

What arthroscopic skills need to be trained before continuing safe training in the operating room?

Tuijthof, Gabrielle; Cabitza, Federico; Ragone, Vincenza; Compagnoni, Riccardo; Randelli, Pietro

DOI

[10.1055/s-0036-1597755](https://doi.org/10.1055/s-0036-1597755)

Publication date

2017

Document Version

Accepted author manuscript

Published in

Journal of Knee Surgery

Citation (APA)

Tuijthof, G., Cabitza, F., Ragone, V., Compagnoni, R., & Randelli, P. (2017). What arthroscopic skills need to be trained before continuing safe training in the operating room? *Journal of Knee Surgery*, 30(7), 718-724. <https://doi.org/10.1055/s-0036-1597755>

Important note

To cite this publication, please use the final published version (if applicable).
Please check the document version above.

Copyright

Other than for strictly personal use, it is not permitted to download, forward or distribute the text or part of it, without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license such as Creative Commons.

Takedown policy

Please contact us and provide details if you believe this document breaches copyrights.
We will remove access to the work immediately and investigate your claim.

What Arthroscopic Skills Need to Be Trained Before Continuing Safe Training in the Operating Room?

Dr. ir. Gabriëlle Tuijthof^{1,2}, Dr. Federico Cabitza³, Dr. Vincenza Ragone⁴, Dr. Riccardo Compagnoni⁵, Dutch
Arthroscopy Society Teaching committee (DAST)⁶, prof. Dr. Pietro Randelli⁴

1. Corresponding author: Dept. of Biomechanical Engineering, Delft University of Technology, Delft, The Netherlands, email: g.j.m.tuijthof@tudelft.nl tel: +31152786780, fax: +31152784700

2. Dept. of Orthopedic Surgery, Academic Medical Centre, Amsterdam, The Netherlands

3. Dipartimento di Informatica Sistemistica e Comunicazione, Università degli Studi di Milano-Bicocca, Milan, Italy

4. Dipartimento Di Scienze Medico-Chirurgiche, Università Degli Studi Di Milano, IRCCS, Policlinico San Donato, Milan, Italy

5. Azienda Ospedaliera Bolognini-Seriate (BG) – Italy

6. Nederlandse Vereniging voor Arthroscopie, Tilburg, The Netherlands

19 **Abstract**

20 Purpose:

21 The purpose was to generate consensus amongst experienced surgeons on ‘what skills a resident should
22 possess before continuing safe training in the operating theatre’.

23 Methods:

24 An on-line survey of 65 questions was developed and distributed to surgeons in the European community. A
25 total of 216 responded. The survey included 15 questions regarding generic and specific skills; 16 on patient
26 and tissue manipulation; 11 on knowledge of pathology; 6 on inspection of e anatomical structures; 5
27 methods to prepare residents; and 12 on specific skills exercises. The importance of each question
28 (arthroscopic skill) was evaluated ranging from 1 (not important at all) to 6 (very important). Chi square test,
29 respondent agreement and a qualitative ranking method were determined to identify the top ranked skills (p <
30 0.05).

31 Results:

32 Top three of general skills considered important was ‘anatomical knowledge’, ‘tissue manipulation’, ‘spatial
33 perception’ and ‘triangulation (all Chi Square >134, p < 0.001, all excellent agreement > 0.85, all ‘high
34 priority’ level). The top ranked two specific arthroscopic skills were ‘portal placement’ and ‘triangulating the
35 tip of the probe with a 30° scope’ (Chi Square >176, p < 0.001, excellent agreement and assigned ‘high
36 priority’).

37 Conclusions:

38 The online survey identified consensus on skills that are considered important for a trainee to possess before
39 continuing training in the OR. Compared to the Canadian colleagues, the European arthroscopy community
40 demonstrated similar ranking.

41

42 **Keywords:** arthroscopy; skills; survey; expert opinion

43 **Introduction**

44 Knee arthroscopy is the most common orthopaedic procedure performed in the United States ¹. At
45 the time of certification by the American Board of Orthopaedic Surgery (ABOS), knee arthroscopy
46 is by far the most recorded procedure on case lists ². It has also been shown to constitute 30% of all
47 orthopaedic procedures performed in Europe ^{3;4}. Although widely performed, arthroscopy requires
48 specific technical skills with a notable initial learning curve that needs careful supervision during
49 training ^{5;6}. During this period, a higher risk of iatrogenic injury exists. A contemporary concept of
50 surgical skills training requires this initial learning curve to take place in a simulated environment
51 away from the patient ⁷. In recent years, substantial progress has been made in the development of
52 simulation programs and tools for the training and assessment of trainee's performance (e.g. ^{8;9}).
53 However, only few studies have tried to determine what specific skills are crucial for a resident to
54 possess before continuing safe training in the operating room. The results of a questionnaire
55 submitted to the members of the Canadian Association of Orthopedic Surgeons are available ¹⁰. In
56 an on-line survey, 101 orthopedic surgeons indicated anatomy identification and navigation skills to
57 be the most important skills for a trainee to possess prior to entering the operating room. Hui, Safir,
58 Dubrowski and Carnahan ¹¹ reported results of 65 orthopedic residents who completed a similar on-
59 line survey.

60 Since the training programs and teaching philosophy are different in different continents ³,
61 the aim of this study was to determine consensus on the arthroscopic skills a trainee should possess
62 before continuing training in the operating room by questioning the community of orthopedic
63 surgeons in Europe.

65 **Methods**

66 An on-line survey was developed based upon the questions of Safir, Dubrowski, Mirsky, Lin,
67 Backstein and Carnahan ¹⁰ and distributed using an open-source platform (www.limesurvey.org).
68 An email was sent to about 1000 members of European Society of Sports Traumatology, Knee
69 Surgery and Arthroscopy (ESSKA) and 400 members of Dutch Arthroscopy Society (NVA) to
70 invite the members to complete the online questionnaire. The open-source platform was configured
71 such that the collected responses could be kept completely anonymous and, at the same time, the
72 system could prevent external users from getting access to the survey.

73 The survey encompassed 65 questions outlining fundamental skills of arthroscopy and
74 methods that a surgical trainee should use to develop such skills. The survey was built up such that
75 ranking was requested on general skills, on specific skills, and on detailed surgical navigation skills,

independently. This structure was chosen to determine overall consensus and eventually to use the highly detailed formulated skills for development of specific exercises. More specifically, the survey consisted of 5 questions on generic skills and 10 regarding specific skills (Table 1); 16 on patient and tissue manipulation, 11 on knowledge of pathology and 6 on inspection of the anatomical structures (Figure 1); 5 questions on practicing methods to prepare residents (Table 2); 3 items on global exercises and 9 on detailed exercises that residents have to be trained in (Table 3). Surgeons were asked to indicate the importance of each arthroscopic skill, method or exercise on a six point ordinal scale with explicit anchors at the extremes ranging from 'not important at all' (score 1) to 'very important' (score 6) to increase response variance while better discriminating central tendency bias. The survey was kept open for 21 days.

Statistical analysis

Statistical analyses were carried out using SPSS Statistics v. 21 (IBM, New York, USA). Results were considered statistically significant when p-values were below the 5% threshold. To verify whether the proposed skills were considered significantly important, all responses were re-codified in dichotomic variables considering scores of 1 and 2 as 'not important' and scores of 5 and 6 as 'important'. A Chi square test was conducted on the equality of response proportions 'important' vs. 'not important'. The rejection of the null hypothesis of equal proportions means that the respondents significantly assigned a high (or low) importance to the proposed skills. The middle values (scores 3 and 4) were not included. Since those responses represented the opinion of the uncertain respondents, verification of any polarization in the response distribution was determined in a dedicated analysis of these subset data by the Chi square test.

Inter-rater agreement relates to the extent to which different evaluating respondents, come to the same decision assigning the same assessment category (important and not important) to the skill under consideration. To measure the strength of consensus amongst the involved raters, an inter-rater agreement score was calculated for each question according to a previous described method (NX2A: Normalised Chi-square based Agreement)¹². Values of agreement less than 0.4 were associated with a 'poor agreement' label, values between 0.4 and 0.75 with 'moderate agreement' and values above 0.75 with 'excellent agreement'.

A Mann-Whitney's U test was performed to study the association between the level of importance assigned by the respondents and their experience (surgeons *versus* residents).

Qualitative ranking method

A qualitative ranking method was developed to identify the top-ranked skills for a trainee to possess before entering an operating room. We proceeded in the following way: 1) the number of times

111 were counted that each skill was ranked first, second, third, and so forth according to the "standard
112 competition ranking" strategy. This is a strategy by which 1) skills that compare equally receive the
113 same ranking number, and a gap is left in the ranking numbers (or "1224" strategy); 2), the
114 normalized sum of all rankings was calculated associating each skill by the number of times it was
115 actually evaluated; 3) a final ranking was created ordering from the skill with the lowest normalized
116 rank sum to the skill with the highest sum.

117 Thus, for each respondent, we derived a relative ranking from his absolute evaluations,
118 which is reasonable for the ordinal nature of the scale employed. Subsequently, we generated a
119 collective skill ranking using all the individual rankings. Even with this method, differences in
120 ranking between single skills are often negligible: this means that we cannot assert whether
121 differences between skills are due to chance (or to selection bias) or related to real differences in the
122 perceived importance of respondents. Thus, we also proceeded with a prioritization process and
123 grouped the skills in priority levels.

124

125 *Priority levels*

126 The number of times were counted of each skill that was ranked in the first three positions for each
127 respondent (n), and the number of times the same skill came in any other position (m). Each skill
128 was assigned to 'high priority' if n was greater than m , and to 'low priority' otherwise. Following
129 this, a Chi square test was performed to evaluate the statistical significance of the difference
130 between n and m . This created a skill prioritization process with 'low priority' not being irrelevant,
131 but only *less* relevant than those at 'high priority'. However, some skills could not be assigned to a
132 priority level with statistical significance, that is the repetition of this survey or involving different
133 raters could lead to different assignment (no generalizability of results). Therefore, the significance
134 was indicated (Tables 1-3, Figure 1).

135 This analysis allows the detection of skills that should be really considered more important.
136 Consequently, we suggest to consider priority levels first to determine the most important skills to
137 focus the teaching efforts (high level skills first, then low level ones). After that, the single skill
138 ranking can be taken to articulate more fine-grained interventions and teaching loads with respect to
139 specific skills that junior surgeons have to master.

140

141 **Results**

142 A total of 216 orthopedic surgeons responded to the survey. Sixty-seven percent of the respondents
143 had more the 10 years of personal experience in doing knee arthroscopy. The number of knee
144 arthroscopies performed by respondents was more than 400 for 10.3% of the respondents, between

200 and 400 for 25.4% of the respondents, between 50 and 200 for 46% of the respondents and less than 50 for the remaining 18.3%. Ten percent of respondents were residents and 90% were orthopedic surgeons. The age of respondents was more than 45 years for 53% of cases.

148

149 *General and specific skills*

150 A Chi square test was significant for all general and specific skills indicating the difference between
151 'low importance' (score 1 or 2) and 'high importance' (score 5 or 6) ($p < 0.001$) (Table 1). This
152 means that the sample exhibited a strong polarization in their response considering the related skills
153 'important to be mastered' in a statistically significant manner. General and specific skills were
154 found to be 'important to be mastered' with an excellent degree of agreement among respondents
155 (Table 1). Although, all general skills that were ranked 1 to 4 were assigned to 'high priority',
156 'anatomical knowledge' was being considered the most important general skill (Table 1). 'Manual
157 dexterity' showed a moderate agreement (0.69) and was assigned a 'low priority' level ($p > 0.05$)
158 (Table 1). Six specific skills were assigned 'high priority' with 'sterility' and 'patient positioning'
159 ranked 1 and 2. Noticeable is that 'tissue manipulation', which is ranked 2 for general skills is given
160 a rather low rank 8 for specific skills (Table 1).

161

162 *Skills regarding 'patient and tissue manipulation', 'knowledge' and 'navigation'*

163 Detailed questions were posed regarding 'patient and tissue manipulation', 'knowledge' and
164 'navigation', as this level of detail is required to develop suitable training tasks and use appropriate
165 training means. 'Patient and tissue manipulation' and 'knowledge' gave three more or less distinct
166 skill categories. The first category had a significant Chi square test ($p < 0.001$), excellent
167 Normalised Chi-square based Agreement and was assigned 'high priority' ($p < 0.001$). The second
168 category had a significant Chi square test ($p < 0.001$), moderate to excellent Normalised Chi-square
169 based Agreement and was assigned either 'high or low priority' that was not significant. The third
170 category had a significant or no significant Chi square test, poor to moderate Normalised Chi-
171 square based Agreement and was assigned 'low priority' ($p < 0.001$). More specific, the Chi square
172 test was not significant for 'triangulating the tip of the probe with a 0° scope' and 'triangulating the
173 tip of the probe with a 70° scope' (Figure 1). 'Precise portal placement', 'triangulating the tip of the
174 probe with a 30° scope' and 'insertion of the arthroscope' were ranked top three for 'patient and
175 tissue manipulation'. 'Use of vaporisator' and 'triangulation with a 0° or 70° scope' were ranked
176 lowest (Figure 1). Knowledge on 'knee anatomy', 'sterility' and 'sequence of an inspection round'
177 were ranked top three, whereas knowledge on 'corpus liberum', 'plica synovialis' and 'hoffa
178 impingement' were ranked lowest (Figure 1).

179 For 'navigation', all six questioned skills had a significant Chi square test ($p < 0.001$),

180 excellent Normalised Chi-square based Agreement and were assigned 'high priority' ($p < 0.001$).
181 These skills were formulated as navigation to inspect the 1) medial and 2) lateral compartment, 3)
182 the intercondylar notch, 4) the suprapatellar pouch, and the 5) medial and 6) lateral gutter.

183

184 *Preferred training means and exercises*

185 Only 'cadaveric specimen', ranked as the number 1 training means, showed a significant Chi square
186 test ($p < 0.001$, excellent Normalised Chi-square based Agreement and was assigned 'high priority'
187 ($p < 0.001$). The 'box trainer model without specific knee characteristic' did not show a significant
188 difference for the Chi square test ($p > 0.05$) and was given a poor agreement (Table 2).

189 All three questioned global exercises: 'identification of structures and navigation with the
190 arthroscope', 'instrument handling' and 'preparation of patient and equipment' had a significant Chi
191 square test ($p < 0.001$), excellent Normalised Chi-square based Agreement and was assigned 'high
192 priority' ($p < 0.001$). 'Tissue manipulation' and 'meniscal suturing' were ranked lowest and
193 assigned to a non significant 'low priority' level (Table 3).

194

195 *Analysis of uncertain respondents*

196 Considering the subset data of uncertain respondents (scores 3 or 4), the Chi square test revealed a
197 significant polarization in response distribution for several skills ($p < 0.05$) (Tables 1-3, Figure 1).
198 The significantly polarization direction was in accordance with respondents that considered skills
199 important to be mastered.

200

201 *Stratified analysis*

202 A stratified analysis of data revealed that ranking of two skills was related to respondents function.
203 Surgeons considered the 'inspection of lateral compartment' the most important skill of inspection
204 of the anatomical structures; whereas residents considered the 'inspection of medial compartment'
205 as the most relevant (Mann-Whitney's U test, $p < 0.05$). 'Instrument handling' was considered the
206 most important global exercise by the residents, whereas the surgeons considered the 'identification
207 of structures and navigation with the arthroscope' as the most important exercise ($p < 0.05$). A
208 significant association was found between the level of importance that respondents assigned to
209 skills and respondents level of expertise. Surgeons perceived a higher grade of importance
210 compared to residents for all skills that reached the statistical significance.

211

212

213 **Discussion**

214 Knee arthroscopy is a technique that requires demanding surgical skills that surgeons should acquire
215 before performing in the operating theatre. This study contributes by presenting consensus on
216 arthroscopic skills that are considered top priority by the European arthroscopic community. Data of
217 our survey were analyzed with an advanced ranking method (priority levels) to determine skills that
218 a young orthopedic surgeon should learn with priority before continuing training in the operating
219 room. The Chi square analysis revealed that for all proposed skills, except three, the sample
220 exhibited a strong polarization in its response considering the related skills ‘important to be
221 mastered’ in a statistically significant manner. This result is logical, since all skills eventually need
222 to be mastered to become a skilled arthroscopist^{3;10}.

223 ‘Anatomical knowledge’ is ranked as the number one general skill and ‘spatial perception’
224 as number three. This is in agreement with the ranking of the Canadian arthroscopic community
225^{10;11}. A difference is that the European community ranks ‘tissue manipulation’ as number 2 and the
226 Canadian community ranks ‘triangulation’ as number 2. But analysing the results of specific skills
227 of this study, it can be seen that ‘tissue manipulation’ is ranked rather medium to low (Table 1,
228 Figure 1) and ‘triangulating with a 30° scope’ is ranked rather high (Figure 1). A reason for this
229 difference in ranking could be that a certain group of respondents initially interpreted the term
230 ‘tissue manipulation’ differently or reconsidered its importance in view of the specific skills.
231 The ranking of specific skills (Table 1) was in correspondence with the detailed questions on
232 ‘patient and tissue manipulation’ and ‘knowledge’ (Figure 1). High priority was given to knowledge
233 on ‘sterility’, because this could immediately compromise patient safety. Furthermore, high
234 consensus was found on ‘patient positioning and preparation’, on ‘knee anatomy and pathology
235 knowledge’, being able to access the knee joint through ‘precise portal placement’ and ‘insertion of
236 the arthroscope’; and ‘navigation’ in all compartments of the knee joint (Table 1, Figure 1).
237 These four skills correspond to the required skills needed to gain access to the pathologic area in the
238 first place^{10;11}. If a resident is not capable of achieving this, therapeutic treatment is not possible at
239 all. So, knowing arthroscopic anatomy, and access and orientation in the joint will contribute to safe
240 performance of the therapy. The European community generally agreed with their Canadian
241 colleagues in ranking the most important skills^{10;11}, so apparently these basic skills are truly the
242 most essential.

243 Interestingly, ‘knowledge on anatomy and pathology of the knee joint’, which was ranked
244 number one in other studies as well^{2;3}, does not necessarily require actual instrument handling during
245 training. Arthroscopic anatomy and knee pathology are suited to be taught with contemporary
246 teaching methods using interactive e-learning modules that incorporate arthroscopic movies,
247 pictures and animated joint structures or using virtual reality simulators which also provide movies
248 and specific exercises focused on anatomy in combination with eye-hand coordination and

249 navigation¹³⁻¹⁵. One other solution being explored is the use of online cognitive simulators, with
250 software hold on a central server, and the simulator addressing those aspects of a surgical task that
251 do not require a complex end user controller that is fixed in one geographical location¹⁶.

252 Another item that requires further discussion is that even though being able to perform
253 ‘precise portal placement’ and ‘insertion of the arthroscope’ are ranked highly (Figure 1)¹⁰, the only
254 truly realistic training means available is a human cadaver specimen. This is a highly realistic
255 training means, but cadaveric specimen pose considerable drawbacks. The portals can be made only
256 once and the task is more difficult than in an actual patient due to untensioned quadriceps muscle.
257 In the time frame between the study by Safir, Dubrowski, Mirsky, Lin, Backstein and Carnahan in
258 2008¹⁰ and our recent survey, no developments have been made to allow the training of portal
259 placement in a simulated setting away from the operating room. The lack of suitable training means
260 for portal placement, might have contributed to the poor to moderate agreement on the usefulness of
261 them (Table 3).

262 Contrary, arthroscopic navigation, triangulation, identification and/or probing of anatomic
263 structures, which were ranked in the top (Figure 1, Table 3), can be elegantly trained in state of the
264 art simulators. So, these skills could be very well implemented in a preoperative training program
265 and fulfil the wishes from the community to use simulators in the curriculum⁷. Also the surveyed
266 detailed exercises (Table 3) are suitable to built in available validated simulators⁸.

267 Finally, when analysing ‘manual dexterity’ and ‘instrument and tissue handling’, the
268 consensus amongst the respondents is less apparent (Table 1, Figure 1). This is probably due to the
269 fact that they are only relevant to possess if the top ranked skills are acquired at some level.
270 However, especially ‘instrument and tissue handling’ are suited to train in simulators with some
271 form of haptic feedback¹⁷⁻¹⁹ and if not mastered increase the risk of delicate tissue damage such as
272 cartilage. The reason is that part of the instrument is inserted blindly and the complex joint shape
273 makes initial proper triangulation difficult^{20;21}. The importance of possessing this skill prior to
274 continuing training in the operating room is confirmed by the study of O’Neill, Cosgarea,
275 Freedman, Queale and McFarland²². Fellowship directors were questioned on the number of
276 procedures that a young orthopedic should perform before operating alone on patients. A total of
277 164 physicians involved in the education of residents and fellows responded and stated that a
278 substantial number of repetitions is needed to become proficient in arthroscopy. A large variability
279 in the number of repetitions estimated to achieve proficiency in all procedures also was found
280 amongst the physicians: on average 50 (standard deviation (SD) 46) repetitions for partial medial
281 meniscectomy and 61 (SD 53) for anterior cruciate ligament (ACL) reconstruction. But the most
282 important aspect to be considered from this study is that the absolute minimum number of
283 procedures needed to achieve proficiency was indicated to be 5-8 for any arthroscopic procedure.

The study has limitations. The response rate was 15%, which is rather low. Although it is similar to the response rates of similar studies^{7;10;11}. This could have led to bias. An example is the polarisation in indicating all skills as being important, because surgeons that are most involved in training and supervising residents probably would have been more willing to participate in the survey. Also the time frame in which the survey was kept open might have been a little short.

Patients are placing an additional demand of accountability on today's physicians and a surgeon must be capable of performing specific procedures in a safe and efficient manner such that the patient will not experience adverse consequence. A young surgeon should acquire specific skills before performing continuing training in the operating theatre^{8;23}. General skills considered important for a trainee to possess prior to train in the operating room were ranked 'anatomical knowledge', 'tissue manipulation', 'spatial perception' and 'triangulation. The top ranked two specific psychomotor skills were 'portal placement' and 'triangulating the tip of the probe with a 30° scope' and the top two on knowledge were 'knee anatomy' and 'sterility'. The list of highly detailed skills and exercises serve the design and development of improved simulators and exercises to train the highest ranked skills. Eventually, this will lead to training programs that are adopted by the entire arthroscopic community as they truly meet the wishes and needs. With this, patient safety will be increased and perhaps a more uniform level of the proficiency of young doctors will be achieved. Compared to the Canadian colleagues, the European arthroscopy community demonstrated similar ranking in skills.

References

- (1) Cullen KA, Hall MJ, Golosinskiy A. Ambulatory surgery in the United States, 2006. *Natl Health Stat Report* 2009;1-25.
- (2) Garrett WE, Jr., Swiontkowski MF, Weinstein JN et al. American Board of Orthopaedic Surgery Practice of the Orthopaedic Surgeon: Part-II, certification examination case mix. *J Bone Joint Surg Am* 2006;88:660-667.
- (3) Georgoulis A, Randelli P. Education in arthroscopy, sports medicine and knee surgery. *Knee Surg Sports Traumatol Arthrosc* 2011;19:1231-1232.
- (4) Grechenig W, Fellingner M, Fankhauser F, Weiglein AH. The Graz learning and training model for arthroscopic surgery. *Surg Radiol Anat* 1999;21:347-350.
- (5) Allum R. Complications of arthroscopy of the knee. *J Bone Joint Surg Br* 2002;84:937-945.
- (6) Hanna GB, Shimi SM, Cuschieri A. Randomised study of influence of two-dimensional versus three-dimensional imaging on performance of laparoscopic cholecystectomy. *Lancet* 1998;351:248-251.
- (7) Karam MD, Pedowitz RA, Natividad H, Murray J, Marsh JL. Current and future use of

- 320 surgical skills training laboratories in orthopaedic resident education: a national survey. *J*
321 *Bone Joint Surg Am* 2013;95:e4.
- 322 (8) Frank RM, Erickson B, Frank JM et al. Utility of modern arthroscopic simulator training
323 models. *Arthroscopy* 2014;30:121-133.
- 324 (9) Madan SS, Pai DR. Role of simulation in arthroscopy training. *Simul Healthc* 2014;9:127-
325 135.
- 326 (10) Safir O, Dubrowski A, Mirsky L, Lin C, Backstein D, Carnahan A. What skills should
327 simulation training in arthroscopy teach residents? *International Journal of Computer*
328 *Assisted Radiology and Surgery* 2008;3:433-437.
- 329 (11) Hui Y, Safir O, Dubrowski A, Carnahan H. What skills should simulation training in
330 arthroscopy teach residents? A focus on resident input. *Int J Comput Assist Radiol Surg*
331 2013.
- 332 (12) Cabitza F, Ragone V, Arrigoni P, Karlsson J, Randelli P. Management of knee injuries:
333 consensus-based indications from a large community of orthopaedic surgeons. *Knee Surg*
334 *Sports Traumatol Arthrosc* 2013;21:708-719.
- 335 (13) Obdeijn MC, Bavinck N, Mathoulin C, van der Horst CM, Schijven MP, Tuijthof GJ.
336 Education in wrist arthroscopy: past, present and future. *Knee Surg Sports Traumatol*
337 *Arthrosc* 2013.
- 338 (14) Tuijthof GJ, Visser P, Sierevelt IN, van Dijk CN, Kerkhoffs GM. Does Perception of
339 Usefulness of Arthroscopic Simulators Differ with Levels of Experience? *Clin Orthop Relat*
340 *Res* 2011.
- 341 (15) Verdaasdonk EG, Stassen LP, Schijven MP, Dankelman J. Construct validity and assessment
342 of the learning curve for the SIMENDO endoscopic simulator. *Surg Endosc* 2007;21:1406-
343 1412.
- 344 (16) Hurmusiadis V, Rhode K, Schaeffter T, Sherman K. Virtual arthroscopy trainer for
345 minimally invasive surgery. *Stud Health Technol Inform* 2011;163:236-238.
- 346 (17) Chami G, Ward JW, Phillips R, Sherman KP. Haptic feedback can provide an objective
347 assessment of arthroscopic skills. *Clin Orthop Relat Res* 2008;466:963-968.
- 348 (18) Moody L, Waterworth A, McCarthy AD, Harley P, Smallwood R. The feasibility of a mixed
349 reality surgical training environment. *Virtual Reality* 2008;12:77-86.
- 350 (19) Fucentese SF, Rahm S, Wieser K, Spillmann J, Harders M, Koch PP. Evaluation of a virtual-
351 reality-based simulator using passive haptic feedback for knee arthroscopy. *Knee Surg*
352 *Sports Traumatol Arthrosc* 2014.
- 353 (20) Obdeijn MC, Horeman T, de Boer LL, van Baalen SJ, Liverneaux P, Tuijthof GJ. Navigation
354 forces during wrist arthroscopy: assessment of expert levels. *Knee Surg Sports Traumatol*
355 *Arthrosc* 2014.
- 356 (21) Tuijthof GJ, Horeman T, Schafroth MU, Blankevoort L, Kerkhoffs GM. Probing forces of
357 menisci: what levels are safe for arthroscopic surgery. *Knee Surg Sports Traumatol Arthrosc*
358 2011;19:248-254.

359 (22) O'Neill PJ, Cosgarea AJ, Freedman JA, Queale WS, McFarland EG. Arthroscopic
360 proficiency: a survey of orthopaedic sports medicine fellowship directors and orthopaedic
361 surgery department chairs. *Arthroscopy* 2002;18:795-800.

362 (23) Modi CS, Morris G, Mukherjee R. Computer-simulation training for knee and shoulder
363 arthroscopic surgery. *Arthroscopy* 2010;26:832-840.
364

365

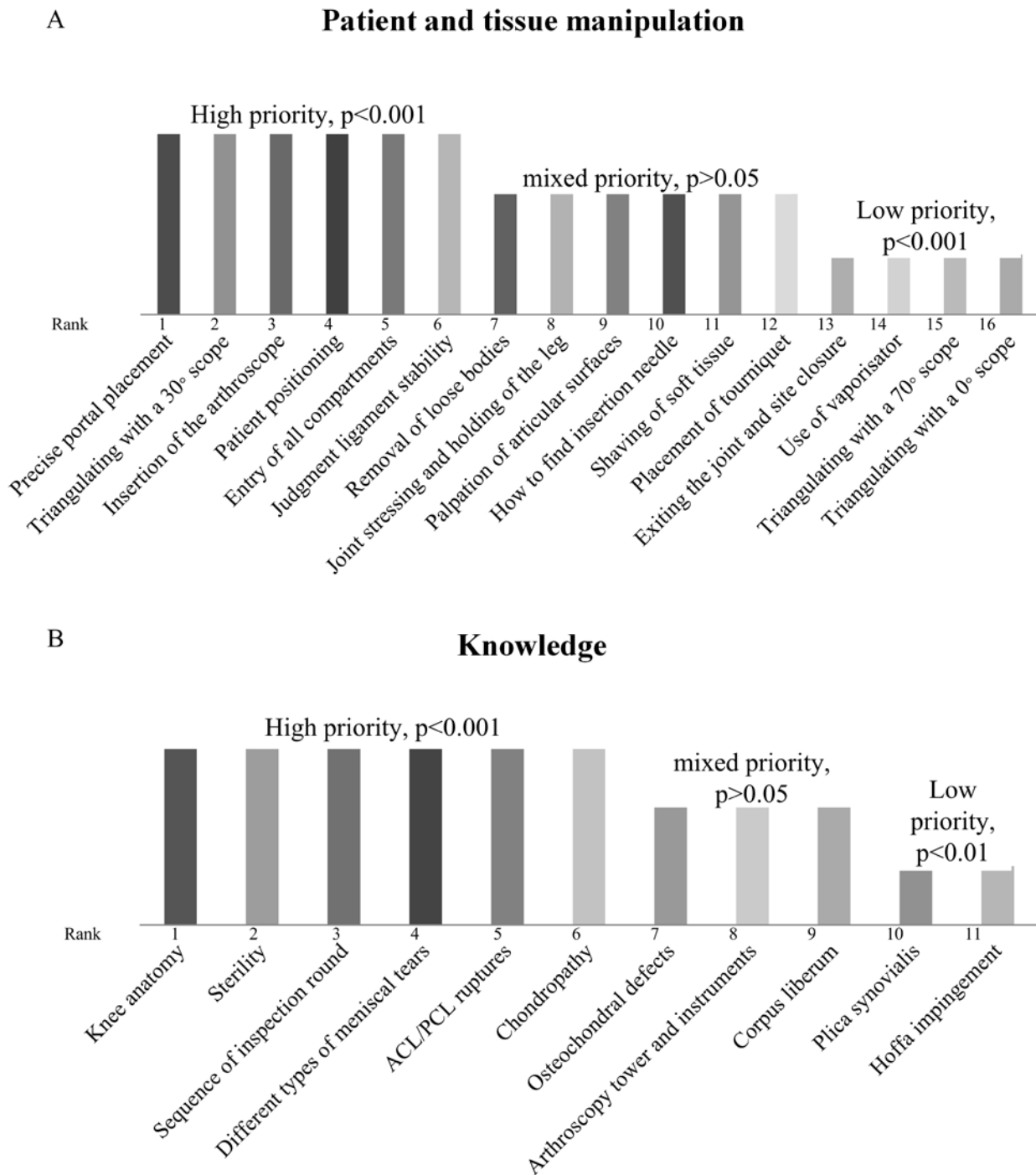


Figure 1 A) Ranking of specific skills on ‘patient and tissue manipulation’. B) Ranking of specific skills on ‘knowledge’. A distinction is made between ‘high priority’, insignificant priority which is either ‘high’ or ‘low’ (mixed priority) and ‘low priority’. Results demonstrating ‘high priority’, all had a Chi Square characteristic with $p < 0.001$ and showed an excellent (>0.75) Normalised Chi-square based Agreement. Results demonstrating ‘low priority’, showed a poor to moderate (<0.75) Normalised Chi-square based Agreement. ^a Skills ranked 7-11,13-16 of ‘patient and tissue manipulation’ and skills ranked 3-7, 9-11 of ‘knowledge’ had a significant polarization in response distribution of uncertain respondents ($p < 0.05$). ‘Patient positioning’ had a borderline significant polarization in response distribution of uncertain respondents ($p = 0.05$). The polarization direction was in accordance with respondents that considered skills important to be mastered

Table 1 Ranking of the general and specific skills. Abbreviations: NX2A, normalized chi-square based agreement; n.s., not significant; OR, operating room.

^ap < 0.001.

^bSkills that had a significant polarization in response distribution of uncertain respondents (p < 0.05). The polarization direction was in accordance with respondents that considered skills important to be mastered.

^cp < 0.05.

^dp < 0.01.

Table 1

Rank	General skills (Chi square p- level: ^a)	Nr respondents	NX2A	Priority Level
1	Anatomical knowledge ^b	200	0.98 excellent	High ^a
2	Tissue manipulation ^b	158	0.85 excellent	High ^a
3	Spatial perception	177	0.95 excellent	High ^a
4	Triangulation	178	0.93 excellent	High ^a
5	Manual dexterity	155	0.69 moderate	Low, n.s.
Rank	Specific skills (Chi square p- level: ^a)			
1	Sterility	196	0.95 excellent	High ^a
2	Patient positioning ^b	185	0.89 excellent	High ^a
3	Knowledge of pathology	169	0.95 excellent	High ^a
4	Preparation before the start of the operation	176	0.93 excellent	High ^a
5	Knowledge of equipment ^b	185	0.97 excellent	High ^c
6	Contact with patient ^b	170	0.82 excellent	High ^d
7	Work-up	165	0.92 excellent	High, n.s.
8	Tissue manipulation ^b	160	0.92 excellent	High, n.s.
9	Hand positions ^b	147	0.81 excellent	Low ^d
10	Overall control in the OR ^b	153	0.84 excellent	Low ^c

Table 2 Ranking of the preferred simulated environment for training. Abbreviations: NX2A, normalized chi-square based agreement; n.s., not significant.

^a $p < 0.001$.

^bSkills that had a significant polarization in response distribution of uncertain respondents ($p < 0.05$). The polarization direction was in accordance with respondents that considered skills important to be mastered.

Table 2

Rank	Simulators (Chi square p- level)	Nr respondents	NX2A	Priority Level
1	Cadaveric specimen ^a	182	0.79 excellent	High ^a
2	Physical knee phantom (e.g. Sawbones model) ^a	109	0.17 poor	High ^a
3	Physical knee phantom equipped with sensors to track performance ^a	131	0.42 poor	High ^a
4	Virtual reality simulator ^{a,b}	139	0.63 moderate	High ^a
5	Box trainer model without specific knee characteristics; n.s. ^b	110	0.003 poor	High ^a

Table 3 Ranking of the exercises which should be practiced before continuing training in the operating room. Abbreviations: ACL, anterior cruciate ligament; n.a., not applicable (100% of response value 1 or 2); NX2A, normalized chi-square based agreement; n.s., not significant; PCL, posterior cruciate ligament.

^ap < 0.001.

^bSkills that had a significant polarization in response distribution of uncertain respondents (p < 0.05). The polarization direction was in accordance with respondents that considered skills important to be mastered.

Table 3

Rank	Detailed exercises	Nr respondents	NX2A	Priority Level
1	Portal placement	203	0.94 excellent	High ^a
2	Identification of different compartments, intercondylar notch incl. ACL and PCL, all important structures in the joint (n.a.) ^b	197	n. a.	High ^a
3	Inspection with the arthroscope) (n.a.) ^b	198	n. a.	High ^a
4	Navigation by visualisation of structures and probing them ^b	190	0.93 excellent	High ^a
5	Insertion arthroscope in anterolateral portal	189	0.95 excellent	High ^a
6	Triangulation such as: pick up a ball with a grasper, place the probe through a ring, removal corpus librum	168	0.95	High ^a
7	Meniscectomy	173	0.84 excellent	High ^a
8	Tissue manipulation	150	0.92 excellent	Low, n. s.
9	Meniscal suturing	156	0.46 moderate	Low, n. s.