Development of a Spine Surgical Skills and Written Assessment for Orthopaedic Surgery Residents

Robert Ryu, MD, Andrew Campbell, MD, Nikhil Jain, MD, Kari Stammen, AT, and Elizabeth Yu, MD

The Ohio State University Wexner Medical Center, Department of Orthopaedics, Columbus, Ohio

OBJECTIVE: The objective of this study was to develop an assessment module for orthopaedic spine surgery residents which is cost-effective and can reliably test knowledge and surgical skills.

DESIGN: A ten-question multiple choice question and hands-on spine sawbones combination assessment was prospectively administered to consenting PGY-3 and PGY-4 residents before and after their 8-week spine rotation. Pre- and postrotation scores were compared using the paired *t*-test.

SETTING: The Department of Orthopaedics, The Ohio State University Wexner Medical Center, a large academic medical centre providing primary and tertiary care.

PARTICIPANTS: Orthopaedic resident physicians.

RESULTS: A total of 21 residents (15 PGY-3, 6 PGY-4) participated in the study. The mean pre- and postrotation written test score was 7.38 ± 1.53 and 9.24 ± 0.83, respectively ($p < 0.001$). Corresponding surgical skills assessment scores were 95.4% ± 4.7 and 97.1% ± 2.6, respectively ($p = 0.10$). Overall, the postrotation written and surgical scores improved and showed less variation about the mean.

CONCLUSIONS: This combination assessment measured improvement in below-average scoring residents and maintenance or improvement in residents with average and above average prerotation scores. (J Surg Ed 76:1094−1100. © 2019 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: Spine surgery, Resident education, Surgical skills, Assessment

COMPETENCIES: Patient Care, Medical Knowledge

INTRODUCTION

The primary aim of academic residency programs is to train resident physicians to provide safe and competent patient care. The optimal method to assess residents' clinical and surgical competence has been debated.[1] Program directors often rely on faculty observation, which is inherently subjective.[2] A variety of methods have been proposed to improve the objectivity of resident competency assessment, including: written examinations, medical record audits, computer-simulated clinical encounters, clinical evaluation exercises, and standardized patients.[1] While these methods may be adequate for gauging clinical knowledge, it is more challenging to assess surgical competence.

Beginning in July 2013, the American Board of Orthopaedic Surgery (ABOS), and the Residency Review Committee mandated the introduction of simulation training to improve surgical aptitude by establishing core competency goals and objectives.[3] The changes were made to help residents acquire fundamental skills early in their training to better prepare them for more advanced training later. Under the direction of the ABOS, a variety of modules have been implemented in an attempt to improve orthopaedic residents' surgical skills, but a module covering orthopaedic spine surgical skills has not yet been created. Furthermore, cadaveric training provides a realistic alternative to in vivo training, but its high cost may be prohibitive for routine use.

The aim of this study was to create a cost-effective and valid module to reliably assess orthopaedic surgery residents' spine surgical skills. The primary objective of this study was to implement a spine surgical skills assessment in an orthopaedic spine rotation and to obtain normative values for each postgraduate year level. The secondary objective was to determine the change in assessment measures following a rotation on the spine service.

Sources of support: None

Correspondence: Inquiries to Elizabeth Yu, MD, Department of Orthopaedics, The Ohio State University Wexner Medical Center, 725 Prior Hall, Columbus, OH 43210; fax: (614) 293-4755; e-mail: Elizabeth.Yu@osumc.edu

  1931-7204/$30.00
https://doi.org/10.1016/j.jsurg.2019.01.011

METHODS

Combination Assessment Module

We developed a two-pronged assessment including a written exam and hands-on skills assessment. The written exam is intended to test residents' clinical knowledge of anatomy and surgical technique. The hands-on skills portion is designed to test residents' manual abilities to perform a surgical task. Lumbar sawbones models were used for the hands-on skill assessment. Lumbar sawbones are more cost-efficient for routine implementation than cadaveric specimens. **These lumbar spine sawbones (part number 1324) were purchased at $70 per unit from Sawbones Worldwide, Pacific Research Laboratories, Inc.**

All residents consented to participate in the study and were then asked to complete both assessments before and after their spine rotation. Residents at our institution rotate through the spine service as PGY-3 residents and return again as PGY-4 residents. The prerotation assessment began with a brief introductory didactic session, followed by a written exam with 10 multiple choice questions **(Appendix 1)**. The **number of correct answers was** recorded **(Appendix 2)**. Next, the resident performed the hands-on assessment **(**Fig. 1**)**. A computed tomography (CT) scan of the sawbones was available to the residents for preliminary planning**. If asked by a resident, the proctor would give instruction on pedicle screw placement, by guiding them on instrument use, reminding them of specific steps, and also describing the appropriate trajectory of a pedicle screw. Additionally, the PGY-3 and PGY-4 residents worked together, helping each other. Nevertheless, each** resident was given 30 minutes to place 12 pedicle screws at levels from L1 to S1. **From L1 to L2, 5.0 mm x 40 mm screws were placed; at L3, 5.0 mm x 45 mm screws were placed; from L4 to L5, 6.0 mm x 45 mm screws were placed; and at S1, 6.0 mm x 50 mm screws were placed.** The number of correctly placed pedicle screws **was** recorded. The senior author, an attending spine surgeon, scored the sawbones models. A point each was deducted for evidence of medial wall, lateral wall, superior wall, or inferior wall breaches. The floor of the pedicle path was assessed and a breach at any level except for S1 was considered a violation and deducted a point. No point was subtracted for either intact or breached floor of S1.

Within 2 weeks of the completion of the spine rotation, residents repeated the written and skills assessments. The postrotation assessment includes the same combination assessment module as given before the rotation. However, the questions on the written assessment were assigned a new random order.

Data Collection and Analysis

The assessment modules were administered to consenting residents in a prospective manner at a single institution beginning from July 2015 to January 2018. The written exam was scored with one point for each correct answer and was scored out of ten by the study coor-

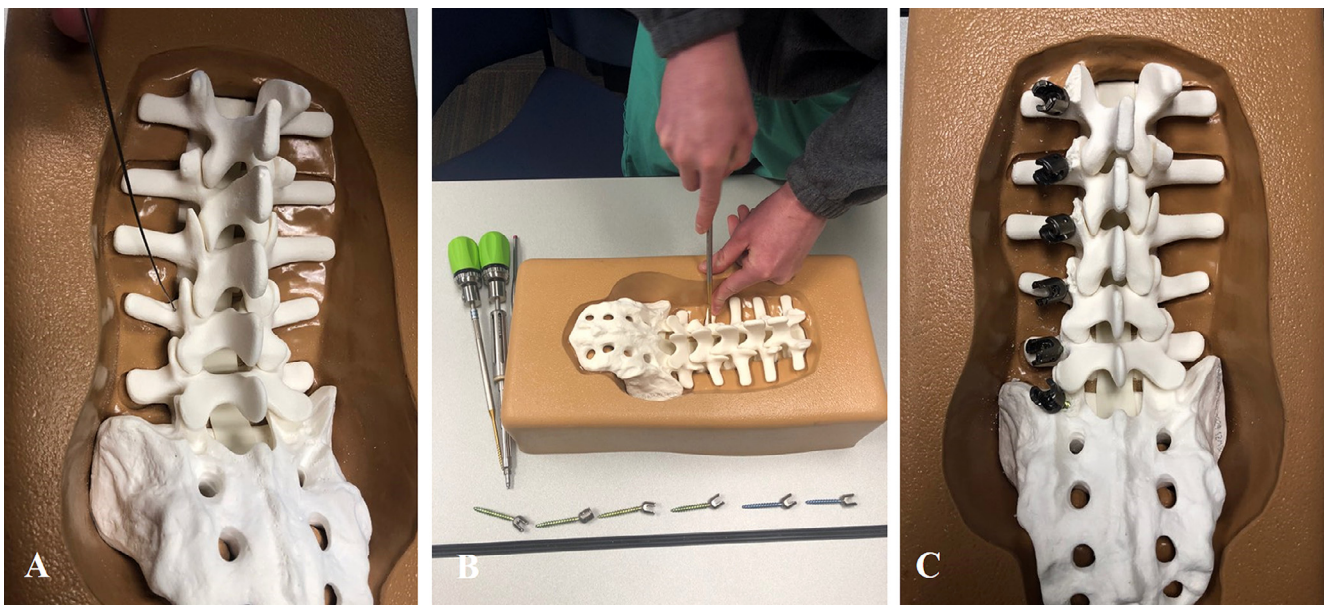

FIGURE 1. Pedicle screw starting position (A). Resident performing surgical skills assessment (B). Pedicle screws inserted on one side from L1 to S1 (C).

dinator. The sawbones were de-identified and presented to the principal investigator (EY) for scoring. The surgical skills assessment was scored as percentage out of the maximum possible score. Although all residents consented to participate, the principal investigator was blinded to residents' willingness to participate in the study as well as to written assessment scores. For the entire sample, scores from the written assessment have been described as mean with standard deviation (SD). Pre- and postrotation assessments were compared by paired t-test. A p value less than 0.05 has been considered as statistically significant. Statistical analysis were performed using SAS software (StataCorp, College Station, TX).

RESULTS

Twenty-one residents were enrolled in the study and completed both the prerotation and postrotation assessment modules. Of these, 15 were PGY-3 level residents' and six were PGY-4 level residents at the first time of participation in the study. Seven PGY-3 residents returned as PGY-4 residents and completed the assessments again.

Individual written test scores for each resident pre- and postrotation have been given in Figure 2. The mean prerotation written test score was 7.38 ± 1.53 out of 10 (range 5-10), and the mean postrotation written score was 9.24 ± 0.83 (range 7-10). There was a statistically significant improvement in written test scores **($p < 0.00001$)**.

Results of the surgical skills assessments are graphically depicted in Figure 3. The mean prerotation surgical skills assessment score was 95.4% ± 4.7 (range 83.3-100); the mean postrotation surgical skills assessment score was 97.1% ± 2.6 (range 91.7-100). There was a mean improvement of 1.7% in surgical skills assessment scores. Although **there appeared to be an improvement in skills,** it was not found to be statistically significant ($p = 0.10$).

Seven residents (resident IDs 001, 005, 007, 009, 010, 012, and 021) completed the study assessment modules over 2-consecutive years, first as PGY-3 and then as PGY-4. The comparison of rotation scores among the seven residents who completed assessments as PGY-3 and a PGY-4 is depicted graphically in Figures 4 and 5. Only pre- and postrotation written scores taken as a PGY-3 showed a significant increase. When taken as a PGY-4 for the second time, the mean prerotation written test score was 9.14 out of 10 (SD:0.90, range 8-10); the mean postrotation written score was 9.71 (SD:0.76, range 8-10). There was not statistically significant improvement in written exam scores ($p = 0.10$). When taken as a PGY-4 for the second time, the mean prerotation surgical skills assessment score was 97.14% (SD: 3.00, range:93.3%-100%); the mean postrotation surgical skills assessment score was 97.5% (SD:1.96, range:95%-100%). There was not a statistically significant improvement in surgical skills scores ($p = 0.80$). When comparing directly the PGY-3 and PGY-4 changes in data, the mean PGY-3 postrotation written score was 9.57 ± 0.53 (range 9-10), and the mean PGY-4 prerotation written score was 9.14 ± 0.89 (range 8-10). This did not represent a statistically significant difference ($p = 0.30$) from

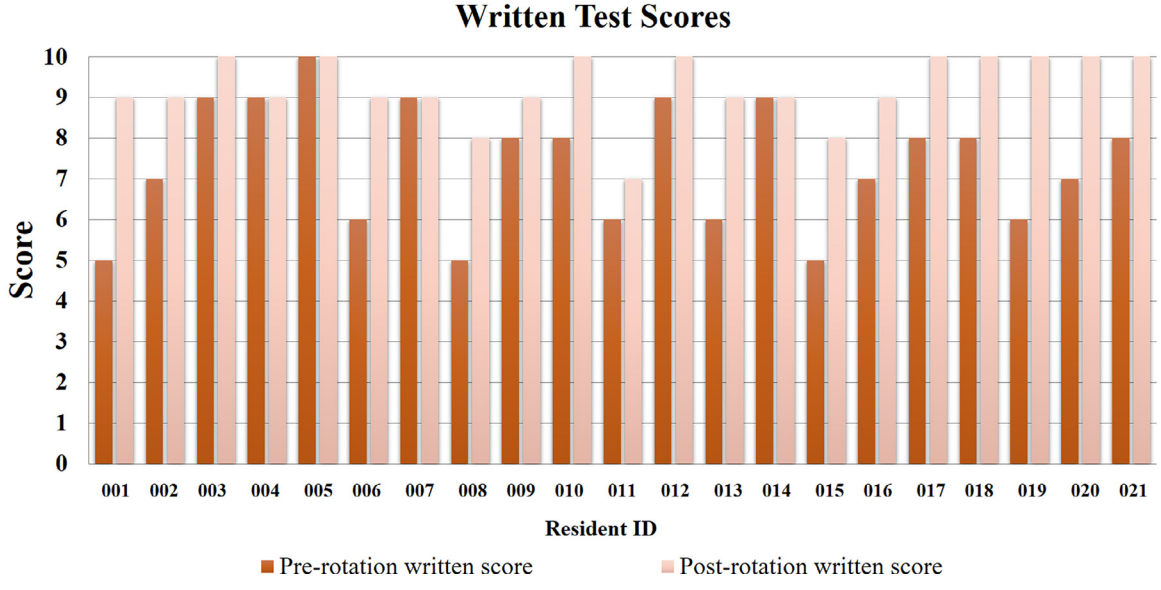

FIGURE 2. Comparison of pre- and postrotation written test scores for each resident.

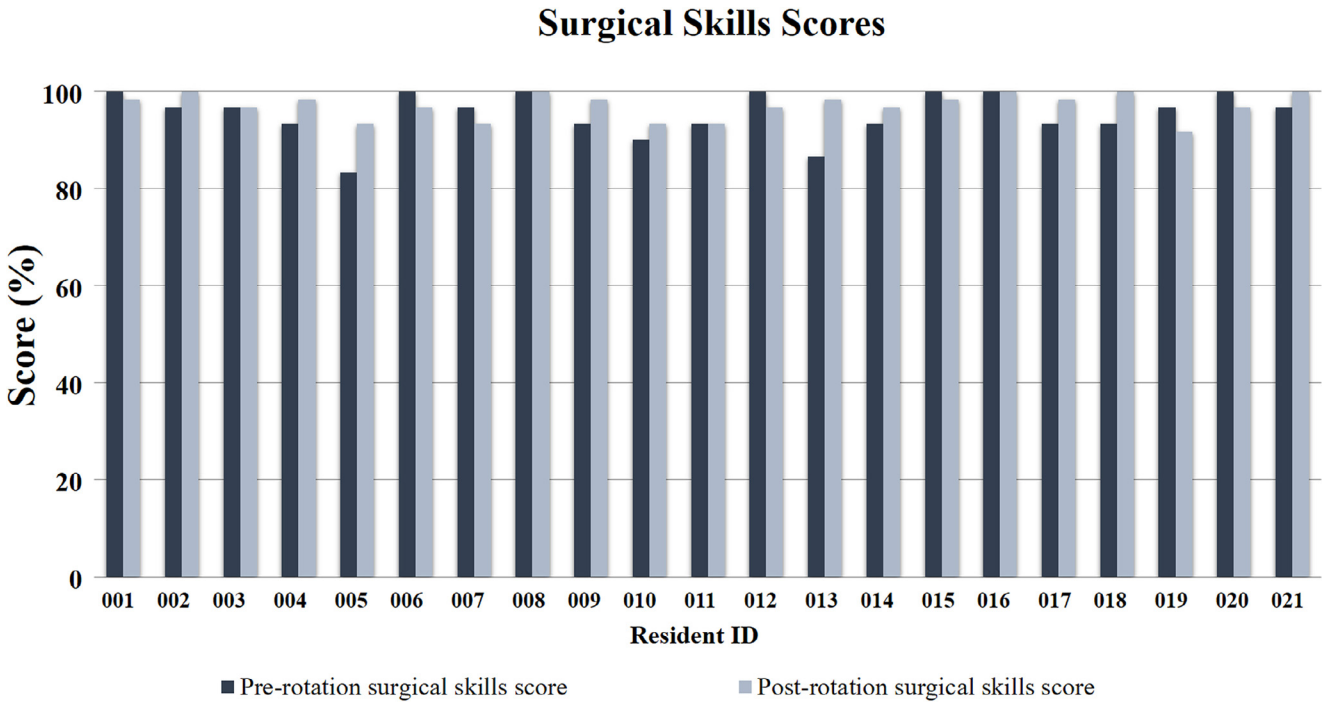

FIGURE 3. Comparison of pre- and postrotation surgical skills exam score for each resident.

postrotation PGY-3 written assessment to prerotation PGY-4 written assessment. For the surgical skills assessment, the mean PGY-3 postrotation skills score was 96.2% ± 2.84 (range 93.3-100), and the mean PGY-4 prerotation skills score was 97.1% ± 3.00 (range 93.3-100); this also did not represent a statistically significant difference ($p = 0.55$) from postrotation PGY-3 skills assessment to prerotation PGY-4 skills assessment.

DISCUSSION

Orthopaedic resident training is evolving as the traditional educational model is supplemented by dedicated clinical skills curricula.[4,5] Simulation-based education tools have been introduced to augment orthopaedic trainees' ability to perform many relevant skills, including manual reduction manoeuvres, casting and bracing,

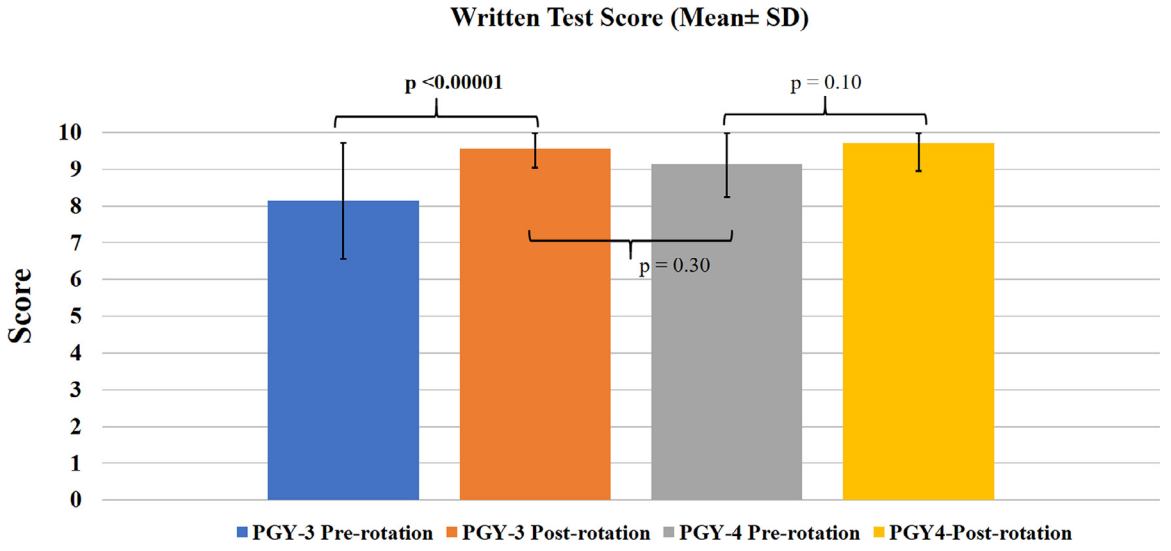

FIGURE 4. Comparison of written scores for residents who completed assessment as PGY-3 and PGY-4 (n = 7).

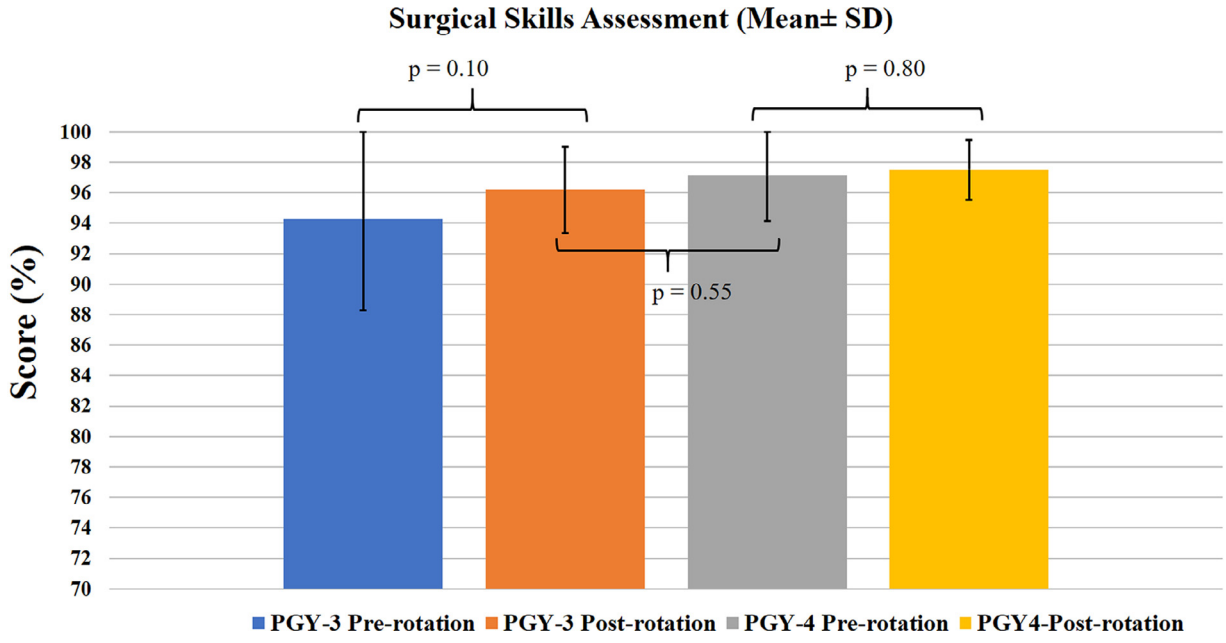

FIGURE 5. Comparison of surgical skills scores for residents who completed assessment as PGY-3 and PGY-4 (n = 7).

arthroscopy, percutaneous pinning, and instrumentation tasks.[6–14] However, literature on integrated spine-surgery resident education is sparse. To our knowledge, this study represents the first report of a combined didactic and simulation-based curriculum in orthopaedic resident spine surgery education.

There are few reports in the neurosurgery literature on spine surgery simulation in the resident curriculum.[15–17] Calio et al. reported that a cadaveric spine surgery training lab may lead to improved resident confidence, satisfaction, and perception of patient safety.[18] However, cadaveric training is limited by expense and accessibility of cadavers. Moreover, the assessment of screw placement may be a challenge in cadaveric specimens. In this study, **at $70 per unit,** inexpensive sawbones models were used, which allowed for rapid and reproducible assessment of resident proficiency in performing a hands-on task.

The vast majority of orthopaedic surgery residents graduate from their program, and 77% to 89% of residents pass part 1 of the ABOS boards.[19] While academic residency programs enable graduates to achieve adequate board scores, ensuring they gather the necessary surgical skills for safe patient care is equally important. In this study a two-pronged assessment was implemented that demonstrated a significant improvement in spine clinical knowledge after a standard PGY-3 spine rotation. Residents' also improved their scores on the surgical skills task. An important finding was that the lowest score on the postrotation assessment was 10% higher, and the variation of scores was more consistent around the mean as compared to the prerotation assessment. This shows that our two-pronged assessment was able to measure improvement in residents who scored below-average before their rotation and showed maintenance or slight improvement of scores in residents who scored average and above average the first time around.

Residents who completed the assessment over 2 consecutive years appeared to reach a plateau in their performance. This likely represents a ceiling effect in the written and surgical skills assessment scores for the given difficulty. We anticipate incorporating written and surgical skills assessments with increasing grades of difficulty in a graduated fashion in the future. Transition to written test to computerized tests is envisioned. Additional tasks will ultimately be developed to test more sophisticated skills in residents who have already demonstrated competence in basic principles of spine surgery.

There are some limitations to this study. First, it was a single institution study with a single sample size. Future studies involving multiple centres across the country will help further validate the effectiveness of our proposed assessment module. The written exam and surgical skills assessment were only related to pedicle screw placement. The limited number and type of questions and surgical skills assessed

led a ceiling effect. Additionally, PGY-3 and PGY-4 residents work together and are coached by the proctor through the prerotation sawbones skills assessment, but not the post-test, which may falsely elevate the prerotation score.

Despite these limitations, our proposed assessment module is the first of its kind to assess orthopaedic residents' spine surgical knowledge and skills in an inexpensive and reproducible manner. The written exam tests the residents' cognitive skills in anatomy and surgical method. The hands-on skills portion tests the residents' physical abilities to perform surgical tasks on a sawbones model. We believe our study provides preliminary confirmation of the concept of two-pronged assessment of residents' knowledge and skills. Such a model can be modified to increase the spectrum and difficulty of questions and skills tested, especially as residents progress through the ranks. Employing this exercise prior to a spine rotation provides residents the opportunity to hone anatomic knowledge and engage in hands-on practice without increased cost of a cadaveric specimen or first-time exposure in vivo.

REFERENCES

1. Silwa JA, Kowalske KJ. Assessing resident clinical competence. *Am J Phys Med Rehabil*. 2000;79:468–473.
2. Noel GL, Herbers JE, Caplow MP, Cooper GS, Pangaro LN, Harvey J. How well do internal medicine faculty members evaluate the clinical skills of residents? *Ann Intern Med*. 1992;117:757–765.
3. ABOS Surgical Skills Modules for PGY-1 Residents. Available at: https://www.abos.org/abos-surgical-skills-modules-for-pgy-1-residents.aspx. (Last accessed: January 15, 2018).
4. Shanedling J, Van Heest A, Rodriguez M, Putnam M, Agel J. Validation of an online assessment of orthopedic surgery residents' cognitive skills and preparedness for carpal tunnel release surgery. *J Grad Med Educ*. 2010;2:435–441.
5. Ford SE, Patt JC, Scannell BP. A comprehensive, high-quality orthopedic intern surgical skills program. *J Surg Educ*. 2016;73:553–558.
6. Ruder JA, Turvey B, Hsu JR, Scannell BP. Effectiveness of a low-cost drilling module in orthopaedic surgical simulation. *J Surg Educ*. 2017;74:471–476.
7. Heaton SR, Little Z, Akhtar K, Ramachandran M, Lee J. Using simulation to train orthopaedic trainees in non-technical skills: a pilot study. *World J Orthop*. 2016;7:475–480.
8. Martin KD, Patterson DP, Cameron KL. Arthroscopic training courses improve trainee arthroscopy skills: a simulation-based prospective trial. *Arthroscopy*. 2016;32:2228–2232.
9. Moktar J, Bradley CS, Maxwell A, Wedge JH, Kelley SP, Murnaghan ML. Skill acquisition and retention following simulation-based training in Pavlik harness application. *J Bone Joint Surg Am*. 2016;98:866–870.
10. Hetaimish B, Elbadawi H, Ayeni OR. Evaluating simulation in training for arthroscopic knee surgery: a systematic review of the literature. *Arthroscopy*. 2016;32:1207–1220. e1.
11. Mayne IP, Brydges R, Moktar J, Murnaghan ML. Development and assessment of a distal radial fracture model as a clinical teaching tool. *J Bone Joint Surg Am*. 2016;98:410–416.
12. Brubacher JW, Karg J, Weinstock P, Bae DS. A novel cast removal training simulation to improve patient safety. *J Surg Educ*. 2016;73:7–11.
13. Riehl J, Widmaier J. A simulator model for sacroiliac screw placement. *J Surg Educ*. 2012;69:282–285.
14. Butler BA, Lawton CD, Burgess J, Balderama ES, Barsness KA, Sarwark JF. Simulation-based educational module improves intern and medical student performance of closed reduction and percutaneous pinning of pediatric supracondylar humeral fractures. *J Bone Joint Surg Am*. 2017 Dec 6;99:e128.
15. Harrop J, Rezai AR, Hoh DJ, Ghobrial GM, Sharan A. Neurosurgical training with a novel cervical spine simulator: posterior foraminotomy and laminectomy. *Neurosurgery*. 2013;73(suppl):194–199.
16. Ray WZ, Ganju A, Harrop JS, Hoh DJ. Developing an anterior cervical diskectomy and fusion simulator for neurosurgical resident training. *Neurosurgery*. 2013;73(suppl):1100–1106.
17. Chitale R, Ghobrial GM, Lobel D, Harrop J. Simulated lumbar minimally invasive surgery educational model with didactic and technical components. *Neurosurgery*. 2013;73(suppl):1107–1110.

18. Calio BP, Kepler CK, Koerner JD, Rihn JA, Millhouse P, Radcliff KE. Outcome of a resident spine surgical skills training program. *Clin Spine Surg*. 2017 Oct;30: E1126–E1129.

19. Surgeons, ABoO Examination statistics. March 30, 2013. Available at: https://abos.org/certification/. part i exam/part i exam statistics.aspx (Last accessed: Febraury 02, 2018).

SUPPLEMENTARY INFORMATION

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jsurg.2019.01.011.