Teaching simulated arthroscopic Bankart repair: residents' assessment at the Annual Shoulder Course

Dominique M. Rouleau, MD, MSc
Rosalie Bedard, MD
Fanny Canet, MSc
Yvan Petit, PhD
Canadian Shoulder and Elbow
  Society

Correspondence to:
D.M. Rouleau
Recherche en orthopédie C2095
Hôpital du Sacré-Coeur de Montréal
5400 boul Gouin ouest
Montréal QC H4J 1C5
dominique.rouleau@umontreal.ca

Background: This study's aim was to evaluate the performance of senior orthopedic residents during simulated arthroscopic anterior stabilization (Bankart repair) before and after a national shoulder review course.

Methods: Participants were assessed before and after the Annual Shoulder Review Course over a 3-day period, using a multiple-choice examination and surgery performance assessment. The surgical evaluation was completed by fellowship-trained surgeons using a standardized procedure checklist and a global rating scale. All Canadian senior orthopedic residents were invited to participate in the course.

Results: The 57 participants showed improvement following the course. The written knowledge evaluation mean score increased, and all 3 surgical performance measurements improved: surgical task time improved from 4:40 min to 2:53 min ($p < 0.001$), surgical technique evaluation increased from 56% to 67% after the procedure checklist ($p < 0.001$), and anchor placement improved for all 3 aspects. Anchor entry point was the sole measure not to improve enough to reach statistical significance ($p = 0.37$).

Conclusion: Our data support the inclusion of dry model surgical simulation as part of a surgical skills course for both training and assessment of orthopedic surgery residents.

Contexte : Le but de cette étude était d'évaluer le rendement des résidents seniors en orthopédie durant une simulation de stabilisation arthroscopique antérieure (intervention de Bankart) avant et après un cours de révision national sur l'articulation de l'épaule.

Méthodes : Les participants ont été évalués avant et après l'Annual Shoulder Review Course sur une période de 3 jours, à l'aide d'un examen à choix multiples et d'une épreuve chirurgicale pratique. L'évaluation chirurgicale était effectuée par des chirurgiens spécialisés, à l'aide d'une liste de vérification normalisée des procédures et d'une échelle d'évaluation globale. Tous les résidents séniors canadiens en orthopédie étaient invités à participer au cours.

Résultats : Les 57 participants ont montré une amélioration après le cours. Les résultats à l'examen écrit ont augmenté, tout comme ceux des 3 évaluations chirurgicales : le temps chirurgical a diminué, passant de 4:40 min à 2:53 min ($p < 0,001$), l'évaluation de la technique chirurgicale a augmenté de 56 % à 67 % selon la liste de vérification ($p < 0,001$) et le positionnement des ancres s'est aussi amélioré pour les 3 positionnements. Le point d'entrée des ancres a été la seule mesure à ne pas s'améliorer suffisamment pour atteindre une portée statistique ($p = 0,37$).

Conclusion : Nos données appuient l'inclusion d'un modèle de simulation sec pour la formation et l'évaluation des résidents en chirurgie orthopédique.

L earning surgical skills can be understood with Fitts and Posner's 3-phase framework for acquiring motor skills.[1,2] The initial cognitive phase is characterized by learners understanding the skills and watching demonstrations. In the associative phase, learners perform the tasks and associate the psychomotor steps with the knowledge acquired during the cognitive phase. The final autonomous phase focuses on repetition and the automatism of psychomotor movements.[1,2]

Effective and efficient surgical skills training strategies are needed to counter the impact of trainee work hour restrictions, increased pressures to enhance operating room efficiency and concerns regarding patient safety.[3,4] Simulation

training with feedback and assessment of surgical skills is increasingly recognized as an education strategy that can assist in the integration of the phases of motor skill learning.[5–7] Simulation training has been implemented and evaluated in a number of disciplines (e.g., aviation, military, medicine, surgery, business).[8,9] The acquisition of minimally invasive techniques such as shoulder arthroscopic techniques, which are known to be challenging to learn and associated with a steep learning curve, requires many hours of practice.[9] Previous studies have shown that shoulder simulation training improves both surgical performance in cadaveric and simulated models.[8] Other studies have shown that surgical skills learned on physical or virtual-reality simulators are transferrable to the operating room.[10]

Arthroscopy simulation is becoming more common in universities and surgical societies.[11,12] One example is the Fundamentals of Arthroscopic Surgery Training (FAST) workstation that is currently used by the Arthroscopy Association of North America, the American Academy of Orthopaedic Surgeons and the American Board of Orthopaedic Surgery during courses offered to residents and practising surgeons.[11,12]

The Canadian Shoulder and Elbow Society (CSES; formerly Joints Canada) Annual Shoulder Review Course committee chose to include a dedicated training session with a surgical simulator to assess the performance of senior orthopedic residents during simulated arthroscopic anterior stabilization (Bankart repair) before and after the CSES Annual Shoulder Review Course. The main purpose of this study was to evaluate the performance of senior orthopedic residents during simulated Bankart repair before and after a national shoulder review course. The primary objective of the study was to assess improvement in knowledge and surgical skills for arthroscopic Bankart procedures. The chosen outcomes were score on a 10-question multiple choice test, surgical performance based on a standardized procedure checklist, and precision of anchor placement. We hypothesized that course participants would show significant improvement in anchor placement precision and on Bankart repair knowledge after the course.

METHODS

Course

The CSES Annual Shoulder Review Course is a 3-day course that covers all aspects of shoulder surgery, including sports medicine, open and arthroscopic techniques, trauma surgery and arthroplasty. The course received the ethics committee approval. Teaching related to the management of shoulder instability, including surgical techniques, consists of a 1-hour case-based small-group session, a 1-hour formal lecture and a 2-hour laboratory session using both Sawbones and cadaveric models.

Participants

All Canadian senior orthopedic residents (postgraduate year [PGY] 4 and 5) and fellows were invited to the CSES Annual Shoulder Review Course in Montreal, Québec. Experienced fellowship-trained shoulder surgeons provided the teaching throughout the review course. There were no exclusion criteria.

Written examination

All participants took a written examination before and after the review course. All participants were unaware of the research topic at the precourse test. The written examination included 10 multiple choice questions chosen according to relevant shoulder instability features and generated by an expert committee in accordance with the Delphi method.[13] There was no time limit for this examination, and no reference material or communication was allowed.

Surgical performance assessment

All participants underwent a surgical performance assessment, using a rating instrument, before and after the review course. The instrument was created following expert consultation and consensus.[13]

Several stations were available to allow the evaluation of multiple residents at the same time. Each station provided written instructions, and the required instruments were available on the station's worktable. Participants were instructed to insert the most inferior of the anteroinferior glenoid suture anchor, using 3 mm Bio-SutureTak anchors (Arthrex), into a synthetic right shoulder physical simulator model, which included synthetic skin and capsule (Sawbones), under arthroscopic guidance with a 30°, 3.5 mm arthroscope. The shoulder was in the beach chair position, but could be modified to the lateral decubitus position if requested. Anterosuperior and anteroinferior portal cannulae were inserted posteriorly before testing. Every resident had to choose the most appropriate cannulae for the procedure. A drill, drill guide, and anchor were available for each trainee.

Experienced, fellowship-trained shoulder surgeons assessed performance using an evaluation form created by a team of experts. The form included a task-specific checklist and an overall global rating scale, based on a 5-point Likert scale, to evaluate surgical technique, including anchor placement and insertion, use of appropriate portals, and camera manipulation. If a visual evaluation of the anchor placement was difficult intraoperatively, the expert assessors could manipulate the camera (once the procedure was completed) to determine the final anchor placement.

Evaluation of anchor placement

The exact position of the anchor was analyzed using a 3D camera (Optotrack 302, NDI) and 3D reconstruction software (Catia V5R20, Dassault system). After each pre- and post-course test, all the glenoids were detached from the synthetic ligaments and tendons. The labrum was slightly elevated. In cases where the anchor was partially inserted through the labrum, the labrum was carefully elevated to expose the anchor.

Every glenoid was then placed against a Plexiglas sheet (Fig. 1). The position was controlled by a line drawn on the translucent sheet. The centre of the Plexiglas sheet and the centre of the glenoid were superimposed. The glenoid was maintained with a clamp. To create a 3D model, a recording of 6 points was made for each specimen with an optoelectronic pointer and a 3D camera (Optotrack 302, NDI). Points A to D were the extremes of a 6 cm × 8 cm rectangle drawn on the Plexiglas sheet (Fig. 1, Fig. 2). Point E was the projection of the entry point of the anchor on the Plexiglas sheet. We measured the distance between anchor and joint surface. Reconstruction of all 5 points was done using computer-aided design software (Catia V5R20, Dassault system). Measurement and calculation of these 5 points using the software extracted the anchor position, including the insertion angle (the angle between the long ax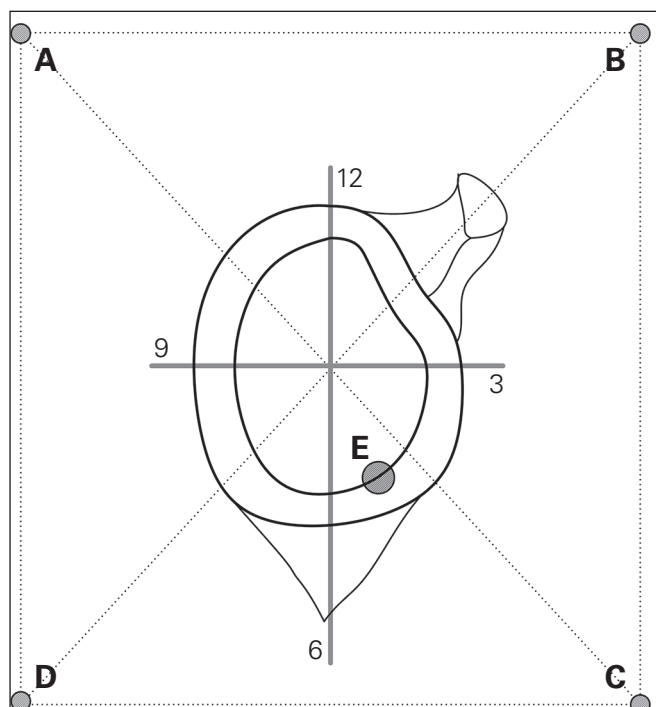is of the anchor and the glenoid joint surface), the glen-oid clock face measurement (position of the entry point on the glenoid surface; depends on point E), and depth of insertion of the anchor from the glenoid surface.

Based on literature review, the course committee determined the ideal position: 5 o'clock (on a right shoulder), a 45° angle of insertion, and a final anchor position 2 mm below the articular surface of the glenoid.[13–18] To determine the specific error of the anchor placement measures, 3 repeated measurements were taken per specimen. The error was calculated as the difference between the measure and the ideal position (e.g., if the entry point is at 4:45 on the clock face, the error will be 5:00 – 4:45 = 0:15). Paired t tests were then performed to compare mean values of measurements before and after the review course.

Statistical analysis

Results are presented as means ± standard deviations (SDs) and 95% confidence intervals (CIs) for continuous variables and as percentages for categorical variables. We used paired t tests to compare pre- and post-course continuous variables and χ^2 tests to compare categorical variables. We considered results to be significant at $p < 0.05$, and we used SPSS software version 23 to perform all tests.

To perform the power calculation, we used duration of procedure, as this is a quantitative measure. We determined that a 25% improvement would be significant, and
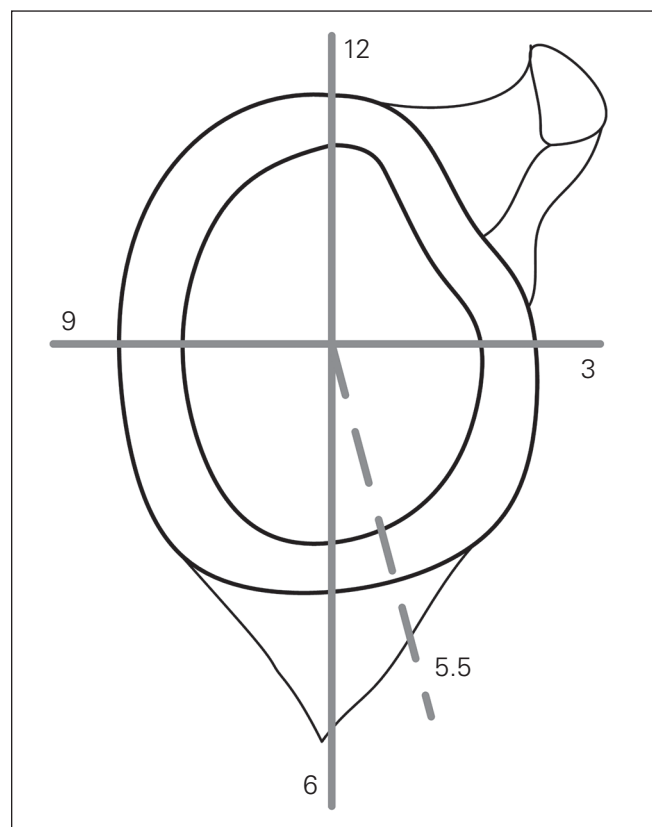

Fig. 1. 3D evaluation of anchor placement set-up. The A-B-C-D square represents the Plexiglas sheet and point E represents the anchor entry point. The centre of the glenoid and Plexiglas sheet are superimposed to show precise entry point coordinates. The anchor tip position is recorded to calculate the angle and depth of the anchor.

Fig. 2. Glenoid clock face measurement.

with a power of 80%, an α of 0.05 and an SD of 30% we needed a minimum of 24 participants per group.

RESULTS

Participants

Fifty-eight participants were recruited for the study: 16 PGY4 residents, 36 PGY5 residents and 6 clinical fellows. Thirty-six participants were men. All 58 residents completed the precourse test and 57 completed the postcourse test.

Written examination

Questions and results of the written examination are shown in Table 1. The mean score on the written examination increased from 59% ± 15% (95% CI 40%–78%) to 68% ± 12% (95% CI 48%–88%) following the course.

Surgical performance assessment

The average total surgical task time decreased from the precourse test to the post-course test by 40%, from 4:40 min (95% CI 2:46-5:34) to 2:53 min (95% CI 2:30-3:16) ($p < 0.001$). Anchor placement, insertion angle and arthroscopic portal choices all improved. Thirty-five students (61%) increased their manipulation skills, 9 students (16%) had no change in their results, and 13 students (23%) decreased their manipulation skills. The mean score for manipulation skills decreased from 71% to 68%. The overall score for the surgical technique assessment improved from 56% before the course to 67% after the course ($p < 0.001$) (Table 2).

Evaluation of anchor placement

To evaluate anchor placement, 58 shoulder models were used for the precourse test. Seven were lost or stolen, and of the remaining 51 models, 8 had no anchor left inside (but the anchor tunnel was present), leaving 43 models with anchors present. For the post-course test 57 models were used, 2 were lost or stolen, and of the remaining 55 models, 11 had no anchor left inside (but the anchor tunnel was present), leaving 44 with anchors present. Results of the anchor placement evaluation are shown in Table 3 and Table 4. The depth of anchor placement was measured on a total of 87 synthetic glenoids with anchors present (pre- and post-course tests). Models without anchors were the result of technical errors.

The precision of the anchors' insertion points improved following course completion ($p < 0.001$); however, no significant improvement was seen in the angle of insertion or the anchor depth. A clock was applied over the glenoid face to quantify entry points.

Entry point before the review course ranged from 1:00 to 7:20 (mean 4:15 ± 1:10); after the course it ranged from 3:05 to 6:00 (mean 4:25 ± 0:35) ($p = 0.37$; Fig. 3). The precision improved, as shown by the significant decrease in deviation for the desired entrance point on the clock face, from 1.0 ± 0.8 hours to 0.6 ± 0.4 hours ($p < 0.001$).

Angle of insertion before the review course ranged from 4° to 79° (mean 43° ± 16°); after the course it ranged from 20° to 76° (mean 44° ± 13°, $p = 0.25$; Fig. 4).

The depth of anchor insertion ranged from –0.7 mm to 20.0 mm precourse (mean 5.7 mm ± 4.0 mm); after the course it ranged from –1.3 mm to 13.4 mm (mean 6.2 mm ± 3.8 mm, $p = 0.43$; Fig. 5). Figures 3, 4 and 5 represent individual matched performances.

DISCUSSION

Bankart repairs are commonly performed for recurrent instability of the shoulder, with the objective of restoring normal shoulder function and stability.[14] This surgical technique commonly requires the insertion of suture anchors into the glenoid rim and reattachment of the torn labrum using sutures fixed on those anchors. The position and number of anchors have been shown to influence clinical outcomes, and mastering this skill contributes to treatment efficacy.[14–19] Senior residents and shoulder clinical fellows improved their knowledge of arthroscopic Bankart lesion repair and their performance of a simulated repair on a dry surgical model. Residents may benefit from courses with curricula that include surgical simulation to both teach and assess surgical skill acquisition, in combination with didactic or small group sessions and cadaveric laboratories. Indeed, the relevance of simulation training as a part of orthopedic residency programs has been gaining in credibility with recent publications.[8,20] Moreover, Angelo and colleagues[21] established the importance of defining specific benchmarks for evaluation in order to achieve progress. In terms of patient safety, this method has the advantage of furthering essential knowledge that is not appropriate for residents to learn in the operating room. Furthermore, residents should be formally assessed on their ability to perform these tasks to a minimal level of competence before performing them in the operating room. In the present study we saw a 40% improvement in the time to completion for the evaluated task, but we also evaluated the quality of the anchor placement; as pointed out in a recent editorial, "a task may be done quickly, but not necessarily well."[22] One of the strengths of this study is the inclusion of residents from all Canadian residency programs, providing a good national overview. Furthermore, it includes technical and theoretical knowledge assessments with a chosen model that closely resembles a real shoulder with synthetic skin and ligaments. This forced participants to look at the screen when performing the procedure and prevented them from seeing the bone insertion point

Table 1. Written examination questionnaire (part 1 of 2)				
Question	Answer	% Success test 1	% Success test 2	*p* value, paired *t* test
1. A 21-year-old male football player (linebacker) suffers a traumatic anterior dislocation of his nondominant shoulder for the first time. If he continues to play football, what is the likelihood of him having a recurrent dislocation of his shoulder? a) < 20% b) 20 to 40% c) 41 to 60% d) > 60%	D	90	89	> 0.99
2. A 21-year-old male football player suffers a traumatic anterior dislocation of his nondominant shoulder for the first time while making a tackle. The mechanism of injury is one of forced abduction external rotation. What is the likelihood of him having a disruption of the antero-inferior glenoid labrum; i.e., a so-called Bankart lesion? a) < 25% b) 25 to 50% c) 51 to 75% d) > 75%	D	71	79	0.058
3. The same patient was treated in a sling for 2 weeks, then rehabilitated his shoulder and tried to play, but his shoulder felt unstable. He sees you at the end of the season. His x-rays are normal. What is the evidence-based best treatment for this patient? a) Advise him to use an external rotation brace for 4 weeks to allow the shoulder to heal properly. b) Continue with active rehabilitation and advise him to have surgery only if he has a recurrent dislocation. c) Advise him to have an arthroscopic surgical repair at the next available time. d) Advise him to have an open Latarjet procedure at the next available time.	C	62	68	0.252
4. A 19-year-old Junior A hockey player sees you at the end of his season wanting surgery to fix his unstable shoulder. He has had 3 documented anterior dislocations, each requiring a physician reduction and several subluxation episodes. He has a small but perceptible Hill Sachs lesion on his x-ray and the anterior contour of his glenoid is blunted, but there is no bony Bankart. What is the evidence-based, best surgical treatment for this patient? a) An arthroscopic Bankart repair. b) An arthroscopic Bankart repair with remplissage. c) An open Bankart repair. d) An arthroscopic Latarjet procedure.	C	10	5	0.182
5. You decide to perform an arthroscopic Bankart repair of his right shoulder. He has a typical Bankart lesion based on preoperative planning. Which of the following portal positions would typically be considered the minimum to perform this procedure? a) A posterior and anterosuperior portal. b) A mid-anterior and an anterosuperior portal. c) A posterior and mid-anterior portal. d) An anterosuperior and a trans-subscapularis portal.	C	34	61	< 0.001
6. You decide to perform an arthroscopic Bankart repair of his right shoulder. You perform a diagnostic arthroscopy through a standard posterior portal. You identify a labral tear that extends from the 7 o'clock to the 3 o'clock position. What additional portals may be needed to perform an optimal arthroscopic repair? a) A mid-anterior and an anterosuperior portal. b) An anterosuperior and supplemental posterior portal. c) A supplemental posterior and trans-subscapularis portal. d) An anterosuperior and a trans-subscapularis portal.	C	12	12	> 0.99
7. You decide to perform an arthroscopic Bankart repair of his right shoulder. You confirm a typical Bankart lesion. Where would you place your first anchor using the glenoid clock face description as the reference point? a) At the 7 o'clock position. b) At the 5 o'clock position. c) At the 3 o'clock position. d) At the 1 o'clock position.	B	64	95	< 0.001
8. You place your first bio-absorbable anchor in the optimal position with respect to the glenoid clock face. With respect to the patho-anatomy, where should the anchor hole be made? a) Through bleeding bone on the glenoid neck. b) On the face of the articular cartilage. c) At the junction of the articular cartilage and the glenoid bone. d) At the position of the anterior labroligamentous periosteal sleeve avulsion lesion.	C	88	93	0.182

Table 1. Written examination questionnaire (part 2 of 2)				
Question	Answer	% Success test 1	% Success test 2	p value, paired t test
9. When creating the hole for anchor placement, where should the angle of insertion be? a) Parallel to the glenoid surface. b) At 45° to the glenoid surface. c) At 90° to the glenoid surface. d) At 75° to the glenoid surface.	B	79	98	< 0.001
10. A patient comes to you with a history of recurrent anterior dislocations of his dominant shoulder. Which of the following would be considered a contraindication for an arthroscopic repair? a) A Hill–Sachs defect and a bony Bankart lesion. b) A Hill–Sachs defect and a Bankart lesion. c) A Hill–Sachs defect and an anterior labroligamentous periosteal sleeve avulsion lesion. d) A Hill–Sachs defect and a glenoid bony lesion.	D	84	79	0.182
Total		59% ± 15%	68% ± 12%	< 0.001

Table 2. Surgical technique evaluation			
Criterion	% Pre-test	% Post-test	p value, paired t test
Criteria evaluated as 1 done or 0 not done			
Anchor placed between 5:00 and 6:00 on the glenoid clock face	52	72	0.017
Insertion point on edge of glenoid cartilage (articular rim)	43	68	0.008
45° angle insertion to the joint surface	43	77	< 0.001
Depth insertion: to the line on anchor guide handle	43	58	0.12
Portal used for anchor placement: above subscapularis tendon (lower portal anterior)	78	95	0.006
Criteria evaluated on Likert scale (1 = very poor; 5 = excellent)			
Camera manipulation: able to maintain a stable and centred image (himself or by asking the assistant to do so) during most of the procedure	71	68	0.59
Overall performance	49	60	< 0.001
Total	56% ± 3%	67% ± 2%	< 0.001

Table 3. Results of anchor placement during simulated Bankart surgery									
	Angle of insertion (°)			Anchor entry point (clock face, hr)			Depth (mm)		
Test	N	Mean ± SD	Range	N	Mean ± SD	Range	N	Mean ± SD	Range
Pretest	51	43.0 ± 16.0	4.0 to 79.1	51	4.3 ± 1.2	1.0 to 7.4	43	5.7 ± 4.0	–0.7 to 20.0
Post-test	55	45.4 ± 13.4	19.9 to 75.7	55	4.5 ±0.7	3.1 to 6.0	44	6.2 ± 3.8	–1.3 to 13.4
p value, paired t test	51	0.25		51	0.37		43	0.43	

Table 4. Error of anchor placement during simulated Bankart surgery									
	Error of angle of insertion (°)*			Error of anchor entry point (clock face, hr)†			Error of depth (mm)‡		
Test	N	Mean ± SD	Range	N	Mean ± SD	Range	N	Mean ± SD	Range
Pretest	51	12.5 ± 10.0	0.1 to 41.0	51	1.0 ± 0.8	0.0 to 3.5	43	4.1 ± 3.6	0.4 to 18.0
Post-test	55	10.8 ± 7.8	0.1 to 30.7	55	0.6 ± 0.4	0.4 to 1.5	44	4.7 ± 3.1	0.0 to 11.4
p value, paired t test	51	0.34		51	< 0.001		43	0.41	

*Error of angle of insertion = angle of insertion, 45°.
†Error of anchor entry point = anchor position on clock face, 5:30.
‡Error of depth = depth, 2 mm.

directly. Entry point measurements were taken by a biomechanical engineering team with cutting-edge technology to ensure the greatest precision possible. Finally, this event was a fantastic opportunity to bring together shoulder surgeons from across the country and promote excellence in shoulder surgery.

Limitations

Limitations of the study include some discrepancies observed when comparing the examiners' evaluations of surgical performance and the 3D camera evaluations. The 3D evaluations showed a reduction of the mean range and

of the error and error range rather than the means themselves (Table 4). The assessments performed by the experts appear to have overestimated the amount of improvement from pre- to post-test in comparison to the 3D anchor evaluations. Possible explanations for this include examiner intra- and interobserver variation, or qualitative improvement of camera management by residents, which gives a more positive impression. Participants may also have improved in the manipulation of the specific anchor instrument through the standard learning curve. Other limitations include the lack of data on participants' prior experience, the absence of a control group, and the absence of expert results for comparison.[23] Future studies could include data from the evaluating surgeons to be used as the
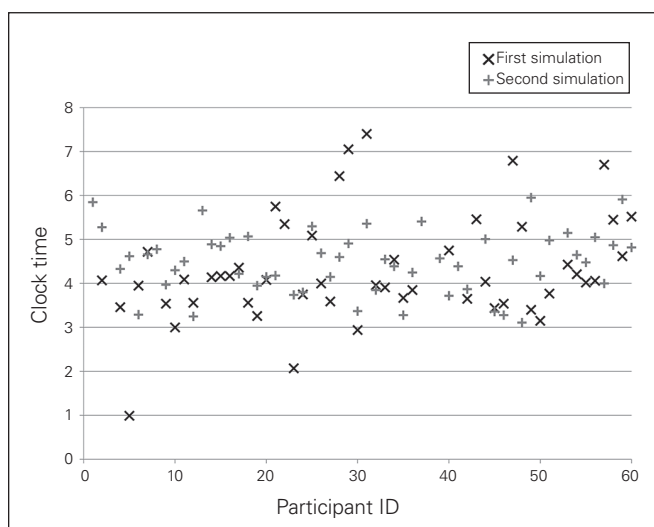
Fig. 3. Position of anchor entry point on the glenoid clock face during the first simulation (pretest) and at the second simulation (post-test).
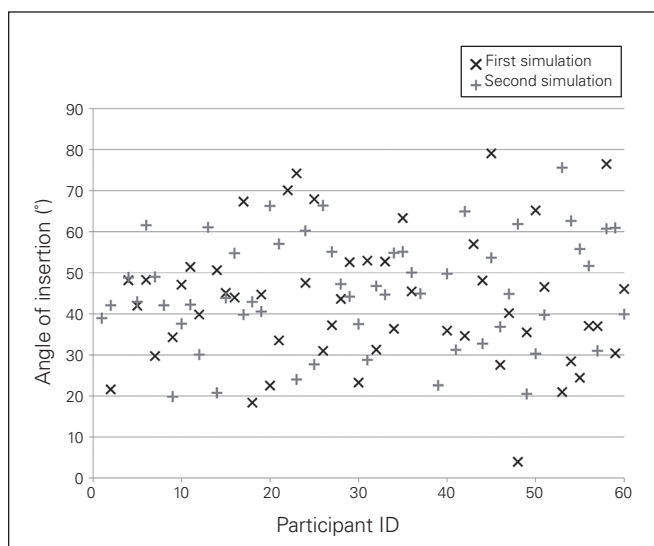
Fig. 4. Angle between the axis of the anchor and the glenoid joint surface during the first simulation (pretest) and at the second simulation (post-test)
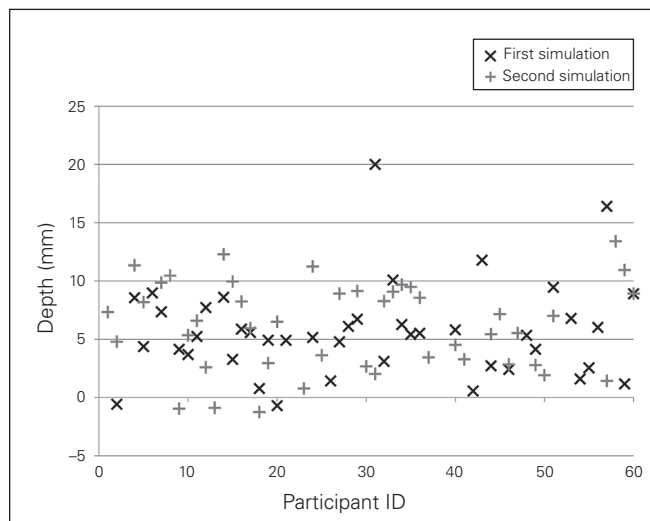
Fig. 5. Depth of insertion of the anchor (from the glenoid surface) during the first simulation (pretest) and at the second simulation (post-test).

gold standard for comparison to establish validated metrics for assessment.[21,23,24] Filming the procedure could also have provided additional material for evaluation, as well as information on left- or right-handedness of the residents, which may influence performance.[25]

Further investigation is required to better understand which methods are suitable for teaching and refining surgical procedures and techniques among senior residents and experienced surgeons, especially in terms of knowledge transfer with performance in the operating room. Many national and international courses offer cadaver training sessions, but these can be costly and difficult to organize compared with traditional didactic teaching methods.[26–28] In a context of limited university budgets, partnerships with the industry remain the only avenue. Performance on arthroscopy simulators has been strongly correlated with performance on cadavers,[29] and the use of simulators to supplement or replace certain parts of courses is appealing.[28] Indeed, it would solve the problem of time lost during the surgical approach before performing the specific step that the course aims to improve. For more experienced surgeons, it is unnecessary to complete all the preparatory stages, especially in arthroscopic surgeries. Using simulators can get the surgeon directly to the specific step that needs to be practised, such as anchor placement in a difficult orientation or learning to use new materials.[7] Recent studies have shown that surgical simulation training can improve performance, and longitudinal integration of skills training should continue throughout a training program.[8,20,30]

Conclusion

Resident knowledge of shoulder instability and simulated performance of an arthroscopy-assisted stabilization improved following a structured intervention. Our data

support the inclusion of dry model surgical simulation as part of a surgical skills course both for training and assessment of orthopedic surgery residents.

References

1. Fitts PM, Posner MI. *Human performance*. Belmont (CA): Brooks/Cole; 1967.

2. Hamdorf JM, Hall JC. Acquiring surgical skills. *Br J Surg* 2000;87:28-37.

3. Pedowitz R, Marsh L. Motor skills training in orthopaedic surgery: a paradigm shift toward a simulation-based educational curriculum. *J Am Acad Orthop Surg* 2012;20:407-9.

4. Zendejas B, Brydges R, Hamstra SJ, et al. State of the evidence on simulation-based training for laparoscopic surgery, a systematic review. *Ann Surg* 2013;257:586-93.

5. Kneebone RL, Scott W, Darzi A, et al. Simulation and clinical practice: strengthening the relationship. *Med Educ* 2004;38:1095-102.

6. Kolozsvari NO, Feldman LS, Vassiliou MC, et al. Sim one, do one, teach one: considerations in designing training curricula for surgical simulation. *J Surg Educ* 2011;68:421-7.

7. Angelo RL, Ryu RK, Pedowitz RA, et al. A proficiency-based progression training curriculum coupled with a model simulator results in the acquisition of a superior arthroscopic Bankart skill set. *Arthroscopy* 2015;31:1854-71.

8. Henn RF III, Shah N, Warner JJ, et al. Shoulder arthroscopy simulator training improves shoulder arthroscopy performance in a cadaveric model. *Arthroscopy* 2013;29:982-5.

9. Michelson JD. Simulation in orthopaedic education: an overview of theory and practice. *J Bone Joint Surg Am* 2006;88:1405-11.

10. Howells NR, Gill HS, Carr AJ, et al. Transferring simulated arthroscopic skills to the operating theatre: a randomised blinded study. *J Bone Joint Surg Br* 2008;90:494-9.

11. Leahy M. Using simulation, metrics to improve orthopaedic surgical skills. *AAOS Now* 2012. Available: www.aaos.org/news/aaosnow/feb12/clinical9.asp (accessed 2014 Aug. 10).

12. Carpenter JE, Hurwitz SR, James MA, et al. ABOS surgical skills modules for PGY-1 residents. The American Board of Orthopedic Surgery; 2014. Available: https://www.abos.org/abos-surgical-skills-modules-for-pgy-1-residents.aspx (accessed 2014 Aug. 10).

13. Dalkey N, Helmer O. An experimental application of the Delphi method to the use of experts. *Manage Sci* 1963;9:458-67.

14. Ilahi OA, Al-Fahl T, Bahrani H, et al. Glenoid suture anchor fixation strength: effect of insertion angle. *Arthroscopy* 2004;20:609-13.

15. Larrain MV, Montenegro HJ, Mauas DM, et al. Arthroscopic management of traumatic anterior shoulder instability in collision athletes: analysis of 204 cases with a 4- to 9-year follow-up and results with the suture anchor technique. *Arthroscopy* 2006;22:1283-9.

16. Sisto DJ. Revision of failed arthroscopic bankart repairs. *Am J Sports Med* 2007;35:537-41.

17. Bohnsack M, Bartels B, Ostermeier S, et al. Biomechanical stability of an arthroscopic anterior capsular shift and suture anchor repair in anterior shoulder instability: a human cadaveric shoulder model. *Knee Surg Sports Traumatol Arthrosc* 2009;17:1493-9.

18. Nho SJ, Frank RM, Van Thiel Gs, et al. A biomechanical analysis of anterior Bankart repair using suture anchors. *Am J Sports Med* 2010;38:1405-12.

19. Ranawat AS, Golish SR, Miller MD, et al. Modes of failure of knotted and knotless suture anchors in an arthroscopic bankart repair model with the capsulolabral tissues intact. *Am J Orthop* 2011;40:134-8.

20. Martin MK, Patterson DP, Cameron KL. Arthroscopic training courses improve trainee arthroscopy skills: a simulation-based prospective trial. *Arthroscopy* 2016;32:2228-32.

21. Angelo RL, Ryu RK, Pedowitz RA, et al. Metric development for an arthroscopic Bankart procedure: assessment of face and content validity. *Arthroscopy* 2015;31:1430-40.

22. Angelo RL. Editorial commentary: a task may be done quickly, but not necessarily well. *Arthroscopy* 2016;32:1335-6.

23. Angelo RL, Ryu RK, Pedowitz RA, et al. The Bankart performance metrics combined with a cadaveric shoulder create a precise and accurate assessment tool for measuring surgeon skill. *Arthroscopy* 2015;31:1655-70.

24. Lubowitz JH, Provencher MT, Brand JC, et al. Expert surgeons can be distinguished from trainees, and surgical proficiency can be defined, using validated metrics and shoulder models. *Arthroscopy* 2015;31:1635-6.

25. Lee JY, Mucksavage P, McDougall EM. Surgical skills acquisition among left-handed trainees-true inferiority or unfair assessment: a preliminary study. *J Surg Educ* 2013;70:237-42.

26. Lewis CE, Peacock WJ, Tillou A, et al. A novel cadaver-based educational program in general surgery training. *J Surg Educ* 2012;69:693-8.

27. Simpson JS. An economical approach to teaching cadaver anatomy: a 10-year retrospective. *Am Biol Teach* 2014;76:42-6.

28. Gasco J, Holbrook TJ, Patel A, et al. Neurosurgery simulation in residency training: feasibility, cost, and educational benefit. *Neurosurgery* 2013;73(Suppl 1):39-45.

29. Martin KD, Belmont PJ, Schoenfeld AJ, et al. Arthroscopic basic task performance in shoulder simulator model correlates with similar task performance in cadavers. *J Bone Joint Surg Am* 2011;93:e1271-5.

30. Dunn JC, Belmont PJ, Lanzi J, et al. Arthroscopic shoulder surgical simulation training curriculum: transfer reliability and maintenance of skill over time. *J Surg Educ* 2015;72:1118-23.