A Porcine Knee Model Is Valid for Use in the Evaluation of Arthroscopic Skills: A Pilot Study

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Abstract

Background Previously validated knee arthroscopy evaluation tools have used human cadaveric knees. This is unsustainable because of the cost and scarcity of these specimens. Porcine (pig) knees are anatomically similar, affordable, and easily obtainable; however, whether porcine knees represent a suitable alternative to human specimens has not been evaluated.

Questions/purposes The purpose of this study was to determine whether porcine knees are similar to human cadaveric knees for the assessment of knee arthroscopy

skills by evaluating (1) the validity of the porcine model (whether trainees of the same level of ability scored similarly when using the two models) and (2) the reliability of the porcine model (whether surgeons with experience achieved higher scores than surgeons with less experience in the porcine model).

Methods Eleven orthopaedic surgery residents (five junior residents and six senior residents), one orthopaedic sports medicine fellow, and three attending orthopaedic surgeons were enrolled. Participants were provided instructions for a proper arthroscopic examination of the knee and asked to identify, and then probe, the listed anatomic structures on both the human and porcine knee specimens. Each participant was asked to demonstrate the following skills: joint manipulation, instrument control and triangulation, fluid management, maintenance of field of view, economy of movement, and efficiency. The Objective Assessment of Arthroscopic Skills (OAAS) and checklist for diagnostic arthroscopy of the knee were used for skills assessment by one observer. Internal consistency, a measure of how well the assessment tool measures the skills being studied, was determined by Cronbach's α and group differences investigated by paired t-test and Wilcoxon signed-rank tests where appropriate. Based on a sample size calculation, a total of 37 subjects would be required for the full-scale research study to achieve a power of 0.80, with α set at 0.05, to detect a difference in OAAS score of 4.73 (25%). This value is outside of the 95% confidence intervals for the human knee.

Results We found the porcine model to have a high level of face validity. There was no difference with the numbers available in total OAAS scores (mean $\pm$ SD; 95% confidence interval [CI]) within subjects between the human (18.93 ± 7.54 ; 14.76–23.11) and porcine (17.87 ± 6.36 ; 14.34–21.39) knees ($p = 0.433$). There was also no

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Each author from the institution at which the human protocol was performed certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

This work was performed at the Pan Am Clinic, Winnipeg, Manitoba, Canada.

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difference ($p = 0.234$) with the numbers available in overall OAAS score among participants working on either human (2.60 ± 1.35 ; 1.85 – 3.35) or porcine (2.33 ± 0.90 ; 1.84 – 2.83) specimens. Internal consistency of the simulation for both the human and porcine knees was high and did not differ between groups (Cronbach's α was 0.919 in the human knee and 0.954 in the porcine knee), suggesting the OAAS outcome score specifically assesses arthroscopic skill of participants in both the human and porcine models. More experienced arthroscopists scored higher than did less experienced trainees; there was high correlation (Pearson's correlation coefficient r , 95% CI) between years of experience and total OAAS scores in human (0.78 ; 0.46 – 0.92) and porcine (0.80 ; 0.49 – 0.93) diagnostic arthroscopy models.

Conclusions The porcine cadaveric knee model was a valid surrogate for the human knee in arthroscopic skills assessment.

Clinical Relevance Trainees can be objectively evaluated using an affordable model that allows summative and formative feedback in the laboratory at a fraction of the cost of previously validated methods.

Introduction

At present, seven of the 14 most common orthopaedic procedures involve arthroscopy [7]. Arthroscopic procedures are difficult to master and trainees must deliberately practice technical skills to reach proficiency [1, 8]. Currently, surgical education is in the midst of change as new ways of training and evaluating residents are being developed [1, 4–6, 8, 9, 12, 14, 17, 20]. In the past, residents honed their skills in the operating room through the traditional method of apprenticeship [1, 2, 8, 9, 12, 17, 20]. Trainees began by observing more experienced surgeons, and their involvement progressed under direct supervision. Procedures were taught on patients with little or no way to practice and objectively evaluate the necessary skills in a risk-free environment. Evaluation was often based on surgical outcomes and the subjective assessment of the attending physician. In recent years, a growing body of research has been aimed at developing a different approach to surgical education, one that uses various simulation models to objectively assess surgical skills [1, 2, 5, 6, 8, 9, 12, 18].

With regard to knee arthroscopy, human cadaveric models and computer simulators have historically been used for skills assessment using validated laboratory-based evaluation tools such as the Objective Assessment of Arthroscopic Skills (OAAS) [1, 8, 18, 19]. Human

cadaveric knees can cost up to USD 500 per specimen plus shipping, and they require expensive infrastructure for storage and disposal [8, 17, 19]. The high cost and relative scarcity of specimens make this arthroscopic training and evaluation model unsustainable for many orthopaedic residency programs [17, 18]. Therefore, most arthroscopy training programs are limited by volume, frequency, and type of procedures performed. In addition, cadaveric wet laboratories are often limited to diagnostic arthroscopy to maximize use of specimens for multiple trainees. Computer simulators provide objective feedback and minimize costs associated with repetition, but again their value is limited to basic arthroscopic skills and capital costs are substantial [3, 20]. Additionally, trainees using computer simulators forego the haptic feedback that real tissue provides [1], and essential skills such as portal placement and access, managing fluid flow, and the ability to accommodate various techniques and instruments are not incorporated into current simulator models. These limitations of computer simulators make flesh-and-bone specimens the ideal arthroscopy training models, even as technology continues to evolve.

In contrast, the porcine (pig) knee is known to have similar anatomy to the human knee, and specimens are readily available and easily acquired in most communities [10, 11, 21]. Porcine knees can be obtained for a cost of less than USD 30 per specimen, and the associated costs of storage and disposal are also lower than those associated with human specimens. As a result of these reduced costs, this model provides residents with the potential for more extensive training with respect to the types of procedures performed. Porcine models have been used in other areas of surgical education including general surgery, but the use of porcine models in orthopaedic surgery has not been fully realized [12, 18]. In particular, the degree to which knee arthroscopy in a porcine model simulates the procedure in a human knee, whether surgical trainees of similar experience would receive similar scores on the OAAS tool when scored on human or porcine knees, and whether surgeons of increasing experience would score more highly on the OAAS—in other words, evidence of face validity and reliability of the porcine model—need to be better defined.

We therefore sought to determine whether assessment of knee arthroscopy skills using a porcine model is similar to assessment using human cadaveric knees by evaluating (1) the validity of the porcine model (whether trainees of the same level of ability scored similarly when using the two models); and (2) the reliability of the porcine model (whether surgeons with experience achieved higher scores than surgeons with less experience using the porcine model).

Materials and Methods

This was a validation and reliability study. The local institutional review board granted approval for the study. Residents, orthopaedic sports medicine fellows, and orthopaedic sports medicine surgeons were recruited to participate and consent was obtained. A total of 15 participants enrolled in the study: 11 orthopaedic residents, one fellow, and three attending surgeons. Participants completed prestudy surveys including level of training and arthroscopic surgical experience. Group allocation was based on level of training. Our group of junior residents included Postgraduate Year (PGY) 1 to 2 residents (five participants), our senior resident group consisted of PGY 3 to 5 residents (six participants), and our group of fully trained surgeons included orthopaedic sports medicine fellows and attending surgeons (four participants). With respect to the attending surgeons, the years of practice (excluding residency) were 5, 22, and 23 years. Number of orthopaedic sports medicine rotations for all participants ranged from no experience to 11 rotations. An orthopaedic sports medicine rotation is 4 weeks of clinics and surgeries, primarily involving open and arthroscopic procedures, involving upper and lower extremities, in both inpatient and outpatient facilities.

Eleven (73%) of 15 participants had previously attended a local resident arthroscopy skills course and four (27%) participants attended an Arthroscopy Association of North America skills course.

A procedure checklist and instructions for a proper arthroscopic examination of a knee, taken from Poss et al. [15], were given to each participant to review 5 minutes before commencement and throughout the duration of participation. Participants were instructed to complete a diagnostic knee arthroscopy on a human cadaveric specimen and a porcine knee specimen in random order using standard arthroscopy equipment (Fig. 1). Ten minutes were allotted for each arthroscopy. Participants were then given an unlimited amount of time to perform a partial meniscectomy on the porcine specimen. The previously validated OAAS form [19] and a published checklist for diagnostic arthroscopy of the knee [15] were used for assessment of each participant. One observer performed all evaluations for the study in person. No intraobserver repeatability testing was performed, because we felt that the process was reproducible based on the previous validation study of the OAAS [19].

To answer our first research question, about whether the model has a high level of face validity, we compared OAAS scores achieved by participants with similar experience between the human cadaveric and porcine knee models. Frequency statistics were generated for years of practice, group allotment, number of completed sports

Fig. 1 This image represents the preparation of a porcine knee specimen for diagnostic arthroscopy.

medicine rotations, and arthroscopic skill courses attended. A Wilcoxon signed-rank test was performed to determine if there was a difference in overall scores within subjects between the human and porcine specimens; a paired t-test was used for total OAAS scores. Cronbach's alpha was calculated as a measure of internal consistency of the simulation for both the human and porcine knee skills assessments. Internal consistency, or homogeneity, of an assessment score indicates how well each question, or items, of the scoring system measures the skill being studied. To answer our second research question, about reliability of the porcine knee arthroscopy model, we determined if increasing arthroscopy experience was correlated with an increase in OAAS score. Pearson's correlation coefficient was used to associate previous arthroscopic experience with overall and total scores for the human and porcine specimens as well as the partial meniscectomy on the porcine knee. A multiple regression was used to determine the association among level of training, number of years in practice, number of completed sports medicine rotations, and group allotment to total OAAS scores on the human and porcine knee. The alpha level was set at $p < 0.05$ to signify a significant difference for all analyses. SPSS 22.0 (IBM Corporation, Armonk,

Fig. 2 Within-subject comparison of total OAAS scores between the human and porcine knee models. Overall group as well as individual group, means, and CIs suggest that there is no difference between models with a large overlap in CIs.

NY, USA) was used to perform statistical analyses. This was an equivalence trial pilot study between human and porcine knees. For us to determine that the two models were comparable with respect to arthroscopic skills, a sample size of 37 would be required to achieve a power of 0.8 with α set at 0.05. Our assumption is that for the porcine knee to be either superior or inferior, the mean total score would have to differ by 25% (ie, 4.73); this value is outside of the 95% confidence intervals for the human knee.

Results

We found the porcine model to have a high level of face validity. There was no difference with the numbers available in total OAAS scores (mean $\pm$ SD; 95% confidence interval [CI]) within subjects between the human (18.93 ± 7.54 ; 14.76–23.11) and porcine (17.87 ± 6.36 ; 14.34–21.39; $p=0.433$) knees (Fig. 2). In addition, there was no difference with the numbers available in the overall OAAS scores achieved by the same subjects between the human (2.60 ± 1.35 ; 1.85–3.35) and porcine (2.33 ± 0.90 ; 1.84–2.83; $p = 0.234$) specimens. The internal consistency of the simulation for both the human and porcine knees was high and similar between groups (Cronbach's α was 0.919 for human specimens and 0.954 for the porcine specimens). The internal consistency, for both the human and porcine knees, is in agreement with the original validation study of the OAAS on a human cadaveric knee model where Cronbach's α was 0.97 [19]. These findings suggest that the OAAS outcome score specifically assessed the arthroscopic

skills of participants in both the human and porcine models.

More experienced arthroscopists scored higher than did less experienced trainees; there was a high correlation (r ; 95% CI) between years of experience and total OAAS scores, both in human (0.78; 0.46–0.92) and porcine diagnostic arthroscopy models (0.80; 0.49–0.93) and the porcine partial meniscectomy (0.84; 0.65–0.96). We found that the number of completed sports medicine rotations was the most significant predictor (unstandardized regression coefficient [B], 95% CI; p) of total OAAS scores in both the human (1.752, 1.28–2.22; $p < 0.001$) and porcine (1.39, 0.90–1.89; $p < 0.001$) specimens.

Discussion

Surgical simulation has increasingly become a topic of interest within the orthopaedic community as training programs strive for optimization of resident work hours and education methods. It is especially challenging to achieve proficiency in arthroscopic surgery without hands-on repetition [13], and although computer simulators have been available for several years, fluid management, dynamic resistance, and haptic feedback are valuable simulation features afforded to the trainee learning on flesh-and-bone specimens. Training with human cadaveric models is expensive, and porcine knees, with anatomy similar to the human knee, are inexpensive and readily available [10, 11, 16, 21]. Although arthroscopic training using porcine knees is not a novel concept, studies have not shown that the porcine knee is similar enough to the human cadaveric knee for arthroscopic skills assessment [3, 10, 21]. This study found that the porcine knee model demonstrated high face validity, because participants attained similar scores on both the human cadaveric and porcine specimens and high reliability with more experienced surgeons achieving higher scores using the porcine model.

This study had a number of limitations. First, this was a pilot study with a small sample size of 15 participants. A post hoc power analysis indicated that the power of this pilot trial was 0.19 (required sample size is 37), but given the large difference in cost, we did not feel that the difference was worth paying for. Second, the assessment of skills using the procedure-specific checklist and OAAS form was unblinded and performed by one observer, and no intraobserver repeatability testing was performed. Despite this, we feel this approach was valid; the original validation study of the OAAS form was blinded through the use of recorded videos of the procedures and graded by five observers [19]. Based on these results, we did not feel that multiple observers were necessary and that blinding was not feasible as a result of the different species of the

models. Our focus was on the comparison of a human cadaveric knee and a porcine knee specimen. Given that the differences in anatomy are quickly apparent to the reviewer watching a recording, they are essentially not blinded to the species of the model. We also believe that the process was reproducible based on the previous validation study of the OAAS [19] such that one observer was sufficient. Third, the porcine model poses a number of unique challenges for the arthroscopist. The thicker skin and large anterior fat pad can make portal placement and initial orientation difficult. Other anatomic differences when compared with the human cadaveric model such as the elongated patella, tighter joint space, and narrow femoral notch also add to the difficulty. Despite these differences, the ability to train and evaluate knee arthroscopy skills on a model that is more challenging than the human knee may be of benefit to the trainee when he or she returns to human knee arthroscopy.

The main finding of this study was that the porcine cadaveric knee model was a valid surrogate for the human knee when evaluating diagnostic knee arthroscopy. The previously validated OAAS scoring system [19] was used to demonstrate that there was no difference in overall score, within subjects, between the human and porcine knee models. This suggests that the participant's score did not change, regardless of whether the individual was using a human or porcine knee. Because the cost and availability of human specimens can be barriers to standardized and regularly scheduled surgical skills training within orthopaedic surgery residency programs, using porcine specimens has the potential to eliminate this barrier.

There was a high correlation between years of experience and total OAAS scores for diagnostic arthroscopy on the human and porcine knees as well as for meniscectomy on the porcine knee. A strong correlation between OAAS scores and years of experience suggests the discriminant validity of each of these models and techniques, which is in agreement with the original study [19]. Although this study has demonstrated a correlation between years of experience and total OAAS scores, in general, it is important to note that the discriminant validity may be limited to the extremes of the spectrum of experience (such as junior residents versus fellows and attendings). For the porcine knee and the OAAS to be used for training, discriminant validity would have to be demonstrated for each skill domain of the evaluation tool so trainees and supervisors could track performance improvements. The finding that the number of orthopaedic sports medicine rotations was the most significant predictor of OAAS score, to our knowledge, has not been previously stated in the literature.

The clinical importance of our findings lies in the ability to objectively evaluate trainee skill level using a model that is of low cost and is easily obtainable. The validation of the

OAAS using a porcine knee model allows training programs to provide objective feedback for their trainees at a fraction of the cost of previously validated methods. In addition, porcine specimens can be procured from a local butcher and do not require special infrastructure for storage or disposal. For the cost of one human cadaveric specimen, an entire residency program could therefore evaluate each resident with individual specimens. The availability and affordability of this model also allow trainees to practice new techniques and procedures without concern over preserving the anatomy of the specimen for the next person. Future studies should focus on the development of a knee arthroscopy training curriculum using porcine knee specimens. The use of animal models for arthroscopy training and evaluation may also be expanded to include other joints.

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