SUBSPECIALTY PROCEDURES

KNEE ARTHROSCOPY

A Simulation Demonstrating the Imperial Knee Arthroscopy Cognitive Task Analysis (IKACTA) Tool

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Abstract

Background: Virtual reality and cadaveric simulations are expensive and not readily accessible¹. Innovative and accessible training adjuncts are required to help meet training needs. Cognitive task analysis (CTA) has been used extensively to train pilots and surgeons in other surgical specialties²⁻⁶. However, the use of CTA tools within orthopaedics is in its infancy. Arthroscopic procedures are minimally invasive and require a different skill set compared with open surgery. Residents often feel poorly prepared to perform this in the operating room because of the steep learning curve associated with acquiring basic arthroscopic skills. We designed the Imperial Knee Arthroscopy Cognitive Task Analysis (IKACTA) tool, which is, to our knowledge, the first CTA tool described in the orthopaedic literature, demonstrating significant objective benefits in training novices to perform diagnostic knee arthroscopy.

Description: The IKACTA tool, which is the combination of the written description of the phases below and the videos (with superimposed audio recordings) of each phase, utilizes simultaneous written and audiovisual modalities to teach diagnostic knee arthroscopy. The procedure was divided into 7 phases: (1) operating room and patient setup, (2) preparation and draping, (3) anterolateral portal placement, (4) examination of the patellofemoral joint and the lateral gutter, (5) examination of the medial compartment and anteromedial portal placement, (6) examination of the intercondylar notch and the lateral compartment, and (7) postoperative care and rehabilitation.

For each phase, there are sections on the technical steps, cognitive decision-making behind each technical step, and potential errors and solutions. Video clips recorded by an expert surgeon in the operating room specific to each phase and audio voice recordings explaining each phase superimposed on the video clips were combined with the written information to design the IKACTA tool.

Alternatives: Not applicable.

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Rationale: This learning tool allows a trainee to learn each technical step, the cognitive decision-making underpinning each step, and potential errors and solutions relevant to each phase of the procedure. Furthermore, the learner can use written and audiovisual modalities simultaneously to learn this technique by reading the written component of the tool first and then watching the relevant video clips with the audio recordings for each phase of the procedure. Alternative training techniques currently include the traditional apprenticeship model, which is becoming increasingly insufficient in the current environment of reduced training hours^{7,8}. Adjuncts to this model are essential to help meet training needs. The IKACTION tool has demonstrated significant objective benefits for novice trainees to learn diagnostic knee arthroscopy⁹. The idea behind this learning tool is for the trainee surgeon to use this tool independent of the trainer, prior to attending the operating room. The tool provides trainees with knowledge and cognitive understanding of the procedural steps before they perform this procedure on patients. They are aware of potential errors and methods to avoid or overcome these errors. We believe that this tool will reduce the initial difficult phase of the learning curve for junior residents and, therefore, will improve training efficiency in the operating room.

Introductory Statement

The Imperial Knee Arthroscopy Cognitive Task Analysis (IKACTION) tool utilizes simultaneous written and audiovisual stimuli to teach each phase of a diagnostic knee arthroscopy procedure, which has demonstrated significant benefits in training this procedure to novices.

Indications & Contraindications

Indications

- Not applicable as this is a training tool.

Contraindications

- Not applicable.

Step-by-Step Description of Procedure

Phase 1: Operating Room and Patient Setup (Video 1)

- Place the patient in the supine position with a tourniquet on the proximal part of the thigh. Provide lateral vertical support at the level of the tourniquet. The patient's feet should be at the end of the bed and the ipsilateral thigh and knee should be at the edge of the bed.
- Apply the skirt (blue plastic cut-off drape) around the tourniquet.
- Perform an examination under anesthesia (EUA). Check for effusion, range of motion, and patellar mobility; perform the anterior-posterior drawer, Lachman, pivot, and dial tests; and assess for varus and valgus laxity.

Cognitive Decision Points

- Ensure that enough valgus stress is possible with the lateral support to work in the medial compartment.
- Ensure that the leg can be placed in the figure-of-4 position to work in the lateral compartment.
- Apply the skirt to ensure that cleansing fluid does not collect under the drape and lead to tourniquet burn.
- Perform the anterior drawer and Lachman tests of the ACL, posterior drawer test of the PCL, varus stress test of the lateral cruciate ligament, valgus stress test of the medial collateral ligament, and the dial test for the posterolateral corner.

Errors and Solutions

- Poor operating-room setup and patient positioning can make the procedure very difficult to perform

Video 1 Demonstrating Phase 1—operating room and patient setup.

Phase 2: Preparation and Draping of the Patient (Video 2)

- Choose a skin preparation—alcoholic solution or Betadine (povidone-iodine) antiseptic solution—apply and wait for it to dry.
- Cover the area from the tourniquet to the ankle with the skin preparation. The foot does not need to be prepared. Use the preparation technique and inflate the tourniquet as shown in Video 2.
- Use the draping technique with a proximal and a foot shut-off and extremity drape (Video 2).
- The camera is white-balanced with a white swab as shown in the video.
- Ensure that all tubing lengths are adjusted as shown in the video.

Cognitive Decision Points

- Ensure that the assistant on the opposite side does not desterilize against the operating table while preparing the patient. The surgeon should ideally stand on the opposite side during preparation to reduce this risk.

Errors and Solutions

- Do not prepare the working area of the knee after the popliteal fossa has been prepared.

Video 2 Demonstrating Phase 2—preparation and draping.

Phase 3: Placement of Anterolateral Portal (Video 3)

- Identify appropriate landmarks—the patellar tendon, patella, lateral femoral condyle, and lateral tibial plateau—and mark them.
- Define the triangle between the lateral border of the patellar tendon, lateral femoral condyle, and lateral tibial plateau and identify the soft spot between these 3 structures.
- Make a vertical stab incision (<5 mm in length) with a number-11 scalpel with the blade facing upward in the center of the soft spot, aiming toward the intercondylar notch.

Cognitive Decision Points

- Face the blade upward to ensure that there is no iatrogenic injury to the lateral meniscus.
- Use a vertical incision as it allows possible extension in case an open procedure is required.
- Ensure that the blade is perpendicular to the skin in both the proximal-distal and the medial-lateral plane and is parallel to the tibial plateau.

Errors and Solutions

- Avoid placing the portal too laterally as it makes it difficult to work in the medial compartment. In this case, reidentify landmarks and redo anterolateral portal placement.
- Avoid facing the blade downward, which places the lateral meniscus at risk of injury.

Video 3 Demonstrating Phase 3—anterolateral portal placement.

Phase 4: Diagnostic Arthroscopy of the Patellofemoral Joint (PFJ) and Lateral Gutter (Video 4)

- Introduce the trocar in the same direction that the incision was made, pointing toward the intercondylar notch with the knee in 80° of flexion.
- Slide the trocar underneath the patella gently while extending the knee to enter the suprapatellar pouch.
- Then introduce the scope into the suprapatellar pouch.
- Ensure that the fluid is turned on.
- Adjust the focus as needed and drain any fat pad or blood that is obscuring the view.
- After obtaining a clear view, examine the PFJ.
- Ensure that the light cord lead is kept at the 3 o'clock position and the camera is parallel to the tibia at all times in this position when the patellofemoral articulation is examined. Patellar tracking can be examined in this position by flexing the knee to 30°.
- Then examine the patella. Check the medial and lateral facets. Ensure that the light lead is pointing down (6 o'clock position) to look up at the patella.
- Examine the trochlea, including the medial and lateral sides. Ensure that the light lead is pointing upward (12 o'clock) to look down on the trochlea.
- Gently guide the scope into the lateral gutter. Examine the gutter, popliteal hiatus, and popliteal tendon.

Cognitive Decision Points

- Take care not to cause iatrogenic injury to the articular cartilage of the patella, trochlea, lateral femoral condyle, and the ACL during trocar and scope introduction.
- Note any patellar maltracking.
- Record damage to the articular cartilage of the patella and trochlea according to the International Cartilage Repair Society (ICRS) and/or Outerbridge classification system.
- Examine the lateral gutter for synovitis and loose bodies.

Errors and Solutions

- Avoid applying too much force when introducing the scope as it can cause iatrogenic injury to important structures.
- Avoid missing the lateral gutter at this stage as doing so can lead to missed loose bodies in the joint if the surgeon does not remember to examine it at the end of the procedure.

Video 4 Demonstrating Phase 4—PFJ and lateral gutter.

Phase 5: Diagnostic Arthroscopy of the Medial Compartment and Anteromedial Portal Placement (Video 5)

- Gently move the scope back to the suprapatellar pouch before guiding it over the medial femoral condyle into the medial gutter.
- After examining the medial gutter, gently withdraw the arthroscope into the anterior aspect of the medial joint and then introduce it into the medial compartment with gradual flexion of the knee.
- To make the anteromedial portal, turn the scope medially with the knee in 90° of flexion.
- Insert a white needle at the center of the red light from the scope over the medial soft spot, aiming toward the intercondylar notch.
- Hold the needle at right angles to the skin during insertion and then view under direct vision to ensure that the desired position of the portal is achieved.
- Make a stab incision in a vertical fashion with a number-15 scalpel with the blade pointing upward in the same direction as the needle.
- With the knee at 90°, the arthroscopy probe is first inserted into the medial compartment. Examine the articular cartilage of the medial femoral condyle and tibial plateau with the probe. The body of the medial meniscus can also be examined in this position.
- Ensure that the medial femoral condyle is examined with the knee in flexion and extension.
- Then extend the knee and apply a valgus and external rotation force to examine the posterior horn of the medial meniscus.

Cognitive Decision Points

- Assess the medial gutter for any loose bodies.
- Check the position of the white needle under direct vision. Ensure that it is not too far medial and is above the level of the medial meniscus. Also check to ensure that it is not too shallow or steep; if it is, the medial femoral condyle will get in the way of the instruments while working on the posterior structures.
- Introduce the scalpel under direct vision to avoid iatrogenic injury to the medial meniscus and medial femoral condyle.
- Move the knee in a range from 0° to 90° to view all weight-bearing portions of the articular cartilage of the femoral condyle with the light lead moved through 180°.
- Record any articular cartilage injury to the medial femoral condyle and/or tibial plateau according to the ICRS and/or Outerbridge grading system.
- Examine the body and the posterior and anterior horns of the medial meniscus and record any tears.
- Note the location and pattern of the tear to plan a further procedure, i.e., a repair or a meniscectomy.

Video 5 Demonstrating Phase 5—anteromedial portal placement and medial compartment.

Errors and Solutions

- Avoid introducing the scalpel blindly as it can cause iatrogenic injury to the medial meniscus, patellar tendon, or the medial femoral condyle.
- Avoid incomplete visualization of all of the weight-bearing portion of the femoral condyle and the tibial plateau.
- Avoid incomplete visualization of the posterior horn of the medial meniscus in a tight knee. Have an assistant provide extension and valgus force to ensure that the posterior horn of the medial meniscus is appropriately examined.

Phase 6: Diagnostic Arthroscopy of the Intercondylar Notch and Lateral Compartment (Video 6)

- With the knee in 90° of flexion, examine the notch.
- Probe the femoral insertion of the anterior cruciate ligament (ACL) to ensure that it is stable.
- Visualize the tibial insertion of the ACL.
- Visualize the posterior cruciate ligament (PCL).
- Keep the probe and the arthroscope in the hiatus formed by the lateral femoral condyle, lateral tibial plateau, and the ACL.
- Bend the knee into the figure-of-4 position to open the lateral compartment and gently guide the arthroscope into the lateral compartment, ensuring that the camera is parallel to the tibia.
- Visualize and probe the posterior horn, body, and anterior horn of the lateral meniscus.
- Visualize and probe the articular cartilage of the lateral femoral condyle and tibial plateau.
- For closure, close the portal sites with 3-0 nonabsorbable mattress sutures and padded adhesive dressings. Use wool and crepe (elastic, nonadhesive) bandage for compression dressing.

Cognitive Decision Points

- Occasionally the ligamentum mucosum or the so-called Hoffa fat pad obscures the view of the ACL. These may need to be debrided to improve the view.
- Probing the ACL is critical to ensure that it is still attached to the medial wall of the lateral femoral condyle.
- The posterior horn of the lateral meniscus is best seen with the knee in flexion while the anterior horn is seen with the knee in slight extension.
- Move the knee in a range from 0° to 90° to view all weight-bearing portions of the articular cartilage of the femoral condyle with the light lead moved through 180°.
- In addition, probe the cartilage to check for pathological softening or any chondral flap tears.
- Assess the meniscus for tears and characterize the type and location to decide on further treatment.

Errors and Solutions

- Avoid mistaking the ligamentum mucosum for the ACL.
- Avoid incomplete visualization of all of the weight-bearing portion of the femoral condyle.
- Avoid incomplete visualization of the anterior horn of the lateral meniscus.

Video 6 Demonstrating Phase 6—notch, ACL, and lateral compartment.

Phase 7: Postoperative Care and Rehabilitation

- Check the neurovascular status after the procedure in recovery.
- Have the patient assessed by the physiotherapist to ensure that he or she is safe for discharge the same day.
- Keep the wool-and-crepe bandage on for 24 hours.
- Perform a wound check in 12 to 14 days and check the portal sites.
- Tailor the rehabilitation and the timing and duration of follow-up according to the therapeutic procedure that was performed.

Cognitive Decision Points

- Use compression dressings to minimize swelling following surgery and use of tourniquet

Errors and Solutions

- No errors for this phase have been identified.

Results

We undertook a randomized double-blinded controlled trial to evaluate the effectiveness of the IKACTA tool to train novice residents in diagnostic knee arthroscopy⁹. A power calculation was performed prior to recruitment. Sixteen novice orthopaedic trainees (those who had performed ≤ 10 diagnostic knee arthroscopies) were randomized into 2 equal groups. The intervention group was given the IKACTA tool, and the control group had no additional learning material. They were assessed objectively (using the validated Arthroscopic Surgical Skill Evaluation Tool [ASSET]¹⁰ global rating scale) on a high-fidelity phantom limb simulator. All participants, using the Likert rating scale, subjectively rated the tool.

The mean ASSET score (and standard deviation) in the intervention (IKACTA) group was 19.5 ± 3.7 points (51.3%) compared with 10.6 ± 2.3 points (27.9%) in the control group, resulting in an improvement of 8.9 points (95% confidence interval, 7.63 to 10.1 points) or 23.4% ($p = 0.002$). All participants agreed that the IKACTA learning tool was a useful training adjunct to learning in the operating room.

Pitfalls & Challenges

- A limitation of the IKACTA learning tool is that we have not yet observed transfer validity into the operating room. Ethically, we were obliged first to evaluate its benefits in the simulated setting prior to testing it in the operating room. Assessment of transfer validity will be undertaken as future work.

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