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Advanced Imaging Techniques for Measuring Hip Axis Length and Femoral Neck-shaft Angle

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Introduction

The hip axis length (HAL) and femoral neck-shaft angle (NSA) are crucial parameters in orthopedic and biomechanical studies. Accurate measurement of these anatomical features is essential for diagnosing hip pathologies, planning surgical interventions and designing orthopedic implants. Traditional methods of measuring these parameters, such as plain radiography, have limitations in terms of accuracy and reproducibility. Advances in imaging technology have led to the development of more precise and reliable techniques for measuring HAL and NSA. This article reviews the latest imaging techniques used for these measurements, highlighting their advantages and potential applications in clinical practice.

Description

Traditional imaging techniques

Plain radiography: Plain radiography, commonly known as X-ray, has been the standard imaging technique for measuring HAL and NSA. It involves capturing a two-dimensional image of the hip joint, which is then used to estimate the lengths and angles. However, this method has several limitations, including distortion due to the projection angle, difficulties in identifying anatomical landmarks and variability in patient positioning [1].

Limitations of Plain radiography

- **Projection distortion**: The two-dimensional nature of X-ray imaging can lead to inaccuracies due to the projection of three-dimensional structures onto a flat plane.
- **Landmark Identification**: Identifying anatomical landmarks on X-rays can be challenging, leading to variability in measurements.
- **Patient positioning**: Variations in patient positioning during X-ray acquisition can affect the accuracy of measurements.

Advanced imaging techniques

Computed tomography (CT): Computed tomography (CT) provides detailed cross-sectional images of the hip joint, allowing for accurate three-dimensional reconstruction. This technique enhances the visualization of bony structures and improves the precision of HAL and NSA measurements [2].

Advantages of CT

- **Three-dimensional imaging**: CT scans provide detailed three-dimensional images, reducing projection distortion.
- **Accurate landmark identification**: Enhanced visualization of anatomical landmarks leads to more precise measurements.
- **Reproducibility**: CT imaging offers high reproducibility, reducing variability in measurements.

Magnetic resonance imaging (MRI)

Magnetic resonance imaging (MRI) uses magnetic fields and radio waves to produce detailed images of soft tissues and bones. MRI is particularly useful for evaluating the soft tissues around the hip joint, such as muscles, tendons and cartilage.

Advantages of MRI

- **Soft Tissue Visualization**: MRI provides excellent contrast between different types of soft tissues, aiding in the assessment of surrounding structures.
- **Non-Ionizing Radiation**: Unlike CT, MRI does not use ionizing radiation, making it safer for repeated use.

Dual-energy X-ray absorptiometry (DEXA)

Dual-energy X-ray absorptiometry (DEXA) is primarily used for measuring bone mineral density but can also be used to assess HAL and NSA. This technique involves the use of low-dose X-rays at two different energy levels to differentiate between bone and soft tissue [3].

Advantages of DEXA

- **Low radiation dose**: DEXA uses a lower radiation dose compared to traditional X-rays and CT scans.
- **Bone density assessment**: In addition to measuring HAL and NSA, DEXA provides valuable information about bone density.

Emerging techniques

3D ultrasound: Three-dimensional ultrasound is an emerging technique that provides real-time imaging of the hip joint without ionizing radiation. It involves the use of high-frequency sound waves to create detailed images of the hip structures.

Advantages of 3D ultrasound

- **Real-time imaging**: 3D ultrasound provides real-time images, allowing for dynamic assessment of the hip joint.
- **No radiation exposure**: This technique does not use ionizing radiation, making it safe for repeated evaluations.
- **Cost-effective**: Ultrasound equipment is generally more affordable and accessible compared to CT and MRI machines.

Stereophotogrammetry: Stereophotogrammetry involves the use of multiple cameras to capture detailed three-dimensional images of the hip joint. This technique is primarily used in research settings for precise biomechanical analyses [4].

Advantages of stereophotogrammetry

- **High precision**: Stereophotogrammetry provides highly accurate three-dimensional measurements.
- **Non-Invasive**: This technique is non-invasive and does not expose

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patients to radiation.

Clinical applications

Preoperative planning: Accurate measurement of HAL and NSA is crucial for preoperative planning in hip surgeries, such as total hip arthroplasty (THA) and hip resurfacing. Advanced imaging techniques provide precise measurements that help surgeons plan the optimal placement of implants and reduce the risk of complications.

Postoperative evaluation

Postoperative evaluation of HAL and NSA is essential for assessing the outcomes of hip surgeries. Advanced imaging techniques enable detailed assessment of implant positioning and alignment, aiding in the identification of potential issues that may require further intervention.

Hip pathology diagnosis

Accurate measurement of HAL and NSA is important for diagnosing various hip pathologies, such as developmental dysplasia of the hip (DDH), femoroacetabular impingement (FAI) and hip fractures. Advanced imaging techniques provide detailed information about the hip joint, aiding in accurate diagnosis and treatment planning [5].

Each imaging modality has its strengths and limitations in measuring HAL and NSA. CT and MRI offer high accuracy and detailed visualization but are limited by cost and accessibility. DXA and digital radiography are more cost-effective and accessible but may lack the precision of 3D imaging techniques. Ultrasound presents a radiation-free alternative but requires skilled operators for accurate measurements. The choice of imaging technique should be guided by the specific clinical scenario, patient characteristics and resource availability to ensure optimal outcomes in the assessment and management of hip disorders.

Conclusion

Advanced imaging techniques have significantly improved the accuracy and reliability of measuring hip axis length and femoral neck-shaft angle. Computed tomography, magnetic resonance imaging, dual-energy X-ray absorptiometry, 3D ultrasound and stereophotogrammetry each offer unique advantages for clinical and research applications. These techniques enhance preoperative planning, postoperative evaluation and diagnosis of hip pathologies, ultimately improving patient outcomes. As technology continues to evolve, further advancements in imaging techniques are expected to provide even greater precision and utility in orthopedic practice.

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Conflict of Interest

There are no conflicts of interest by author.

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