Methodological Standardization in Knee Joint Ultrasound: A Comprehensive Research Procedure

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ABSTRACT

Background: Knee ultrasonography is a key diagnostic and research tool for evaluating joint effusion, synovitis, tendon, and ligament integrity. Despite its widespread use, methodological inconsistencies across studies—ranging from patient positioning to probe settings—limit reproducibility and cross-study comparability.

Objective: To outline a standardized, evidence-based procedure for knee joint ultrasound suitable for research applications, aligning with international guidelines to ensure methodological rigor and reproducibility.

Methods: A comprehensive research framework was developed incorporating standardized participant selection, equipment calibration, scanning parameters, patient positioning, and both static and dynamic maneuvers

Results: Implementing standardized ultrasound protocols minimizes measurement variability, improves the accuracy of synovial and vascularity assessment, and enhances longitudinal monitoring of therapeutic responses.

Conclusion: Methodological standardization in knee ultrasound strengthens data validity, promotes reproducibility, and facilitates integration of imaging biomarkers into clinical and translational musculoskeletal research. The outlined framework serves as a template for future multicenter and longitudinal ultrasound studies.

Keywords: Knee ultrasound; musculoskeletal imaging; methodological standardization; dynamic ultrasound; research protocol.

INTRODUCTION

Musculoskeletal ultrasound (MSUS) is an indispensable modality for evaluating the knee joint's soft tissues, articular cartilage, synovium, tendons, and ligaments. Its portability, lack of ionizing radiation, and ability to provide real-time dynamic assessment make it a valuable tool for both clinical and research purposes. Despite its diagnostic strengths, methodological heterogeneity—spanning equipment parameters, patient positioning, scanning planes, and image interpretation—has limited reproducibility and cross-study consistency.

Recognizing this gap, international working groups such as Eular–Omeract and EURO-Musculus/Usprm have emphasized the need for standardized scanning procedures and scoring systems. These frameworks recommend detailed specifications on probe frequency, Doppler gain, patient posture, region of interest selection, and timing related to interventions such as injections or physiotherapy. Adherence to such methodological rigor ensures that ultrasound findings reflect true biological changes rather than procedural variability.

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A comprehensive, standardized approach is therefore crucial for generating reliable, comparable data across research centers. The present framework consolidates evidence-based procedural steps—covering participant inclusion criteria, equipment settings, scanning techniques, and data analysis—into a unified, reproducible model for knee joint ultrasound research.

Study Design and Participant Selection

1. A randomized, controlled, or observational cohort design is typically used depending on research objectives.

2. Participants are recruited based on inclusion and exclusion criteria relevant to the pathology under study (e.g., osteoarthritis, ligament injury).

3. Baseline demographics, clinical assessment (pain scores, KOOS/WOMAC), and prior imaging (radiographs when applicable) are documented.

1. Randomized Controlled Trial (RCT)

1. Most rigorous option for assessing treatment effect.

2. Patients with musculoskeletal inflammatory disorders (e.g., tendinopathies, fasciitis, arthritis) would be randomized into:

Intervention group → receives galvanic therapy.

Control group → sham therapy, standard care, or no treatment.

1. Ultrasound imaging would be done pre- and post-intervention to assess objective changes (e.g., vascularity, echogenicity, tendon thickness, effusion).

2. Advantage: establishes causality and minimizes bias.

3. Limitation: more resource-intensive, ethical considerations if sham therapy is used.

2. Controlled Clinical Trial (Non-randomized)

1. Patients are allocated into groups but not randomized.

2. Ultrasound outcomes compared between galvanic therapy and usual care.

3. Easier to conduct than RCT, but higher risk of selection bias.

3. Observational Cohort (Prospective or Retrospective)

Prospective cohort:

1. Patients receiving galvanic therapy are followed over time.

2. Ultrasound findings compared before and after treatment.

3. Sometimes a control group (no galvanic therapy) is included.

Retrospective cohort:

1. Use existing medical records and ultrasound reports before/after galvanic therapy.
2. Advantage: more feasible, lower cost.
3. Limitation: can only show association, not causation. Susceptible to confounding factors.

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4. Pre-Post (Within-Subject) Design

1. Single-arm study: patients serve as their own controls.
2. Ultrasound performed pre-treatment and post-treatment (short- and/or long-term follow-up).
3. Advantage: simple and cost-effective, good for pilot/feasibility studies.
4. Limitation: lacks a control group → changes may reflect natural healing or placebo effects.

Core inclusion criteria

Age: **18–50 years.**

Rationale: adult population; the upper age limit is selected based on the possible beginning of knee osteoarthritis in individuals over 50.

Clinical diagnosis of a focal musculoskeletal inflammatory condition at a single anatomical site (examples: Achilles tendinopathy, plantar fasciitis, trochanteric bursitis) based on history and exam.

Symptoms of at least 6 weeks' duration but ≤24 months.

Rationale: exclude very acute self-resolving cases; allow subacute–chronic instances where intervention is relevant. Modify bounds based on the target population.

Baseline pain/disability threshold: e.g., average pain ≥4/10 on VAS over the prior week OR functional score below a site-specific cutoff (VISA-A <70 for Achilles).

Rationale: ensures clinically meaningful baseline severity.

Ultrasound confirmation of inflammatory features at the target site on screening scan, defined as at least one of:

1. Power Doppler signal ≥ Grade 1 within ROI (semiquantitative 0–3), OR
2. Hypoechoic tendon area consistent with tendinopathy plus peritendinous fluid/effusion, OR
3. Bursal thickening with Doppler signal.
4. Rationale: ensures imaging-visible inflammation that can be measured pre-post.

Willingness & ability to attend treatment sessions and follow-up scans, and provide informed consent.

Core exclusion criteria

1. **Implanted electrical medical device** (e.g., pacemaker, ICD, deep brain stimulator) or cardiac conduction device where electrical stimulation is contraindicated.
   Rationale: safety risk with external electrical currents.
2. **Pregnancy or breastfeeding.**

   Rationale: unknown safety; regulatory/IRB caution.
3. **Local skin lesions or infection at electrode sites** (open wound, cellulitis, severe dermatitis) or broken skin preventing safe electrode placement.
4. **Known epilepsy or uncontrolled seizure disorder** (if your institutional safety policy considers electrical stimulation a risk).

   Rationale: some protocols exclude uncontrolled seizures for electrical stimulation studies.

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5. **Current systemic inflammatory disease with active systemic therapy** likely to change local inflammation rapidly (e.g., newly started/changed dose within prior 3 months of systemic corticosteroids, biologic DMARDs). Consider excluding patients on high-dose systemic steroids (>10 mg prednisone equivalent/day). *Rationale:* systemic treatments confound local imaging response.

6. **Local corticosteroid injection at the target site within the prior 3 months** (or other local biologic injection such as PRP within 6 months), or scheduled injection during study period. *Rationale:* injections have large effects on ultrasound and symptoms.

7. **Planned surgery at the target site during the follow-up period** or significant structural lesion incompatible with conservative therapy (e.g., full-thickness tendon rupture requiring surgery). *Rationale:* prevents mixing surgical outcomes with therapy effects.

8. **Severe peripheral neuropathy or sensory loss at the treatment area** (e.g., advanced diabetic neuropathy) if it impairs the ability to sense stimulation or increases the risk of burns. Use of anticoagulation or bleeding diathesis that, in the investigator's judgment, makes repeated electrode placement unsafe, or active skin bleeding disorders at the site. (This can be site-specific; many trials allow stable anticoagulation.)

9. **Concurrent participation in another interventional clinical trial** for the same condition. Inability to comply with follow-up or provide consent (e.g., cognitive impairment, planned relocation). Symptom duration floor/ceiling adjustments: e.g., require ≥3 months for chronic tendinopathy studies; extend upper limit beyond 24 months if you want long-standing cases. Limit to a single site or unilateral disease to simplify ultrasound ROI and analysis (exclude bilateral symptomatic cases unless you will treat only one side). Medication stability window: require a stable analgesic/NSAID dose for the prior 2 weeks and throughout the study, or record doses as covariates. Exclude prior major surgery at the same site (e.g., previous tendon repair) if it changes baseline anatomy and imaging interpretation. Limit to certain imaging severity: e.g., include only PD grade 1–3 but exclude structural grade indicating degeneration > specified threshold. Exclude diabetes with HbA1c > X if wound healing or neuropathy is a concern.

10. **Age subgroup restrictions** (e.g., exclude >65) if device safety has not been tested in older adults.

Imaging-specific exclusions/requirements

1. Must have baseline ultrasound with documented PD grade and image that meets SOP (machine settings, ROI).

2. Exclude if baseline imaging shows a frank full-thickness tear, large retraction, or surgical hardware in the ROI.

3. Standardize timing: do not allow baseline ultrasound within 48 hours after injection or an intense physical therapy session that could transiently alter vascularity.

Screening tests & baseline assessments

1. Targeted medical history/medications (recent steroids, biologics, anticoagulants).

2. Pregnancy test for women of childbearing potential.

3. Device/implant checklist (pacemaker, etc.).

4. Baseline ultrasound with standardized protocol (store images/DICOM).

5. Baseline VAS pain, validated functional score (VISA-A, WOMAC, etc.), and analgesic use log.

6. Safety labs only if clinically indicated (not routinely required).

Rationale & practical notes

1. Excluding recent local injections and recent systemic therapy changes is crucial because they produce large imaging changes that confound treatment effect attribution to galvanic therapy.

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2. Requiring ultrasound-confirmed inflammation ensures you measure a population where imaging can detect change; otherwise, you risk floor effects.

3. Safety exclusions (implanted electrical devices, pregnancy, open skin) are standard for electrical stimulation interventions.

4. Be explicit about timing windows (e.g., "no steroid injection within 3 months prior to baseline ultrasound; no new systemic immunomodulators within 3 months") in the protocol.

Baseline Assessment

1. **Pain score**: VAS 0–10 at rest and activity.

2. **Functional score**: KOOS for knee, DASH for elbow.

3. **Ultrasound**: standardized acquisition with PD vascularity grade, tendon thickness (mm), effusion/bursal volume (ml or mm), and synovial hypertrophy grade.

4. **Photography**: store DICOM or cine loops for blinded central review.

5. **Concomitant meds/therapies**: NSAIDs, physiotherapy, braces.

SOP

A standard procedure for a research project involving ultrasound of the knee joint includes several core steps to ensure methodological rigor, reproducibility, and alignment with clinical standards. These steps address participant selection, equipment, scanning protocol, assessment features, outcome measurement, and data analysis.

Study Design and Participant Selection

1. A randomized, controlled, or observational cohort design is typically used depending on research objectives.

2. Participants are recruited based on inclusion and exclusion criteria relevant to the pathology under study (e.g., osteoarthritis, ligament injury).

3. Baseline demographics, clinical assessment (pain scores, KOOS/WOMAC), and prior imaging (radiographs when applicable) are documented.

Ultrasound Equipment and Settings

1. High-frequency linear transducers (7–15 MHz) are recommended for optimal resolution of superficial knee structures.

2. Equipment settings, including depth, gain, and focus, should be standardized before each scan to reduce variability.

Standardized Scanning Protocol

- The protocol should specify patient positioning (usually supine with knee in extension or slight flexion).

A systematic scanning order covers:

1. Suprapatellar region (for effusion and synovitis)
2. Medial and lateral joint lines (menisci, collateral ligaments)
3. Anterior knee (quadriceps and patellar tendons)
4. Posterior knee (popliteal cysts, hamstring tendons)
5. Dynamic maneuvers (e.g., valgus/varus stress) may be used to assess ligament integrity and joint instability.

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Structures and Pathology to Assess

1. Commonly assessed features include synovial effusion, synovitis, osteophytes, meniscal extrusion, ligament/tendon injury, and cartilage status.
2. Scoring systems or atlases may be employed for semiquantitative assessment of features (effusion, osteophyte, synovial hypertrophy, etc.).
3. Both grayscale and, when indicated, Doppler imaging are used to evaluate vascularity and inflammatory changes.

Outcome Measurement and Data Collection

1. Standardized forms and digital image archiving are used for data capture.
2. Outcomes include changes in clinical scores (pain, function), ultrasound findings, and, in interventional studies, response to treatment.
3. Inter- and intra-reader reliability is often assessed for protocol validation.

Ethical Considerations and Quality Assurance

1. Ethics committee approval and informed consent are required.
2. Sonographer and reader training are crucial for reproducibility and reliability.

Data Analysis

1. Correlations between ultrasound findings and clinical/radiographic outcomes are statistically analyzed.
2. Protocols usually specify blinding of image interpreters to clinical information to reduce bias.

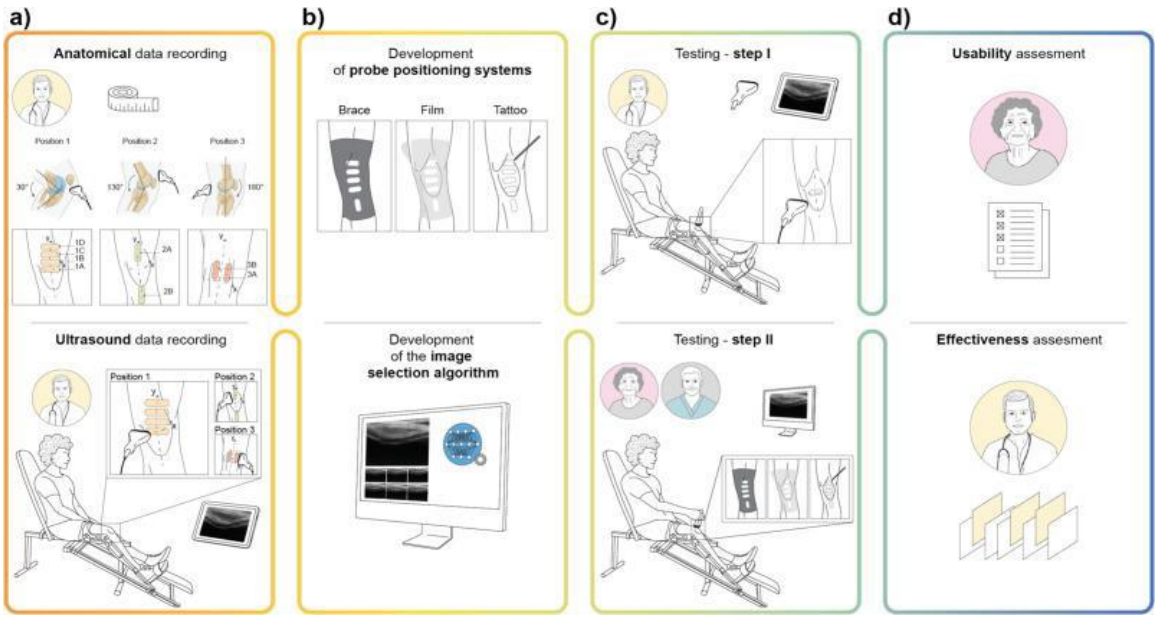

Figure 1. Study design for effective assessment in knee joint ultrasound

Step-by-Step Dynamic Maneuvers

Step-by-step dynamic maneuvers for knee ultrasound combine specific patient movements and transducer placements to assess ligamentous, tendinous, and joint integrity. Example images from validated teaching atlases and protocols optimize training and reproducibility.

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Valgus Stress Test (Medial Collateral Ligament)

1. Patient supine, knee flexed 20–30°.
2. Apply valgus pressure while placing the transducer over the medial joint line.
3. Observe for MCL fiber continuity and gapping.
4. Example labeled image: Medial knee with fiber strain/gapping.

Varus Stress Test (Lateral Collateral Ligament)

1. Patient supine, knee flexed.
2. Apply varus pressure, transducer on the lateral joint line.
3. Assess LCL continuity and laxity.
4. Example labeled image: Lateral collateral ligament under stress.

Quadriceps Activation Test

1. Patient contracts quadriceps (extension), transducer over the suprapatellar region.
2. Evaluate femoral cartilage movement and patellar tendon distension.
3. Example image: Suprapatellar view labeled for quadriceps activation.

Baker's Cyst Compression

1. Patient prone, knee extended.
2. Gentle pressure compresses the popliteal fossa. The transducer visualizes cyst shape/change.
3. Example image: Popliteal cyst labeled with compression effect.

Meniscal Mobility

1. Patient's knee flexed, transducer along the joint line.
2. Perform passive flexion-extension and valgus-varus maneuvers.
3. Visualize meniscal extrusion/movement.
4. Example image: Medial meniscus labeled under dynamic maneuver.

Accessing Example Labeled Images

1. EURO-MUSCULUS/USPRM knee protocol PDF includes labeled example images for each dynamic maneuver and anatomical area.
2. Netter-based teaching atlases (Jacobson, MSKUS) provide stepwise diagrams paired with dynamic scans for clinical and research training.

Using these resources, research and clinical teams can standardize dynamic ultrasound maneuvers with reference images to guide training, documentation, and scoring.

Knee Ultrasound Protocol

1. Knee compartments: Anterior, Medial, Lateral, Posterior

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2. Key structures to label: Quadriceps tendon, Patellar tendon, Suprapatellar bursa, Prepatellar bursa, Infrapatellar tendon, Medial and Lateral Collateral Ligaments (MCL, LCL), Menisci (medial and lateral), Popliteal fossa structures (including popliteal artery and vein)

3. Typical scanning planes: Long axis (LA) and Short axis (SA) views for tendons and ligaments

4. Patient positioning: Supine for anterior, medial, lateral views; prone for posterior

5. The knee is divided into four compartments: Anterior, Medial, Lateral, and Posterior.

6. For each compartment, key anatomical structures are labeled with directional arrows.

7. Anterior compartment includes: Quadriceps tendon (long and short axis), Suprapatellar bursa, Patella, Patellar tendon (long and short axis), and Infrapatellar tendon.

8. Medial compartment includes: Medial collateral ligament (MCL), Medial meniscus, Pes anserinus tendons, and bursa.

9. Lateral compartment includes: Lateral collateral ligament (LCL), Lateral meniscus, and Iliotibial band.

10. Posterior compartment includes: Popliteal artery and vein, Semimembranosus tendon, Gastrocnemius muscle, Popliteal fossa.

11. Typical probes used: High-frequency linear probe (7-15 MHz).

12. Patient positioning cues: Supine for anterior/medial/lateral scans, prone for posterior.

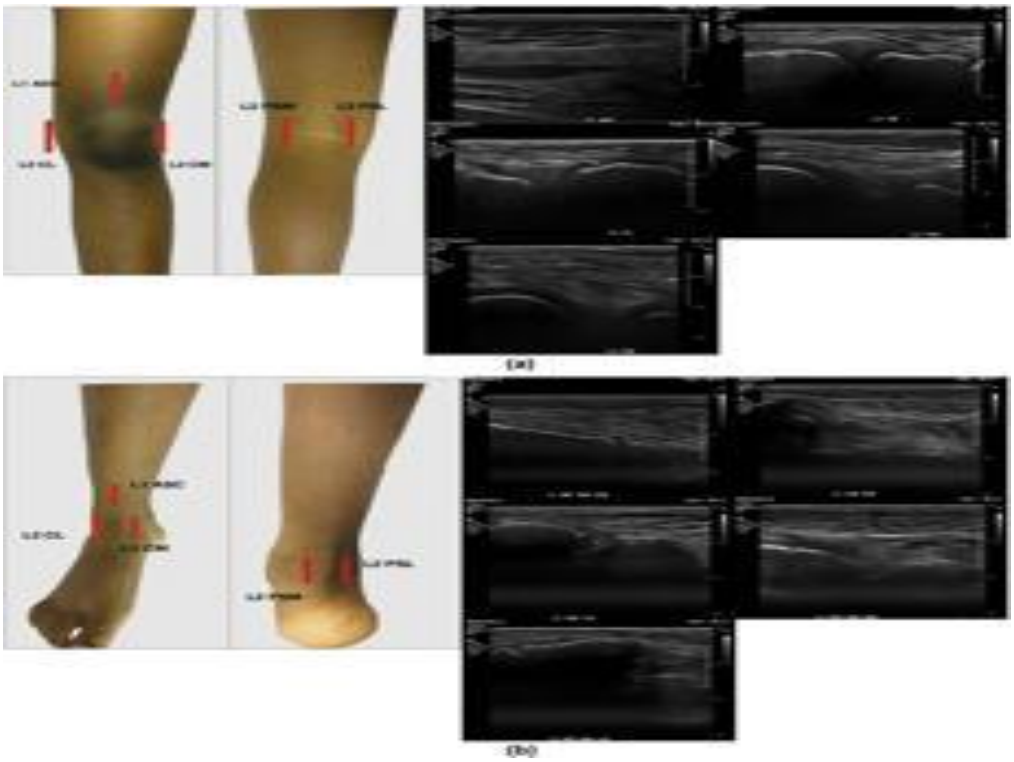

Figure 2. Representative clinical and ultrasound images showing probe placement and sonographic findings in musculoskeletal tendon evaluation.

(a) Anterior knee: probe positioning over the patellar tendon and corresponding longitudinal ultrasound images demonstrating tendon morphology and echotexture.

(b) Posterior ankle: probe placement along the Achilles tendon and associated sonograms showing normal fibrillar pattern and insertional anatomy.

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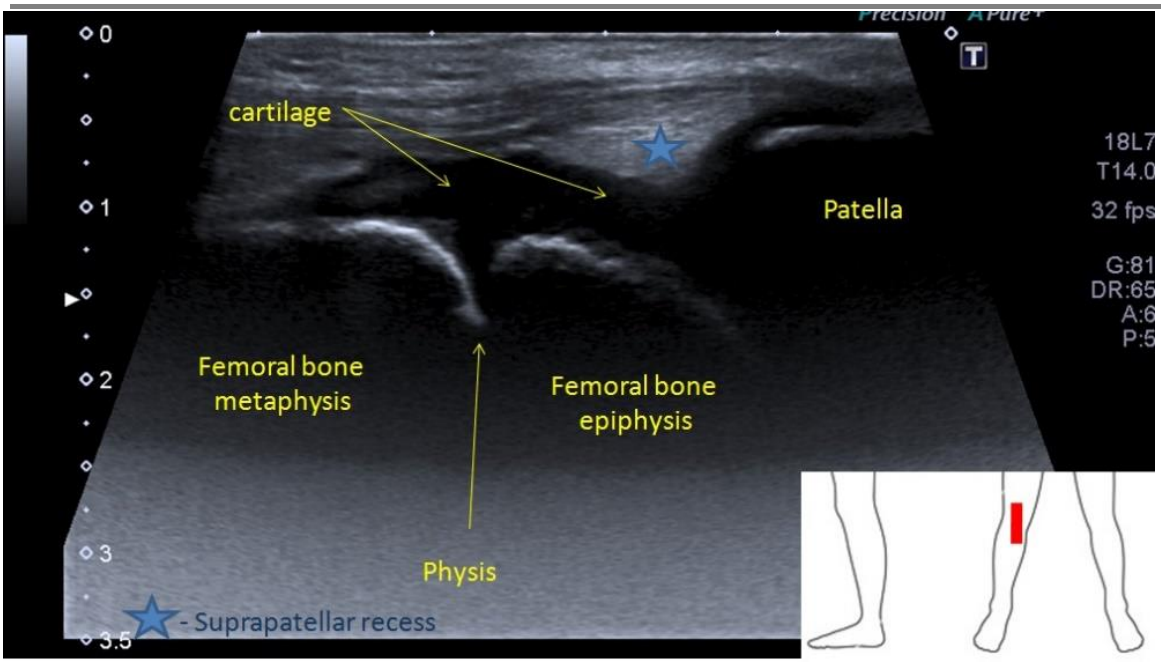

Figure 3. Knee ultrasound demonstrating normal pediatric knee anatomy**.** This linear probe image confirms the presence of the open physis (growth plate) separating the femoral metaphysis and epiphysis. The hypoechoic layer of cartilage and the A/P depth in the suprapatellar recess (blue star) are crucial for assessing joint integrity and effusion.

Ultrasound Scanning Checklist

Patient Positioning

1. Supine with knee flexed 20-30 degrees with support under the knee (anterior, medial, lateral scans)
2. Prone with knee slightly flexed and supported (posterior scans)

Probe Type

High-frequency linear probe (7-15 MHz)

Scanning Regions and Probe Positions

Region	Probe Position/Orientation	Key Structures to Scan	Notes
Anterior Knee	Probe longitudinally over the quadriceps tendon	Quadriceps tendon, suprapatellar bursa, patella	Use ample gel over the prepatellar area
	Probe longitudinally and transversely over the patellar tendon	Patellar tendon, infrapatellar bursa	Examine the tendon insertion on the tibial tuberosity
Medial Knee	Probe longitudinally over the medial collateral ligament	Medial collateral ligament (MCL), medial meniscus, pes anserinus bursa	Assess MCL and adjoining meniscal borders
	Probe transversely along the pes anserinus tendons	Sartorius, gracilis, and semitendinosus tendons	
Lateral Knee	Probe longitudinally over the lateral collateral ligament	Lateral collateral ligament (LCL), lateral meniscus, and iliotibial band	Adjust the probe angle slightly posteriorly
Posterior	Patient prone, probe transverse and	Popliteal artery and vein, semimembranosus-gastrocnemius bursa,	Slight flexion enhances

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Knee	longitudinal in the popliteal fossa	posterior capsule	venous filling

Scan Planes

1. Use both long axis (longitudinal) and short axis (transverse) views for tendons and ligaments
2. Evaluate dynamic changes with patient knee movement if possible

Key Assessment Points

1. Fluid collections (bursae, joint recesses)
2. Tendon integrity (tears, thickness)
3. Ligament continuity and thickening
4. Meniscus shape and surface (bulges, cysts)
5. Neurovascular structures (popliteal artery/vein patency)
6. Pathology documentation: measure fluid collections, cysts, vascularity

Scanning Techniques

The technique below demonstrates how to identify normal anatomy. Remember to assess all musculoskeletal anatomy dynamically and thoroughly.

Divide the knee into 4 compartments.

1. Anterior
2. Medial
3. Lateral
4. Posterior

Anterior Knee

Transverse scan plane for the quadriceps

Transverse suprapatellar region:

•RF: Rectus Femoris •VI: Vastus intermedius

•VL: Vastus Lateralis •VM: Vastus Medialis

Suprapatellar scan plane.

Longitudinal suprapatellar region showing the suprapatellar bursa and quadriceps tendon.Prepatellar scan planeTo avoid loss of contact, use plenty of thick gel or a standoff.Infrapatellar scan plane.The infrapatellar tendon.Also called the patella ligament.

The insertion of the infrapatellar tendon onto the tibial tuberosity. Note: The normal physiological amount of fluid is along the underside of the tendon.

Transverse Infrapatellar tendon: Note its width to understand the area you need to examine longitudinally.

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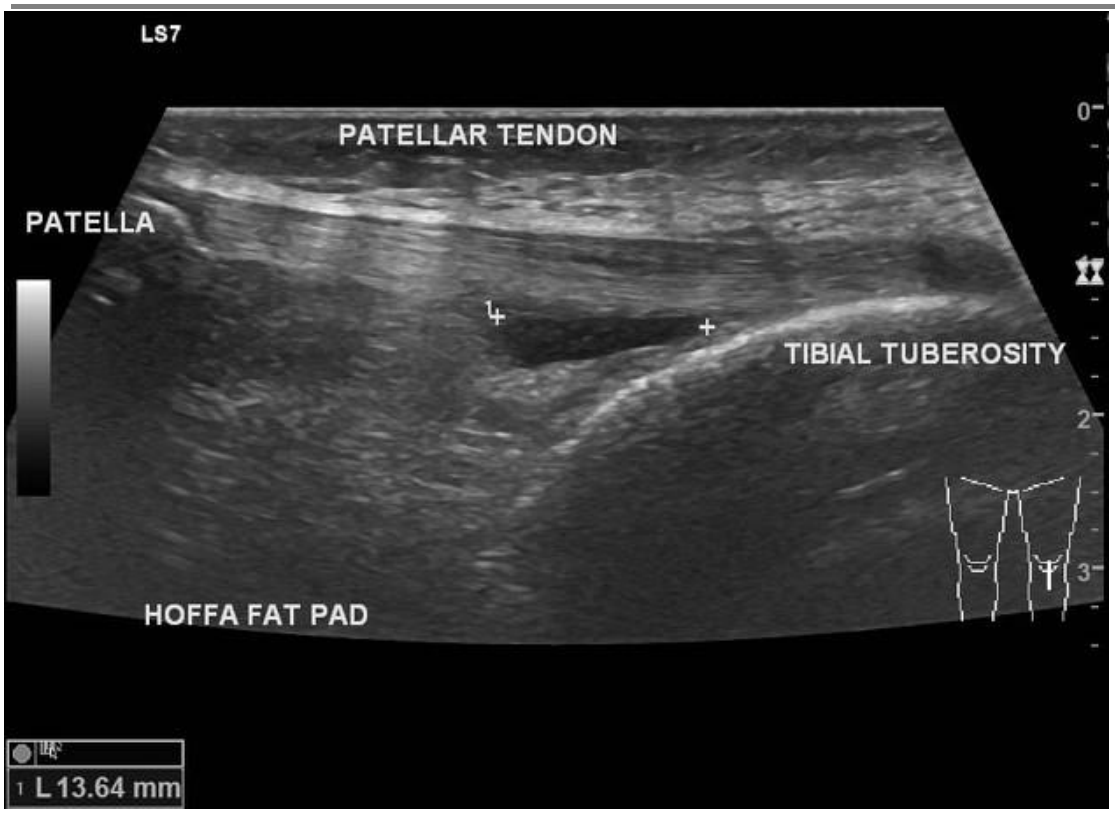

Figure 4. Longitudinal ultrasound image of the anterior knee demonstrating the patellar tendon extending from the inferior pole of the patella to the tibial tuberosity. The Hoffa fat pad is visualized deep to the tendon, and a hypoechoic area is noted at the distal tendon attachment, consistent with focal tendinopathy or partial tear.

Medial Knee

Medial collateral ligament (MCL) – Joint space/meniscus – Pes Anserinus.Medial knee joint scan plane.The medial collateral ligament (green) directly overlying the medial meniscus (purple).Pes anserinus scan plane.The Pes Anserine bursa and tendon insertion are medial to the Infrapatellar tendon on the tibia, adjacent to the MCL insertion.

Remember the Pes Anserine tendons as (sergeant) SGT:

Sartorius, Gracilis, and semi-tendinosis.

Lateral Knee

Lateral knee joint scan plane.Assess the Lateral collateral ligament, the Iliotibial band insertion, and the peripheral margins of the lateral meniscus. Unlike the medial side, the LCL is separated from the meniscus by a thin tissue plane.

Ilio-Tibial Band.

Rotate the probe off the LCL, with the toe of the probe angled slightly posteriorly.

Posterior Knee

Popliteal fossa scan planeMedial aspect of the popliteal fossa showing the semimembranosus/gastrocnemius plane.Ultrasound of the Popliteal vein and artery in transverse.Without and with compression to exclude DVT.

Confirm both arterial and venous flow and exclude a popliteal artery aneurysm. If a Popliteal aneurysm is discovered, always extend the examination to the other leg and the abdomen. There is a risk of bilateral and high association with aortic aneurysm.

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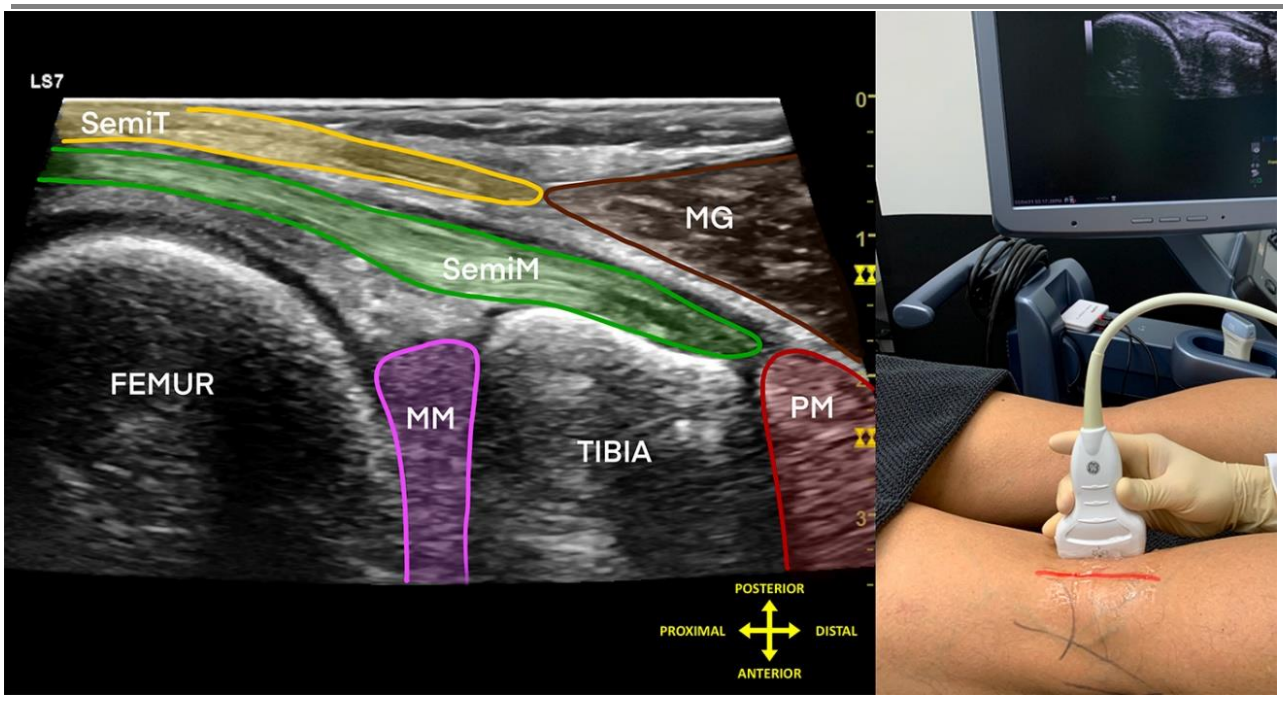

Figure 5. Ultrasound evaluation of the posterior knee showing probe placement and labeled sonographic anatomy. The semitendinosus (SemiT), semimembranosus (SemiM), medial gastrocnemius (MG), and popliteus muscle (PM) are visualized in relation to the femur, tibia, and medial meniscus (MM). The corresponding clinical image illustrates correct transducer positioning for posterior knee scanning.

Scan Protocol

Role of Ultrasound

Ultrasound is essentially used for the external structures of the knee. It is a valuable diagnostic tool in assessing the following indications; Muscular, tendinous and ligamentous damage (chronic and acute), Bursitis, Joint effusion, Popliteal vascular pathology, Hematomas, Masses such as Baker's cysts, Lipomas, for classification of a mass e.g. solid, cystic, or mixed; post-surgical complications e.g. abscess, oedema, Guidance of injection, aspiration or biopsy, Relationship of normal anatomy and pathology to each other.

Limitations

It is recognized that ultrasound offers little or no diagnostic information for internal structures such as the cruciate ligaments. Ultrasound complements other modalities, including plain X-ray, CT, MRI, and arthroscopy.

Patient Preparation

None required.

Equipment setup

Use of a high-resolution probe (7-15MHZ) is essential when assessing the superficial structures of the knee. Careful scanning technique to avoid anisotropy (and possible misdiagnosis). Beam steering or compounding can help to overcome anisotropy in linear structures such as tendons. Good color/power / Doppler capabilities when assessing vessels or vascularity of a structure. Be prepared to change the frequency output of the probe (or probes) to adequately assess both superficial and deeper structures.

Common Pathology

1. Joint effusion
2. Baker's cyst

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3. Collateral ligament injury
4. Patella tendinopathy
5. Meniscal bulging/cysts
6. Quadriceps injury
7. Pes anserine bursitis/tendinopathy
8. Patella retinaculum pathology

Scanning Technique

Posterior Fossa

Patient prone on bed, knee flexed slightly with a pad under the ankle for support. Survey the entire fossa to identify the normal anatomy, including the Popliteal artery and vein (patency, aneurysm, thrombosis), Posterior joint (joint effusion), and Medial popliteal fossa bursa between the semimembranosus tendon and medial gastrocnemius muscle (Baker's cyst). Document the normal anatomy and any pathology found, including measurements and vascularity if indicated.

Anterior Knee

Patient lies supine on the bed with the knee flexed 20 – 30 degrees. Alternatively, the patient may sit on the side of a raised bed with the foot resting on the Sonographer's knee for support. Identify the normal anatomy, including Quadriceps tendon (tears, M/T junction, tendonitis), Suprapatellar bursa (bursitis-simple/complex, synovial thickening, loose bodies), Patella (gross changes e.g. erosion, bipartite, fracture), Patella tendon (tears, tendonitis, insertion enthesopathy), Infrapatellar bursa (tendonitis, tears, bursitis, fat pad changes), and Infero-Medial – Pes anserine bursa

Lateral And Medial Knee

May be scanned as above. Assess the medial and Lateral Collateral ligaments and meniscal margins. Joint lines (ligament tears or thickening, meniscal bulging/cysts, joint effusion, gross bony changes)

Basic Hardcopy Imaging

A knee series should include the following minimum images:

1. Quadriceps tendon – long, trans +/- MT junction
2. Suprapatellar bursa
3. Pre patella – long
4. Patella tendon – long, trans, insertion onto tibial tuberosity
5. Medial meniscus and MCL
6. Lateral Meniscus and LCL
7. Popliteal artery and vein to demonstrate patency
8. Medial Popliteal Fossa
9. Document the normal anatomy and any pathology found, including measurements and vascularity if indicated.

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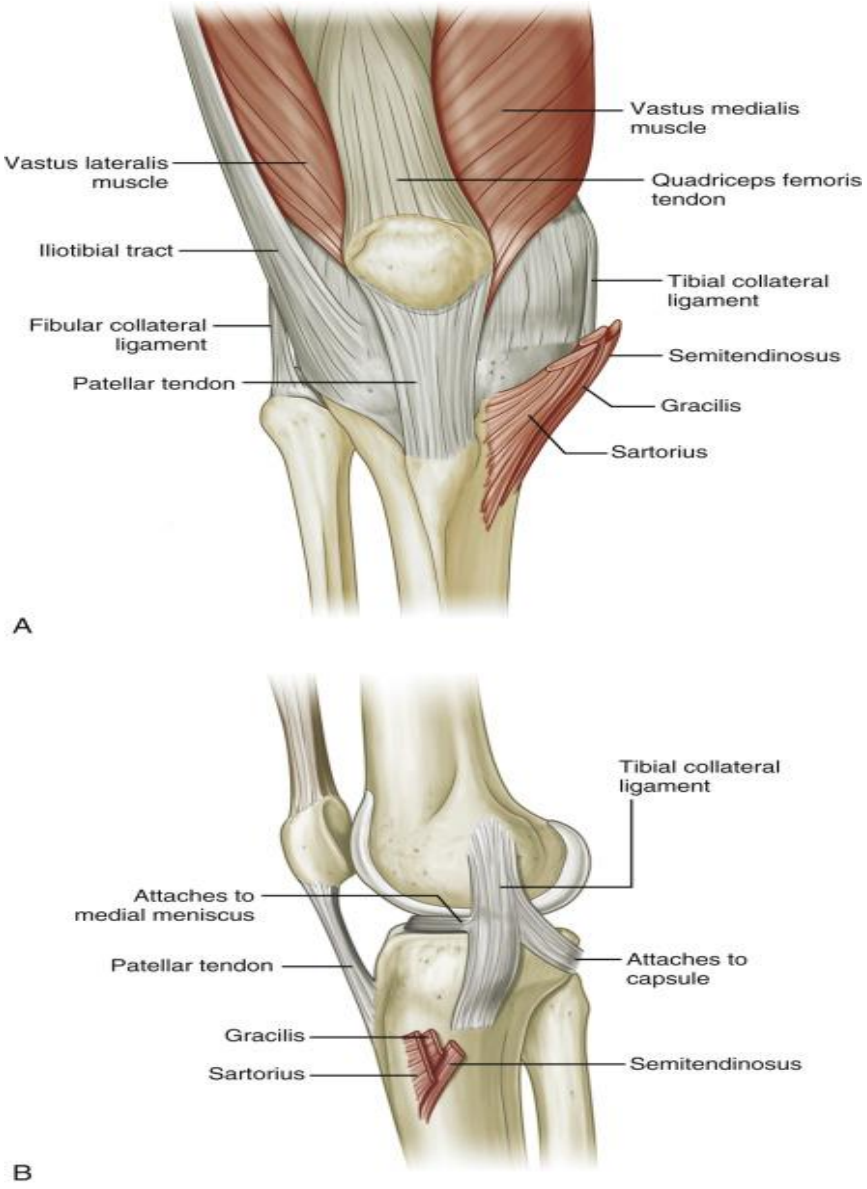

Figure 6. Knee Anatomy.

A, Anterior view of the knee. B, Medial view of knee (From Drake R, Vogl W, Mitchell A: Gray's Anatomy for Students. Philadelphia, 2005, Churchill Livingstone)

CONCLUSION

Establishing a standardized methodological framework for knee joint ultrasound ensures that imaging data are accurate, reproducible, and clinically interpretable. By aligning with internationally validated guidelines and incorporating reference images and dynamic maneuvers, researchers can reduce inter-observer variability and enhance study comparability. This structured protocol promotes methodological transparency and sets a foundation for high-quality, multicenter musculoskeletal ultrasound research.

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