKT (7.6±4.5 min *vs* 5.8±2.9 min, $P=0.17$) nor was there a difference in the mean time interval between tasks (190.4±40.4 min *vs* 176.4±65.2 min, $P=0.43$). The +POWER group had a higher mean score for the MC task (21.43±0.54 *vs* 19.86±0.51, $P=0.04$) but not the iSKT task (3.50±0.23 *vs* 3.54±0.25, $P=0.92$) (Fig. 4). The technical performance scores demonstrated excellent reliability using our operative assessment device (Cronbach ∝ = 0.88). The mean time interval between the POWER and the start of the first task (MC) was 66 minutes.

Technical performance during the POWER was found to correlate with intraoperative performance. Both the cautery efficiency score (0%–100%) achieved for Skill Task #8 on the VR simulator and the number of laparoscopic needle throws

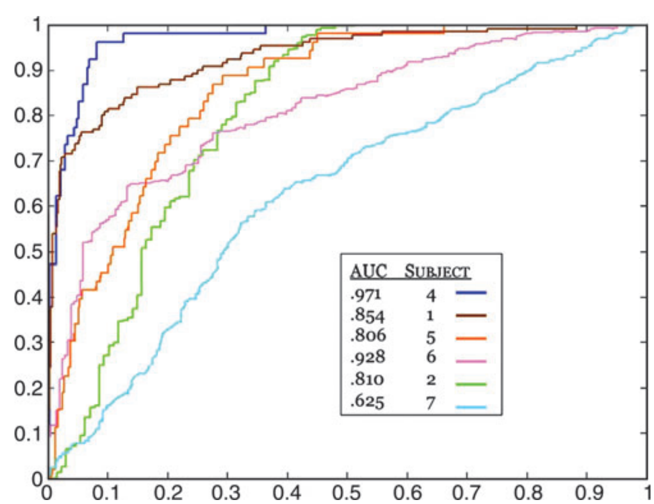

FIG. 3. Cognitive performance (receiver operating characteristic curve for Index of Cognitive Activity). AUC = area under curve.

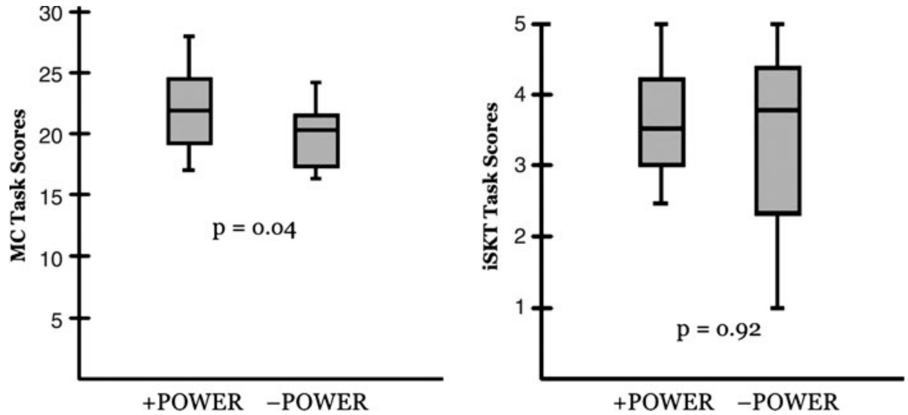

FIG. 4. Technical performance. MC = mobilization of the colon.

successfully performed during the 15 minute POWER on the box trainer correlated strongly with intraoperative hand movement smoothness scores (Spearman r = 0.87 and r = 0.90, respectively), while only the cautery efficiency score correlated to technical performance (r = 0.60 for iSKT score).

Discussion

Concert pianists, professional baseball players, Broadway dancers, and even rock stars are all considered skill-based performers and are measured by the expertise with which they deliver their public performances. All engage in deliberate practice and warm-up before performing to create the ideal conditions to deliver an expert performance. There is a significant body of literature that has demonstrated the performance benefits of warm-up exercises in sport[8–11]as well as dance and music.[12–14]

To date, there has been a relative paucity of literature on the concept of a POWER in surgery. In 2006, Do and associates[15] demonstrated that 15 minutes of basic skill task warm-up exercises on a laparoscopic pelvic trainer significantly improved subsequent laparoscopic performance in obstetrics and gynecology residents and medical students. In 2009, Kahol and colleagues[16] demonstrated that performing 15 to 20 minutes of basic surgical warm-up tasks on a VR simulator resulted in a substantial increase in surgical skills proficiency during subsequent surgically related tasks performed in a laboratory testing situation, a finding that was consistent across differing levels of surgical training including senior, experienced surgeons.

In a more recent study, Calatayud and coworkers[17] examined the impact of performing three laparoscopic skill tasks using a VR surgical simulator on surgical performance during an actual live laparoscopic cholecystectomy (LC). Warm-up tasks were performed immediately before the surgical case in the operating room (OR) and lasted 15 minutes. Using a generic Objective Structured Assessment of Technical Skills global rating scale to evaluate surgical performance, the authors found that there was a significant improvement in the scores for LCs completed with warm-up compared with those completed without (median 28.5 vs 19.25, $P = 0.042$).

Our main objective was to determine if the performance of a POWER resulted in improved cognitive, psychomotor, and technical performance during laparoscopic renal surgery. Our study demonstrated that engaging in a 20-minute POWER, approximately 1 hour before surgery, results in significant improvements in cognitive and psychomotor performance during live laparoscopic renal surgery. In addition, and perhaps most importantly, a POWER significantly improved initial technical performance (MC task) in the operative procedure. The POWER did not, however, correlate with technical performance during a task (iSKT) carried out approximately 4 hours after POWER (mean time interval between tasks was 190 min and 176 min for +POWER and −POWER, respectively). This may indicate that the beneficial effects of a POWER are time-sensitive. A majority of the subjects did not operate between the MC and iSKT tasks, and so this "cooling-off" period may explain the lack of correlation between POWER and iSKT score. Conversely, performing the MC task may have served as a warm-up exercise for the iSKT task among subjects in the −POWER group. Further study is warranted with regard to this time variable and should examine the impact of POWER at various time intervals before surgery.

Surgeon performance during the POWER also correlated with intraoperative cognitive and psychomotor performance, and to a lesser degree technical performance. Although not a primary end point of this study, this finding is interesting in that surgeon performance during the POWER may be used to predict surgical performance in the OR. If confirmed on follow-up studies, this may have significant implications regarding assessment of surgeon readiness for elective surgery. Significant focus has recently been placed on evaluating surgeon readiness for elective surgical procedures. In an editorial, Nurok and associates[18] recently recommended that sleep-deprived surgeons reschedule elective procedures because of the known associated risk of surgical complications. Similarly, surgeons who are unable to perform, either due to illness, fatigue, or other factors, at a predetermined acceptable level of proficiency on POWER, could also be asked to reschedule elective procedures—or at the very least, perform "practice" exercises to bring their technical skill level to baseline before operating. A POWER would thus be used as a method of screening surgeons who may be at risk of a suboptimal surgical performance on any given day.

The main limitation of this study was the small sample size. With only 14 cases in each arm, the generalizability of our findings may be limited. Despite this, however, we did find statistically significant differences between the two study groups. Another limitation of this study is that study cases were not rigorously controlled. Although all complex cases were excluded, patient and disease factors, such as anatomy, body habitus, and pathology, were not standardized between groups. Attending surgeons were asked, at the end of each case, to rate the procedure as either easier than average, average, or difficult to control for the innate differences among cases. No significant difference in "level of difficulty" was found between +POWER and −POWER cases. Finally, this study only included urologic trainees (residents and fellows) and as such, does not address the question of whether a POWER is beneficial to attending surgeons already experienced in laparoscopic renal surgery.

With only one other study also demonstrating the benefits of a POWER in the OR, it is important for further, large-scale studies to confirm the findings of our study. It will also be important to determine the optimal duration and timing of a POWER as well as determine the optimal format of the POWER. For example, will a POWER consisting of basic laparoscopic skill tasks in a pelvic trainer be equivalent to VR simulator tasks? What role will a POWER consisting of a VR procedure and patient-specific high-fidelity program have and how will this impact intraoperative performance? Finally, future studies will need to answer the most important question of whether a POWER results in improved patient outcomes.

Conclusion

Surgical trainees who engage in a 20-minute POWER before laparoscopic renal surgery demonstrate improved intraoperative cognitive, psychomotor, and technical performance. Performance during the POWER may also predict surgeon performance during live surgery.

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Disclosure Statement

No competing financial interests exist.

References

1. Driskell J, Cooper C, Moran A. Does mental practice enhance performance? J Appl Sport Psychol 1994;79:481–491.
2. Feltz DL, Landers DM. The effects of mental practice on motor skill learning and performance: A meta-analysis. J Sport Psychol 1983;5:25–57.
3. Immenroth M, Bürger T, Brenner J, et al. Mental training in surgical education: A randomized trial. Ann Surg 2007;245: 385–391.
4. Arora S, Aggarwal R, Sevdalis N, et al. Development and validation of mental practice as a training strategy for laparoscopic surgery. Surg Endosc 2010;24:179–187.
5. Ericsson KA. Deliberate practice and the acquisition and maintenance of expert performance in medicine and related domains. Acad Med 2004;79(suppl 10):S70–S81.
6. McDougall EM, Corica FA, Boker JR, et al. Construct validity testing of a laparoscopic surgical simulator. J Am Coll Surg 2006;202:779–787.
7. Vassiliou MC, Feldman LS, Andrew CG, et al. A global assessment tool for evaluation of intraoperative laparoscopic skills. Am J Surg 2005;190:107–113.
8. Volianitis S, McConnell AK, Koutedakis Y, Jones DA. Specific respiratory warm-up improves rowing performance and exertional dyspnea. Med Sci Sports Exerc 2001;33:1189–1193.
9. Bishop D. Warm up II: Performance changes following active warm up and how to structure the warm up. Sports Med 2003;33:483–498.
10. Chattong C, Brown LE, Coburn JW, Noffal GJ. Effect of a dynamic loading warm-up on vertical jump performance. J Strength Cond Res 2010;24:1751–1754.
11. Faigenbaum AD, McFarland JE, Schwerdtman JA, et al. Dynamic warm-up protocols, with and without a weighted vest, and fitness performance in high school female athletes. J Athl Train 2006;41:357–363.
12. Giudetti L, Emerenziani GP, Gallotta MC, Baldari C. Effect of warm up on energy cost and energy sources of a ballet dance exercise. Eur J Appl Physiol 2007;99:275–281.
13. Motel T, Fisher KV, Leydon C. Vocal warm-up increases phonation threshold pressure in soprano singers at high pitch. J Voice 2003;17:160–167.
14. Amir O, Amir N, Michaeli O. Evaluating the influence of warmup on singing voice quality using acoustic measures. J Voice 2005;19:252–260.
15. Do AT, Cabbad MF, Kerr A, et al. A warm-up laparoscopic exercise improves the subsequent laparoscopic performance of Ob-Gyn residents: A low-cost laparoscopic trainer. JSLS 2006;10:297–301.
16. Kahol K, Satava RM, Ferrara J, Smith ML. Effect of short-term pretrial practice on surgical proficiency in simulated environments: A randomized trial of the "preoperative warm-up" effect. J Am Coll Surg 2009;208:255–268.
17. Calatayud D, Arora S, Aggarwal R, et al. Warm-up in a virtual reality environment improves performance in the operating room. Ann Surg 2010;251:1181–1185.
18. Nurok M, Czeisler CA, Lehmann LS. Sleep deprivation, elective surgical procedures, and informed consent. N Engl J Med 2010;363:2577–2579.

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Abbreviations Used

EEG = electroencephalography
ICA = Index of Cognitive Activity
iSKT = intracorporeal suturing and knot tying
LC = laparoscopic cholecystectomy
MC = mobilization of the colon
OR = operating room
PGY = postgraduate year
POWER = preoperative warm-up exercise routine
VR = virtual reality

(*Appendix follows →*)

Appendix 1. Technical Performance Assessment Device

DATE/Videotape # ________________ Reviewer ________________________

Please read this evaluation form through once. Then view the videotape of the laparoscopic renal surgery and complete all the assessment categories below. If any of the listed items was not seen or did not apply to the particular anatomical task, please mark N/A

	Yes	No	N/A
Incision along line of Toldt			
Management of colon (adequate mobilization from Gerota's fascia)			
Management of spleen/liver (adequate mobilization)			
Psoas muscle exposed			
Suturing (reapproximation of line of Toldt)			

	N/A	1	2	3	4	5
Respect for tissue		Frequently used unnecessary force or caused damage	Occasional unnecessary force used or slight tissue damage	Careful handling of tissue with occasional inadvertent tissue damage	Careful handling of tissues with minimal tissue damage	Consistently handled tissues appropriately
Uses retractors appropriately and effectively		None used	Poor exposure by poorly placed retractors	Used retractors with good exposure some of the time	Used retractors with good exposure most of the time	Excellent use of retractors with good consistent exposure
Hemostasis		Severe uncontrolled bleeding	Major bleeding but with control	Minor bleeding that interferes with exposure	Minor bleeding that occasionally interferes with exposure	Excellent hemostasis with minimal bleeding
Management of instruments		Poor	Fair	Satisfactory	Good	Excellent
Dissection along tissue planes		Poor	Fair	Satisfactory	Good	Excellent
Lap Suturing (see task check list below)		0–2	3–4	5–6	7–8	9–10
Is this surgery classified as		Poor	Fair	Satisfactory	Good	Excellent

		Score	
Skill Task No.	Task Description	0 No	1 Yes
1	Needle held ½-⅔rd from the tip at appropriate angle		
2	Number of attempts to position the needle (≥ 3 = No; < 3 = Yes)		
3	Needle entry at single point and perpendicular to tissue plane		
4	Needle passed through the tissue with continuous rotational movement, and follow through on curve of needle		
5	Needle held in visual field at all the times		
6	Number of attempts at wrapping the suture (for knot tie (> 3 = No; ≤ 3 = Yes)		
7	Smoothly executed throws, no fumbles		
8	All knots tied squarely		
9	Knot was tight with no air knots or slipped knots		
10	Executed suturing with no tissue trauma or suture tear of the tissue		
	Total score		