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

Publication date
2017

Document Version
Accepted author manuscript

Published in
Journal of Knee Surgery

Accepted author manuscript. Link to published article (Thieme) :http://dx.doi.org/10.1055/s-0036-1597755

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

Dr. ir. Gabriëlle Tuijthof[1,2], Dr. Federico Cabitza[3], Dr. Vincenza Ragone[4], Dr. Riccardo Compagnoni [5], Dutch Arthrocopy Society Teaching committee (DAST) [6], prof. Dr. Pietro Randelli[4]

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

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.

Keywords: arthroscopy; skills; survey; expert opinion

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 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

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.

General and specific skills

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

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

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

For 'navigation', all six questioned skills had a significant Chi square test ($p < 0.001$), excellent Normalised Chi-square based Agreement and were assigned ‘high priority’ ($p < 0.001$). These skills were formulated as navigation to inspect the 1) medial and 2) lateral compartment, 3) the intercondylar notch, 4) the suprapatellar pouch, and the 5) medial and 6) latter gutter.

Preferred training means and exercises

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

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

Analysis of uncertain respondents

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

Stratified analysis

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

Discussion

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

'Anatomical knowledge' is ranked as the number one general skill and 'spatial perception' as number three. This is in agreement with the ranking of the Canadian arthroscopic community [10;11]. A difference is that the European community ranks 'tissue manipulation' as number 2 and the Canadian community ranks 'triangulation' as number 2. But analysing the results of specific skills of this study, it can be seen that 'tissue manipulation' is ranked rather medium to low (Table 1, Figure 1) and 'triangulating with a 30° scope' is ranked rather high (Figure 1). A reason for this difference in ranking could be that a certain group of respondents initially interpreted the term 'tissue manipulation' differently or reconsidered its importance in view of the specific skills.

The ranking of specific skills (Table 1) was in correspondence with the detailed questions on 'patient and tissue manipulation' and 'knowledge' (Figure 1). High priority was given to knowledge on 'sterility', because this could immediately compromises patient safety. Furthermore, high consensus was found on 'patient positioning and preparation', on 'knee anatomy and pathology knowledge', being able to acces the knee joint through 'precise portal placement' and 'insertion of the arthroscope'; and 'navigation' in all compartments of the knee joint (Table 1, Figure 1).

These four skills correspond to the required skills needed to gain access to the pathologic area in the first place [10;11]. If a resident is not capable of achieving this, therapeutic treatment is not possible at all. So, knowing arthroscopic anatomy, and access and orientation in the joint will contribute to safe performance of the therapy. The European community generally agreed with their Canadian colleagues in ranking the most important skills [10;11], so apparently these basic skills are truly the most essential.

Interestingly, 'knowledge on anatomy and pathology of the knee joint', which was ranked number one in other studies as well [2;3], does not necessary require actual instrument handling during training. Arthroscopic anatomy and knee pathology are suited to be taught with contemporary teaching methods using interactive e-learning modules that incorporate arthroscopic movies, pictures and animated joint structures or using virtual reality simulators which also provide movies and specific exercises focused on anatomy in combination with eye-hand coordination and navigation [13-15]. One other solution being explored is the use of online cognitive simulators, with software hold on a central server, and the simulator addressing those aspects of a surgical task that do not require a complex end user controller that is fixed in one geographical location[16].

Another item that requires further discussion is that even though being able to perform ‘precise portal placement’ and ‘insertion of the arthroscope’ are ranked highly (Figure 1) [10], the only truly realistic training means available is a human cadaver specimen. This is a highly realistic training means, but cadaveric specimen pose considerable drawbacks. The portals can be made only once and the task is more difficult than in an actual patient due to untensioned quadriceps muscle. In the time frame between the study by Safir, Dubrowski, Mirsky, Lin, Backstein and Carnahan in 2008 [10] and our recent survey, no developments have been made to allow the training of portal placement in a simulated setting away from the operating room. The lack of suitable training means for portal placement, might have contributed to the poor to moderate agreement on the usefulness of them (Table 3).

Contrary, arthroscopic navigation, triangulation, identification and/or probing of anatomic structures, which were ranked in the top (Figure 1, Table 3), can be elegantly trained in state of the art simulators. So, these skills could be very well implemented in a preoperative training program and fulfil the wishes from the comminuty to use simulators in the curriculum [7]. Also the surveyed detailed exercises (Table 3) are suitable to built in available validated simulators [8].

Finallly, when analysing ‘manual dexterity’ and ‘instrument and tissue handling’, the consensus amongst the respondents is less apparent (Table 1, Figure 1). This is probably due to the fact that they are only relevant to possess if the top ranked skills are acquired at some level. However, especially ‘instrument and tissue handling’ are suited to train in simulators with some form of haptic feedback [17-19] and if not mastered increase the risk of delicate tissue damage such as cartilage. The reason is that part of the instrument is inserted blindly and the complex joint shape makes initial proper triangulation difficult [20;21]. The importance of possessing this skill prior to continuing training in the operating room is confirmed by the study of O’Neill, Cosgarea, Freedman, Queale and McFarland [22]. Fellowship directors were questioned on the number of procedures that a young orthopedic should perform before operating alone on patients. A total of 164 physicians involved in the education of residents and fellows responded and stated that a substantial number of repetitions is needed to become proficient in arthroscopy. A large variability in the number of repetitions estimated to achieve proficiency in all procedures also was found amongst the physicians: on average 50 (standard deviation (SD) 46) repetitions for partial medial meniscectomy and 61 (SD 53) for anterior cruciate ligament (ACL) reconstruction. But the most important aspect to be considered from this study is that the absolute minimum number of 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, Fellinger 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

surgical skills training laboratories in orthopaedic resident education: a national survey. *J Bone Joint Surg Am* 2013;95:e4.

(8) Frank RM, Erickson B, Frank JM et al. Utility of modern arthroscopic simulator training models. *Arthroscopy* 2014;30:121-133.

(9) Madan SS, Pai DR. Role of simulation in arthroscopy training. *Simul Healthc* 2014;9:127-135.

(10) Safir O, Dubrowski A, Mirsky L, Lin C, Backstein D, Carnahan A. What skills should simulation training in arthroscopy teach residents? *International Journal of Computer Assisted Radiology and Surgery* 2008;3:433-437.

(11) Hui Y, Safir O, Dubrowski A, Carnahan H. What skills should simulation training in arthroscopy teach residents? A focus on resident input. *Int J Comput Assist Radiol Surg* 2013.

(12) Cabitza F, Ragone V, Arrigoni P, Karlsson J, Randelli P. Management of knee injuries: consensus-based indications from a large community of orthopaedic surgeons. *Knee Surg Sports Traumatol Arthrosc* 2013;21:708-719.

(13) Obdeijn MC, Bavinck N, Mathoulin C, van der Horst CM, Schijven MP, Tuijthof GJ. Education in wrist arthroscopy: past, present and future. *Knee Surg Sports Traumatol Arthrosc* 2013.

(14) Tuijthof GJ, Visser P, Sierevelt IN, van Dijk CN, Kerkhoffs GM. Does Perception of Usefulness of Arthroscopic Simulators Differ with Levels of Experience? *Clin Orthop Relat Res* 2011.

(15) Verdaasdonk EG, Stassen LP, Schijven MP, Dankelman J. Construct validity and assessment of the learning curve for the SIMENDO endoscopic simulator. *Surg Endosc* 2007;21:1406-1412.

(16) Hurmusiadis V, Rhode K, Schaeffter T, Sherman K. Virtual arthroscopy trainer for minimally invasive surgery. *Stud Health Technol Inform* 2011;163:236-238.

(17) Chami G, Ward JW, Phillips R, Sherman KP. Haptic feedback can provide an objective assessment of arthroscopic skills. *Clin Orthop Relat Res* 2008;466:963-968.

(18) Moody L, Waterworth A, McCarthy AD, Harley P, Smallwood R. The feasibility of a mixed reality surgical training environment. *Virtual Reality* 2008;12:77-86.

(19) Fucentese SF, Rahm S, Wieser K, Spillmann J, Harders M, Koch PP. Evaluation of a virtual-reality-based simulator using passive haptic feedback for knee arthroscopy. *Knee Surg Sports Traumatol Arthrosc* 2014.

(20) Obdeijn MC, Horeman T, de Boer LL, van Baalen SJ, Liverneaux P, Tuijthof GJ. Navigation forces during wrist arthroscopy: assessment of expert levels. *Knee Surg Sports Traumatol Arthrosc* 2014.

(21) Tuijthof GJ, Horeman T, Schafroth MU, Blankevoort L, Kerkhoffs GM. Probing forces of menisci: what levels are safe for arthroscopic surgery. *Knee Surg Sports Traumatol Arthrosc* 2011;19:248-254.

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

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

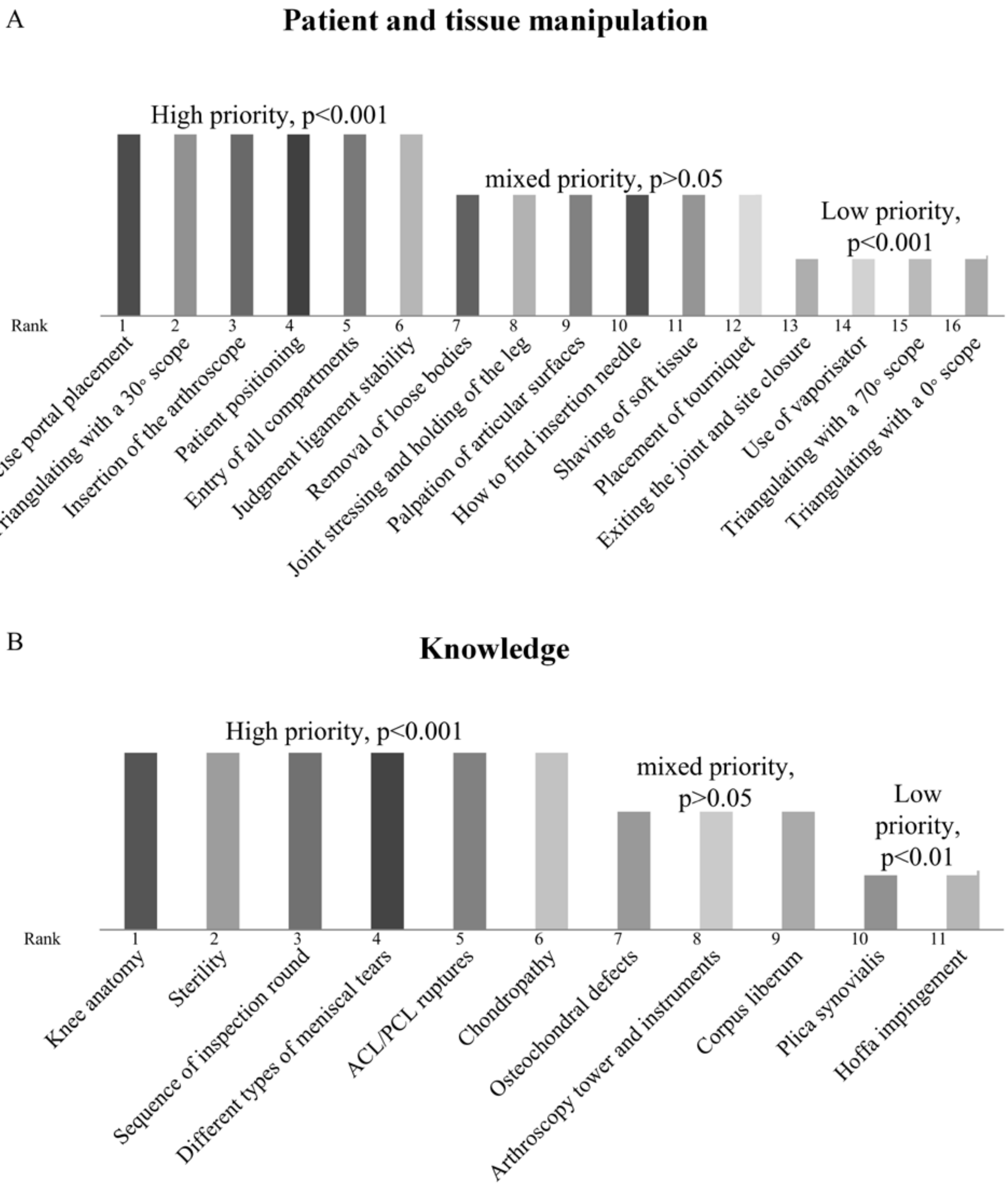

Figure 1 A) Ranking of specific skills on ‘patient and tissue manipuation’. B) Ranking of specific skills on ‘knowledge’. A distinction is made between ‘high priority’, insignificant priority which is either ‘high’ or ‘low’ (mixed priority) and ‘low priority’. Results demonstrating ‘high priority’, all 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

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]

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.