Musculoskeletal imaging, analysis and model building in clinical reasoning 1 (MIAMI-1)

Academic year 2023-2024

Student's module book

Please think green, consider the environment before printing

Content

Part 1 General information

1 Planning group and coordination

You will receive this module during the first semester. The module covers 6 ECTs. You will gain knowledge and insight about the clinical reasoning process in relation to musculoskeletal complaints, diagnostics imaging, the related medical engineering and the analysis of the results. This process will be supported by profound knowledge and insight in the anatomy of the regions covered, followed by dissection training of these regions during the intensive on campus training week. During this week there will also be sessions in function of medical imaging and clinical reasoning.

This module is organized using a blended learning approach. Lectures will be online (asynchronous (= pre-recorded) and synchronous (= live)). Working sessions, responsory colleges and Q&A's will be live online. Next to this, you will also work on an assignment/portfolio.

At the end of the module during the intensive week, you will be evaluated.

The module has been developed by a group of teachers with different backgrounds. For general questions about the module, please contact the module coordinator.

Role	**Name**	**e-mail**	**Picture**
Module coordinator / Tutor clinical reasoning	Matthias Eggermont	matthias.eggermont@vub.be	
Tutor anatomy / dissection	Erik Cattrysse	erik.cattrysse@vub.be	
Tutor clinical reasoning	David Beckwée	david.beckwée@vub.be	
Tutor anatomy	Aldo Scafoglieri	aldo.scafoglieri@vub.be	
Tutor medical imaging (physics)	Nico Buls	nico.buls@vub.be	
Tutor medical imaging	Lode Goethals	lode.goethals@vub.be	
Tutor clinical reasoning	Jonathan Thompson	j.thompson1@yorksj.ac.uk	

2 Introduction

The main objective of this program is to educate a new type of health professional that combines competencies in regard to prevention, vitality and rehabilitation in primary care (physiotherapy) with competencies in medical engineering, ICT and technology.

Students in this program will learn to invent and think of technological solutions for challenges in prevention, vitality and rehabilitation to enhance personalized patient care. In the end, this will lead to the prevention or delay of functional decline and more effective rehabilitation strategies for patients.

The students will also gain transversal skills, which allow them to form a bridge between health care (and it's specific challenges), technology and business/industry, and to manage and communicate their projects in the digital era.

2.1 Content and aim of the module

2.1.1 Content

In this course there will be 4 major parts:

- An introductory path
  Basic information about the module and specific background knowledge (via knowledge clips, papers, …) will be shared via the learning platform. This will be a kind of library were students can look-up necessary knowledge when it becomes relevant (just in time learning).

- Clinical decision making (CDM)
  This topic consists of three case-reports were students will have to reason about the patients musculoskeletal complaint. The use of red flags for serious pathology during the screening of the patient is highlighted during the clinical reasoning process. We intend that students transfer transdisciplinary knowledge of content learned during the whole module into their clinical reasoning process. The didactical model that we use (ao. Think-Pair-Share) allows us to adjust the degree of complexity throughout the module. After a combination of self-assignments and online pairing sessions, students will share their information about their process in mingled groups during the share-moment (on campus) at the end of the module.

- Anatomy
  This topic consists of lectures (flipped classrooms) about the advanced anatomy of the same three regions related to the case-reports described in the CDM part. Following the advanced anatomy course a demonstration of the region specific dissection will be available (knowledge clips). After every region a responsory college or Q&A-session will be planned. At the end of the module, during the intensive week, an on campus anatomical dissection course is planned.

- Medical Imaging
  This topic consists of lectures (flipped classrooms) about the basic physics of medical imaging techniques such as: RX, MRI, US and CT. We relate these forms of imaging to the same three regions related to the case-reports described in the CDM part. Following the basic physics part, students will learn about clinical image analysis using the specific imaging techniques. For this part there will be a mix of flipped classrooms, knowledge clips and online synchronous lessons. As for all topics, if online asynchronous lectures are used, a Q&A-

session is planned accordingly. At the end of the module, during the intensive week, an on campus visit to the hospital is planned for demonstration and reasoning about the aforementioned medical imaging techniques.

2.1.2 Learning outcomes

1. The student has a profound knowledge and comprehension of the clinical relevance of the anatomy and is able to discuss the clinical relevance.
2. The student has a thorough theoretical knowledge of the osteology and arthrology of the knee region.
3. The student has a profound 3-dimensional knowledge of the human musculoskeletal anatomy (myology, peripheral neurology, vascularization).
4. The student is able to differentiate between different anatomical structures.
5. The student knows the morphological features, functions and eventually innervation and vascularization of the visible anatomical structures.
6. The students can derive the function of the anatomical structures based on their topographical organization.
7. The student is able to describe specific anatomical regions on the (pre-)dissected specimen.
8. The student is able to link the dissected and visible anatomical structures to his profound and pre-existing knowledge of osteology and arthrology.
9. The students is able to demonstrate the relationship between the visible structures and his knowledge and experience in palpatory anatomy, clinical knowledge and of musculoskeletal rehabilitation.
10. The students shows respect towards the human body.
11. The student is able to reflect on the impact of specific musculoskeletal rehabilitation and/or imaging techniques based on profound knowledge and comprehension of macroscopic human anatomy.
12. The student is aware of laws and safety measures (social environment, sustainability,…) of medical imaging.
13. The student has knowledge of medical diagnostics and measurements by means of medical equipment.
14. The student has knowledge about the principles of different imaging modalities of medical imaging within the diagnostic review.
15. The student is able to recognize and identify the determinants of illness and health, current prevention and health care problems, questions and challenges in the field of rehabilitation.
16. The student is able to recognize anatomical structures and pathological images.
17. The student is able to interpret clinical images (from normal to pathological).
18. the student is able to situate the different medical imaging techniques in a diagnostic perspective according to their relevance relative to the strengths and limitations of the specific technique.
19. the student is able to recognize normal from basic but clearly pathological situation in medical images.
20. Knowledge and implementing principles and skills of Evidence-Based Practice related to assessment and intervention in the physical therapy and other domains.
21. Screen and analyze the client's health problem through targeted history-taking and, if necessary, physical examination to decide whether the problem falls within the domain of physiotherapy and is suitable for technical solutions.
22. Methodically identify, analyze, and diagnose the problem and to relate this to the client's presenting health problem in consultation with the patient (physiotherapy diagnosis) as well as critically evaluate the quality of the measurement and assessment and design and realize possible solutions.
23. Think conceptually, asking critical questions and see cross-reference, thinking from different perspectives.

3 Educational activities

This module will consist of theoretical lessons, practical sessions, group assignment and an intensive on-campus week at the Vrije Universiteit Brussel. For more information about the planning of the lessons, if the lessons are synchronous (live, online), asynchronous (pre-recorded) or for the planning of the on-campus week, check the information on the digital learning platform.

For questions about the educational activities or planning, please contact the module coordinator.

4 Testing and grading (evaluation)

To evaluate the different topics in this module we use a mix of oral exams, written exams, assignments (group) and peer-evaluations (adjustment factor on clinical reasoning assignment).

The **final grade** is composed based on the following categories:

- Written Exam determines 50% of the final mark.
- Practical Exam determines 35% of the final mark.
- CDM-assignment/potyfolio determines 15% of the final mark.

For more detailed information about the grading, check the digital learning platform or ask the dedicated teaching staff of each topic.

5 Literature

Literature is described in each separate section in this module book. Mainly the references can be retrieved from PubMed or via the VUB library.

6 Sessions

See the online planning for up-to-date information about the lessons.

Part 2 The Knee

Case description
A 65-year-old male patient attended his physiotherapy appointment complaining of right knee pain which is of gradual onset over the past 18 months. There was no specific acute incident or injury. Symptoms are variable and he reports good days and bad days with his knee.

The pain was described as a dull ache in the medial aspect of the knee with occasional sharper pain on sudden movements. He reports a VAS score of 6/10. There is some intermittent swelling of the knee. No specific mechanical locking or giving way is reported.

Symptoms worse on weight bearing activity and he can walk up to 2km before needing to rest due to his knee pain.

General health: Hypertension, Type II Diabetic, BMI 30

Medication: simple analgesia for the knee

1 Clinical decision making

How:

- asynchronous introduction (video will be uploaded on the learning platform)
- followed by 3 working sessions (see online schedule)

1.1 Specific outcomes for this lesson

1. The student is aware of laws and safety measures (social environment, sustainability,…) of medical imaging.
2. The student is able to recognize and identify the determinants of illness and health, current prevention and health care problems, questions and challenges in the field of rehabilitation.
3. The student is able to situate the different medical imaging techniques in a diagnostic perspective according to their relevance relative to the strengths and limitations of the specific technique.
4. Knowledge and implementing principles and skills of Evidence-Based Practice related to assessment and intervention in the physical therapy and other domains.
5. Screen and analyze the client's health problem through targeted history-taking and, if necessary, physical examination to decide whether the problem falls within the domain of physiotherapy and is suitable for technical solutions.
6. Methodically identify, analyze, and diagnose the problem and to relate this to the client's presenting health problem in consultation with the patient (physiotherapy diagnosis) as well as critically evaluate the quality of the measurement and assessment and design and realize possible solutions.
7. Think conceptually, asking critical questions and see cross-reference, thinking from different perspectives.

1.2 Prior knowledge for this lesson:

1.2.1 Literature:

- Books:
  - Cooper N. & Frain J. (2017). Abc of clinical reasoning. John Wiley & Sons.
  - Higgs J. Jensen G. M. Loftus S. & Christensen N. (2019). Clinical reasoning in the health professions (Fourth). Elsevier.
  - Glaser A. N. (2014). High-yield biostatistics epidemiology and public health (4th rev.). Chapter 7: Statistics in Medical Decision Making, Lippincott Williams & Wilkins.

- Articles:
  - Baeyens, J. P., Serrien, B., Goossens, M., & Clijsen, R. (2019). Questioning the "SPIN and SNOUT" rule in clinical testing. Archives of physiotherapy, 9, 4. https://doi.org/10.1186/s40945-019-0056-5.

1.3 Content description:

- This part will consist of 3 working sessions:
  - In the first working session we will talk about the first two steps of our methodological approach (inventarisation and working diagnosis).
  - In the second working session we will talk about the next two steps of our

methodological approach (examination and physiotherapeutic diagnosis and prognosis. In this session we will focus less on physiotherapy, but more on medical imaging and its use in ruling IN or OUT a pathology. We will also focus on the relevance relative to the strengths and limitations of the specific technique proposed in function of the several hypothesis formed in session 1.

- In the third working session we will round up our first case-study. In the second session choices were made about medical imaging techniques. For every of these modalities, reason about: clinimetrics, benifitis, harms, alternatives and it's role on illness perception/beliefs in patients. During this session you will share and critically discuss your findings with your fellow students.

All course content will be available on Canvas under Musculoskeletal imaging, analysis and model building in clinical reasoning part 1 - 012004

1.4 Additional information, slides, articles

2 Advanced anatomy of the Knee

How:

- asynchronous (video will be uploaded on the learning platform)
- followed by a responsory college (see online schedule)

2.1 Specific outcomes for this lesson

1. The student has a thorough theoretical knowledge of the osteology and arthrology of the knee region
2. The student has a profound 3-dimensional knowledge of the human musculoskeletal anatomy (myology, peripheral neurology, vascularization)
3. The student has a profound knowledge and comprehension of the clinical relevance of the anatomy
4. The student is able to reason and discuss the clinical relevance of region specific anatomy

2.2 Prior knowledge for this lesson:

The student needs a good basic knowledge of the regional anatomy of the knee

2.2.1 Literature:

- Books:
  - THIEME Atlas of Anatomy, Three Volume Set, Third Edition Udo Schumacher
  - Gray's Atlas of Anatomy, Drake R. et al (Elseviers)
  - Similar anatomy atlases

- Articles:
  - De Maeseneer, M., et al., Ultrasound of the knee with emphasis on the detailed anatomy of anterior, medial, and lateral structures. Skeletal Radiology, 2014. 43(8): p. 1025-1039.
  - De Maeseneer, M., et al., Posterolateral supporting structures of the knee: findings on anatomic dissection, anatomic slices and MR images. European Radiology, 2001. 11(11): p. 2170-2177.
  - Getgood, A., et al., The anterolateral complex of the knee: results from the International ALC Consensus Group Meeting. Knee Surgery Sports Traumatology Arthroscopy, 2019. 27(1): p. 166-176.
  - Grammens, J., et al., Small medial femoral condyle morphotype is associated with medial compartment degeneration and distinct morphological characteristics: a comparative pilot study. Knee Surgery Sports Traumatology Arthroscopy, 2021. 29(6): p. 1777-1789.
  - Hedderwick, M., et al., The oblique popliteal ligament: an anatomic and MRI investigation. Surgical and Radiologic Anatomy, 2017. 39(9): p. 1017-1027.
  - Kraeutler, M.J., et al., Current Concepts of the Anterolateral Ligament of the Knee Anatomy, Biomechanics, and Reconstruction. American Journal of Sports Medicine, 2018. 46(5): p. 1235-1242.
  - Lansdown, D. and C.B. Ma, The Influence of Tibial and Femoral Bone Morphology on Knee Kinematics in the Anterior Cruciate Ligament Injured Knee. Clinics in Sports Medicine, 2018. 37(1): p. 127-+.
  - Liu, F., et al., Morphology of the medial collateral ligament of the knee. Journal of Orthopaedic Surgery and Research, 2010. 5

- Lopomo, N., S. Zaffagnini, and A.A. Amis, Quantifying the pivot shift test: a systematic review. Knee Surgery Sports Traumatology Arthroscopy, 2013. 21(4): p. 767-783.
- Matsuda, S., et al., Femoral condyle geometry in the normal and varus knee. Clinical Orthopaedics and Related Research, 1998(349): p. 183-188.
- McGinty, G., J.J. Irrgang, and D. Pezzullo, Biomechanical considerations for rehabilitation of the knee. Clinical Biomechanics, 2000. 15(3): p. 160-166
- Misir, A., K.I. Yildiz, and T.B. Kizkapan, Wider femoral and mediolaterally narrower tibial components are required for total knee arthroplasty in Turkish patients. Knee Surgery Sports Traumatology Arthroscopy, 2019. 27(7): p. 2155-2166.
- Robinson, J.R., A.M.J. Bull, and A.A. Amis, Structural properties of the medial collateral ligament complex of the human knee. Journal of Biomechanics, 2005. 38(5): p. 1067-1074.
- Voos, J.E., et al., Posterior Cruciate Ligament Anatomy, Biomechanics, and Outcomes. American Journal of Sports Medicine, 2012. 40(1): p. 222-231

- Websites:
  - https://www.anatomystandard.com

  - Knowledge clips online (via VUB Library):
    - Acklands Video Atlas of Human Anatomy:
    - https://biblio.vub.ac.be/vlink/WWWURN.csp?ID=ACA
    - Anatomy atlas Virtual Body https://www.visiblebody.com/

2.2.2 Content description:

- This lecture and associated Q&A session will cover the following topics:
  - Review of basic anatomy:
    - osteology of the knee
    - artrology of the knee
    - myology of the knee
    - innervation of the knee
    - vascularisation of the knee
  - Advanced (clinical) anatomy topics regarding the knee
  - Anatomical variability and variation in the knee region

All course content will be available on Canvas under Musculoskeletal imaging, analysis and model building in clinical reasoning part 1 - 012004

2.3 Additional information, slides, articles

3 Medical imaging of the Knee

How:

- asynchronous (video will be uploaded on the learning platform)
- followed by a Q&A session (see online schedule)

3.1 Specific outcomes for this lesson

1. The student has knowledge of medical diagnostics and measurements by means of medical equipment.
2. The student has knowledge about the principles of different imaging modalities of medical imaging within the diagnostic review.
3. The student is able to recognize anatomical structures and pathological images.
4. The student is able to interpret clinical images (from normal to pathological).
5. The student is able to situate the different medical imaging techniques in a diagnostic perspective according to their relevance relative to the strengths and limitations of the specific technique.
6. The student is able to recognize normal from basic but clearly pathological situation in medical images.

3.2 Prior knowledge for this lesson

The student needs a good basic knowledge of the regional anatomy of the knee

3.3 Introduction

The knee joint, a pivotal weight-bearing structure of the human body, is prone to a wide range of pathologies that can significantly impact an individual's mobility and quality of life. Medical imaging plays a crucial role in the assessment, diagnosis, and management of these knee conditions. This course aims to provide a comprehensive understanding of the techniques used in knee imaging, the normal findings on various imaging modalities, and the identification of common knee pathologies.

3.3.1 Importance of knee imaging

Knee-related issues are among the most common musculoskeletal complaints, affecting people of all ages and activity levels. From athletes, pushing their bodies to the limit, to elderly individuals, facing age-related degeneration, the knee's health is of paramount importance. An accurate and timely diagnosis is essential for guiding appropriate treatment strategies, which can range from conservative management to surgical intervention.

Imaging modalities offer unparalleled insights into the internal structures of the knee, allowing clinicians to visualize bones, cartilage, ligaments, tendons, and surrounding soft tissues. This visual information is instrumental in forming a precise diagnosis, devising treatment plans, monitoring progress, and making informed decisions about the patient's care.

3.3.2 Overview of imaging modalities

Medical imaging techniques for knee assessment include radiography (Rx), computed tomography (CT) , ultrasound (US), and magnetic resonance imaging (MRI). In addition we will briefly mention the role of bone scintigraphy. In cases of neoplastic malignancy or inflammatory pathology, positron emission tomography (PET) can be applied both in diagnosis and to assess response to treatment.

Each imaging modality offers unique advantages and is chosen based on the clinical scenario, suspected pathology, and the information required.

Radiography (Rx): X-ray images provide a quick and economical way to assess bony structures, identify fractures, joint alignment, and degenerative changes.

Ultrasound (US): Real-time, dynamic ultrasound offers excellent visualization of soft tissues, making it valuable for assessing ligaments, tendons, bursae, and detecting fluid accumulation. Deeper tissues such as cruciate ligaments, menisci and joint cartilage cannot, or only moderately be assesses using US. The bony cortex can be assesses in trauma settings using US, but fracture assessment is preferably performed using Rx / CT

Computed Tomography (CT): Computed tomography provides detailed cross-sectional images, ideal for assessing complex fractures, bone tumours, and bony anatomy.

Magnetic Resonance imaging (MRI): Magnetic resonance imaging offers exceptional soft tissue contrast, making it the gold standard for evaluating ligaments, cartilage and tendons.

Bone scintigraphy / bone scan / Single Photon Emission Computed Tomography (SPECT): is a nuclear medicine imaging technique that plays a role in the evaluation of various musculoskeletal conditions. It involves the use of a radioactive tracer that is injected into the bloodstream and accumulates in areas of increased osteoblastic activity. The emitted gamma rays are detected by a gamma camera, creating images that can provide valuable information about bone health and abnormalities. Bone scintigraphy is sensitive to osteoblastic changes in bone metabolism. It can help detect various bone abnormalities, such as fractures, stress reactions, infections, and bone tumours

Positron Emission Tomography (PET):
A Positron Emission Tomography (PET) scan is a nuclear medicine imaging technique that provides information about the metabolic activity of tissues in the body. It is often used to visualize and analyse various physiological and pathological processes at the molecular level. PET scans are particularly valuable for assessing metabolic changes, such as increased glucose uptake, which can be indicative of various conditions, including cancer, neurological disorders, and heart disease.

3.3.3 Role in diagnosing knee pathologies

The knee is susceptible to a range of pathologies that can be broadly categorized into traumatic, inflammatory, neoplastic (tumour-related), and degenerative conditions. Medical imaging is indispensable in identifying and characterizing these conditions.
By analysing imaging findings, clinicians can distinguish between ligament sprains and tears, differentiate between different types of arthritis, identify stress fractures, localize tumours, and assess the extent of cartilage damage. Moreover, imaging aids in tracking disease progression, monitoring treatment efficacy, and aiding surgeons in preoperative planning.

This course will guide you through each imaging modality, starting from the normal anatomy and moving on to various pathological conditions. It will equip learners with the knowledge and skills required to interpret images, correlate findings with clinical presentations, and make well-informed medical decisions.

In the following sections, we will explore the intricacies of normal knee imaging findings using radiography, ultrasound, CT, MRI and nuclear imaging techniques. We will also delve into the most common knee pathologies, including traumatic injuries, inflammatory conditions, tumours, and degenerative changes. In addition to this theoretical overview, real cases will be presented in supplemental files using clinical images from daily practice.

In conclusion, medical imaging of the knee is an indispensable tool in modern medicine, enabling accurate diagnosis and optimal patient care. By the end of this course, you will possess a comprehensive understanding of knee imaging techniques and the ability to recognize and interpret various knee pathologies, contributing to enhanced patient outcomes and well-informed medical decision-making.

3.4 Normal Image findings on radiography

3.4.1 Role of radiography

Classical knee radiography, commonly known as X-rays, continues to play a crucial role in current medicine, especially in the field of orthopaedics and musculoskeletal imaging. Despite the advancements in other imaging modalities like MRI and CT, knee radiography remains an essential tool for various reasons. X-rays are often the first-line imaging modality used to evaluate knee pain or trauma. They provide a quick and cost-effective way to obtain an initial overview of the knee joint's bony structures. X-rays are highly effective in identifying fractures including avulsion fractures, and articular fractures. Fracture assessment guides immediate patient management and treatment. Radiographs offer a clear view of joint alignment, helping diagnose conditions like malalignment, and degenerative changes that affect joint stability. X-rays are valuable for assessing osteoarthritis progression by visualizing joint space narrowing, subchondral sclerosis, and osteophyte formation, key markers of degenerative joint disease. Orthopaedic surgeons rely on X-rays to plan surgeries, such as joint replacement or realignment procedures, as they provide critical information about bone structure and alignment. X-rays are commonly used to evaluate paediatric knee conditions, including growth plate injuries, joint abnormalities, and congenital anomalies. Serial X-rays over time can monitor the progression of certain conditions, such as arthritis or bone healing post-fracture. X-ray machines are widely available in medical facilities, making them accessible and cost-effective compared to more advanced imaging modalities. While radiation exposure is a consideration, X-rays typically involve lower radiation doses compared to other modalities, like CT. Proper justification and optimization practices minimize unnecessary radiation exposure.

X-rays remain a fundamental tool in medical education, enabling trainees to learn and understand normal anatomy and common pathologies.

However, it's important to note that while X-rays provide excellent information about bone structures, they have limitations in visualizing soft tissues and more subtle pathologies. In cases where soft tissue or detailed evaluation is required, imaging modalities like MRI or ultrasound may be recommended in addition to X-rays.

In summary, classical knee radiography continues to hold a vital place in medical practice, offering a rapid and essential assessment of bony structures and aiding in diagnosis, treatment planning, and patient management.

3.4.2 Standard X ray examination of the knee

Radiographic assessment of the knee typically involves two standard views: the anteroposterior (AP) view and the lateral view. These views provide a comprehensive evaluation of the knee joint's bony structures, alignment, and spaces.

In addition to these views, a femoro- patellar view acquisition may be performed. This view is also known as “skyline view” or Merchant’s view.

In case of doubt, supplemental obliques views may be acquired, but in recent years the choice to add CT has taken over in these “difficult” cases.

In the assessment of degenerative osteoarthritis a supplemental tunnel view or “schuss” image may be performed.

Antero-Posterior (AP) View:
In this view, the patient is positioned upright with the knee extended. The X-ray beam is directed perpendicularly, passing through the anterior aspect of the knee and exiting through the posterior aspect.

Lateral View:
For the lateral view, the patient is standing, with the lateral side of the knee against the detector. The X-ray beam is directed horizontally from the lateral to the medial side of the knee.

Femoro-patellar view:
The patient is in the prone position with knee flexed around 60°, the X ray tube is angulated caudo-cranially.

Schuss view:
A knee X-ray Schuss view, also known as the weight-bearing or stress view, is a specialized X-ray projection used to evaluate the knee joint while the patient is standing and bearing weight on the affected leg. This view provides valuable information about the joint space, alignment, and any potential abnormalities that may not be as clearly visualized in standard non-weight-bearing X-ray views. The term "Schuss" is derived from the German word for "shooting" or "shooting position," as this X-ray view is taken while the patient is in a specific position that simulates the mechanical forces and stresses the knee joint experiences during weight-bearing activities. The patient stands facing the X-ray machine with the affected knee flexed at a specific angle, usually around 30 degrees. The other leg remains extended for balance and support. The Schuss view allows for assessment of the joint space width between the femur and tibia. The knee X-ray Schuss view is a valuable addition to the standard anteroposterior (AP) and lateral views commonly used to assess the knee joint. It provides a dynamic perspective of the joint under the forces it encounters during activities such as walking or standing. This view can aid in diagnosing and monitoring knee conditions, especially those related to joint degeneration.

3.4.3 Technical aspects

To achieve optimal radiographs, factors such as patient body composition, patient positioning, X-ray tube voltages, and exposure times must be considered.

In X-ray imaging, the variables kV (kilovolt) and mAs (milliampere-seconds) are crucial parameters that control the quality and quantity of X-rays produced. These variables influence the overall image quality, contrast, and radiation dose delivered to the patient. Although somewhat beyond the scope of this course, a short mention of these parameters:

Kilovolt (kV) is a measure of the voltage applied to the X-ray tube. It determines the energy level of the X-rays produced. The kV setting affects the penetration ability of the X-rays and influences the contrast and overall image quality.

Higher kV: Produces X-rays with higher energy levels, resulting in greater penetration through the body. This is useful for imaging thicker or denser body parts and for obtaining a lower-contrast image.

Lower kV: Produces X-rays with lower energy levels, resulting in less penetration. Lower kV settings are suitable for imaging less dense body parts and for obtaining higher-contrast images with more distinct differences between structures.

Adjusting the kV setting can significantly impact the visual appearance of the X-ray image and the amount of radiation delivered to the patient.

mAs (Milliampere-Seconds): Milliampere-seconds (mAs) is a combination of the current (milliamperes) and the exposure time (seconds) used in the X-ray tube. It controls the quantity of X-rays produced during the exposure.

Higher mAs: Delivers more X-rays to the detector, resulting in a higher amount of radiation and improved image quality. Higher mAs settings are suitable for thicker body parts or areas that require more X-rays to create a clear image.

Lower mAs: Delivers fewer X-rays, resulting in a lower amount of radiation and decreased image quality. Lower mAs settings can be used for thinner body parts or areas where less radiation is needed.

Adjusting the mAs setting affects the image's brightness and signal-to-noise ratio. Higher mAs settings generally lead to brighter images with less noise, but they also result in higher radiation exposure.

Balancing the appropriate kV and mAs settings is essential to achieve optimal image quality while minimizing patient radiation exposure. Radiologic technologists and medical professionals adjust these parameters based on factors such as the patient's anatomy, the specific body part being imaged, the desired image quality, and the ALARA principle (As Low As Reasonably Achievable) for radiation safety.

3.4.4 Normal Knee Anatomy and Common Variants

3.4.4.1 Normal Anatomy Observed on X-rays:

Femur: The femoral condyles, including the lateral and medial condyles, articulate with the tibia. The intercondylar notch lies between them. The femur's bony landmarks help assess alignment and joint spaces.

Tibia: The tibial plateau consists of the lateral and medial tibial plateaus. The intercondylar eminence separates these and provides attachments for ligaments.

Patella: The patella is visible in the patellofemoral joint. Its position and alignment are important indicators of patellar tracking and stability.

3.4.4.2 Common Variants and Anomalies:

Fabella: A small sesamoid bone situated within the lateral head of the gastrocnemius muscle. Its presence is a normal variant but can occasionally contribute to knee pain.

Bipartite Patella: An accessory ossification centre that does not fuse with the main body of the patella. It appears as a small, separate fragment on the superolateral aspect of the patella.

Tibial Tuberosity Ossification Centre: The centre for the patellar tendon's attachment to the tibia, ossifies over time and fuses in adolescence.

These are just a few normal variants. Several extensive books have been written on normal variant in the different imaging modalities. Understanding these normal variations is essential to distinguish them from pathological conditions. A rule of thumb is: when in doubt, compare with X-ray images of the contralateral side. This is especially helpful in children, where ossification centres may vary enormously.

3.5 Knee on ultrasound: Normal Image Findings and Exam protocol

3.5.1 Introduction to the Knee on Ultrasound

Ultrasound is a versatile and non-invasive imaging modality that offers real-time visualization of soft tissues, making it invaluable for assessing the knee joint's complex anatomy. A knee ultrasound exam provides detailed insights into ligaments, tendons, bursae, synovium, and other soft tissue structures. The most important advantages of ultrasound are:

- The possibility to use Dynamic Imaging: Ultrasound provides real-time images, which allows for dynamic assessment of the knee joint. This is particularly useful for evaluating joint movement, assessing ligament integrity, and identifying fluid accumulation within the joint space.
- Guidance for Procedures: Ultrasound can be used to guide needle placement during various procedures, such as joint injections, aspirations, and (rarely) biopsies. The real-time imaging helps ensure accurate needle placement, reducing the risk of complications and increasing the success rate of procedures.
- Soft Tissue Assessment: Ultrasound is effective at visualizing soft tissues such as tendons, ligaments, muscles, and bursae. This is important for assessing injuries like tendon tears, ligament sprains, and muscle strains.
- Rapid Imaging: Ultrasound is readily available, even portable devices exist, and relatively quick to perform compared to other imaging methods like MRI. This can be particularly beneficial in urgent situations where a quick assessment is needed.
- Cost-Effectiveness: Ultrasound is generally more cost-effective than other imaging modalities, making it a preferred choice in certain clinical scenarios.
- Safety: Ultrasound uses non-ionizing radiation, which means it does not expose patients to potentially harmful ionizing radiation as in X-rays or CT scans.

However, it's important to note that ultrasound has limitations as well. The most important issue is that ultrasound is "user dependent", meaning that the quality of ultrasound images can be influenced by the skill and experience of the operator. Adequate training and expertise are crucial to obtain accurate and meaningful images. To counter this, a standardised examination technique, which will be explained in detail in this chapter is important to ensure visualisation of all the major important anatomical structures.

Although ultrasound has a high sensitivity for more superficial structures, it has limited penetration through bone and deep tissues, making it less suitable for fully assessing structures within the knee joint, especially in patients with larger body sizes. Structures such as joint cartilage, menisci or cruciate ligament cannot be fully assessed using ultrasound

3.5.2 Standardised Imaging Technique for Knee Ultrasound

Use a high-frequency linear array transducer (7-15 MHz) for optimal resolution and penetration of superficial structures. In knee imaging this probe will suffice in almost every patient. In extreme setting a convex probe may be used to better visualize deeper tissues. Although, when this is necessary, ultrasound will be of moderate to no contribution in these patients. Apply copious amounts of water-based ultrasound gel to the skin over the knee joint. This facilitates sound wave transmission and eliminates air gaps that could distort the image.

Standardised imaging of the knee includes imaging of the different sides of the joint, starting with the anterior part, then medial side, lateral side and posterior side.

To examine the anterior part of the knee, place the patient in a comfortable supine position with the knee slightly flexed to ensure good tension in the extensor apparatus. A small cushion can be placed under the knee to relax the muscles. Start the examination by identifying the quadriceps tendon and the musculotendinous junction between the muscle bellies and the tendon. Follow the tendon all the way to the patellar insertion searching for tendon thickening, heterogeneity, or calcification at the site of insertion. Bellow this tendon evaluate the suprapatellar fat pad and the pre-femoral fat fad. Between these fat pads lies the suprapatellar recess, where fluid effusions can be evaluated.

Follow the superficial fibbers of the quadriceps tendon over the patella, and beyond the patella all the way to the tibial tuberosity via the patellar tendon. Superficially evaluation of the subcutaneous tissue should be performed to evaluate signs of prepatellar bursitis. More distally, distension of the infrapatellar bursae needs to be excluded. Both superficial and deep infrapatellar bursae exist. It should be noted that a small amount of fluid in the deep infrapatellar bursa is within physiological borders. Deep to the patellar tendon the Hoffa fat pad can be evaluated.

After evaluation of the anterior side the medial side is examined. For this the knee can remain slightly flexed, with addition of external rotation of the tibia. In the medial compartment an evaluation of the medial “joint line” can be made, visualising the peripheral parts of the medial meniscus and degenerative narrowing of the joint space can be seen as well as osteophytes emerging from the bony borders. Superficial to the medial meniscus, the medial collateral ligament can be evaluated, consisting of a superficial and deep component. Note the close relationship between this medial collateral ligament and the medial meniscus. The superficial component of the medial collateral ligament should be followed distally all the way to the tibial insertion, which is surprisingly distal and spans the medial genicular artery. At the side of insertion of the medial collateral ligament, three tendon insertions can be seen which form the “pes anserinus”. These are the distal tendons of the M. Sartorius, M. Gracilis and M. Semintendinosus. (a simple mnemonic to help remember these names is “**Sa**y **Gra**ce before **Te**a). At this site you can look for signs of tendinitis or inflammation of the bursae, which, in normal circumstances should not be visible.

Following examination of the medias side, switch to the lateral side. For this, the tibia / foot can be internally rotated. In analogy to the medial side, we start by examining the lateral joint line. This shows a moderate view of the lateral meniscus and allows evaluation of the joint space. The evaluation of the lateral collateral ligament can be a little more challenging than the visualisation of the medial meniscus. The easiest way to visualise the lateral collateral ligament is to start by palpating the fibular head: lateral and somewhat posteriorly located. Position the distal part of the probe on the fibular head and angulate the proximal part anteriorly. This will show the lateral collateral ligament, which can be follow proximally. After visualisation of the lateral collateral ligament, keep the probe on the fibular head and angulate the proximal part more posteriorly. This will yield a good view of the distal M. Biceps femoris tendon. After evaluation of the insertions on the fibular head, slide the probe more anteriorly to evaluate the insertion of the iliotibial band on Gerdy’s tubercle. This thick fibrillar structure can easily be found and should be followed to the proximal side, over the lateral femoral epicondyle, where band thickening or bursitis must be excluded (signs of runner’s knee).
The final part to be evaluated is the posterior side of the knee. For this part the patient is

best positioned prone with the leg in extension. The posterior part of the knee can by divided in three subdivisions: the posteromedial, posterolateral and central part. Starting with the posteromedial side the easiest anatomical reference point is the muscle belly of the medial gastrocnemius which should be followed proximally to its insertion with the typical “boomerang” shaped tendon. Next to the medial gastrocnemius we can see the M. Semimembranosus tendon. Between both an important bursa “Baker’s cyst” can be visualised. Above the M. Semimembranosus the tendon of the M. Semitendinosus can be seen. On the posterolateral side you can find the M. Biceps femoris and the lateral gastrocnemius with its insertion on the lateral femoral epicondyle. Don’t be fooled by a possible fabella in the tendon of the lateral gastrocnemius. This should not be mistaken for a calcifying tendonitis. In the central posterior site you can evaluate the popliteus muscle with its thick tendon inserting on the lateral condyle. The popliteus is triangular shaped and close the tibial cortex, deep to the popliteal artery. The last muscle belly to evaluate is the plantaris muscle belly, located between the gastrocnemius and soleus muscle bellies. To finish the exam the popliteal vessels and nerves should be evaluated. In some cases an asymptotic popliteal artery aneurysm can be identified.

3.6 Knee MRI

Magnetic Resonance Imaging (MRI) of the knee allows a comprehensive evaluation of the joint's intricate structures, providing high-resolution images of both soft tissues and bones. Understanding the normal findings on knee, MRI is crucial for accurate interpretation and differentiation from pathological conditions. MRI uses a combination of strong magnetic fields and radio waves to create detailed images of the internal structures of the body. In knee imaging, MRI provides several advantages: it provides highly detailed images of both soft tissues and bony structures within the knee joint. This includes the ligaments, tendons, muscles, cartilage, bones, and surrounding structures. MRI can generate images in multiple planes, allowing for a comprehensive view of the knee joint from different angles. This is essential for accurate assessment and diagnosis. MRI is particularly effective at detecting and characterizing soft tissue injuries such as ligament tears (e.g., ACL, PCL), meniscal tears, tendinopathies, muscle strains, and other soft tissue pathologies. MRI is one of the best tools for evaluating the condition of articular cartilage within the knee joint. It can help identify cartilage defects, degeneration, and other abnormalities. MRI can detect bone abnormalities, including stress fractures, bone tumours, and infections, which might not be as easily identified with other imaging methods. MRI can visualize joint effusions (fluid accumulation) and inflammation within the knee joint, aiding in the diagnosis of conditions such as arthritis and synovitis. MRI is a non-invasive imaging technique that does not involve ionizing radiation, making it a safe choice for repeated imaging and for certain patient populations, such as pregnant women. Despite its many advantages, there are also some considerations when using MRI for knee imaging: MRI can be more expensive and less accessible than other imaging modalities, which can influence its availability for some patients. Some patients might feel uncomfortable due to the confined space of the MRI machine. Some individuals with certain medical devices (e.g., pacemakers, cochlear implants) or conditions may not be suitable candidates for MRI due to safety concerns related to the magnetic fields.

In summary, MRI is a versatile and powerful tool for knee imaging, providing detailed and comprehensive information about the structures within the knee joint. It is especially valuable for evaluating soft tissue injuries, cartilage health, and bone abnormalities, making it a fundamental imaging modality in the assessment and management of various knee conditions.

Various MRI sequences are used in knee imaging to provide a comprehensive assessment of the joint's anatomy and pathology. These sequences offer different types of information about the tissues and structures within the knee. Here are some of the key

MRI sequences commonly used in knee imaging:

1 T1-Weighted Imaging (T1WI):
- Provides excellent anatomical detail and tissue characterization.
- Highlights anatomy, aiding in assessing bone, cartilage, and fat.
- Ligaments and tendons appear dark, making it useful for evaluating surrounding structures.

2 T2-Weighted Imaging (T2WI):
- Sensitive to water content and pathology-related changes.
- Visualizes soft tissues, fluid collections, oedema, and inflammation.
- Helps in assessing meniscal and ligamentous injuries.

3 Proton Density-Weighted Imaging (PDWI):
- Balances both T1 and T2 weighting.
- Useful for distinguishing subtle differences in tissue composition.
- Provides good contrast between soft tissues.

4 Short Tau Inversion Recovery (STIR):
- Suppresses fat signal and enhances visualization of oedema and fluid.
- Helpful for detecting bone marrow oedema, stress fractures, and joint effusions.

5 Fluid-Sensitive Sequences (e.g., Fat-Suppressed T2WI):
- Suppression of fat signal allows better detection of oedema and fluid.
- Ideal for evaluating synovitis, joint effusions, and soft tissue injuries.

6 Gradient Echo (GRE) Sequences:
- Provides a rapid acquisition of images, useful for patients with limited ability to remain still.
- Can enhance detection of certain types of cartilage abnormalities.

3.7 Knee trauma

3.7.1 Introduction

Trauma of the knee is a common injury. The mainstay of its initial imaging assessment is still the conventional radiograph. Multiple ligamentous structures contribute to stability of the knee, and demonstration of a fracture should alert to the possibility of concomitant injury to these soft tissue structures. Some types of bone injury are specifically associated with certain age groups and knowledge of this is helpful, particularly when the conventional radiographs appear normal. During growth the abundant cartilaginous structures (physes and apophyses) are the weakest links in the bone-joint-tendon-ligament complex, and fractures in the vicinity of the knee have peculiar characteristics in this age group. In the older person, particularly a female with osteoporosis, fractures of the lateral tibial plateau may be easily overlooked. These can be highlighted by including internal and external oblique views or CT when the injury is suspected. There are important neurovascular structures closely related to the distal femur, primarily posteriorly and laterally. The possibility of associated damage to these structures is paramount when evaluating bone trauma to the knee joint at any age (e.g. knee dislocation in the adult and physeal fractures in the child with epiphyseal separation). Concomitant bony injuries, particularly at the hip and ankle joints, should also be considered in association with fractures of the knee.

3.7.2 Fracture types

Supracondylar Fractures: Supracondylar fractures occur just above the level of the condyles, are frequently slightly transverse oblique, may be comminuted and not infrequently extend into the joint. The distal fragment is frequently angulated posteriorly owing to the pull of the gastrocnemius muscle attached posteriorly just above the femoral condyles. There is also a risk of associated vascular injury to the popliteal vessels behind the knee joint. Radiography can easily assess these fractures.

Distal Femoral Physeal fractures: Distal femoral physeal (and proximal tibial physeal) injuries are usually due to a valgus or hyperextension force at the knee. Since physeal injuries occur prior to skeletal fusion, such injuries can be associated with a high incidence of growth disturbance due to posttraumatic tethering across the physis. Distal femoral physeal fractures are much rarer than those occurring at the ankle or affecting the upper limb. They are associated with ligamentous injuries of the knee joint. They are classified according to the Salter Harris classification of physeal injuries. Salter Harris (SH) type I fractures are indistinguishable from growth plates on radiography. Higher grade SH fracture can be sufficiently detected using radiography.

Fractures of the Proximal Fibula: Fractures of the head and neck of the fibula rarely occur in isolation and are usually associated with fracture of the lateral tibial condyle, ligamentous injuries of the knee or fracture of the ankle. Proximal fibula fracture can be detected using only radiography. Associated ligamentous injuries should be assessed using ultrasound, or even better using MRI.

Fractures of the Patella: Patellar fractures occur from direct or indirect forces. Direct force is the most common and can occur in all age groups. Fractures of the patella can be classified into:

- Marginal (vertical)
- Stellate
- Transverse
- Avulsion
- Comminuted

Vertical fractures in adults are usually the result of direct injury and involve the lateral facet. They include the entire thickness of the patella. A medial marginal fracture in children may traverse the entire thickness of bone or there may be a medial tangential osteochondral fracture. These longitudinally oriented fractures are usually nondisplaced and are best seen on axial or oblique views. Patellar fractures occurring due to indirect forces result when the intrinsic strength of the patella is exceeded by the pull of the musculotendinous expansion attaching to it. This can occur with falls, with the knee in flexion and severe contraction of the quadriceps tendon. After the patella fractures, continuing quadriceps muscle action results in tearing of the medial and lateral quadriceps expansions. The typical fracture in this situation is a transverse fracture. Transverse fractures are best seen in a lateral projection. The bone only may be fractured, the articular cartilage remaining intact with the gap maximal anteriorly and least posteriorly. Even if a fracture is comminuted, the fragments will be dose together if the surrounding soft tissues of the quadriceps expansion are intact.

Femoral Condylar Fractures: Femoral condylar fractures may involve one or both condyles. The fractures are usually associated with high impaction and may be comminuted and displaced with resultant loss of congruity of joint surfaces. Fractures confined to one condyle are usually obliquely oriented. The mechanism of injury is thought to be axial loading with a varus or valgus force. There is usually significant associated soft tissue injury due to disruption of ligamentous attachments.

Fractures of the Tibial Plateau: Fractures of the tibial plateau occur due to a combination of valgus and compression forces generated by impaction of the femoral condyles against the tibial plateau. The lateral tibial condyle and plateau are weaker than the medial plateau, and fractures are thus more likely to occur here. Also the femoral condyles are stronger than the tibial plateau, and thus with impaction injury the plateau is more vulnerable. Varus stresses and adduction of the tibia occur much less frequently than valgus stress; hence the greater propensity for injury to involve the lateral condyle. A number of classifications of fractures of the tibial plateau have been used. That given here is the one proposed by Schatzker.

Fractures of the Tibial Spine and Intercondylar Eminence: Fractures of the tibial spine and intercondylar eminence are more common in children than in adults. The injury is most commonly seen in conjunction with high-energy plateau fractures and is frequently avulsion in nature, typically occurring at the site of origin of the ACL. In older children and adults, the ACL is usually torn within its substance without an associated avulsion fracture. The mechanism of injury is thought to be hyperextension combined with strong rotational forces. There is an incidence of associated ligamentous injuries and this is greater in adults than children. Intercondylar Eminence fracture can be difficult to detect on standard radiography. Indirect signs of fractures such as hemarthroses can be detected, prompting further evaluation using CT or MRI.

Osteochondral Fractures: Osteochondral fractures involve the medial or lateral femoral condyle or the patella. These fractures are usually identified on the basis of a small bone fragment located intra-articular. They can, however, sometimes be very difficult to appreciate since even a large fragment may contain only a very small ossified component that is difficult to see on plain radiographs and even CT. Associated bone oedema can easily be assessed using MRI.

Dislocation: Dislocation of the knee at the femorotibial joint is a rare injury. It is associated with a considerable force, such as may occur with a severe automobile injury. There is a high association with injury to the popliteal artery. After reduction of the knee joint additional MRI should be performed to assess the integrity of the menisci, cruciate ligaments, cartilage and the presence of bone oedema.

It is rare for patients to present with acute dislocation of the patella. Rather, most give a history suggestive of dislocation of the patella that has either relocated spontaneously or has been reduced by the patient.

Stress fractures: Stress fractures most commonly occur in young fit adolescents or young adults as a result of repetitive stress to metabolically normal bone The most common site in the knee is the proximal shaft of the tibia. Other sites may involve the neck and proximal shaft of the fibula. Radiography and CT are relatively insensitive in the early stages of stress fractures an insufficiency fractures. Only in later stages the fracture line and associated callus formation can be visualised. Diagnosis of stress fractures in early stages can be done by bone scan or MRI

Insufficiency Fractures: Insufficiency fractures can occur as a result of normal stresses in metabolically abnormal bone such as osteoporosis. They are therefore most common in elderly females. The tibial plateau, most commonly the medial plateau, is usually affected, although fractures may occur a little more distally and involve the medial cortex

Osgood-Schlatter Lesion: The Osgood-Schlatter lesion occurs when the tibial tubercle is in the apophyseal stage and when the secondary ossification centre has appeared. The cartilage overlying the ossification centre anteriorly and posteriorly can resist tension forces better than the bone of the ossification centre.

Sinding-Larsen-Johansson Disease: A condition seen most commonly in adolescents that consists in pain, tenderness and soft tissue swelling over the lower pole of the patella associated with bony fragmentation. The lesion is likely due to a traction phenomenon in which repeated minor trauma at the proximal attachment of the patellar tendon, initially commencing as inflammation, is followed by calcification or ossification or in which patellar fracture or avulsion produces one or more distinct ossification sites. Similar findings can be seen in athletes with «jumper's knee". Early diagnosis is can be made on ultrasound. Later stages can be diagnosed on radiography or CT.

It's important to note that the severity and treatment of knee fractures can vary widely depending on factors such as the specific bones involved, the type of fracture (e.g., displaced or non-displaced), the patient's age and overall health, and the presence of associated injuries. Treatment can range from conservative measures like immobilization and physical therapy to surgical interventions involving fixation with screws, plates, or other hardware.

3.7.3 Meniscal Tears

Meniscal tears are common injuries that occur in the knee. Menisci serve to cushion and stabilize the knee joint. Different types of meniscal tears can occur, often classified based on their location and pattern. It's important to note that the classification of meniscal tears can sometimes be challenging, as tears can vary in size, shape, and location. The specific type of meniscal tear affects the treatment approach, which can range from conservative measures like rest, physical therapy, and anti-inflammatory medication, to arthroscopic surgery to repair or remove the damaged tissue. Accurate diagnosis and appropriate treatment planning are crucial for optimal outcomes.

Several imaging modalities can be used to diagnose meniscal tears in the knee. The choice of modality depends on factors such as the suspected severity of the tear, the patient's symptoms, and the availability of resources. The most commonly used imaging modalities for diagnosing meniscal tears include:

- Magnetic Resonance Imaging (MRI): MRI is the most accurate imaging techniques for evaluating meniscal tears. It provides detailed images of the soft tissues, including the menisci. Different MRI sequences can highlight various aspects of meniscal anatomy and pathology, helping to identify tears, their location, and their characteristics. MRI can also assess the extent of associated injuries, such as ligament damage or bone bruises.

- Ultrasound: Ultrasound can be used to evaluate meniscal tears, especially in cases where MRI is contraindicated or unavailable. However, ultrasound is not as sensitive as MRI for detecting smaller tears or evaluating the entire meniscus.

- Computed Tomography (CT) Scan: CT arthrography (CT with contrast injected into the joint) can provide additional information about meniscal tears and other soft tissue abnormalities.

MRI remains the most frequently used and reliable non-invasive imaging technique for evaluating meniscal tears and other knee joint pathologies.

3.7.4 Ligamentous injury

MRI and ultrasound are both valuable tools for evaluating ligamentous injuries in the knee. Depending on the ligament involved ultrasound may be the preferred modality, other ligaments may only be visualised on MRI

- <u>Anterior Cruciate Ligament (ACL) and Posterior Cruciate Ligament (PCL):</u> Sagittal and coronal MRI sequences are used to visualize the ACL and PCL, respectively. High-quality MRI can show signs of ligament disruption, such as discontinuity or abnormal signal intensity. On ultrasound, only a minor portion of the PCL can be seen in some patients.

- <u>Medial Collateral Ligament (MCL) and Lateral Collateral Ligament (LCL):</u> Axial and coronal MRI sequences are used to assess the MCL and LCL. MRI can show ligament thickening, discontinuity, or abnormal signal. Ultrasound is well suited to evaluate both the collateral ligaments. The lateral collateral ligament may be a bit more difficult to image.

- <u>Iliotibial band</u>: MRI and ultrasound can assess the iliotibial band (ITB)

X-rays: X-rays are not used to directly visualize ligaments, but they can help assess for any associated bone fractures or avulsion injuries that might occur with severe ligamentous trauma.

3.8 Inflammatory pathology of the knee

To assess inflammatory pathology of the knee, such as arthritis or synovitis, several imaging modalities can be useful. The choice of modality depends on the specific clinical context and the information needed. The best imaging modalities for assessing inflammatory knee conditions include:

<u>Magnetic Resonance Imaging (MRI):</u> MRI is a powerful tool for evaluating inflammatory knee conditions. It provides detailed images of soft tissues, including the synovium (lining of the joint), cartilage, and bone. MRI can show signs of synovitis (inflammation of the synovium), joint effusion (fluid accumulation), and bone marrow oedema (increased fluid in bone marrow), which are common features of inflammatory arthritis. Additionally, MRI can help differentiate between various types of arthritis, such as rheumatoid arthritis and osteoarthritis.

<u>Ultrasound:</u> Ultrasound can provide real-time imaging of soft tissues and is particularly useful for assessing synovitis and joint effusion. It can visualize inflamed synovial tissue, detect fluid accumulation within the joint, and assess the vascularity of the synovium. Ultrasound can also guide interventions such as joint aspirations or injections. Bursitis, both prepatellar and infrapatellar bursal effusion can easily be detected using ultrasound and aspiration of fluid can be performed, under strict aseptic conditions to avoid further infection.

<u>Nuclear Medicine Scintigraphy (Bone Scan):</u> Nuclear medicine techniques, such as bone scintigraphy (bone scan), can help assess the degree of inflammation and activity in the knee joint. While not as specific as MRI, bone scans can show areas of increased bone metabolism, which can be indicative of inflammation or arthritis. However, bone scans are often used in conjunction with other imaging modalities for a more comprehensive evaluation.

<u>Radiographs (X-rays) / CT</u>: While X-rays do not directly visualize soft tissues, they can be useful in assessing joint space narrowing, bony erosions, and changes characteristic of chronic inflammation, especially in chronic forms of arthritis like rheumatoid arthritis. Radiographs can also help monitor disease progression over time.

<u>Positron Emission Tomography (PET):</u> PET scans with a radiotracer like FDG (fluorodeoxyglucose) can show increased metabolic activity in inflamed tissues, including synovitis. PET-CT scans can provide information about the extent and distribution of

inflammation in the knee.

3.9 Bone tumours:

3.9.1 Benign bone tumours:

Several types of benign bone tumours can occur in or around the knee joint. Some of the most frequent benign bone tumours in this region include:

Osteochondroma: Osteochondromas are the most common benign bone tumours. They often occur near the growth plates in the long bones, including around the knee joint. Osteochondromas are bony projections capped with cartilage. They usually present as painless, slow-growing masses. In the knee area, they can be found around the distal femur or proximal tibia. The calcified parts of the osteochondroma can be visualised using X-ray of CT, MRI can be helpful to visualise the cartilage cap.

Giant Cell Tumour of Bone: Giant cell tumours are locally aggressive benign tumours that commonly affect the knee joint. They usually occur in the epiphysis (end) of long bones, such as the distal femur or proximal tibia. These tumours can cause pain, swelling, and joint instability. Although benign, they can be locally destructive and may require surgical treatment. X-ray shows a radiolucent Lesion: GCTBs typically appear as a well-defined, eccentric, and expansile radiolucent lesion on X-rays. They often have a "soap bubble" or "geographic" appearance due to their characteristic pattern of bone destruction. The tumour can cause thinning and expansion of the bone cortex adjacent to the lesion. Unlike some other bone tumours, GCTBs usually do not show calcifications on X-rays. GCTBs often appear hypointense on T1-weighted MRI images due to the presence of fibrous tissue. The tumour is typically hyperintense on T2-weighted images due to the presence of oedema, haemorrhage, and the high water content of the tissue. Post-contrast MRI images may show enhancement at both the tumour periphery and the central portion of the lesion. CT scans can provide detailed information about the extent of bone destruction caused by the tumour. The soap bubble appearance seen on X-rays can be better visualized with CT. CT scans can also show cortical breakthrough and thinning caused by the expanding tumour. Biopsy of the lesion is often required to confirm the diagnosis. Histopathological examination reveals characteristic multinucleated giant cells, along with mononuclear stromal cells. It's important to note that while GCTB is generally benign, it can exhibit locally aggressive behaviour and has a tendency to recur after surgical removal. Close monitoring and appropriate management are essential for optimal patient care.

Enchondromas are benign tumours that originate from cartilage. They often affect the small bones of the hands and feet but can also occur around the knee joint. Enchondromas can sometimes cause pain and weaken the bone, potentially leading to fractures. They are commonly seen in the distal femur or proximal tibia. Enchondromas typically appear as well-defined, geographic radiolucent lesions on X-rays. They often have a stippled or popcorn-like appearance due to calcifications within the cartilaginous tissue. Enchondromas are often centrally located within the medullary cavity of the bone. Enchondromas generally appear as low-signal-intensity lesions on T1-weighted MRI images due to their cartilaginous nature. Enchondromas can have variable signal intensity on T2-weighted images, depending on the amount of cartilaginous tissue, calcifications, and cystic changes present. Enchondromas usually do not show significant enhancement on post-contrast MRI images. Biopsy of the lesion is often required to confirm the diagnosis. Histopathological examination reveals characteristic cartilaginous tissue with scattered chondrocytes.

Simple Bone Cyst (Unicameral Bone Cyst): Simple bone cysts are fluid-filled sacs that can weaken the bone and potentially cause fractures. They are often seen in the metaphysis (near the growth plate) of long bones, including the bones around the knee joint. These cysts can cause pain and swelling but are usually asymptomatic and are often discovered incidentally on imaging studies. The imaging hallmarks of a simple bone cyst include a lucent (radiolucent) lesion on X-rays. They often have a characteristic "fallen fragment sign," which is a fracture fragment within the cyst cavity. The cyst is typically located eccentrically within the bone, often near the metaphysis (growth plate) of a long bone. Simple bone cysts show a well-defined, fluid-filled cavity on MRI scans. The cyst cavity is hypointense on T1-weighted images and hyperintense on T2-weighted images due to the fluid content. Simple bone cysts usually do not show significant enhancement on post-contrast MRI images. CT scans can demonstrate the low attenuation (similar to water) of the cyst's fluid contents.

Fibrous Dysplasia: Fibrous dysplasia is a condition where normal bone is replaced by fibrous tissue. While not a tumour in the traditional sense, it can cause bone deformities and pain. Fibrous dysplasia can affect the bones around the knee joint and lead to changes in bone shape. Fibrous dysplasia often appears as a "ground glass" or "cloudy" radiolucent lesion on X-rays. This appearance is due to the mixture of fibrous tissue and immature bone. The lesion can cause bone expansion and thinning of the cortex. This may lead to bowing deformities in long bones. Fibrous dysplasia typically appears hypointense on T1-weighted MRI images due to the fibrous tissue component. The signal intensity on T2-weighted images can vary, depending on the amount of fibrous tissue and bone present. CT scans can demonstrate the ground glass appearance seen on X-rays. The mixture of fibrous tissue and immature bone contributes to the cloudy appearance. Fibrous dysplasia may show mild to moderate uptake on technetium bone scans, reflecting the increased metabolic activity of the involved bone. A bone biopsy is often performed to confirm the diagnosis. Histopathological examination reveals a mixture of fibrous tissue and trabeculae of woven bone, with varying degrees of cellular activity. Specific Types of fibrous dysplasia have been described: for example McCune-Albright Syndrome: This syndrome is characterized by polyostotic fibrous dysplasia, along with other features like café-au-lait skin spots and endocrine abnormalities. Mazabraud Syndrome: This syndrome involves the combination of fibrous dysplasia with intramuscular myxomas (benign tumours of connective tissue) in multiple locations. Imaging plays a critical role in diagnosing and monitoring fibrous dysplasia, as well as planning appropriate management strategies. Regular follow-up imaging may be recommended to assess changes in the lesion over time.

3.9.2 Malignant Bone tumours:

Malignant bone tumours are rare but serious conditions that can occur in or around the knee joint. Some of the most frequent malignant bone tumours in this region include:

Osteosarcoma: Osteosarcoma is the most common primary malignant bone tumour. It usually occurs in the long bones, and around the knee joint is a common location, particularly in the distal femur and proximal tibia. Osteosarcoma is aggressive and tends to affect adolescents and young adults. It can cause pain, swelling, and fractures.

Chondrosarcoma: Chondrosarcoma is a malignant tumour that arises from cartilage cells. While most chondrosarcomas occur in the pelvis or ribs, they can also develop around the knee joint, particularly in the distal femur. Chondrosarcomas can vary in their behaviour, from low-grade to high-grade malignancies.

Ewing Sarcoma: Ewing sarcoma is a rare malignant bone tumour that predominantly affects children and young adults. It can occur in various bones, including the bones around the knee joint. Ewing sarcoma can cause pain, swelling, and fever. It often requires a combination of surgery, chemotherapy, and radiation for treatment.

Secondary Bone Tumours (Metastases): Secondary bone tumours are tumours that spread to the bone from other primary sites, such as the lung, breast, prostate, or kidney. Metastatic tumours can occur in various bones, including around the knee joint. They can cause pain, fractures, and other symptoms.

It's important to emphasize that malignant bone tumours are relatively rare. However, when a malignant tumour is suspected based on symptoms, imaging findings, and clinical evaluation, prompt and accurate diagnosis is crucial for appropriate management. A multidisciplinary approach involving orthopaedic oncologists, radiologists, pathologists, and other specialists is essential for the diagnosis, staging, and treatment of malignant bone tumours in selected hospitals.

General signs of aggressive / malignant bone lesions:

- Aggressive bone lesions demonstrate destructive features. On X-rays or radiographs, it may appear as a large, irregularly shaped mass that disrupts the normal bone architecture. The lesion may have ill-defined or permeative margins, indicating its invasive nature.

- Codman's triangle is a triangular area of bone reaction that can be seen on X-rays. It forms when the tumour lifts the periosteum (the outer covering of bone) away from the bone surface, creating a triangular shadow. Similarly, a sunburst appearance can be observed when the tumour penetrates the cortex and elevates the periosteum, resulting in radiating spicules.

- Sarcomas may display a mottled appearance on X-rays due to areas of both increased and decreased bone density. These regions can correspond to areas of tumour necrosis and new bone formation.

- On MRI, malignant bone tumours often presents as a mass that extends into adjacent soft tissues. MRI can show the extent of tumour involvement, its relationship with surrounding structures, and whether there's any involvement of neurovascular structures.

- Osteosarcoma is often metabolically active and shows increased FDG uptake on positron emission tomography-computed tomography (PET-CT) scans. PET-CT can help in staging and monitoring treatment response.

3.10 Degenerative changes of the knee

Various imaging modalities can provide valuable insights into the changes associated with knee osteoarthritis. The imaging findings of knee osteoarthritis can vary based on the specific modality used. Here are the typical findings on different imaging modalities:

X-rays (Radiographs): X-rays are commonly used for assessing knee osteoarthritis due to their availability and ability to visualize bony changes. Typical findings include:

- Joint Space Narrowing: Gradual loss of cartilage leads to reduced space between the bones.
- Osteophytes: Formation of bone spurs at the joint margins as a response to cartilage loss.
- Subchondral sclerosis: Increased bone density at the joint surfaces due to stress and remodelling.
- Subchondral cysts: Fluid-filled cavities within the bone beneath the cartilage.

Magnetic Resonance Imaging (MRI): MRI provides detailed images of soft tissues, cartilage, and bone, making it valuable for assessing knee osteoarthritis. MRI findings include:

- Cartilage Thinning: Loss of cartilage integrity and reduction in cartilage volume.
- Bone Marrow Lesions: Increased signal intensity in the subchondral bone due to microfractures and inflammation.
- Osteophytes: Bone spurs that can be visualized in detail.
- Synovitis: Inflammation of the synovial lining.
- Meniscal Changes: Degenerative changes in the menisci.
- Effusion: Accumulation of joint fluid.

Ultrasound: Ultrasound can assess soft tissues, cartilage, and some bone features. Typical findings in knee osteoarthritis include:

- Joint Effusion: Fluid accumulation within the joint.
- Osteophytes: Visible as hyperechoic bony outgrowths.
- Cartilage Changes: Thinning and loss of smooth cartilage appearance.
- Synovial Thickening: Enlargement of the synovial lining.
- Baker's Cyst: Fluid-filled swelling behind the knee due to synovial fluid accumulation.

The choice of imaging modality depends on factors such as the clinical presentation, the information needed, and the available resources. Combining clinical evaluation, patient history, and imaging findings is important for accurate diagnosis and treatment planning in knee osteoarthritis.

3.11 Additional information, slides, articles

Part 3 The Shoulder

Case description

A 50-year-old female patient attended her physiotherapy appointment complaining of left shoulder pain which started about 6 weeks ago following a full day of painting. The pain was described as a dull ache. She reports a VAS score of 4 which rises to 9 with arm certain movement. Patient also reports some loss of active range of movement.

The patient had previously been diagnosed with right breast cancer 7 years ago which resulted in have a radical mastectomy. She had regular screening and until recently, was taking tamoxifen every day, was having bone scans and breast screening once a year, and PET-CT (Positron Emission Tomography-Computed Tomography) taken once every two years to observe potential progress, there were no traces of recurrence or metastasis evident.

1 Clinical decision making

How:

- asynchronous introduction (video will be uploaded on the learning platform)
- followed by 3 working sessions (see online schedule)

1.1 Specific outcomes for this lesson

1. The student is aware of laws and safety measures (social environment, sustainability,…) of medical imaging.
2. The student is able to recognize and identify the determinants of illness and health, current prevention and health care problems, questions and challenges in the field of rehabilitation.
3. The student is able to situate the different medical imaging techniques in a diagnostic perspective according to their relevance relative to the strengths and limitations of the specific technique.
4. Knowledge and implementing principles and skills of Evidence-Based Practice related to assessment and intervention in the physical therapy and other domains.
5. Screen and analyze the client's health problem through targeted history-taking and, if necessary, physical examination to decide whether the problem falls within the domain of physiotherapy and is suitable for technical solutions.
6. Methodically identify, analyze, and diagnose the problem and to relate this to the client's presenting health problem in consultation with the patient (physiotherapy diagnosis) as well as critically evaluate the quality of the measurement and assessment and design and realize possible solutions.
7. Think conceptually, asking critical questions and see cross-reference, thinking from different perspectives.

1.2 Prior knowledge for this lesson:

1.2.1 Literature:

- Books:
  - Cooper N. & Frain J. (2017). Abc of clinical reasoning. John Wiley & Sons.
  - Higgs J. Jensen G. M. Loftus S. & Christensen N. (2019). Clinical reasoning in the health professions (Fourth). Elsevier.
  - Glaser A. N. (2014). High-yield biostatistics epidemiology and public health (4th rev.). Chapter 7: Statistics in Medical Decision Making, Lippincott Williams & Wilkins.

- Articles:
  - Baeyens, J. P., Serrien, B., Goossens, M., & Clijsen, R. (2019). Questioning the "SPIN and SNOUT" rule in clinical testing. Archives of physiotherapy, 9, 4. https://doi.org/10.1186/s40945-019-0056-5.

1.3 Content description:

- This part will consist of 3 working sessions:
  - In the first working session we will talk about the first two steps of our methodological approach (inventarisation and working diagnosis).
  - In the second working session we will talk about the next two steps of our

methodological approach (examination and physiotherapeutic diagnosis and prognosis. In this session we will focus less on physiotherapy, but more on medical imaging and its use in ruling IN or OUT a pathology. We will also focus on the relevance relative to the strengths and limitations of the specific technique proposed in function of the several hypothesis formed in session 1.

- In the third working session we will round up our first case-study. In the second session choices were made about medical imaging techniques. For every of these modalities, reason about: clinimetrics, benifitis, harms, alternatives and it's role on illness perception/beliefs in patients. During this session you will share and critically discuss your findings with your fellow students.

All course content will be available on Canvas under Musculoskeletal imaging, analysis and model building in clinical reasoning part 1 – 012004

1.4 Additional information, slides, articles

2 Advanced anatomy of the Shoulder

- How:
  - asynchronous (video will be uploaded on the learning platform)
  - followed by a Q&A session (see online schedule)

2.1 Specific outcomes for this lesson

1. The student has a thorough theoretical knowledge of the osteology and arthrology of the shoulder region
2. The student has a profound 3-dimensional knowledge of the human musculoskeletal anatomy (myology, peripheral neurology, vascularization)
3. The student has a profound knowledge and comprehension of the clinical relevance of the anatomy
4. The student is able to reason and discuss the clinical relevance of region specific anatomy

2.2 Prior knowledge for this lesson:

The student needs a good basic knowledge of the regional anatomy of the shoulder

2.2.1 Literature:

- Books:
  - THIEME Atlas of Anatomy, Three Volume Set, Third Edition Udo Schumacher
  - Gray's Atlas of Anatomy, Drake R. et al (Elseviers)
  - Similar anatomy atlases

- Articles:
  - Barbaix, E., et al., The sternoclavicular joint: variants of the discus articularis. Clinical Biomechanics, 2000. 15: p. S3-S7.
  - Bontempo, N.A. and A.D. Mazzocca, Biomechanics and treatment of acromioclavicular and sternoclavicular joint injuries. British Journal of Sports Medicine, 2010. 44(5): p. 361-369.
  - Brewin, A., M. Hill, and H. Ellis, The Prevalence of Cervical Ribs in a London Population. Clinical Anatomy, 2009. 22(3): p. 331-336.
  - Cay, N., et al., Is coracoacromial arch angle a predisposing factor for rotator cuff tears? Diagnostic and Interventional Radiology, 2014. 20(6): p. 498-502.
  - Colegate-Stone, T., et al., Classification of the morphology of the acromioclavicular joint using cadaveric and radiological analysis. Journal of Bone and Joint Surgery-British Volume, 2010. 92B(5): p. 743-746.
  - De Maeseneer, M., et al., CT and MR arthrography of the normal and pathologic anterosuperior labrum and labral-bicipital complex. Radiographics, 2000. 20: p. S67-S81.
  - Grainger, A.J., et al., MR anatomy of the subcoracoid bursa and the association of subcoracoid effusion with tears of the anterior rotator cuff and the rotator interval. American Journal of Roentgenology, 2000. 174(5): p. 1377-1380.
  - Harry, W.G., J.D.C. Bennett, and S.C. Guha, Scalene muscles and the brachial plexus: Anatomical variations and their clinical significance. Clinical Anatomy, 1997. 10(4): p. 250-252.
  - Kurtz, C.A., et al., Symptomatic Os acromiale. Journal of the American Academy

of Orthopaedic Surgeons, 2006. 14(1): p. 12-19.
- Merrill, A., K. Guzman, and S. Miller, Gender differences in glenoid anatomy: an anatomic study. Surgical and Radiologic Anatomy, 2009. 31(3): p. 183-189
- Modarresi, S., D. Motamedi, and C.M. Jude, Superior Labral Anteroposterior Lesions of the Shoulder: Part 2, Mechanisms and Classification. American Journal of Roentgenology, 2011. 197(3): p. 604-611.
- Moor, B.K., et al., Is there an association between the individual anatomy of the scapula and the development of rotator cuff tears or osteoarthritis of the glenohumeral joint? A RADIOLOGICAL STUDY OF THE CRITICAL SHOULDER ANGLE. Bone & Joint Journal, 2013. 95B(7): p. 935-941.
- Moor, B.K., et al., Relationship of individual scapular anatomy and degenerative rotator cuff tears. Journal of Shoulder and Elbow Surgery, 2014. 23(4): p. 536-541.
- Ouellette, H., et al., Re-examining the association of os acromiale with supraspinatus and infraspinatus tears. Skeletal Radiology, 2007. 36(9): p. 835-839.
- Panni, A.S., et al., Histological analysis of the coracoacromial arch: Correlation between age-related changes and rotator cuff tears. Arthroscopy-the Journal of Arthroscopic and Related Surgery, 1996. 12(5): p. 531-540.
- Sakoma, Y., et al., Coverage of the Humeral Head by the Coracoacromial Arch: Relationship with Rotator Cuff Tears. Acta Medica Okayama, 2013. 67(6): p. 377-383.
- Sanli, E.C., M. Aktekin, and Z. Kurtoglu, A case of large scalenus minimus muscle. Neurosciences, 2007. 12(4): p. 336-337.
- Scafoglieri, A., et al., Evidence of increased axillary blood flow velocity without increased handgrip strength and endurance in persons with a fibromuscular axillary arch. Folia Morphologica, 2015. 74(4): p. 486-492.

- Websites:
  - https://www.anatomystandard.com

  - Knowledge clips online (via VUB Library):
    - Acklands Video Atlas of Human Anatomy:
    - https://biblio.vub.ac.be/vlink/WWWURN.csp?ID=ACA
    - Anatomy atlas Virtual Body https://www.visiblebody.com/

2.2.2 Content description:

- This lecture and associated Q&A session will cover the following topics
  - Review of basic anatomy
    - osteology of the shoulder region
    - artrology of the shoulder region
    - myology of the shoulder region
    - innervation of the shoulder region
    - vascularisation of the shoulder region
  - Advanced (clinical) anatomy topics regarding the shoulder region e
  - Anatomical variability and variation in the shoulder region

All course content will be available on Canvas under Musculoskeletal imaging, analysis and model building in clinical reasoning part 1 - 012004

2.3 Additional information, slides, articles

3 Medical imaging of the Shoulder

How:

- asynchronous (video will be uploaded on the learning platform)
- followed by a Q&A session (see online schedule)

3.1 Specific outcomes for this lesson

1. The student has knowledge of medical diagnostics and measurements by means of medical equipment.
2. The student has knowledge about the principles of different imaging modalities of medical imaging within the diagnostic review.
3. The student is able to recognize anatomical structures and pathological images.
4. The student is able to interpret clinical images (from normal to pathological).
5. The student is able to situate the different medical imaging techniques in a diagnostic perspective according to their relevance relative to the strengths and limitations of the specific technique.
6. The student is able to recognize normal from basic but clearly pathological situation in medical images.

3.2 Prior knowledge for this lesson

The student needs a good basic knowledge of the regional anatomy of the knee

3.3 Introduction

The shoulder joint stands as an intricate marvel of anatomical engineering, where function and form converge to facilitate an array of movements while maintaining essential stability. As we delve into the medical imaging's role in understanding the shoulder, we will also provide a succinct overview of the crucial anatomical structures that define this joint. The shoulder joint represents a prime example of the body's adeptness at reconciling opposing demands. On one hand, it is a paramount enabler of extraordinary mobility, allowing a vast range of movements encompassing flexion, extension, abduction, adduction, rotation, and circumduction. This mobility, however, is intricately intertwined with the need for stability. Balancing on the cusp of two contrasting needs, the shoulder exhibits a delicate equilibrium between unfettered motion and steadfast support.

3.4 Main anatomical structures of the shoulder

The shoulder joint actually consists of five articulations: three synovial and two virtual or physiological. The three synovial joints are the glenohumeral, acromioclavicular and sternoclavicular joints. The two virtual joints are the scapulothoracic an subacromial “joints”.

3.4.1 Humerus

The proximal third of the humerus has several surface features of great functional importance, as they are the attachment sites for the various tendons. There are two tuberosities or tubercles. The greater tuberosity is locate laterally and the lesser in an anterior and somewhat medial position. Between the two lies an indentation known as the bicipital groove, a landmark, through which the tendon of the long head of the biceps passes. The supraspinatus tendon inserts on the superior facet of the greater tuberosity, leaving a very characteristic footprint. It is important to examine this, as it is a common site of pathology. The insertional footprints of the rotator cuff tendons are arranged not in parallel but in continuity with each other.

3.4.2 Scapula:

The scapula is a flat posterior bone with a complex shape. It has a large anterior protuberance, the coracoid process, and another, even larger, superior to the rotator cuff: the acromion. In some cases, the secondary acromial ossification centre does not fully fuse with the rest of the scapula, by the end of the growth phase, giving rise to what is known as an os acromiale. This is one of the ossification centres that take longest tot fuse, so we must be cautious in evaluating imaging tests in younger persons.

3.4.3 Glenuhumeral joint:

The glenohumeral joint is largely incongruent: the shallow glenoid cavity forms the socket portion of the ball-and-socket joint. It accommodates the head of the humerus, enabling a wide spectrum of movement. However, so much joint freedom predisposes to instability. To counteract this, there is the labrum, a fibrocartilaginous rim that surrounds the bony edge of the glenoid cavity, thus increasing the congruence of the joint and therefore its stability. The labrum also serves as an anchor point for ligaments and tendons. Another important part of the glenohumeral joint is the joint capsule, which has distinct thickenings within it: the glenohumeral ligaments. In addition there are two important ligaments that arise from the coracoid process: the first is the coraco-humeral ligament, which extends to the humerus, forming part of the rotator cuff interval. The second ligament is the coracoacromial ligament, which inserts on the acromion, helping to form the roof of the subacromial space.

3.4.4 Acromioclavicular joint

This is a diarthrodial joint with a very strong capsule, located between the medial border of the acromion and the lateral border of the clavicle. It usually contains a wedge shaped or meniscoid fibrocartilage, of variable morphology, originating in the superior part of the capsule. The joint is stabilized by capsular reinforcements above and below it: the superior and inferior acromio-clavicular ligaments, which essentially prevent anteroposterior and mediolateral displacement. There are two powerful coracoclavicular ligaments responsible for preventing superior displacement of the clavicle: the more medial is the conoid ligament and the more lateral is the trapezoid ligament. As well as these ligaments, there are two other very important stabilizers: the trapezius and deltoid muscles, through their attachments on the acromion and the clavicle.

3.4.5 Muscles and tendons

The most important muscle group of the shoulder joint is known as the rotator cuff. This comprises a network of four tendons (supraspinatus, infraspinatus, teres minor, and subscapularis). The rotator cuff envelops the shoulder joint, bolstering its stability and contributing to various movements.

The long head of the biceps brachii originates from the supraglenoid tubercle, which is a bony projection above the glenoid cavity of the scapula. It travels along the bicipital groove of the humerus before inserting into the radial tuberosity of the radius bone in the forearm. The long head plays a significant role in shoulder stability and movement, especially when the arm is raised or flexed. The short head of the biceps brachii originates from the coracoid process of the scapula. It runs alongside the long head and merges with it as they both form the biceps muscle belly. The short head also inserts into the radial tuberosity of the radius bone. While the short head contributes to the overall function of the biceps muscle, it is the long head that has more influence on shoulder mechanics due to its attachment on the scapula. The deltoid muscle is a large, triangular muscle located on the outer part of the shoulder. It is one of the primary muscles responsible for the movement and stabilization of the shoulder joint. The deltoid muscle consists of three distinct parts or "heads" that work together to perform various actions: Anterior Deltoid: This part of the deltoid originates from the lateral third of the clavicle (collarbone). Its main function is shoulder flexion, which involves raising the arm forward. It also assists in horizontal adduction, where the arm moves across the body in front of you. Middle Deltoid: The middle part of the deltoid originates from the lateral edge of the acromion process, a bony projection of the scapula. It is responsible for shoulder abduction, which involves raising the arm sideways away from the body. The middle deltoid is particularly active during lateral raises. Posterior Deltoid: This portion of the deltoid originates from the spine of the scapula. It plays a significant role in shoulder extension, where the arm is moved backward. It also assists in horizontal abduction, where the arm moves away from the body to the back. The deltoid muscle works in conjunction with other muscles around the shoulder joint, such as the rotator cuff muscles and the trapezius, to ensure smooth and controlled movement of the arm.

3.4.6 Bursae

Bursae, fluid-filled sacs, reduce friction between moving structures. The subacromial and subdeltoid bursae play a vital role in cushioning the rotator cuff tendons.

3.5 Overview of imaging modalities

3.5.1 Radiography

Radiography, also known as X-ray imaging, plays a significant role in the medical imaging of the shoulder. It is one of the foundational and most widely used imaging techniques that provides valuable insights into the bone and joint structures of the shoulder complex. While radiography might not capture the soft tissues as comprehensively as other modalities like MRI or ultrasound, it is instrumental in assessing bone health, alignment, fractures, and certain joint abnormalities within the shoulder region. Radiographs excel at depicting bone anatomy and detecting fractures. In the context of the shoulder, radiography can identify fractures of the clavicle, humerus, scapula, and other bones comprising the shoulder girdle. It provides a clear visualization of the bone contours, helping clinicians assess the alignment of fractured segments and guiding appropriate treatment plans. Radiography can reveal joint space narrowing and changes in joint alignment, which are indicative of degenerative conditions such as osteoarthritis. By comparing images over time, we can monitor the progression of arthritis and tailor interventions accordingly. Radiographs are effective in identifying calcifications within the shoulder joint, such as those related to conditions like calcific tendinitis. These calcifications appear as distinctive peri-articular opacities on X-ray images. Prior to surgical procedures involving the shoulder, radiographs provide surgeons with essential information about bone quality, fracture patterns, and joint alignment. This aids in planning surgical approaches and selecting appropriate implants, if needed. Radiographs can be used for postoperative follow-up to assess the healing progress of fractures or surgical interventions in the shoulder region. It's important to note that while radiography is valuable for assessing bone structures and certain pathologies, it has limitations in visualizing soft tissues, such as tendons, ligaments, and muscles. In situations where a more comprehensive evaluation of the soft tissues is required, complementary imaging modalities like MRI and ultrasound may be employed.

3.5.2 Ultrasound

Ultrasound imaging, is a valuable modality in the medical imaging of the shoulder. It offers real-time visualization of soft tissues, making it particularly useful for assessing tendons, ligaments, muscles, and other dynamic structures within the shoulder joint. Ultrasound's ability to provide high-resolution, detailed images in a non-invasive manner makes it an essential tool for diagnosing a wide range of shoulder conditions. Ultrasound excels in imaging soft tissues, making it an ideal choice for evaluating tendons, ligaments, muscles, and bursae within the shoulder. It can detect abnormalities such as tears, inflammation, thickening, and calcifications in these structures. Ultrasound is particularly effective in diagnosing rotator cuff tears. It can provide detailed information about the extent, location, and characteristics of the tear, aiding in treatment planning. Ultrasound can visualize conditions like tendinitis (inflammation of tendons), tendinosis (degeneration of tendons), and calcific tendinitis (calcium deposits in tendons). Inflammation of the bursae, fluid-filled sacs that reduce friction between tissues, can be easily detected through ultrasound. It helps assess the severity and location of bursitis. Although sometimes difficult, Ultrasound can detect excess fluid within the joint space (joint effusion), which might be indicative of various shoulder pathologies. Ultrasound can reveal muscle tears, strains, and other injuries, helping healthcare professionals determine the extent of the damage and plan appropriate treatment. Ultrasound is used for guided procedures such as injections, aspirations, and minimally invasive treatments. It provides real-time visualization, allowing for accurate placement of needles or instruments. One of the unique advantages of ultrasound is its ability to capture real-time images of the shoulder in motion. This dynamic assessment can help diagnose conditions that might not be evident in static images. Ultrasound is not depending upon ionizing radiation. While ultrasound is highly beneficial for evaluating soft tissues, it may have limitations in visualizing deep structures, such as bones and certain deep-seated pathologies.

3.5.3 Magnetic Resonance Imaging (MRI)

MRI is a powerful imaging modality that plays a significant role in the medical imaging of the shoulder. MRI offers exceptional soft tissue contrast and multiplanar imaging capabilities, making it an essential tool for diagnosing a wide range of shoulder conditions. Its ability to provide detailed images of not only soft tissues but also bones, joints, and other structures makes it particularly valuable in comprehensive shoulder evaluations. Here's an overview of the role of MRI in medical imaging of the shoulder. MRI is unparalleled in its ability to visualize soft tissues in great detail. It is used to assess tendons, ligaments, muscles, bursae, cartilage, and other structures within the shoulder complex. MRI is highly effective in diagnosing rotator cuff tears, providing detailed information about the size, location, and characteristics of the tear. It helps guide treatment decisions and surgical planning. MRI can identify labral tears, which are common in shoulder injuries. It helps visualize the labrum, a cartilage structure that deepens the glenoid cavity, and assess the extent of tears or abnormalities. MRI can reveal joint abnormalities, including osteoarthritis, rheumatoid arthritis, and other degenerative changes within the shoulder joint. MRI is used to assess inflammation, bursitis, and other soft tissue pathologies within the shoulder. It provides insights into the extent and severity of inflammation. In addition to soft tissues, MRI can visualize bones and identify bone abnormalities, fractures, tumours, and infections within the shoulder region. MRI can be employed to evaluate blood vessels and vascular structures in cases of suspected vascular issues or anomalies. radiation and ability to provide comprehensive soft tissue visualization. While MRI is highly versatile and offers comprehensive insights, it's important to consider factors such as patient comfort, contraindications (e.g., patients with certain types of implants), and cost when choosing this imaging modality. Additionally, MRI may not be suitable for emergency situations where immediate diagnosis is required. In summary, MRI is a cornerstone of medical imaging for the shoulder, offering detailed insights into soft tissues, bones, joints, and various pathologies. Its ability to provide multiplanar, high-resolution images makes it an indispensable tool for diagnosing and guiding the treatment of a wide range of shoulder conditions.

3.6 Normal Image Findings on Radiography

3.6.1 Standard X ray examination of the shoulder

Standard X-ray examination of the shoulder consists of 5 acquisitions

1) AP overview in neutral position
2) AP glenoid (Grashey) view
3) AP shoulder in external rotation
4) AP shoulder in internal rotation
5) Lateral or scapular (Y-view) acquisition

The AP overview examination in neutral position gives a full overview of the shoulder joint. This view is the most commonly obtained view of the shoulder and the easiest to perform by the technologist, particularly in severely traumatised patients. The patient can be examined either standing or supine with the trunk not rotated. Structures that should be visualised include the entire scapula, the entire clavicle and the proximal humerus. The gleno-humeral, AC joint and sterno-clavicular joint should be visualised.

The Grashey method, also known as the Grashey view, is a specific radiographic projection used to image the shoulder joint in a true anteroposterior (AP) plane. This technique provides a clear view of the glenohumeral joint. The Grashey view is particularly useful for assessing conditions like glenohumeral joint osteoarthritis, fractures, and dislocations.

Images in external and internal rotations are useful to detect calcifications around the gleno-humeral joint. In external rotation the greater tubercle of the proximal humerus is in profile. In internal rotation, the lesser tubercle is in profile.

The lateral "Y-view" is the orthogonal view of the AP projection and gives a profile view of the scapula, which can demonstrate the degree and direction of suspected dislocations.

3.6.2 Technical aspects

AP overview in neutral position: Patient in erect position, back against the detector (AP), both shoulders against the detector, arm in neutral position, arms against the body. X-ray tube 100-115 cm, horizontal beam, no angulation Collimation should include the SC joint medially, the angulus inferior of the scapula (inferior), skin of the humerus laterally and above the AC joint cranially

Grashey view: Patient in erect position, back against the detector (AP), affected shoulder against the detector in posterior oblique position (35°). X-ray tube 100-115 cm, horizontal beam, no angulation.

Shoulder in external rotation: Patient in erect position, back against the detector (AP), both shoulders against the detector, arm in external rotation. X-ray tube 100-115 cm, horizontal beam, no angulation.

Shoulder in internal rotation: Patient in erect position, back against the detector (AP), both shoulders against the detector, arm in internal rotation. X-ray tube 100-115 cm, horizontal beam, no angulation.

Y view: Patient in erect position, anterior oblique position (between 45-60°) against the detector (PA), relaxed position with depression of the shoulder, neutral arm position, in "Napoleon" position or posteriorly: to avoid humeral superposition over the scapula. X-ray tube 100-115 cm, horizontal beam, no angulation.

3.6.3 Normal findings on radiography

Since the scapula is not oriented in a true coronal plane, but lies in a coronal oblique plane (40°), the AP view is not perpendicular to the scapula and is not tangential to the glenohumeral joint space. Then, the obliquity of the beam with respect to the axis of the scapula results in an elliptical appearance of the glenoid cavity. The anterior rim of the glenoid fossa projects medially while the posterior rim projects laterally. Since the humeral head overlies the glenoid, assessment of the glenohumeral space is suboptimal in this view.

When obtaining Grashey view, the X-ray beam is directed tangential to the glenohumeral joint and to the subacromial space. The patient is standing in a 40° posterior oblique position with the shoulder to be examined in contact with the examining table. In this position the scapula lies parallel to the cassette and allows an optimal tangential view of the glenohumeral joint. The articular surface of the glenoid cavity is seen in profile and, in normal conditions, no overlap of the glenoid cavity and humeral head is observed. The coracoid process overlies the medial aspect of the humeral head. Due to the orientation of the beam, the inferior surface of the acromion appears as a regular cortical line. The different rotations of the arm allow good evaluation of the humeral head structures. The internal rotation visualises the lesser tuberosity (LT) in profile. The LT appears as a triangular structure seen in the most medial aspect of the head that projects over the glenoid cavity. Due to the larger size of the greater tuberosity (GT) the anterior two thirds of it are imaged face-on while the posterior third is seen in profile. In neutral rotation the LT is visualised „en face“ while the middle portion of the GT is seen „en profile“. External rotation allows profile visualisation of the LT and of the anterior portion of the GT. The biceps sulcus lies between the two tuberosities and can be examined in profile both in maximal external and internal rotation and „en face“ in neutral rotation. Due to tangential orientation of the beam, the anterior and posterior rims of the glenoid fossa are superimposed. The glenohumeral joint space width can be accurately evaluated and reflects the thickness of both the humeral and glenoid cartilages. A thin curvilinear radiolucency extending from the under surface of the acromion to the GT and located deep to the deltoid muscle can be frequently imaged in AP projection, especially if this is obtained with internal rotation of the arm. The finding corresponds to the fat located on either side of the subacromial synovial bursa.

The Y view image shows the scapula imaged as a Y, formed by the coracoid (anteriorly), the body of the scapula (inferiorly) and the acromion (posteriorly). In normal conditions the humeral head appears centred on the Y. The subacromial space and the scapulothoracic spaces are seen tangentially. The LT is imaged between the scapula and the chest wall. The GT is seen „en face“. The acromion is well visualised in this view. Its shape can be assessed and classified into three main types: flat, curved and hooked, assessing the risk for impingement syndrome and secondary rotator cuff tears.

3.7 Normal Image Findings on Ultrasound

3.7.1 Introduction to shoulder ultrasound

Ultrasound of the shoulder has several advantages compared to competing imaging methods. It is non-invasive, provides good spatial and excellent contrast resolution, allows for routine dynamic investigations, is widely available and relatively inexpensive on a per-examination basis. On the other hand, ultrasound appears to depend on the experience of the examiner performing the investigation. In addition, evidence regarding the diagnostic value of ultrasound for certain abnormalities such as labral or capsular lesions, determination of muscle atrophy and fatty degeneration and articular cartilage damage is very limited. Ultrasound is not useful for the assessment of intraosseous abnormalities unless they cause abnormalities of bone surfaces, such as fractures with cortical disruption. Finally, although a single ultrasound examination is inexpensive in most fee schedules from the point of view of national health care systems, ultrasound may be a relevant cost factor due to the large number of examinations performed. Adequate equipment, examination technique and documentation of imaging findings is crucial if ultrasound has to act as an accepted determinant in an imaging algorithm. This chapter reviews a standardised sonographic imaging method of the shoulder.

3.7.2 Standardised imaging technique for shoulder ultrasounds

To assess the shoulder on ultrasound, linear probes with frequencies between 7 and 15 MHz are mainly used. In some cases, probes with frequencies from 15 to 18 MHz may be suitable, in very thin patients for example, or when visualizing the AC joint, but convex probes are rarely needed.

To image the shoulder effectively, a comfortable position is recommended, both for the sonographer and for the patient. It is therefore advisable to have the latter seated, ideally on a backless revolving stool, making it easy to examine the anterior and posterior aspect of the shoulder and perform dynamic manoeuvres effortlessly.

To evaluate every structure adequately, this involves placing the patient in particular positions, since certain tendons need to be displaced from their original location, concealed behind the acromion, to make them accessible to ultrasound.

In the anterior part of the shoulder, the structures to be examined in the region include the tendons of the long and short heads of the biceps, the subscapularis, pectoralis major and coraco-brachialis muscles and the coraco-acromial ligament. To assess them, it is advisable to begin by locating the long head of the biceps tendon, which is easy to find within the bicipital groove, making it a very useful sonographic landmark to start from.

The biceps consists of two distinct portions or heads which joint distally to form a single muscle. The short head is the more medial and originates from the coracoid process by a flat tendon immediately anterior to the coracobrachialis muscle. The long head forms a tendon which courses through the bicipital groove, becomes intra-articular, and turns to attach onto the supraglenoid tubercle, in close relationship with the superior labrum, to which it gives off expansions.

There is a transverse humeral ligament which jumps from the lesser tot the greater tuberosity, forming a ceiling that closes the bicipital groove and thereby stabilizing the long head of the biceps within it. More distally, where the muscular component of the long head of the biceps begins, lies the pectoralis major tendon, which also plays a part in stabilizing the LHB by crossing over it. The subscapularis muscle arises in the subscapular fossa. It inserts onto the lesser tuberosity with an attachment about 2 cm wide.

To evaluate the structures of the anterior aspect of the shoulder sonographically, place the patient in what is known as “position 1”, seated on a stool with the forearm in supination and the back of the hand resting on the homolateral knee, these details should be strictly adhered to, as positioning the patient correctly is very important for locating the structures easily and consistently, especially when the examiner is relatively new to ultrasound. Begin the examination, by placing the probe transverse to the axis of the arm in the middle of the anterior deltoid, about 3 or 4 cm below the acromion, which you can locate by palpation to get you bearings. If the patient is positioned correctly, you will see the anterior cortical surface of the humerus, where you will be able to distinguish the greater and lesser tuberosities and the bicipital groove between them. An oval shaped image can be seen within it, corresponding to the long head of the biceps tendon. Due to anisotropy, it may be hyperechoic or hypoechoic, depending on the angle at which the probe meets the beam. Sometimes it is surrounded by a small quantity of fluid, which is normal. There is a small anterior circumflex artery, which accompanies it and must not be mistake for sign of inflammation on doppler. Immediately superficial tot the biceps, a hyperechoic sheet can be seen, corresponding to the transverse humeral ligament. If the probe is then moved in a distal direction, following the biceps, and maintaining the same orientation, as far as its myotendinous junction, you will be able to see a tick, fibrillar hyperechoic structure that crosses it superficially from medial and lateral and inserts in the humerus: this is the pectoralis major tendon. It is always advisable to examine the tendons in both the longitudinal and transverse axes. To do so, the next step is to return to the bicipital groove and rotate the probe 90° over the biceps tendon.

To assess the subscapularis, place the probe once again in the initial position, transverse to the groove, ensuring you have a good view of the lesser tuberosity and then ask the patient to perform an external rotation with the arm against the body. This will pull the subscapularis outward, making it accessible to the probe. You will see the subscapularis tendon in its longitudinal axis as far as its insertion on the lesser tuberosity, right up to the medial lip of the bicipital groove. Some fibres of the subscapularis reinforce the transverse humeral ligament.

To examine the coracoacromial ligament I suggest returning once more to the starting position over the bicipital groove, but this time place the probe more medially and move it upward until you detect a rounded hyperechoic image with posterior acoustic shadowing, corresponding to the coracoid process. Locate this at the medial end of the probe and rotate the lateral end toward the acromion, but without losing sight of the coracoid process at the medial end. You will be able to see a well-defined, somewhat hypo-echoic structure appear between the two bones: this is the coraco-acromial ligament. Coursing underneath is the supraspinatus tendons.

In the superior aspect of the shoulder, we will examine the supraspinatus tendons, and the subacromial subdeltoid bursa. The supraspinatus muscle originates from the supraspinatus fossa and inserts via a broad tendon onto its footprint on the most superior part of the greater tuberosity. The supraspinatus is a highly complex structure, with a microscopic structure of its tendon showing five layers.

The subacromial-subdeltoid bursa is located very close to the tendon superficially, which is not considered a part of the tendon. It is lined internally with a synovial tissue and its function is to facilitate the gliding of the various tendons in the subacromial space, reducing frictions with the acromion. In normal conditions, the bursa does not communicate with the glenohumeral joint, since the rotator cuff in interposed between them, separating both.

The subcoracoid bursa is located inferior to the coracoid process, between the subscapularis and coracobrachialis muscles, reducing friction between them.

To be able to detect these superior structures properly, place the patient in position 2, also known as the modified Crass position, with the shoulder retracted and the hand resting on the homolateral gluteal region, as the patient were putting their hand into the back pocket of their trousers. It is important that the elbow should not be tuned outward, as this involves an internal rotation of the shoulder, making it more difficult to locate the long head of the biceps, which is the initial reference point. Start the examination of the supraspinatus be placing the probe transverse to the long axis of the humerus, about 2 cm below the bony edge of the acromion, until you detect a bright, hyperechoic, oval image, if the probe meets it perpendicularly. This structure is the tendon of the long head of the biceps, in its intra-articular course, cranial to its passage through the bicipital groove. Having found it, rotate the probe over it until you see its longitudinal axis. You must avoid oblique sections and be patient until you can see the whole tendon properly in this axis. Once you have performed this manoeuvre correctly, the orientation of the probe will also be the long axis of the supraspinatus, and you simply have to be careful not to alter it while you sweep the probe in a lateral directions. Look for the characteristic shape of the footprint and evaluate the supraspinatus tendon meticulously, making anteroposterior sweeps and always avoiding any rotation of the probe. To obtain the best image, the probe needs to be fanned while making the lateral movements, bearing in mind that the shoulder is spherical in shape, trying always to keep the ultrasound beam perpendicular to its surface. It is important to remember that the supraspinatus and infraspinatus insertions have a common area in which their tendon fibres are intermingled and are very difficult to distinguish from each other, therefore, as you follow the supraspinatus tendon posteriorly, at some point you will already be seeing the most anterior portion of the infraspinatus.

In the absence of pathology, the bursa is more difficult to see. It appears as a thin anechoic layer between two hyperechoic layers, which are its walls.

In the posterior aspect of the shoulder the infraspinatus muscle originates in the infraspinous fossa and inserts on the posterosuperior facet of the greater tuberosity, merging in its most anterior part with the insertions of the supraspinatus. It has a characteristic broad intramuscular tendon. The teres minor also originates in the infraspinous fossa in its inferior part. It has a characteristic oval cross section and inserts caudally next to the infraspinatus. Its tendon is much smaller. Just below the spine of the scapula you can evaluate the posterior part of the glenohumeral joint, part of the posterior labrum, and the spino-glenoid notch.

To evaluate these posterior elements the sonographer stands behind the patient. The patient is placed in position 3 where he is asked to place the hand of the side to be examined on the contralateral shoulder; this will cause the infraspinatus end teres minor to slide behind the acromion and make them accessible to the probe. To evaluate these tendons, place the probe immediately under the scapular spine, oriented perpendicular to it. At this point, the transducer is positioned in the transverse axis of the infraspinatus muscle, which will be easily recognizable by the fact that is has a broad intramuscular tendon within it, located at mid depth of the muscle. Immediately caudal to it, smaller and with an oval cross section lies the teres minor. To scan the infraspinatus tendon insertion, assess it initially in the transverse axis. To do so, you need to follow it to its insertion with the same probe orientation. Having examined it, return to the starting point over the intramuscular tendon of the infraspinatus, rotating the probe 90° without losing the tendon and proceed to image the infraspinatus in its longitudinal axis. Immediately deep to it, you will be able to see part of the posterior aspect of the glenohumeral joint and a small portion of the posterior labrum. Finally, evaluate the teres minor, returning to the initial position in the short axis of the infraspinatus and moving the probe in a caudal direction. A muscle with an oval cross section with a much narrower intramuscular tendon will appear. Then, after rotating the probe, evaluate the muscle and tendon in their longitudinal axis.

3.8 Shoulder MRI

Shoulder MRI remains one of the most common indications for orthopaedic and sports medicine patient visits. Frequently encountered pathologies include rotator cuff and biceps pathology, anteroinferior glenohumeral instability, labral tear, and osteoarthrosis of the acromioclavicular and glenohumeral joints.

MRI of the shoulder is typically performed in three orthogonal planes—axial, coronal, and sagittal—with respect to the glenohumeral joint. A coronal sequence should be perpendicular to the short axis of the glenoid articular surface, while the sagittal is parallel to the short axis of the glenoid articular surface, and the axial is perpendicular to the long axis of the glenoid articular surface. Both fat- and fluid-sensitive sequences are obtained in all three orthogonal planes. Fat-sensitive sequences are best for detailed anatomy and osseous evaluation, while fluid-sensitive sequences are best for evaluation of tendons or labrum. In certain instances, such as tumour evaluation, intravenous contrast may be administered. For MR arthrography, which is best for visualizing labral pathologies, dilute intra-articular gadolinium is administered into the joint prior to MRI.

In the shoulder, the protocol can and should be tailored to the specific indication or clinical question the examination will benefit if every plane is imaged. The mainstay in musculoskeletal imaging are water-sensitive sequences, this can be achieved with conventional STIR or fat-saturated images or with intermediate-weighted images. At least one T1-weighted sequence should be included to ease the assessment and interpretation of bone marrow and/or soft tissue lesions.

3.9 Shoulder trauma

Injuries to the shoulder are common and it is important to have a rational imaging strategy for assessment. The shoulder is however a complex region with its major axes lying obliquely to the body and thus even obtaining conventional films in two planes at right angles can be difficult. The majority of injuries are assessed and monitored by plain radiographs and in only a small percentage of cases is imaging such as computed tomography (CT), magnetic resonance imaging (MRI) and ultrasound is required. Plain films usually allow an accurate diagnosis to be quickly made so that treatment can be commenced, and will also give guidance as to the necessity for and type of any specialised imaging. A thorough knowledge of the radiographic views, normal appearances of the structures on plain films and the types of injuries which may be encountered is essential. Obtaining consistently good plain films is vital.

3.9.1 Gleno-humeral joint trauma

Anterior GH dislocation: this is easily recognisable on routine views because of the complete lack of congruity at the joint with obvious displacement of the humeral head even on the anteroposterior view as well as the lateral projection. On the anteroposterior view the humeral head usually appears externally rotated.

Posterior GH dislocation: This may occur from either significant direct trauma or secondary to electric shocks or convulsions and they may be bilateral. Nocturnal epileptic fits may cause a dislocation which can be ‘silent’. Posterior dislocations of the humerus are frequently missed because the injury is not common, the clinical findings are not appreciated, the abnormalities on the anteroposterior view are difficult to detect, an associated fracture is thought to account for all the symptoms and a lateral fi lm is not obtained. On the anteroposterior view the two most important signs of a posterior dislocation are a circular appearance of the humeral head due to marked internal rotation and a widened joint space. The appearance of the humeral head has been likened to a light bulb and is known by many as the ‘light bulb sign’.

3.9.2 Acromioclavicular trauma

The acromioclavicular joint is a synovial joint within a capsule which is strengthened by superior, inferior, anterior and posterior ligaments of which the superior ligament which is the strongest. The joint space normally measures 3–5 mm and a difference of more than 2 mm between the two sides should indicate an abnormality. The alignment at the joint is judged by observing the inferior aspects of the clavicle and the acromion process and they are normally congruent, but comparison with the opposite uninjured side and weight bearing X rays may be of value. The coracoclavicular ligament is the prime suspensory ligament of the upper limb and its fibres pass from the outer inferior aspect of the clavicle to the base of the coracoid process. It has two components, namely the conoid and trapezoid ligaments. The ligament is not visible on plain films but if torn calcification and ossification may develop in its bed and this is readily identified. The normal distance between the inferior aspect of the clavicle and superior aspect of the coracoid is 1.1–1.3 cm. On some radiographs the appearances would suggest that there is a joint between the clavicle and coracoid process. This articulation is recognised by a downward bony outgrowth with a smooth cortical margin projecting from the clavicle towards the coracoid process leaving a small gap between the two bones. A classification for acromioclavicular dislocations shows in type I injury, which is essentially a sprain, the radiographs appear normal except for possibly some soft tissue swelling, whilst in type II injury there is subluxation shown by widening of the joint space and superior displacement of the clavicle but the coracoclavicular distance is normal or only minimally increased. In type III injury dislocation is seen with the clavicle being displaced above the superior border of the acromion and the coracoclavicular distance is increased. Type IV injury is similar to type III but there is a posterior displacement of the clavicle and this is best appreciated on an axial view of the shoulder. In type V injury there is marked separation between the clavicle and scapula with the coracoclavicular distance increased by two to three times and the scapula is displaced inferiorly. The deltoid and trapezius are detached from the clavicle. Type VI injury is rare and the clavicle is dislocated inferiorly to the acromion. The coracoclavicular distance is decreased if the clavicle is subacromial in position or reversed if the clavicle is dislocated to a subcoracoid position.

3.9.3 Proximal humerus trauma

Injuries in this region are more common in elderly persons with a higher incidence in women and usually occur due to a direct blow or falling onto the outstretched hand. Fractures of the proximal humerus tend to occur along the approximate lines of epiphyseal union and can thus be separated into four distinct fragments, namely the greater and lesser tuberosities, the humeral head and shaft.

Anteroposterior and lateral views usually enable a diagnosis of a fracture to be made, although in some circumstances where the displacement is minimal MRI or CT may be required to demonstrate

the lesion. Both anteroposterior and lateral projections such as the axial, modified axial, scapular Y, or transthoracic view will be required for a full analysis of the injury to be made and it is the lateral projection which frequently shows most angulation and displacement. CT scanning with sagittal, coronal and three-dimensional reconstructions can be of great value in assessing displacement, comminution and associated glenoid fractures in complex injuries

3.9.4 Fractures of the clavicle

The clavicle is one of the commonest bones to be fractured occurring in both children and adults. Fractures are usually easily clinically detected because of its subcutaneous position and the majority are revealed on frontal projections, but for the detection of some and a more accurate evaluation of fragment position views with tilt of the X-ray tube may be required. The tube angulation can vary and be as much as 30–45°. Fractures of the clavicle are classified according to their anatomical site. Fractures of the middle third of the clavicle account for approximately 80% of the injuries and are usually due to a fall onto the outstretched hand or onto the shoulder.

3.9.5 Fractures of the scapula

The basic radiographic views to assess the scapula are anteroposterior and Y view. If difficulty is
encountered obtaining these views or a more detailed analysis is required prior to surgery then CT should be employed and three dimensional, oblique coronal and oblique sagittal reconstructions should be made. Fractures of the scapula can be divided into four main categories depending on the anatomical position; the regions include: (1) the glenoid and neck, (2) coracoid, (3) acromion and (4) body. Combinations of the fractures may frequently be encountered.

3.10 Impingement and rotator cuff disease:

Shoulder pain and chronic reduced function are frequently heard complaints in an orthopaedic outpatient department. The symptoms are often related to the unique anatomic relationships present around the glenohumeral joint. Impingement of the rotator cuff and adjacent bursa between the humeral head and the coracoacromial arch are among the most common causes of shoulder pain. Subacromial impingement syndrome is a painful compression of the supraspinatus tendon, the subacromial subdeltoid bursa, and the long head of the biceps tendon between the humeral head and the anterior portion of the acromion occurring during abduction and forward elevation of the internally rotated arm. Any abnormality that disturbs the relationship of the subacromial structures may lead to impingement. Several forms of impingement have been differentiated. Causes leading to impingement can be classified as intrinsic (intra tendinous) or extrinsic (extra tendinous). Impingement is further characterized as primary or secondary to another process, such as instability.

3.10.1 Bursal effusion

The subacromial bursa is located between the acromion and coracoacromial ligament superiorly, and the rotator cuff and rotator interval inferiorly, medially reaching the undersurface of the acromioclavicular joint. The subdeltoid bursa is placed between the deltoid muscle and the lateral aspect of the humeral neck. Both bursae communicate in 95% with each other, forming the so-called subacromial–subdeltoid bursa, which does not communicate with the glenohumeral joint. Fluid distending the subacromial–subdeltoid bursa is a non-specific finding, as it may be encountered in association with subacromial impingement, partial or complete rotator cuff tears, and calcifying tendinitis. During impingement of the supraspinatus tendon the subacromial–subdeltoid bursa becomes compressed between the greater tuberosity of the humeral head and the anterior portion of the acromion. This chronic compression can result in an inflammatory reaction of the bursal synovium and secretion of fluid into the bursa. Fluid is not detected in the normal bursa. Fluid in the bursa is recognized on T2-weighted images by the increased signal intensity of the subdeltoid–subacromial bursa which indicates local bursal inflammation

3.10.2 Tendinosis, partial thickness tears and full thickness rotator cuff tears

Tendinosis of the rotator cuff tendons can be imaged using ultrasound, or MRI if necessary.

The supraspinatus tendon is the most frequently affected, probably because of its important role in raising the upper extremity. Its structure is unique and quite complex, as it is made up of five separate layers. To evaluate the rotator cuff tendons, the initial test of choice and currently the most widely used, is ultrasound, which has also shown a diagnostic reliability rather similar to MRI.

The characteristic findings in tendinopathy consist primarily of thickening of the tendon, often in its entirety. This increase in thickness is usually accompanied by changes in density of the tendon, in which some loss of the typical fibrillary pattern is observed, with hypoechogenicity in the case of more recent tendinopathies and heteroechogenicity in chronic cases. Due to the non-uniform process of tendinopathy, it is not uncommon to find all these changes in a greater or lesser degree in the same affected tendons. In degenerative tendinopathies in general, another important issue on ultrasound is evaluation of the presence or absence of neovascularization using power doppler. The presence of neovessels has been associated with an active inflammatory process and with the intensity of the symptoms, although not all authors agree on this.

Calcific tendinopathy consists of an accumulation in the form on intratendinous deposition of calcium hydroxyapatite crystals, located in the rotator cuff. It is a common pathology which typically follows a self-limited clinical course. Its cause remains unknown. The most frequent location is in the supraspinatus tendon, followed by the infraspinatus and subscapularis. Rotator cuff tendons tears are one of the most common pathologies in orthopaedic practice. They affect a wide spectrum of patients, ranging from sport related to occupational settings, although in most cases they are due to the clinical course of rotator cuff tendon degeneration itself. The most common tears among the rotator cuff tendons are those of the supraspinatus tendon. There are various theories regarding the causal factors related to rotator cuff tendon tears. The mechanical theory argues that the main cause is repetitive microtrauma. The degenerative theory considers age specific structural weakness of the tendon to be the basic cause. When the tear is acute, the typical ultrasound image will be that of a hypoechoic tendon, thickened by oedema, around an area that is anechoic due to being occupied by fluid. In cases of chronic rupture the diagnosis is more difficult since the defect is typically filled with a fibrinoid material whose echogenicity is sometimes very similar to that of the degenerated tendon.

3.11 Shoulder instability:

Shoulder dislocations account for 90% of shoulder instability cases and usually occur after a fall during sport or work activities. In a younger person's shoulder, the labrum is often torn away from the bone when the shoulder dislocates or the shoulder subluxes. The labrum can also be damaged or torn with repetitive overhead use of the arm such as in throwing, tennis, and rock climbing. Damage to the labrum can be painful by itself, but most of the pain and disability comes from abnormal motion when the shoulder is used. The shoulder can also be unstable due to ligament or capsular laxity (looseness) and not specifically from a torn labrum. Labral injuries and shoulder instability can occur in a variety of locations and patterns. The most common of these is an anterior labral tear (in the front of the shoulder), usually the result of an anterior subluxation or dislocation. The next most common pattern of injury is a superior labral tear (at the top of the glenoid) which usually happens from repetitive overhead activities like baseball, volleyball, tennis, surfing/swimming, and even rock climbing. It can also occur from an acute traction injury, such as grabbing a rock hold or the rung of a ladder while falling, causing the arm to be pulled upward. These tears are referred to as SLAP (superior labrum, anterior to posterior) tears. The shoulder can also dislocate or be unstable in a posterior direction (toward the back of the shoulder). This is either the result of repetitive "pushing" stress or from an injury that pushes the head to the back of the socket. The last pattern of instability occurs as result of general laxity (looseness) in the ligaments and the shoulder capsule. This is usually accompanied by laxity in other joints (patients are typically female and often very flexible). For these patients, their shoulder is inherently unstable. As a result, it can become irritated or injured by a change in activity or strength, without a definitive labral tear. An MRI is often needed for diagnosis and to plan the size and scope of the operation. For shoulder instability and labral problems, an MRI with intra-articular contrast may be warranted. This is the best modality to see the glenoid labrum, which allows us to assess the amount of injury and the possibility of re-injury or another dislocation.

6.1 Additional information, slides, articles

Part 4 The Spine

Case Description

A 65 year old male patient attended a physiotherapy appointment complaining of LBP which is an intermittent and variable level of pain over the past 12 months and appears to be gradually worsening.

He also reports bilateral aching in the lower legs, particularly on walking and prolonged standing. He can walk for 1km before he feels he needs to sit and rest to allow the pain to ease and can then continue. He reports the distance he can walk has reduced over the past few months

No Cauda Equina problems. No paraesthesia. No other red flags.

The pain was described as a dull ache in the lumbar spine VAS 4/10. The lower leg symptoms are an intermittent ache/heaviness feeling.

2. Advanced anatomy of the Spine and spinal canal

- How:
  - asynchronous (video will be uploaded on the learning platform)
  - followed by a Q&A session (see online schedule)

4.1 Specific outcomes for this lesson

1. The student has a thorough theoretical knowledge of the osteology and arthrology of the spine and spinal canal
2. The student has a profound 3-dimensional knowledge of the human musculoskeletal anatomy (myology, peripheral neurology, vascularization)
3. The student has a profound knowledge and comprehension of the clinical relevance of the anatomy
4. The student is able to reason and discuss the clinical relevance of region specific anatomy

4.2 Prior knowledge for this lesson:

The student needs a good basic knowledge of the regional anatomy of the spine and spinal canal

4.2.1 Literature:

- Bogduk N., Clinical Anatomy of the Lumbaar Spine and sacrum, fourth edition, 2005, Elsevier pp251
- Goubert D., Van Oosterwijck J., Meeus M., Danneels L., 2016, Structural Changes of Lumbar Muscles in Non-Specific Low Back Pain, Pain Physician, 19:E985-E1000 • ISSN 2150-1149
- A.Scafoglieri, Neurovascular anatomy (of the spine), reader VUB, (pdf online on Canvas)
- Ibrahim A., Darwish H., The costotransverse ligaments in Human: a detailed anatomical study, 2005, Clinical Anatomy, 18:340–345

4.2.2 Books:

- THIEME Atlas of Anatomy, Three Volume Set, Third Edition Udo Schumacher
- Gray's Atlas of Anatomy, Drake R. et al (Elseviers)
- Similar anatomy atlases

4.2.3 Websites

- https://www.anatomystandard.com

- Knowledge clips online (via VUB Library)
  - Acklands Video Atlas of Human Anatomy: https://biblio.vub.ac.be/vlink/WWWURN.csp?ID=ACA
  - Anatomy atlas Virtual Body https://www.visiblebody.com/

4.2.4 Content description:

- This lecture and associated Q&A session will cover the following topics
    - Review of basic anatomy
        - osteology of the spine and spinal canal
        - artrology of the spine and spinal canal
        - myology of the spine and spinal canal
        - innervation of the spine and spinal canal
        - vascularisation of the spine and spinal canal
    - Advanced (clinical) anatomy topics regarding the spine and spinal canal e
    - Anatomical variability and variation in the spine and spinal canal

All course content will be available on Canvas under Musculoskeletal imaging, analysis and model building in clinical reasoning part 1 - 012004

Part 5 Intensive week on campus

- How:
  - On campus week. For a detailed planning look at the schedule on the learning platform.

5. Anatomical dissections

5.1 Specific outcomes for this session

- The student has a detailed 3-dimesional knowledge of the human musculoskeletal anatomy (myology, peripheral neuro-anatomy, vascularisation). He pays special attention to human anatomical variation and variability, including anomalies. He has a special interest in its clinical relevance for musculoskeletal rehabilitation.
- The student recognizes the dissected anatomical structures
- The student can differentiate between different anatomical structures
- The student knows the morphological features, the function and the vascularisation and innervation of every dissected and visible anatomical structure
- The student is able to explain the function of anatomical structures based on its topographical representation
- The student is able to demonstrate the interrelationship between muscles, vessels and nerves based of the dissected anatomical structures
- The student is able to comment and demonstrate specific topographical regions on the dissected specimen
- The student is able to link the dissected and visible anatomical structures to his profound and pre-existing knowledge of osteology and arthrology.
- The student is able to link the dissected and visible anatomical structures to his

clinical knowledge and experience of musculoskeletal rehabilitation

- The student is able to reflect on the impact of specific musculoskeletal rehabilitation techniques based on e profound knowledge and comprehension of macroscopic human anatomy

5.2 Specific expectations for this session

- The student participates actively in the hands-on dissection
- The student is able to answer questions regarding the visible structures
- The student recognizes anatomical variation and eventual variants

5.3 Prior knowledge for this session

Lecture: lectures advances anatomy of the knee, shoulder, and spine

5.3.1 Books:

- THIEME Atlas of Anatomy, Three Volume Set, Third Edition Udo Schumacher
- Gray's Atlas of Anatomy, Drake R. et al (Elseviers)
- Similar anatomy atlases

5.3.2 Websites

- https://www.anatomystandard.com

- Knowledge clips online (via VUB Library)
  - Acklands Video Atlas of Human Anatomy: https://biblio.vub.ac.be/vlink/WWWURN.csp?ID=ACA
  - Anatomy atlas Virtual Body https://www.visiblebody.com/

5.3.3 Preparation for this session:

- Acklands Video Atlas of Human Anatomy: https://biblio.vub.ac.be/vlink/WWWURN.csp?ID=ACA
- Dissection protocol (cfr infra)

5.4 Dissection Protocol –anatomy of the limbs, trunk and Neck

5.4.1 SESSION 1

- Introduction: general approach and guidelines for working in the anatomy lab

VENTRAL approach

Incision lines are demonstrated by teacher

- Dissection of the skin per body region

5.4.2 SESSION 2

- Inspection of superficial structures (at least one per region)
- Removal of all subcutaneous tissues at the level of fascia generalis (FG)

5.4.3 SESSION 3

- Opening FG in all region's (!! CAVE tractus iliotibialis).
- Further dissection of superficial layers:
    - U.L.: M.biceps brachii + sulcus bicipitalis medialis
      firt layer of fore-arm flexors
      removing aponeurosis of the hand
      thenar & hypothenar muscles
    - L.L.: M.quadriceps femoris
      Adductor compartment
      extensore compartment
      lower legg ,
    - Neck : M. platysma, M.sternocleidomastoideus
    - Trunk: M.pectoralis major
      M. rectus abdomimis
      M. obliquus externus abdominis
- Dissection of axillary region (removal of subcutaneous tissue and lymph nodes (if present)
- Inspection for presence of Arc of Langer
- Students loo in detail for all visible muscles and describe in detail the origins, innervation, vascularisation and functions.
- Indacte with the correct names all visible Aa., Vv., Nn.
- Special attention for: trigonum off Scarpa ; bounderies and content
  (Mm.,A.,V.,Nn.)
  sulcus bicipitalis and content pes
  anserinus
  retinaculae extensorum/flexorum of ankle

5.4.4 SESSION 4

- Section of following muscles (only if relevant to proceed to deeper dissection):
    - M.biceps brachii
    - First layer of flexor muscles of lower arm at the level of the wrist
    - M. sartorius
    - M. rectus femoris
    - M. adductor longus
    - Extensorencompartment of the lower leg at elvel of the tendons
    - M.sternocleidomastoideus
    - M.pectoralis major

- Further preparation of diepr muscle layers
    - U.L.: M. brachialis
      M. coracobrachialis
      Deep layer of fore-arm flexors
      Dissection of skin and one of the fingers e
      arcus palmaris superficialis
    - L.L.: M. vastus intermedius
      M. adductor brevis
      muscles of the dorsal
      part of the foot
      peroneus
      compartment
    - (Neck: observation of supra- and infrahyoidale muscles)
    - Trunk: M. pectoralis minor
      M. obliquus internus abdominis
      M. transversus abdominis
      M. pyramidalis

- Recognizing en defining all Aa. And their branches

- Special attention for: plexus brachialis
  ramus profundus n. radialis
  lacuna
  musculorum/vasorum
  sensory part of n. peroneus profundus
  three cranial nerves (X, XI, XII)
  line of Douglas / Linea Arcuata

5.4.5 SESSION 5

- Transverse section of (onlu when neede for further deeper dissection):
    - M. flexor digitorum profundus
    - M. flexor pollicis longus
    - M. omohyoideus
    - M. pectoralis minor
- Preparation of the following structures:
    - Mm. lumbricales en interossei
    - arcus palmaris profundus
    - Mm. scalenii
- opening retinaculum flexorum and inspect structure and content of carpal tunnel
- Opening the knee joint and inspection of menisci and ligaments
- Rehearsal of all Mm., Aa., Vv. and Nn.
    - Special attention to: scalenus gates (boudneries and content)
    - hiatus/canalis adductorius
    - chiasma tendinum
      Guyon's canal
      n. interosseus anterior
      n. frenicus
      plexus brachialis, pars infraclavicularis
      ligaments of the art. cubiti
      musculus obturator externus, joint capsule of the jip en opening of the hip joint

5.4.6 SESSION 6

- finalizing ventral approach and rehearsal
- See also special topics of SESSION 5

5.4.7 SESSION 7

Corpses are turned over with support of the staff.

DORSAL approach

- Removal of the skin and subcutaneous tissue.
- Removal of all subcutaneous tissue till level of FG
- Opening of FG in all regions .
- Preparation of superfical muscles
- Recognising all Aa., Vv. and Nn.
- Special attenion to: - planta pedis
  - fossa poplitea (bounderies and content)

5.4.8 SESSION 8

- Continued preparation of superfical muscles :
    - U.L.: M.triceps brachii
      Extensors of the fore-arm
      M. anconeus
    - O.L. : M. gluteus maximus
      hamstrings
      M. triceps surae
      Removing plantar aponeurosis
    - Neck : M. trapezius
    - Trunk : M. lattissimus dorsi
      fascia thoracolumbalis
- Recognizing and defining all Aa., Vv., Nn.
- Special attention to: 'anatomical snuff box' (content and bounderies)
  Complete trajectory of n. radialis
  M. plantaris
  n. ischiadicus

    - Transverse section of the following muscles:
    - M. lattisimus dorsi
    - M.gluteus maximus
    - Achilles tendon
    - caput mediale/laterale M. gastrocnemicus

5.4.9 SESSION 9

- release of M. trapezius @ processi spinosi and lig. nuchae
- Dissection of:
    - "muslces of the scapula" (17)
    - Mm. Romboidei
    - Mm. serrati posteriores
    - External rotators of the hip
    - M.popliteus
    - planta pedis
- special attention to : - extensoren compartments of the wrist
  - fossa poplitea and content (A. poplitea + *7 branches*)
  - plexus lumbosacralis
- Transvers section of the following muscles:
    - M. quadratus femoris
- Rehearsal of all Mm., Aa., Vv. and Nn.
- Special attention to: - Chiasma cruralis & plantaris
  - Rotator cuff
  - M. obturatorius externus

5.4.10 SESSION 10

- Preparation of het joint capsule and ligaments of the shoulder, elbow and wrist

SHOULDER
- Observering at at least one shoulder:
  Attachment of rotator cuff muscles
  N. suprascapularis
  Ligamentum transversum superior +inferior
- Opening the shoulder joint together with staff and removal of the caput humerale
- Observation of the long head of biceps tendon glenohumeral ligaments and labrum

WRIST
- Observation of :
  Lig collaterale ulnare
  Lig collaterale radiale
- Opening of the wrist
- Observing triangulair fibrocartilagineous complex (TFCC)

HIP, KNEE & ANKLE
- Removal of capsule

5.4.11 SESSION 11 en 12

VENTRAL APPROACH when necessary

- Removal of capsule and ligaments of schoulder, elbow, hip, knee and ankle at the other side

SHOULDER
- Preparation of other shoulder
- Transvers section of ligaments in the following order (checking the joint stability at each step)
    - Lig coracoacromiale
    - Lig glenohumerale: superior>medius>inferior
    - Lig coracoclaviculare: trapezoideum>conoideum
- Opening the joint

ELBOW
- Preparation of the capsule and ligaments
- Transvers section of ligaments in the following order (checking the joint stability at each step)
    - Lig collaterale radiale
    - Lig collaterale ulnare
    - Lig anulare radii
- Opening the joint

HIP

- Preparation of the capsule and ligaments
- Transvers section of ligaments in the following order (checking the joint stability at each step)
    - Labrum
    - Lig teres
    - Fossa acetabuli
    - Lig transversum acetabuli
- Opening the joint

KNEE

- Preparation of the capsule and ligaments
    - Transvers section of ligaments in the following order (checking the joint stability at each step)
        - Capsule
        - LCA
        - LCP
    - Transvers section of ligaments in the following order (checking the joint stability at each step)
        - Lig collaterale laterale
        - Lig collaterale mediale
        - capsule
- Observing the following structures:
        - Menisci
        - Lig transversum genus
        - Posterior capsule

ANKLE

- Preparation of the capsule and ligaments
    - Transvers section of ligaments in the following order (checking the joint stability at each step)
        - Lig deltoideum
        - Lig talofibulare anterius
        - Lig tibiofibulare anterius
- Opening of the talocrural joint
    - Transvers section of ligaments in the following order (checking the joint stability at each step)
        - Lig bifurcatum
        - Lig calcaneonaviculare plantare
        - Lig interosseum
- Opening the talo-calcaneal joint
- Observation of joint surfaces

3.2 Work Group Session 2 …

- Specific outcomes for this session
- Specific expectations for this session
- Prior knowledge for this session
    - Lecture
    - Literature
    - Books
    - Websites
    - Knowledge clips online
    - …
- Preparation for this session?