

- 1 **Can surgical trainees achieve arthroscopic competence at the end of training programs: a**
- 2 **cross sectional study highlighting the impact of working time directives.**

3 **ABSTRACT**

4 **Purpose**

5 Our objective was to provide training guidance on procedure numbers by assessing how the
6 number of previously performed arthroscopic procedures related to both competent and expert
7 performance in simulated arthroscopic shoulder tasks. The null hypothesis was that the
8 recommended minimum number of arthroscopic cases in UK training are adequate to achieve
9 competency.

10

11 **Methods**

12 A cross-sectional study assessing simulated shoulder arthroscopic performance was undertaken.
13 45 participants of varying experience performed two validated tasks: a simple diagnostic task
14 and a more complex Bankart labral repair task. All participants provided logbook numbers for
15 previously performed arthroscopies. Performance was assessed using a Global Rating Scale
16 (GRS) and motion analysis. Receiver operating characteristic (ROC) curve analyses were
17 conducted to identify optimum cut points for task proficiency at both ‘competent’ and ‘expert’
18 levels.

19

20 **Results**

21 Increasing surgical experience resulted in significantly better performance for both tasks as
22 assessed by GRS or motion analysis ($p < 0.0001$). ROC curve analyses demonstrated 52 previous
23 arthroscopies were needed to perform to a ‘competent’ level at the diagnostic task and 248 to be
24 ‘competent’ at the complex task. To perform at an expert level, 290 and 476 previous
25 arthroscopies respectively were needed.

26

27 **Conclusions**

28 This study provides quantified guidance for arthroscopic training and highlights the positive
29 relationship between arthroscopic case load and arthroscopic competency. We have estimated
30 that the number of arthroscopies required to achieve competency in a basic arthroscopic task
31 exceed those recommended in some countries. . These estimates provide useful guidance to those
32 responsible for training programmes.

33

34 **Clinical Relevance**

35 The numbers to achieve competent arthroscopic performance in the assessed simulated tasks
36 exceed what is recommended and what is possible during surgical training programmes in some
37 countries.

38 **INTRODUCTION**

39 Traditionally orthopaedic surgical training has been delivered through an apprenticeship model
40 with trainees increasing their level of involvement in surgical procedures at the discretion of their
41 trainers.^{1,2} The introduction of working time directives have resulted in a relatively unpublicised
42 yet dramatic reduction in training time in some countries, including the United Kingdom (UK)³⁻
43 ⁶. Similar restrictions introduced in the United States of America by the Accreditation Council
44 for Graduate Medical Education (ACGME) in 2011 have raised concerns regarding patient
45 outcomes and resident education, with little overall difference observed in resident well-being.⁷⁻⁹

46
47 The introduction of minimally invasive surgery in some specialties has resulted in higher
48 complication rates during initial skill acquisition, with some trainees finding these new skills
49 difficult to acquire.¹⁰⁻¹⁴ In orthopaedics an increasing number of procedures are performed
50 arthroscopically. It is acknowledged that while a substantial number of repetitions are required to
51 attain arthroscopic competency, the exact numbers are unknown. It is unlikely there is one ‘fixed
52 number’ because of the variety of arthroscopic operations and variations in the innate skills of
53 trainees.¹⁵ In the UK trainee surgeons must perform a minimum of 40 arthroscopic procedures
54 during their 6 year training programme. This target makes no distinction between joint or
55 complexity, and is not clearly based on any particular evidence.¹⁶ Our group has recently
56 published estimates for the number of diagnostic knee arthroscopies required to reach competent
57 and expert proficiency.¹⁷ However we did not explore this issue with regards to a more complex
58 task. Such guidance would be of value to those setting national standards, curricula and running
59 residency training programmes in the face of working time restrictions.

60

61 Our objective was to provide training guidance on procedure numbers by assessing how the
62 number of previously performed arthroscopic procedures related to both competent and expert
63 performance in simulated arthroscopic shoulder tasks. The null hypothesis was that the
64 recommended minimum number of arthroscopic cases in UK training are adequate to achieve
65 competency.

66

67 **METHODS**

68 A cross-sectional study was undertaken to investigate the impact of previous arthroscopic case
69 load on the ability to achieve competency on a simple and a complex simulated arthroscopic
70 shoulder task.

71

72 Participants

73 Institutional review board approval was granted for this non-patient study. Each candidate was
74 provided with an information sheet and gave informed consent. Over a four month period, 45
75 participants with varying degrees of arthroscopic experience were invited to take part in this
76 cross sectional training study. In addition to faculty members, current medical students, interns
77 and orthopaedic trainees rotating through our institution were eligible for inclusion. Exclusion
78 criteria included prior exposure to the arthroscopic task and simulator used in this study. There
79 were 14 novices with no arthroscopic experience (medical students and interns), 27 orthopaedic
80 trainees of varying experience and 4 expert orthopaedic surgeons with a specialist shoulder
81 interest were recruited on statistical advice so to enable the planned ROC analysis. The numbers
82 of all previous arthroscopies performed were collected via surgical logbooks for each participant.
83 All previous arthroscopies performed were included but unsurprisingly for the trainee group,
84 these were made up mainly of knee arthroscopies and to a lesser extent shoulder arthroscopies.

85

86 Simulator-based assessment of surgical skill

87 The simulated arthroscopic tasks were conducted in a surgical skills laboratory using the Alex
88 Shoulder Professor II benchtop model (Sawbones Europe, Malmö, Sweden). This is a life-sized
89 simulator with arthroscopic portals that allow conventional arthroscopic instruments to be used
90 in a beech chair position. A standard 30 degree arthroscope, camera and high definition display
91 were used for all cases (Smith and Nephew Endoscopy, Huntingdon, UK).

92
93 The study involved two previously validated simulated tasks (20,27). The first task was a more
94 straight forward diagnostic triangulation task involving a systematic exploration of the shoulder
95 using the arthroscopic probe to touch a series of marked points within the model. These points
96 were numbered from 1-9 and corresponded to important landmarks visualised during real-life
97 diagnostic arthroscopies of the shoulder (see figure 1).

98
99 The second task was a simulated arthroscopic Bankart (labral) repair. This involved fixing a
100 detached labrum to the glenoid by screwing a single loaded suture anchor into the glenoid,
101 passing a suture arthroscopically through the labrum with a suture passer and then tying a secure
102 arthroscopic knot using a knot pusher and finally using a suture cutter to divide the suture ends.
103 The model was prepared with a standardized predrilled hole in the peripheral anterior glenoid to
104 accept the suture anchor.

105
106 Each task was preceded by a video presentation outlining the technique. It was watched once by
107 each of the participants. Following the video there was a short opportunity for participants to
108 practice tying their knots on a separate bench top model. All the tasks had standardised starting
109 and finishing positions.

110

111 Motion Analysis

112 A three-dimensional electromagnetic motion tracking system (PATRIOT; Polhemus, Colchester,
113 Vermont) was used to objectively monitor surgical performance. This system uses a fixed emitter
114 and two small electromagnetic sensors worn on the dorsum of both hands. The movement
115 information is automatically converted using custom software (MATLAB, version 6.5; The
116 MathWorks, Natick, Massachusetts) to provide three outcome measures; ‘total path length’
117 (distance moved by the hands during the task); ‘number of hand movements’ performed and the
118 overall ‘time taken’ to complete the task. This objective technique has been extensively validated
119 for skill assessment in arthroscopy¹⁸⁻²².

120

121 Global Rating Scale (GRS)

122 A validated ^{22,23} GRS was used to rate the performance of each candidate for the two different
123 tasks. It uses six testable domains measuring instrument handling, depth perception, bimanual
124 dexterity, flow of operation, efficiency, and quality of the final product. Each domain was rated
125 using a Likert scale with anchors at 1, 3 and 5 points, giving a maximum possible score of 30
126 points and a minimum of 6. An independent observer not involved in collecting the data
127 assigned the GRS based on the blinded video recordings taken automatically by the arthroscopic
128 equipment and an external web cam. These video files were anonymised via a random number
129 allocation and the webcam videos cropped so that any identifiable features were obscured. A
130 proportion of these videos were rated by a further blinded assessor for inter-observer variability.
131 For the Bankart task, the adequacy of the repair was also assessed using a pass/fail assessment,
132 with a fail being awarded if there was cut-through of the suture, incorrect positioning of the

133 anchor, a loose knot, or if there was gapping of the repair on probing of the repair after the task.

134

135 The primary outcome measure was assessment of arthroscopic performance using a validated
136 GRS. This was then used to estimate the number of arthroscopies required to achieve competent
137 and expert proficiency in the simulated tasks.

138

139 Statistical Analysis

140 Non-parametric tests were used as the data was not normally distributed according to the
141 Kolmogorov-Smirnov test. Inter-rater reliability for GRS scoring was determined using the
142 Cronbach alpha coefficient. The Kruskal-Wallis test was used to determine the differences
143 between groups for each simulation task. Where a significant difference was found, pairwise
144 comparisons between the groups were made using the Mann–Whitney U test. The Spearman
145 rank correlation coefficient was used to analyse the correlation between the GRS and motion
146 analysis parameters as well as performance between the two different simulation tasks.

147

148 To assess the importance and influence of number of previous procedures performed on GRS,
149 ROC analyses were performed for each arthroscopic task. A score of 5/5 in each domain (30/30)
150 was set as an ‘expert’ performance. This essentially reflected a flawless arthroscopic
151 performance in the simulated setting. A score of 4/5 in each domain (total 24/30) was set as a
152 ‘competent’ performance threshold as this was still judged to reflect a safe arthroscopic
153 performance at these particular tasks with minimal errors and perhaps more representative of the
154 performance levels actually achieved by most by the end of residency programmes. The
155 optimum point on the ROC curve for sensitivity and specificity was determined, and number of

156 cases at this point recorded. A p-value of 0.05 was considered statistically significant.

157

158 Source of Funding

159 This project was supported by the Association for Simulated Practice in Healthcare (ASPiH), a
160 CAE Healthcare grant and by the National Institute of Health Research Oxford Biomedical
161 Research Unit.

162

163 **RESULTS**

164 45 individuals participated in this study (14 novices, 27 trainees and 4 experts). No participants
165 were excluded or failed to complete the study. While all 45 participants were able to perform the
166 simple diagnostic task. 9 of the novices were unable to complete the Bankart task due to its
167 complexity and so worst case scores were allocated to these individuals. There was an expected
168 broad range of previous arthroscopic experience in the trainee group (table 1), with the vast
169 majority of prior arthroscopic experience gained outside of the shoulder, predominantly knee
170 arthroscopy.

171

172 Global Rating Scale

173 Two observers individually assessed a random selection of 16 videos (19.8% of the total) and
174 excellent inter-rater reliability was noted (Cronbach $\alpha = 0.86$). Thereafter a single rater went on
175 to score the GRS for the remaining 65 videos. The Kruskal-Wallis test demonstrated significant
176 differences in GRS scores for both the diagnostic triangulation task ($p = 0.0001$) and the Bankart
177 task ($p = 0.0001$) (figure 2). Pair-wise comparisons of GRS performances between experience
178 groups using the Mann-Whitney U test demonstrated significant differences between each group
179 (table 2).

180

181 Motion Analysis.

182 All motion parameters improved for both tasks, across groups with increasing experience. The
183 Kruskal-Wallis test demonstrated significant differences ($p = 0.0001$) for all metrics across all
184 groups. Figure 3 is a graphical representation of the difference in performance between the 3
185 groups in terms of ‘hand movement’ motion analysis metrics. A similar pattern was observed for
186 ‘time taken’ and ‘total path length’. Pair-wise comparisons of motion data using the Mann-
187 Whitney U test demonstrated significant differences between each group for each task (table 2),
188 further demonstrating and confirming the construct validity of these tasks.

189

190 Impact of Previous Arthroscopic Experience

191 The number of previous arthroscopies performed by every participant was strongly correlated
192 with performance on the arthroscopic task using GRS (table 3).

193

194 Number of arthroscopic procedures required in order to reach different levels of performance

195 Receiver operating characteristic (ROC) analyses were performed to determine ‘minimum
196 numbers’ of previous arthroscopic procedures required to reach a competent level and expert
197 level as previously defined in the statistical analysis section. ROC curve analyses demonstrated
198 52 previous arthroscopies were needed to perform to a ‘competent’ level at the diagnostic task
199 and 248 to be ‘competent’ at the complex task. To perform at an expert level, 290 and 476
200 previous arthroscopies respectively were needed (table 4).

201

202 **DISCUSSION**

203 This study supports the accepted correlation between previous arthroscopic experience and
204 performance on a given arthroscopic task. Using ROC analysis we have estimated the number of
205 arthroscopic operations trainees need to perform in order to reach a given level of performance in
206 two simulated tasks. Of concern, the number to achieve competency in a simple shoulder task
207 exceeds the current minimum number in some countries. In recent years there has been increased
208 emphasis on competency and quality of training, and less on operative numbers. Given the
209 relationship between case load and performance, a role for minimum recommended cases
210 performed during training remains relevant. ..Our aim was not to provide absolute figures, but
211 rather provide guidance to the surgical education community. Although the ROC curve
212 sensitivity and specificities for the ‘competent’ level performance estimates were not as high as
213 the expert level estimates, the Area Under the Curve (AUC) for all analyses were greater than 0.8
214 implying reliable results, especially if they are taken as a guide. The results highlight the
215 importance of task complexity on both competent and expert performance level. The finding that
216 more complex tasks require greater experience will not be of surprise to most. Most educators
217 would also accept that whilst achieving expert performance is the ideal outcome, surgical
218 training programmes are usually only able to produce ‘safe and competent’ surgeons, with expert
219 skills continuing to develop post training.

220

221 In the UK, i orthopaedic trainees are required to perform a minimum of 40 ‘arthroscopic
222 operations’ by the end of training. It is unclear how these numbers have been decided, but the
223 suggestion is that they are deemed sufficient for trainees to progress to independent practice. Our
224 study estimates 52 arthroscopies are needed just to perform the more simple diagnostic shoulder
225 arthroscopy to a ‘competent’ level. These results therefore cast doubt on whether a minimum

226 number of 40 total arthroscopies is adequate for independent practice. Furthermore, attaining
227 competence in basic arthroscopy does not imply seamless progression to more complex
228 therapeutic tasks, which often have significant learning curves. For example, the estimated cases
229 required to attain a competent level of performance in the more complex Bankart task is even
230 less achievable.

231 This study highlights the impact of recent changes to surgical training. Achieving the number of
232 cases required to reach competent levels of performance are no longer possible, in part due to the
233 reduction in surgical training time in some countries.^{3,4,5} This was highlighted by a recent
234 national interrogation of current UK surgical trainee logbooks. The maximum mean number of
235 arthroscopic procedures by training region was recorded at 82, with the average number of
236 procedures being half this, and the minimum being 28.²⁴ Given these numbers, our study
237 suggests it is extremely difficult to attain 'competent' performance levels within the current
238 training framework. As working time regulations seem unlikely to be eased, alternative solutions
239 need to be found. Logically this shortfall can only be addressed by additional training such as
240 additional fellowships post training, or reinforcing arthroscopic learning and training outside of
241 the operating theatre using valid simulation methods.

242
243 Simulation based training seems likely to be a vital new adjunct in surgical training. Prior work
244 has demonstrated improved learning and performance through simulation based training^{21,22,25-27}

245 There is now a growing argument that simulation should be integrated into training programmes
246 to improve learning, and to help reduce any skills gap. Within the UK, simulation is set to
247 become part of the orthopaedic curriculum, although no realistic resources are yet in place to
248 support such a move.. A similar recognition of the importance of simulation in training has been

249 highlighted in the USA²⁸, with collaboration between the American Academy of Orthopaedic
250 Surgeons, the Arthroscopy Association of North America and the American Board of
251 Orthopaedic Surgery to evaluate and improve the delivery of arthroscopic training using
252 simulation. The Fundamentals in Arthroscopic Surgery Training (FAST) program is one example
253 which aims to develop a recognised arthroscopic education programme for generic arthroscopic
254 skills.²⁹ The Copernicus Initiative has also demonstrated the effectiveness of proficiency based
255 training with simulation programmes for Bankart repair.³⁰ The experience and success of such
256 projects may potentially encourage their expansion.

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258

259 **LIMITATIONS**

260 The present study focused on shoulder arthroscopy, and provides guidance for two specific tasks,
261 and may be criticised as being joint specific. Other arthroscopic procedures and joints present
262 their own challenges, but it is likely that similarly high numbers of procedures are required to
263 achieve competent and expert performance. Our study assessed performance on arthroscopic
264 shoulder tasks, but appreciate that the majority of arthroscopic experience for trainees was
265 gained from knee arthroscopy. However, we feel a number of generic arthroscopic skills are
266 common to both joints. Therefore significant experience in knee arthroscopy is likely to translate
267 to improved performance in shoulder arthroscopy. A final limitation is the accuracy of trainees'
268 surgical logbooks. The majority of logbooks do not document the proficiency with which a case
269 was performed. They may also contain inaccurate records – both as to the proportion of a
270 procedure performed, and the number of cases performed.

271

272 **CONCLUSIONS**

273

274 This study provides quantified guidance for arthroscopic training and highlights the positive
275 relationship between arthroscopic case load and arthroscopic competency. We have estimated
276 that the number of arthroscopies required to achieve competency in a basic arthroscopic task
277 exceed those recommended in some countries. . These estimates provide useful guidance to those
278 responsible for training programmes.

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374 **Figure Legend**

375 Figure 1. Arthroscopic view for diagnostic task showing numbered point and arthroscopic probe
376 (left glenohumeral joint).

377

378 Figure 2. Box and whisker plots demonstrating performance in the two tasks as assessed by GRS
379 scores for each of the subject groups (Novice, Trainee and Expert). (Note: In all plots, the box
380 represents the interquartile range, the bold line in the box represents the median, and the
381 whiskers represent the 2.5 and 97.5 percentiles. Outlier values are represented by the small
382 circles)

383

384 Figure 3: Box and whisker plots demonstrating the difference in hand movements between the
385 groups (Novice, Trainee and expert) for the two tasks. (Note: In all plots, the box represents the
386 interquartile range, the bold line in the box represents the median, and the whiskers represent the
387 2.5 and 97.5 percentiles. The outlier values are represented by the small circles)

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395 **Tables**

396

397

	Total arthroscopies	Shoulder arthroscopies	Non-shoulder arthroscopies
Novices	0	0	0
Trainees	302.9 (18.0 - 975.0)	42.2 (0.0 - 347.0)	260.4 (18.0 - 965.0)
Experts	1429.8 (830 - 2035.0)	906.0 (318.0 - 1377.0)	523.8 (278.0 - 658.0)

398 Table 1. Arthroscopic experience according to surgical logbooks of participants. Figures
399 reported as mean (minimum - maximum), rounded to one decimal point.
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401

	Participant experience level			Pairwise testing	
	Novice	Trainee	Expert	Novice vs. Trainee†	Trainee vs. Expert†
Diagnostic Time (seconds)	419.8±217.6 (145.7 - 920.7)	146.6±66.1 (72.0 - 381.2)	69.7±2.4 (66.8 - 72.5)	0.0001	0.0018
Diagnostic Hand Movements	338.9±183.1 (86.0 - 654.0)	137.0±63.7 (67.0 - 372.0)	68.0±12.7 (57.0 - 83.0)	0.0001	0.0047
Diagnostic Path Length (centimetres)	3139.8±1538.9 (1053.0 - 6122.9)	1336.7±539.4 (364.9 - 2837.3)	660.8±91.8 (578.1 - 782.8)	0.0001	0.0056
Diagnostic GRS	12.5 (10)	25 (5)	29 (0.8)	0.0001	0.0064
Bankart Time	472.9±48.1 (343.7 - 493.7)	318.4±69.0 (205.1 - 464.6)	217.5±65.0 (161.8 - 300.9)	0.0001	0.0251
Bankart Hand Movements	446.96±35.7 (330.0 - 461.0)	386.3±81.9 (268.0 - 640.0)	280.8±66.2 (218.0 - 374.0)	0.003	0.0292
Bankart Path length	5063.7±713.2 (3190.8 - 5452.4)	4062.8±932.6 (2088.0 - 7314.2)	3114.4±556.5 (2636.1 - 3906.3)	0.0003	0.0251
Bankart GRS	6 (7.5)	18 (5)	29 (4.3)	0.0001	0.0015

402
403 *Table 2. Performance results for arthroscopic tasks grouped by experience level. Time taken,*
404 *hand movements and path length reported as mean±standard deviation (minimum -*
405 *maximum). GRS reported as median (interquartile range). Figures rounded to one decimal*
406 *place. † p-value of Mann-Whitney U test.*
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Spearman rank correlation	Diagnostic shoulder GRS	Bankart GRS
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coefficient (rs)			
Number of arthroscopies performed	r_s value	0.7683	0.7698
	p value	< 0.0001	< 0.0001

410 *Table 3. Correlation between number of previous arthroscopies performed and GRS on the two*
411 *simulated tasks.*

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	Diagnostic task		Bankart task	
	Number of procedures	AUC	Number of procedures	AUC
Competent level of performance	52 95% CI (2 to 102) sensitivity 72.2% specificity 66.7%	0.82	248 95% CI (38 to 458) sensitivity 100% specificity 80%	0.96
Expert level of performance	290 95% CI (126 to 454) sensitivity 100% specificity 79.1%	0.86	476 95% CI (293 to 659) sensitivity 100% specificity 90.1%	0.94

414 *Table 4. Optimum cut-off points of ROC curves to estimate number of procedures to reach a*
415 *given level of performance, with area under the curve (AUC) shown for each analysis. (CI =*
416 *Confidence interval)*