Face, Content and Construct Validity of a Novel Robotic Surgery Simulator

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Purpose: We evaluated the face, content and construct validity of the novel da Vinci® Skills Simulator™ using the da Vinci Si™ Surgeon Console as the surgeon interface.

Materials and Methods: We evaluated a novel robotic surgical simulator for robotic surgery using the da Vinci Si Surgeon Console and Mimic™ virtual reality. Subjects were categorized as novice—no surgical training, intermediate—surgical training with fewer than 100 robotic cases or expert—100 or more primary surgeon robotic cases. Each participant completed 10 virtual reality exercises with 3 repetitions and a questionnaire with a 1 to 10 visual analog scale to assess simulator realism (face validity) and training usefulness (content validity). The simulator recorded performance based on specific metrics. The performance of experts, intermediates and novices was compared (construct validity) using the Kruskal-Wallis test.

Results: We studied 16 novices, 32 intermediates with a median surgical experience of 6 years (range 1 to 37) and a median of 0 robotic cases (range 0 to 50), and 15 experts with a median of 315 robotic cases (range 100 to 800). Participants rated the virtual reality and console experience as very realistic (median visual analog scale score 8/10) while expert surgeons rated the simulator as a very useful training tool for residents (10/10) and fellows (9/10). Experts outperformed intermediates and novices in almost all metrics (median overall score 88.3% vs 75.6% and 62.1%, respectively, between group $p < 0.001$).

Conclusions: We confirmed the face, content and construct validity of a novel robotic skill simulator that uses the da Vinci Si Surgeon Console. Although it is currently limited to basic skill training, this device is likely to influence robotic surgical training across specialties.

Key Words: prostate; prostatectomy; robotics; computer simulation; surgical procedures, minimally invasive

Abbreviations and Acronyms

VAS = visual analogue scale

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With increasing popularity of robot-assisted surgery in urology and growing health care costs greater attention has been placed on the methodology of robotic surgeon training and the learning curve associated with the adoption of the da Vinci Surgical System. Herrell and Smith reported that a learning curve of greater than 150 robot-assisted prostatectomies was needed by an experienced open surgeon who had performed greater than 2,500 open radical prostatectomies to match his open radical prostatectomy perioperative outcomes.[1] Several other groups looking at robot-assisted prostatectomy learning curves consistently reported that operative time for robotic

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prostatectomy significantly decreases with experience.[2–6] Blood loss,[5] complications[4] and positive margin rates[7,8] also improve with experience.

Virtual reality simulation for medical procedures has an increasing role in medical training. Simulation technologies, whether skill or cognition based, have been developed with validity studies in the literature on endoscopy,[9] transesophageal echocardiography,[10] transurethral prostate resection[11,12] and laparoscopy.[13,14] With the recent surge in robotic surgery, simulation technologies for the da Vinci Surgical System have been developed with mock-ups of da Vinci controls and virtual reality exercises simulating da Vinci function. One such simulator, the dV-Trainer™, has undergone initial validity studies.[15–17]

A limitation of the dV-Trainer and other such robotic simulators may be that they do not use the da Vinci surgeon console as the surgeon interface. Since a significant portion of robotic skill acquisition deals with efficient use of the surgeon console and its various functions, a simulator that incorporates the actual console would theoretically be ideal. Recently a prototype of the first virtual reality simulator for da Vinci robotic surgery was developed that is integrated with the da Vinci Si Surgeon Console. Before its implementation as a training tool and perhaps as an evaluator of competency the simulator requires independent validation. The initial steps of validation include assessment for realism to the user (face validity), usefulness as a training tool as viewed by expert users (content validity) and the ability to differentiate levels of surgical experience (construct validity). We present what are to our knowledge the initial face, content and construct validation studies of the prototype da Vinci Skills Simulator.

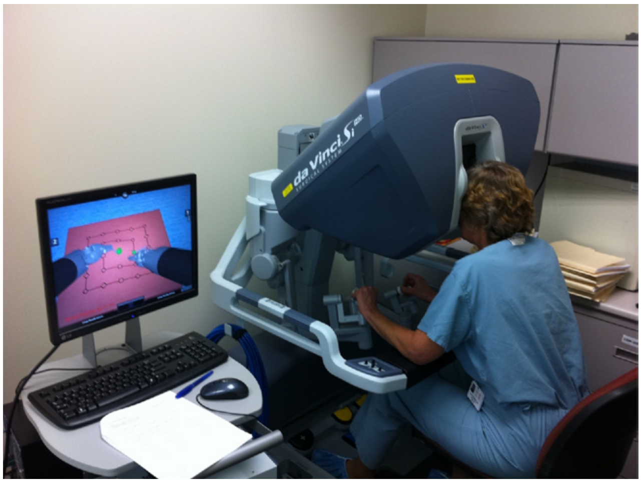

Figure 1. da Vinci Skills Simulator prototype integrated with da Vinci Si Surgeon Console.

MATERIALS AND METHODS

The prototype simulator consisted of a da Vinci Si Surgeon Console, a da Vinci Si processing unit adapted for simulation and a personal computer running Windows® XP with Mimic virtual reality software (fig. 1). Although we evaluated a prototype unit in which the processing unit and personal computer were mounted on a separate cart, the production version features an integrated backpack unit that attaches to the da Vinci Si Surgeon Console. It is not compatible with prior generation consoles. The integrated software and hardware platform redirects the surgeon movement of the console master controllers to manipulate the virtual robotic instruments in a computer generated environment.

Participants were enrolled in a prospective, institutional review board approved study. Subjects were categorized as novice—no surgical training, intermediate—surgical training but fewer than 100 cases of robotic surgical experience or expert—100 or more cases as the primary surgeon (threshold defined a priori). Participants first completed a prestudy questionnaire on demographics and self-report of surgical experience. One of 3 proctors then presented a standardized orientation of controller functions and administered a practice round consisting of 3 virtual reality exercises to ensure basic understanding of console controller functions, ie camera control and clutch, and common virtual reality tasks. Each subject subsequently completed 10 virtual reality exercises with 3 repetitions (fig. 2). The 10 exercises were selected as representative of the 26 virtual reality exercises available on the simulator at the time of prototype testing. Before each exercise on round 1 the proctor explained the task with the visual aid of screenshots taken from the exercise.

After completion of the exercises participants filled out a post-study questionnaire to assess simulator realism (face validity) and its usefulness as a training tool (content validity) based on a VAS of 1—worst to 10—best. The simulator computer recorded participant performance based on specific metrics, including the number of object drops (inadvertent drop of object picked up), virtual instrument economy of motion (distance traveled), time with excessive instrument force application beyond the preset threshold, number of robotic instrument collisions, distance traveled by instruments out of view of the surgical field, distance traveled by the master (physical) controller, number of missed targets (ie needle tip missing the intended point of entry or exit), time to task completion, time with misapplied energy (ie monopolar vs bipolar), number of disrupted vessels without appropriate hemostasis and volume of blood loss. Not all metrics were measured in all study exercises. An overall score was also calculated at the completion of each exercise that was a weighted average of the individual metrics measured in the given exercise. An algorithm developed by Mimic Technologies converted individual metric units into percent scores out of 100% and assigned each individual metric a weight of 1.0 except the master workspace range, which was assigned a weight of 0.2.

Statistical power was estimated at the beginning of the study based on available data in the literature on robotic simulator performance.[16] Overall scores of experts and

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