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

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1   **What Arthroscopic Skills Need to Be Trained Before**

2   **Continuing Safe Training in the Operating Room?**

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Abstract

Purpose:

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

Methods:

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

Results:

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

Conclusions:

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

Introduction

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

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

Methods

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

The survey encompassed 65 questions outlining fundamental skills of arthroscopy and methods that a surgical trainee should use to develop such skills. The survey was built up such that 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

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

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

Priority levels

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

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

Results

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

145 200 and 400 for 25.4% of the respondents, between 50 and 200 for 46% of the respondents and

146 less than 50 for the remaining 18.3%. Ten percent of respondents were residents and 90% were

147 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) latter 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.

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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 compromises patient safety. Furthermore, high
234   consensus was found on 'patient positioning and preparation', on 'knee anatomy and pathology
235   knowledge', being able to acces 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 necessary 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   navigation [13-15]. 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 location[16].

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   2008 [10] 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 comminuty to use simulators in the curriculum [7]. Also the surveyed

266   detailed exercises (Table 3) are suitable to built in available validated simulators [8].

267   Finallly, 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 feedback [17-19] 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 McFarland [22]. 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.

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

289 Patients are placing an additional demand of accountability on today's physicians and a
290 surgeon must be capable of performing specific procedures in a safe and efficient manner such that
291 the patient will not experience adverse consequence. A young surgeon should acquire specific skills
292 before performing continuing training in the operating theatre [8;23]. General skills considered
293 important for a trainee to possess prior to train in the operating room were ranked 'anatomical
294 knowledge', 'tissue manipulation', 'spatial perception' and 'triangulation. The top ranked two
295 specific psychomotor skills were 'portal placement' and 'triangulating the tip of the probe with a
296 30∘ scope' and the top two on knowledge were 'knee anatomy' and 'sterility'. The list of highly
297 detailed skills and exercises serve the design and development of improved simulators and exercises
298 to train the highest ranked skills. Eventually, this will lead to training programs that are adopted by
299 the entire arthroscopic community as they truly meet the wishes and needs. With this, patient safety
300 will be increased and perhaps a more uniform level of the proficiency of young doctors will be
301 achieved. Compared to the Canadian colleagues, the European arthroscopy community
302 demonstrated similar ranking in skills.

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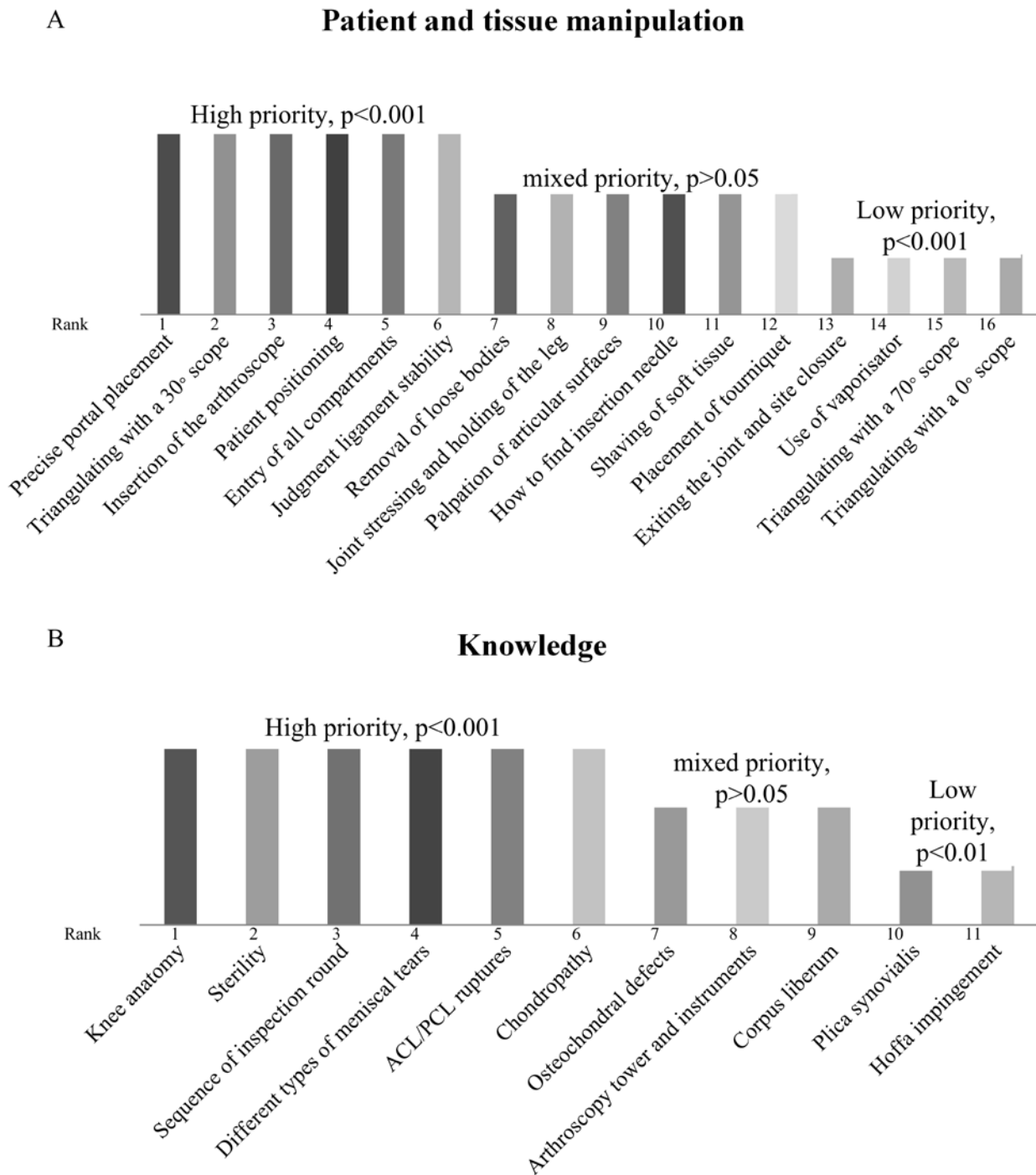364

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Figure 1 A) Ranking of specific skills on 'patient and tissue manipuation'. 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

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

[a]p < 0.001.

[b]Skills 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.

[c]p < 0.05.

[d]p < 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 positioningb[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.
[b]Skills 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]

15

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.

[a]$p < 0.001$.

[b]Skills 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.