Establishing Benchmarks for the Fundamentals of Arthroscopy Surgery Training (FAST) Program

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Table of Contents

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Abstract

Background: Surgical education has shifted from the traditional Halsteadian apprenticeship model toward incorporating simulation due to work hour restrictions, increasing case complexity, and economic and liability pressures. Building on the success of the Fundamentals of Laparoscopic Surgery in general surgery, the Fundamentals of Arthroscopic Surgery Training (FAST) program was developed to establish proficiency benchmarks for orthopedic trainees in basic arthroscopic skills.

Objective: Establish benchmarks for five Fundamentals of Arthroscopy Surgery Training (FAST) workstation modules.

Methods: Sports medicine fellowship trained faculty were given instructions on the modules, two minutes of practice time, and then performed each task three times with both their dominant and nondominant hand. For each module, mean faculty performance was used to establish an efficiency benchmark (time) and precision benchmark (errors).

Results: The Probing module should be completed in less than 95 seconds with no errors. The Ring Transfer module should be completed in less than 134 seconds with no more than 1 error. The Maze module should be completed in less than 99 seconds with no errors. The Meniscectomy module should be completed in less than 68 seconds with no more than 1 error. Lastly, the Suture Passing module should be completed in less than 195 seconds with no more than 1 error.

Conclusions: The FAST workstation can be utilized as a proficiency-based learning tool for residents to safely and effectively develop arthroscopic skills outside of the OR. These benchmarks were established via a method previously validated in surgical simulation and balance precision and efficiency for skills that are felt to be generalizable and transferable to arthroscopic surgeries.

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Original Manuscript

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Introduction:

Historically, surgical education has been based upon the Halsteadian apprenticeship model where surgical trainees primarily acquire technical skills in the operating room while assisting and later performing procedures on live patients. In recent years, there has been a paradigm shift away from this ideology within Orthopedic Surgery.[1] This is attributed to multiple factors, not limited to resident work hour restrictions, increased case complexity and variety, risk of liability, and social, and economic pressure. Simulation in surgical education has been suggested as a potential avenue to fill the gap, allowing trainees opportunities to obtain valuable experience in a low-risk, more cost-effective environment. In concordance with this, the Accreditation Council for Graduate Medical Education (ACGME) now requires that residency programs include surgical skills training in their curricula; this mandate has also been echoed by the American Board of Orthopaedic Surgery (ABOS) and the Residency Review Committee (RRC).

Simulation as an educational tool has been validated extensively in the field of General Surgery. The Fundamentals of Laparoscopic Surgery program (FLS), developed in 1997 by the Society of American Gastrointestinal and Endoscopic Surgeons, combines cognitive and physical skills components shown to improve a given student's laparoscopic abilities over the course of the curriculum.[2] The FLS program has been studied rigorously and validated since its release.[3-9] Currently, a passing score is required by the American Board of Surgery as pre-requisite to sit for the certification exam. This has been well received by trainees, surgeons, and the public. As a result of this successful program in General Surgery, the field of Orthopaedics has explored the development of a similar program.

In 2011, the Arthroscopy Association of North America (AANA), the American Board of Orthopaedic Surgery (ABOS), and the American Academy of Orthopaedic Surgeons (AAOS) came together in a joint effort to establish the Fundamentals of Arthroscopic Surgery Training program (FAST). The program is based on the tenet that fundamental surgical skills are best obtained sequentially, and that proficiency can be established through the successful completion of a basic skills curriculum. A curriculum and simulator have been developed for the FAST program and proficiency benchmarks for knot tying have been established.

The purpose of this investigation was to establish preliminary benchmarks for five additional FAST workstation modules: Probing, Ring Transfer, Maze Navigation, Partial Meniscectomy, and Suture Passage.

Methods:

The Arthroscopy Association of North America (AANA) offered a voluntary skills training course for residents and faculty at the Orthopaedic Learning Center in Chicago, Illinois on December 7-9, 2017 and January 18-20, 2018. During downtime of the course, participants were recruited and provided with an information sheet outlining participation in the study. Participation was voluntary. Two separate cohorts of 20 faculty each completed orthopaedic simulations to improve their skill. The Institutional Review Board at the University of Rochester provided Exempt status and provided a waiver of documentation of consent. For each module, the subject was given a list of written instructions and allowed to practice for a period of 2 minutes. Then, each subject performed the task 3 times with their dominant hand and 3 times with their non-dominant hand. The order of dominant/ non-dominant completion was randomized so that exactly half of the faculty started with their non-dominant hand. The time it took each subject to complete the module as well as the number of errors committed was recorded. Cohort 1 performed Probing, Ring Transfer, and Maze Navigation. Cohort 2 performed Partial Meniscectomy and Suture Passage.

Modules:

Probing: During the probing task, the subject is instructed to identify and probe 10 of the numbers on the module. These are provided by the proctor in a randomly determined sequence (Figure 1) as determined by a random number generator.[10] 10 numbers were generated from a lower limit of 1 and upper limit of 21. No duplications were allowed, and the results were not sorted and were displayed as integers. Probing an incorrect number of results in failure of the module.

Figure 1. Probing Testing Module

Ring Transfer: During the ring transfer task, the subject is instructed to transfer 8 rings from pegs on one side of the module to the pegs on the other side and then back again (Figure 2). The rings are initially placed on the opposite side of the working portal. For example – if the working portal (the one used to insert the ring grasping instrument) is on the right, the rings are placed on the left side of the module. If the subject drops a ring they are asked to continue the task. The number of dropped rings indicates the number of errors recorded.

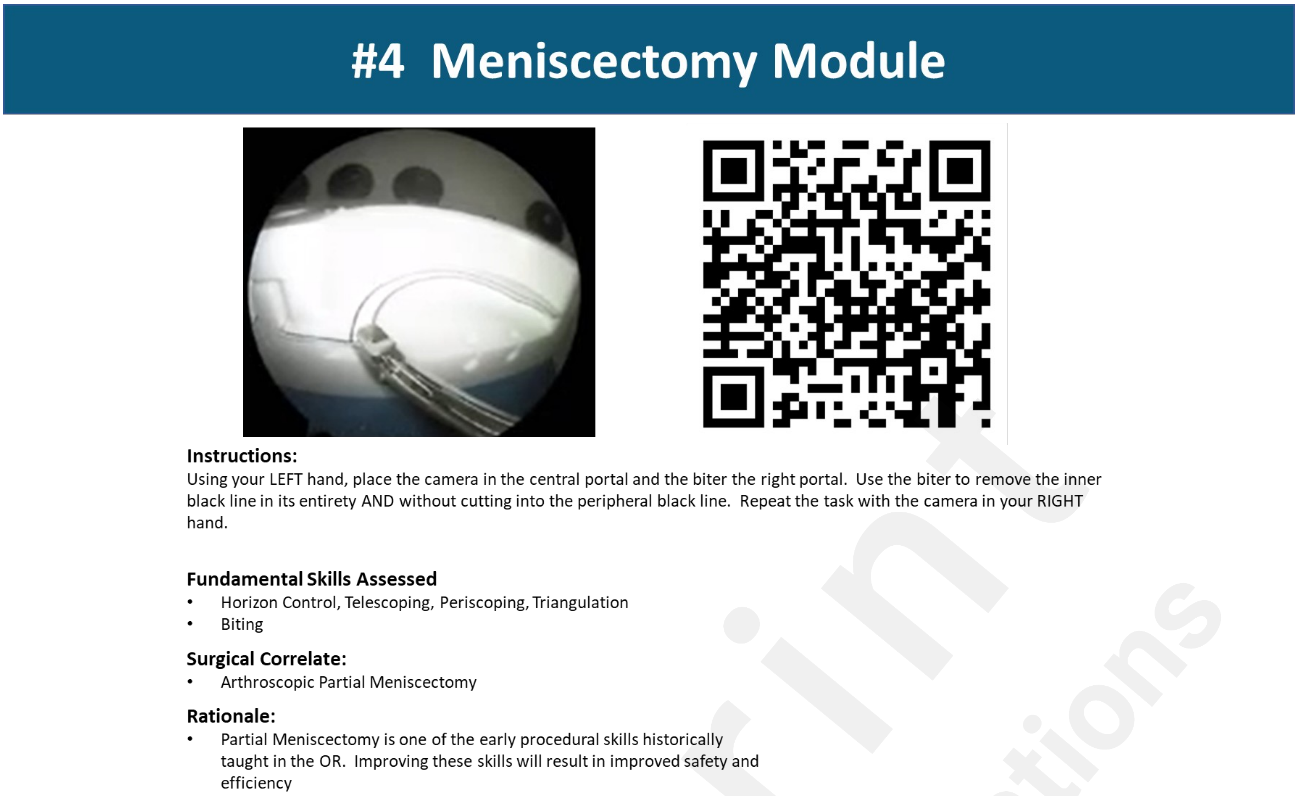
Figure 2. Ring Transfer Module

Maze: During the maze task, the subject is asked to use an arthroscopic probe to push a 3mm ball bearing though the maze (Figure 3). If the ball skips the track but stays on the platform, the subject may continue. If the ball jumps off the platform completely, this results in failure of the module.

Figure 3. Maze Testing Module

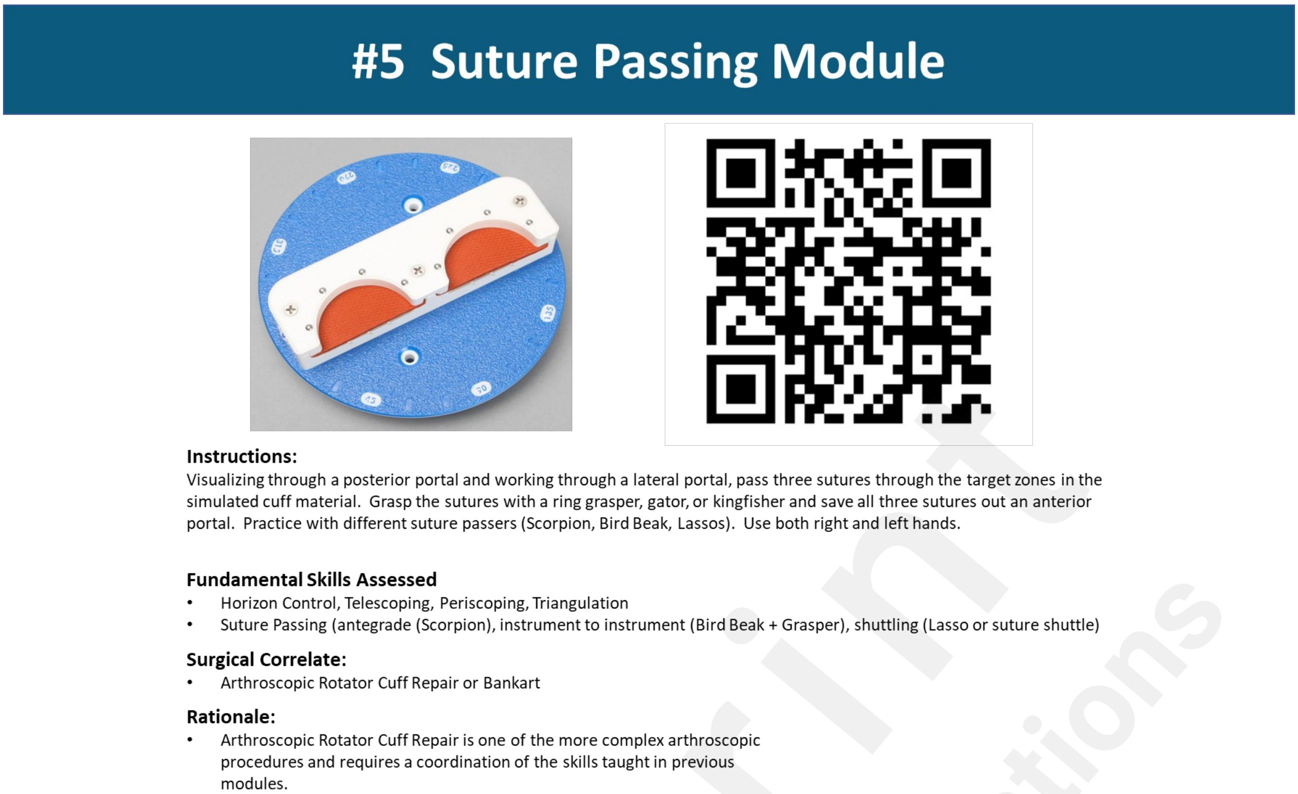
Meniscectomy: During the meniscectomy task, the subject is instructed to resect a paper "meniscus" template by removing all of the inner black line while leaving a complete outer black line margin (Figure 4). Failure to remove any part of the inner black line is called under-resection. Penetrating any part of the outer black line is called over-resection. Both under and over resection are counted as errors. Each instance is recorded as a separate error.

Figure 4. Meniscectomy Module



Suture Passing: During the suture passing task, the subject is instructed to use an antegrade suture passing device to pass three suture limbs from three previously loaded eyelets through the simulated rotator cuff as close to the pre-marked "targets" as possible (Figure 5). After passage, distance of the suture from the target is measured in millimeters and the total distance of all three sutures from their respective targets are recorded. A distance of more than 1mm of the pre-marked targets is considered an error. Unloading a suture from the eyelet results in failure of the module.

Figure 5. Suture Passing Module



Analysis:

Descriptive statistics were used for demographic variables, experience, handedness, efficiency (time) score, and precision (error) score. Mean performance time for all subjects was determined. Any value lying more than 2 standard deviations (SD) from the mean was excluded. The trimmed mean was used as the basis for determining the proficiency level benchmark for each task. Efficiency benchmarks were set at the minimum threshold of the mean time of the expert cohort. Precision benchmarks were set at the mean number of errors committed by subjects rounded to the nearest whole number. The benchmark was established as the mean performance when data from both hands was aggregated.

Results:

The mean age of the subjects was 43.9 (SD +- 9.0). They had an average of 10.5 (SD +- 8.3) years in practice and performed approximately 277 (SD +-125) arthroscopic cases per year. All were sports medicine fellowship trained and all were male. 7.5% were left-handed. There were no significant differences in demographic data between cohorts from the two courses (Table 1).

Table 1. Demographics

	Cohort 1	**Cohort 2**	**Mean**	**SD**	**P-Value**[1]
Age	43.1	44.65	43.9	8.96	.591
Gender	All Men	All Men	-	-	-
Percent Fellowship Trained	100%	100%	-	-	-
Average Years in Practice	9.5	11.4	10.5	8.28	.475
Number of Scopes per Year	275	278.25	277	125	.936
Percent Right-Handed	90%	95%	-	-	.548

Note: For age, number of years in practice, and number of scopes per year, two-sided t-tests were used to test for statistical significance. For handedness, chi squared test was used. No differences were statistically significant.

Probing:

Dominant Hand:

Efficiency: The mean time to complete the task was 92.5 (+- 17.6) seconds.

Precision: No errors were recorded.

Non-Dominant Hand:

Efficiency: The mean time to complete the task was 97.3 (+- 13.6) seconds.

Precision: No errors were recorded.

No difference between dominant and non-dominant hand was detected (*$P = 0.35$*).

Benchmark:

Complete the task in less than 95 seconds with no errors.

Ring Transfer:

Dominant Hand:

Efficiency: The mean time to complete the task was) 117.5 (+- 26.7) seconds.

Precision: The mean number of errors (dropped rings) was 0.6 (+-0.8).

Non-Dominant Hand:

Efficiency: The mean time to complete the task was 151.3 (+- 38.1) seconds.

Precision: The mean number of errors (dropped rings) was 1.1 (+-0.9).

Dominant/Non-Dominant hand performance was significantly different ($P < 0.001$).

Benchmark:

Complete the task in less than 134 seconds with no more than 1 dropped ring.

Maze:

Dominant Hand:

Efficiency: The mean time to complete the task was 89.1 (+- 24.3) seconds.

Precision: The mean number of errors (lost ball) was 0.2 (+-0.4).

Non-Dominant Hand:

Efficiency: The mean time to complete the task was 108.6 (+- 25.0) seconds.

Precision: The mean number of errors (lost ball) was 0.1 (+-0.3).

Dominant/Non-Dominant hand performance was significantly different ($P = .020$).

Benchmark:

Complete the task in less than 99 seconds with no errors (lost balls).

Meniscectomy:

Dominant Hand:

Efficiency: The mean time to complete the task was 73.2 (+- 20.7) seconds.

Precision: The mean number of errors (over or under-resection) was 0.1 (+-0.3).

Non-Dominant Hand:

Efficiency: The mean time to complete the task was 63.7 (+- 23.6) seconds.

Precision: The mean number of errors (over or under-resection) was 0.1 (+-0.3).

Dominant/Non-Dominant hand performance was not significantly different ($P = .140$).

Benchmark:

Complete the task in less than 68 seconds with no more than 1 area of over or under-resection.

Suture Passing:

Dominant Hand:

Efficiency: The mean time to complete the task was 177.5 (+- 41.2) seconds.

Precision: The mean number of errors (distance from target) was 0.5 (+-0.6).

Non Dominant Hand:

Efficiency: The mean time to complete the task was 211.9 (+- 40.9) seconds.

Precision: The mean distance in mm from the target was 0.6 (+-0.8).

Dominant/Non-Dominant hand performance was significantly different (*P* < *.001*).

Benchmark:

Complete the task in less than 195 seconds with no more than 1mm of distance from the target area (per target) and no suture anchor unloads.

For all modules, benchmark time is the mean performance between both hands. So, for example, if the right hand takes 60 seconds, and the left hand takes 30 seconds, the benchmark time is 45 seconds (90 / 2). Benchmarks for all modules are summarized in Table 2.

Table 2. Benchmarks

Module	Benchmark Time (seconds)[1]	Benchmark Errors
Probing Module	< 95	No Errors
Ring Transfer Module	< 134	No more than 1 dropped ring
Maze Module	< 99	No balls off platform
Meniscectomy Module	< 68	Only 1 area of over or under-resection
Suture Passing Module	< 195	< 1 mm of distance from the target area (per target) and no suture anchor unloads

Note: Benchmark time is the mean performance between both hands. So for example, if the right hand takes 60 seconds, and the left hand takes 30 seconds, the time to compare against the benchmark is 45 (90 / 2).

Discussion:

The FAST program consists of a curriculum, a simulator, and a series of tests, which enable trainees to iteratively practice fundamental skills outside of the operating room and ideally before performing surgery on patients. Training such motor skills outside of the OR is crucial especially in arthroscopy which has a steep learning curve.[11] The FAST program's hands-on design is in alignment with the Institute of Medicine's recommendations for graduate medical education. They aim to transition from process driven training to a more outcome-driven approach. Instead of the assumption that residents acquire their needed skills after completing a certain number of procedures or after a certain amount of time in training, the Institute recommends evaluating proficiency in such skills before advancement.[12] The FAST program utilizes this proficiency-based progression approach to training that encourages "deliberate practice" to improve motor skills.[13] With the establishment of benchmarks for each FAST module, a resident is able to receive real time objective feedback on their performance and encouraged to strive to be comparable to experienced arthroscopy surgeons. With the accessibility of the workstations, residents are able to obtain additional practice repetitions and adjust their technique as needed to meet the established standard.

The FAST program can be integrated as early as intern year of orthopedic training so that young surgeons can develop foundational psychomotor skills before even touching an arthroscope in the OR. This early exposure to arthroscopic instruments and techniques can instill confidence in a new resident and their abilities, help them develop good habits early, and potentially decrease patient morbidity. Studies have demonstrated that medical students and residents who train with simulators perform better in the OR than their counterparts without simulator training.[14] With improved resident performance in the OR, a faculty member walking a resident through the case would likely feel more comfortable increasing resident autonomy and valuable OR time can be spent teaching and instructing on the unique nuances of a particular case instead of on basic skills.

The FAST workstations are easily accessible, cost-effective, and efficient. They require a simple set up and at our institution, they are available in the skills laboratory for all residents to use at any time.

Residents can easily independently set up the workstation in the laboratory as long as they have an arthroscopy tower or USB camera with which to practice. Currently we have each of the testing modules set up in front of a computer monitor with all the instruments available that are necessary to complete the task. We have a QR code that links to a video of the task and instructions mounted on the wall above each of the modules (Figure 6). We utilize iPevo cameras when a stationary light source is sufficient (knot tying) and Sawbones USB cameras when a replica of an arthroscope is required (ring transfer). We have found that having easy to access instructions and all modules already set up increases simulator utilization and maximizes resident time. We typically introduce FAST during a 2-3 hour session with all interns that is proctored by an instructor during their skills month. This familiarizes them with the simulator and modules. They are expected to practice to proficiency and then use the simulators to refine their skills prior to their arthroscopic rotations.

Figure 6. Simulation Lab Set-Up

Prior papers have aimed to establish clear quantitative benchmarks for simulation training based on the mean performance of an experienced surgeon cohort.[15] One such paper by Pedowitz et al. established the benchmark for the knot tying module in the FAST program, which is the last module to be completed in the series.[16] It evaluated the performance of 50 faculty members in attendance at

Arthroscopy Association of North America resident arthroscopy courses. The two faculty cohorts had an average of 19.3 and 19.9 years of experience in practice. A benchmark was established using data from the more successful of the two faculty cohorts and established proficiency as equal to 2 knot failures or less out of 5 knot attempts when using the knot tester workstation. This randomized, prospective study then evaluated a training group of 44 postgraduate year 4 or 5 orthopedic residents. They were divided into 3 subgroups: group A received standard didactic training, group B was allowed additional knot tying workstation practice, and group C underwent proficiency-based progression training with the knot tying workstation. While the aggregate resident knot failure rate of 26% was higher than the 22% knot failure rate of the faculty, resident group C had only an 11% knot failure rate with 94% of residents in this group passing the threshold. This paper demonstrated both a system to establish a benchmark standard as well as proved that proficiency-based progression training improves the likelihood of meeting said benchmarks. The arthroscopic knot tying station is the last in the sequence of the FAST workstation modules as it tests one of the more complex skills in arthroscopy. The purpose of the current investigation was to establish objective benchmarks for the remaining five additional FAST workstation modules: Probing, Ring Transfer, Maze Navigation, Partial Meniscectomy, and Suture Passage.

These benchmarks derived from the performance of fellowship-trained sports medicine faculty were designed to be both realistic and achievable for residents. The six modules progress from basic skills to more complex tasks. The first module, Probing, allows residents to establish basic arthroscopic skills of horizontal control, telescoping, periscoping, and triangulation in order to feel comfortable performing a diagnostic arthroscopy. Gaining familiarity with the arthroscope in this module lays the foundation for establishing visualization in the remainder of the tasks and in the OR. The second module, Ring Transfer, enforces these skills and allows the resident to develop proficiency with the arthroscopic grasper for when they are tasked with performing an arthroscopic loose body removal.

The dexterity with the instruments developed in this module is applicable to using arthroscopic instruments to manipulate tissues or implants in all arthroscopic procedures. The next module, Maze Navigation, builds on prior probing skills from the first module and develops tracking skills with nonstationary objects. This skill is necessary to develop before interventional arthroscopy can be performed. While the first three modules focus more on skills generalization, the final three modules correlate even more closely with specific surgical interventions thereby focusing more on skills transfer. The fourth module directly simulates completing a partial meniscectomy with a benchmark designed to encourage adequate amount of resection. During this practice, residents develop more familiarity with a biter and the ability to maneuver more deliberately and precisely. Resection of a paper "meniscus" is a safer alternative to a new resident damaging cartilage with the biter or over resecting and destabilizing a meniscus tear because they are using a biter for the first time in an actual patient's knee. The second to last task, Suture Passage, integrates the use of other new instruments including an antegrade suture passer, a piercing suture passer/retriever, and a suture lasso or suture shuttle. This task's surgical correlate is an arthroscopic rotator cuff repair or Bankart repair, which are some of the more complex arthroscopic procedures. Completion of this task relies on the mastery and coordination of skills obtained in the previous modules. The last module, Knot Tying, allows residents to evaluate the biomechanical integrity of their arthroscopic knots in a setting safer than discovering loose knots in a failed arthroscopic suture repair. In conclusion, a resident's ability to meet the time constraints and limit their errors for each task translate into a more efficient and accurate performance in the OR which promotes patient safety.

In establishing the benchmarks, there was a statistically significant difference between the faculty surgeons' dominant and non-dominant hand with the Ring Transfer, Maze, and Suture Passing. However, surgeons have to be ambidextrous. Which hand holds the arthroscope and which holds the remaining instruments is often based on the laterality of the procedure. Previous studies have shown that experienced arthroscopic surgeons are more ambidextrous than novices.[17] Therefore, the FAST program requires all tasks be completed with the right hand and the left hand in separate attempts in order to develop skills in both hands regardless of hand dominance. Establishing separate benchmarks for the dominant and the non-dominant hand based on the differences seen in the expert cohorts was considered. That said, scientific ideal and practicality need to be weighed equally in this case. The FAST Program puts multiple new demands on trainees and faculty at the programs that adopt it. Ultimately, in order to be successfully adopted, it needs to be easy to implement. Based upon our experience facilitating many FAST courses at the Orthopaedic Learning Center in Chicago and at multiple residency programs, it was felt that a single benchmark for each task was necessary. We also discussed whether to take the mean performance of both hands or to set the benchmark at the level of the dominant hand. The mean performance was chosen. This was felt to be the best compromise between ensuring adequate ambidexterity while also recognizing that differences exist, even in expert faculty. The FAST program is designed to enhance surgical skills and promote deliberate, repetitive practice, to a benchmark. We were concerned that setting the benchmark to that of the faculties dominant hand performance may make it significantly harder to achieve for the trainees. The goal is for residents to be able to pass the FAST program by the end of their 3rd year in training and it was felt that the likely significant increase in repetitions required to meet the more stringent benchmark would be frustrating and time consuming for residents who already have many other competing demands. Passing the FAST program at the end of the PGY-3 year does not mean that residents are proficient at arthroscopy. It means that they have sufficiently practiced and likely have improved their basic fundamental arthroscopic skills by meeting a minimum threshold of performance. They still have additional years in residency to build upon the skills acquired in the FAST program. Further study evaluating the transfer validity of the FAST Program to objective surgical improvement in the OR will ultimately be the best way to determine the appropriateness of these benchmarks. This benchmarking is foundational work that is required to enable such an investigation.

The development of the FAST program benchmarks is one of the factors that allow this to be a self-sufficient progression learning tool setting it apart from other skills programs. In 2007, the Carolinas Medical Center (CMC) integrated a laparoscopic skills curriculum into their general surgery residency program.[18] A skills laboratory coordinator needed to be present to record the duration of participation in each task and keep track of errors. In contrast, the FAST program is designed as a web-based program residents can access independently at a time convenient for them. A stopwatch is built into the program to record time to complete a task and each task has a section to input the number of errors. These factors determine progression to the next module, all of which can be done at the resident's own pace. The paper about the CMC program by Stafanidis et al. describes feedback occurring after each training session or when a resident is called in by the coordinator. With the FAST program, instant feedback is available with the clear benchmarks established for each task.

Limitations/Future Studies

A limitation of this study was that the included subjects consisted exclusively of faculty teaching at the AANA Fundamentals of Arthroscopic Surgery Residents Course. Ultimately, this was a convenience sample due to the significant logistical hurdles that would have been required should we have chosen another methodology to obtain data from a large number of expert Orthopaedic surgeons. This may introduce a selection bias of surgeons who may not be fully representative of a wider population of sports fellowship trained surgeons. The included cohort were deemed experts by virtue of their completed training, but there were outliers among the subjects' performance. There were 21 outlier data points out of a total of 320 data points, which were subsequently excluded from the data set before formulating the benchmarks. Another limitation of this study is that it does not demonstrate feasibility of the FAST program or transfer validity. Further studies will be needed to establish these factors. Further investigation is also needed to determine the average number of repetitions and practice time required to meet the proficiency benchmarks. This can be then sub-analyzed based on training level. This will provide a clearer estimated duration of the FAST programs for other orthopedic residency programs interested in integrating the FAST program into their curriculum. Further application of the FAST program can also be used to assess whether those who reach proficiency benchmarks perform better than those with no simulation training on other simulated surgical procedures and in the OR for comparable surgical procedures. Lastly, further studies are needed to investigate which subset of residents achieve the most benefit from the FAST program as determined by the greatest improvement in arthroscopic skills. This can be used to determine in which year of residency training the FAST program should be integrated.

Conclusions:

The FAST workstation and its modules are a proficiency-based learning tool for residents to safely and effectively develop fundamental arthroscopic skills outside of the OR. This study established time and error benchmarks based on experienced faculty performance to promote efficiency and precision during resident arthroscopic training.

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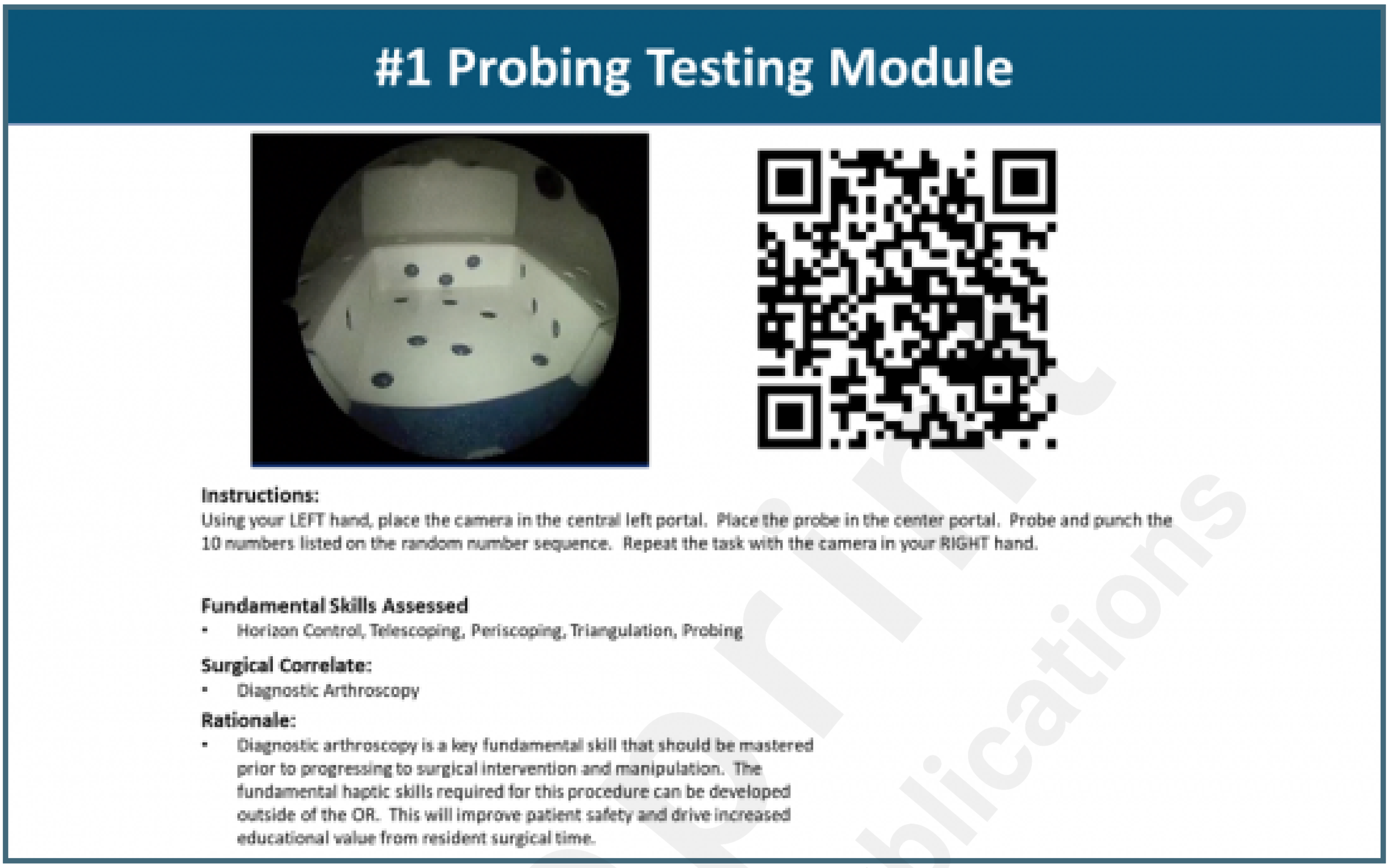
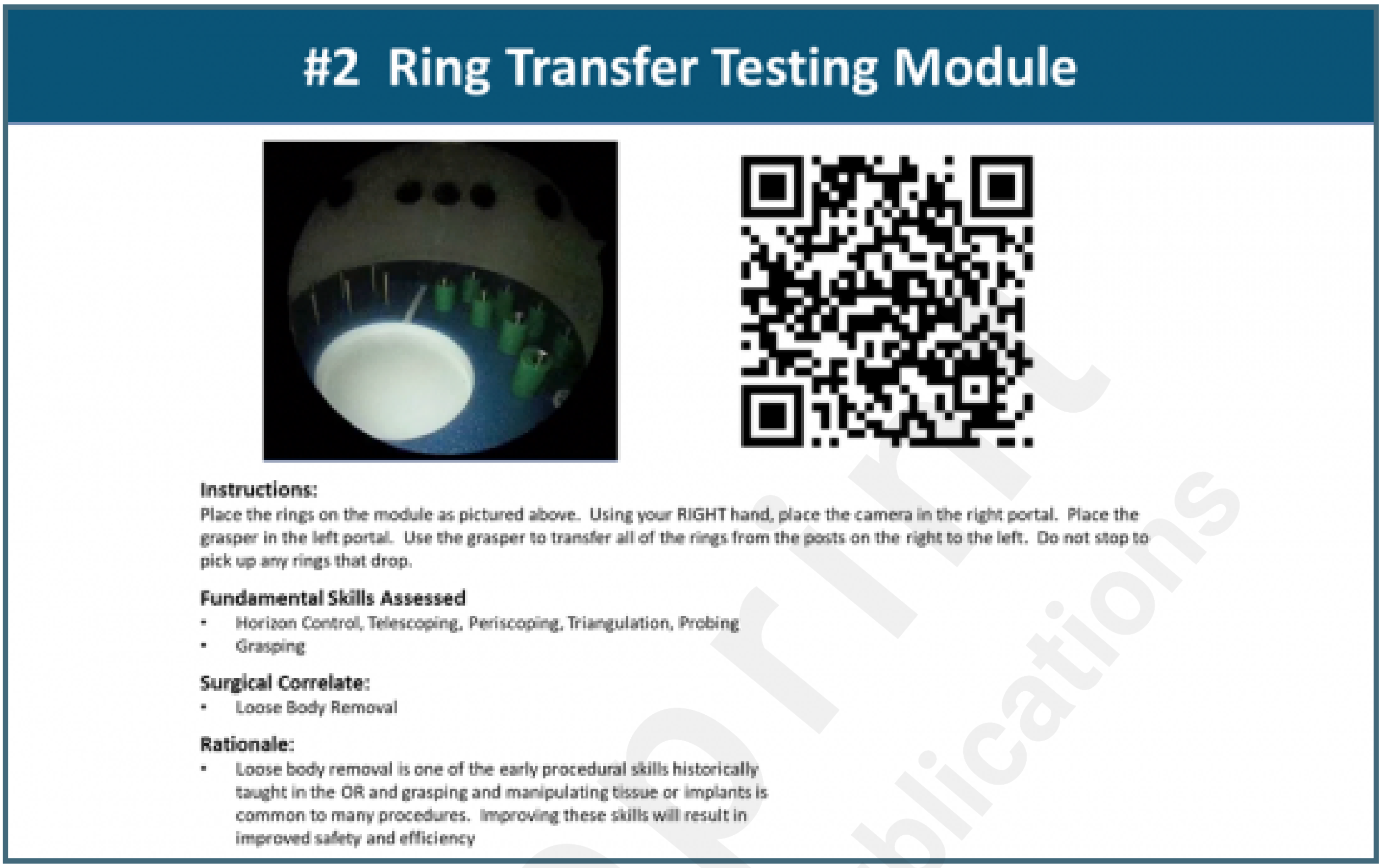
Supplementary Files

Figures

Probing testing module.

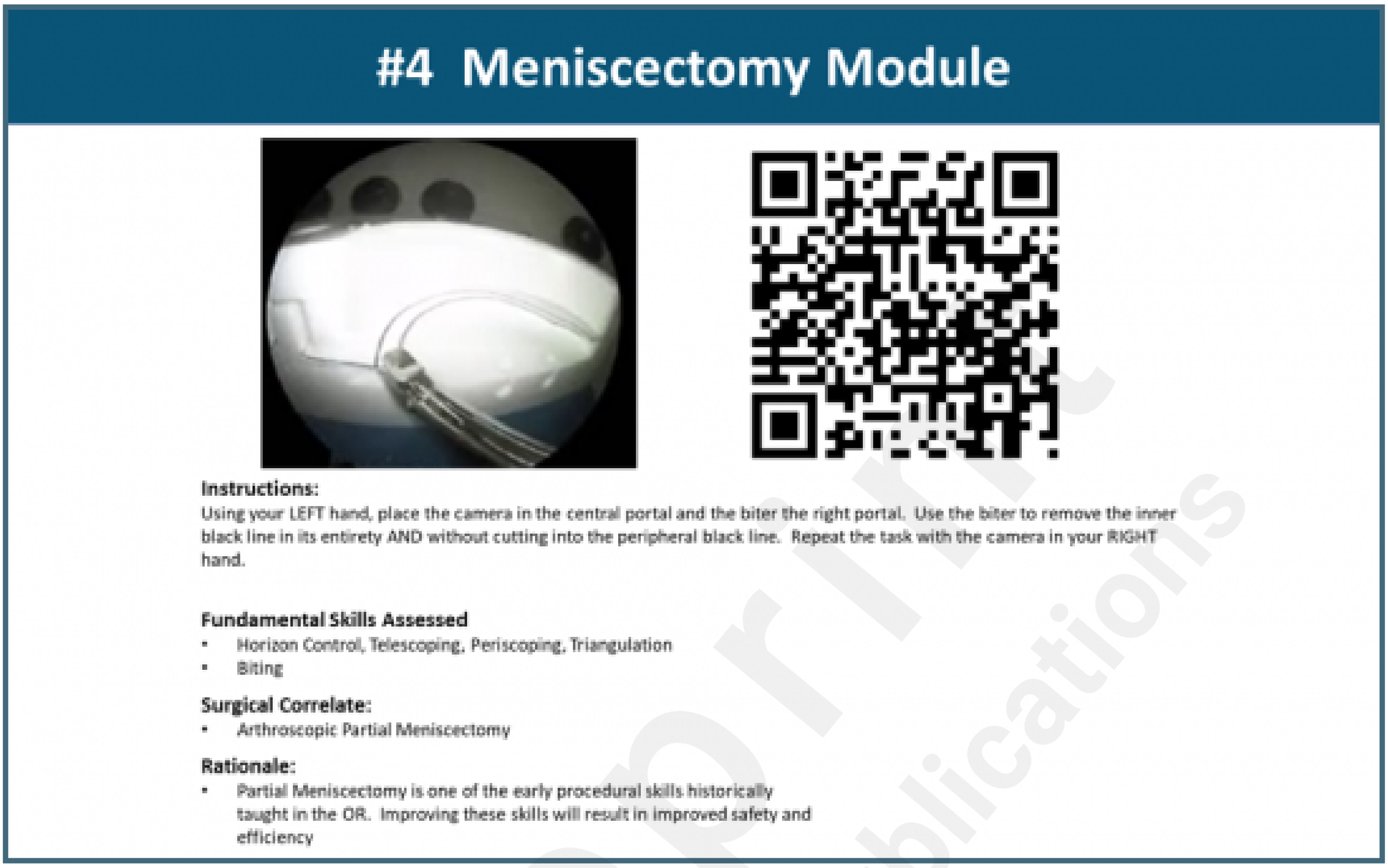


Ring transfer module.

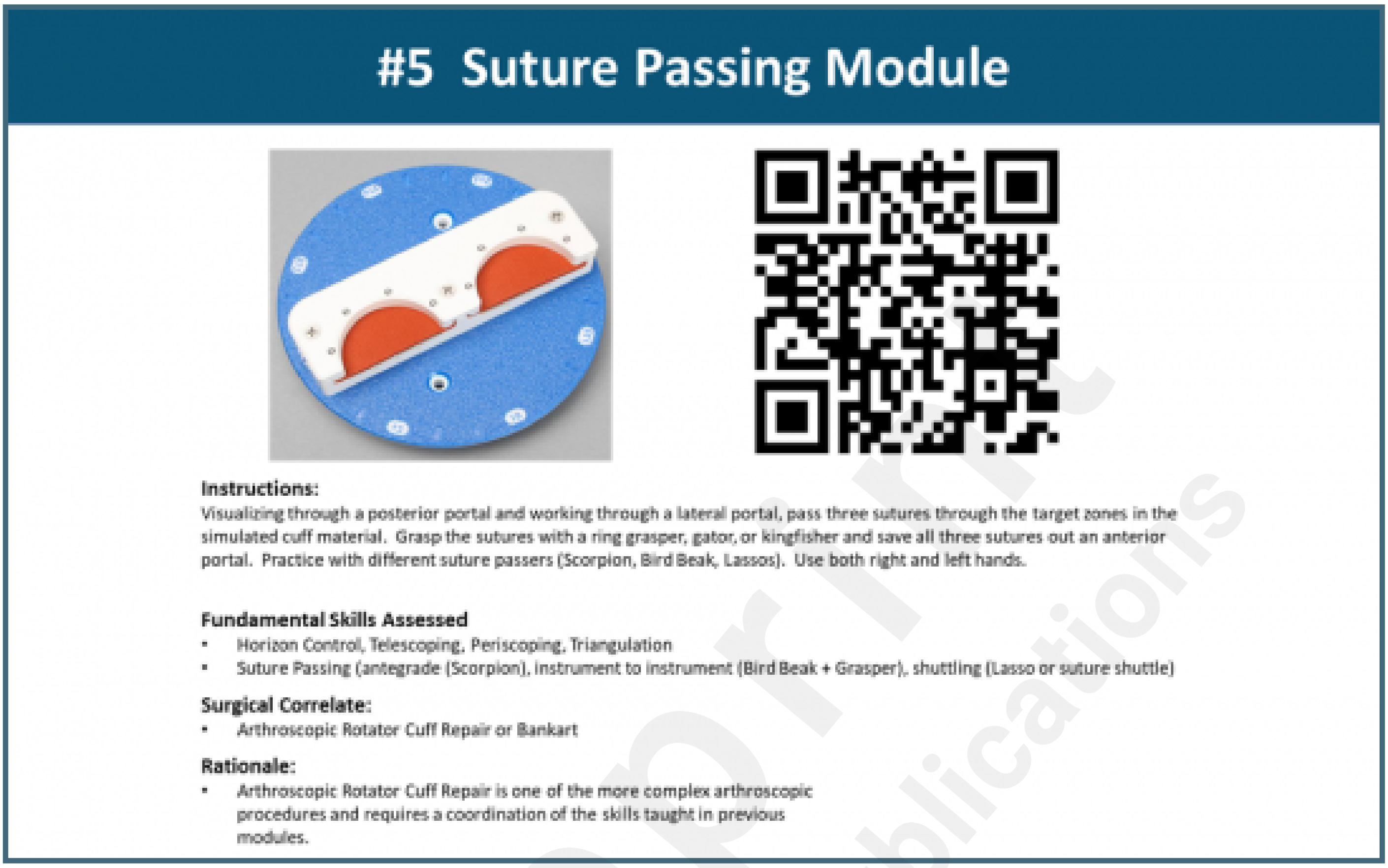


Maze testing module.

Meniscectomy module.



Suture passing module.



Simulation lab set-up.