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ORIGINAL ARTICLE

Impact of vertical and horizontal malrotation on measurements of anteroposterior radiographs of the scapula: need for standardized images in modern omometry

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Background: An increasing number of parameters measured on anteroposterior radiographs are used for the evaluation of the bony geometry of the scapula. Inhomogeneous acquisition of images is common because of the lack of standardization in radiographic positioning. Images with malrotation around the horizontal axis of the scapula are particularly frequent. We hypothesized that malrotated images would result in large variations in measured radiographic parameters and that image standardization using qualitative and semiquantitative "omometric" criteria would decrease these variations in measurements. "Omometry" is a newly introduced umbrella term that contains all standardized measurements on plain radiographs of the shoulder, analogous to the term "coxometry," which is widely used for the radiographic assessment of the osseous pelvis and hip.

Methods: In this experimental, cadaveric radiographic study, 7 dry-bone human scapula cadaveric specimens from anonymous donors were used to obtain 210 radiographs. We incrementally rotated (steps of 3°) every scapula around its horizontal and vertical axis, with a total range of 42° per each axis. Then, we measured 5 radiographic parameters on every image and observed their change with malrotation. Furthermore, we introduced 4 omometric criteria defining an appropriate (presence of ≥3 criteria) radiographic image to improve standardization of scapular image acquisition.

Results: Overall, measured values remained stable within a narrow range of ±9° of malrotation. Beyond this range, values of all parameters significantly deviated (>±2°) from the initial value. Measurements on appropriate images were significantly less prone to deviation. Within the appropriate images, those with 4 criteria showed a higher specificity than those with 3 criteria.

Conclusion: There is significant variation in values of measured radiographic parameters on anteroposterior radiographs of the scapula with substantially malrotated images. With the use of the 4 newly introduced semiquantitative and qualitative omometric criteria, which define an appropriate image, reliability of the measured parameters can be significantly improved.

No ethical approval was necessary according to the local ethical regulations.

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Level of evidence: Anatomy Study; Imaging

Keywords: Shoulder; radiograph; malrotation; omometry; standardization; radiographic criteria

Plain radiographs of the shoulder provide important information in the diagnostic workup of various shoulder disorders. Apart from directly visible acute and chronic bony pathologies, many indirect signs may be used as surrogate markers for different soft-tissue lesions.[7,18] Although conventional radiographs lost their impact in the diagnosis of soft-tissue disorders with the introduction of cross-sectional imaging studies and magnetic resonance imaging in particular, they are of high diagnostic value in the clinical routine as well as orthopedic and radiologic research because of their common availability, low cost, and reasonable radiation exposure. Many absolute and relative measured parameters such as bone-to-bone distances, angles, and ratios or indexes were described on anteroposterior radiographs of the shoulder.[2-5,10,13,17,19] Some of these have made their way into the daily routine over the years, while others are used for scientific purposes only. Quantitative and qualitative measurements highly depend on the direction of the central x-ray beam and the film-focus distance as part of the cumulative 2-dimensional imaging product. In pelvic or hip surgery, in which radiographic assessment of coxometric parameters such as acetabular version and femoral head coverage is crucial, radiographic parameters are only measured on standardized anteroposterior radiographs.[9,20,21] However, there is limited knowledge and consensus regarding standardized anteroposterior radiographs of the shoulder. Projection of the glenoid as a single, thin, concave sclerotic line has been defined as the "true anteroposterior," or Grashey, view of the shoulder and the ideal exposure of the glenohumeral joint in terms of rotation around the vertical axis of the scapula.[8] In the literature, no clear agreement is available on a standardized projection of the anteroposterior scapula regarding the horizontal axis. Textbooks for radiographic technicians describe a "visible subacromial space" consistent with a correct imaging technique.[15] However, measurement reliability of radiographic parameters is prone to malrotated images.[21] The farther the measured structures lie in the periphery of the center of rotation, the more vulnerable the parameter is to different projection angles of the central beam.

The term "omometry," as well as "omometric," is newly introduced in this study and includes quantitative and qualitative measurements on plain shoulder radiographs, analogous to the widely used term "coxometry" for radiographic characterization of the pelvis. The term "coxometry" was introduced in 1963 by French orthopedic surgeons defining standardized radiographic measurements on plain radiographs of the pelvis and hip to define pathologic osseous conditions such as hip dysplasia.[12] Coxometric parameters are still routinely used to plan surgical procedures such as pelvic osteotomies.

In this study, we wanted to measure the radiographic effect of vertical and horizontal malrotation of the scapula on different radiographic parameters and to introduce a set of qualitative and semiquantitative radiographic imaging criteria, which allow a standardized anteroposterior radiograph of the scapula to be obtained. We hypothesized that malrotation of the scapula would significantly alter measured radiographic parameters and that the use of a set of omometric criteria would help to improve measurement reliability and, therefore, standardization of anteroposterior radiographs of the shoulder.

Materials and methods

Cadaveric specimens

In this experimental, cadaveric radiographic study, 7 dry-bone human scapula cadaveric specimens from anonymous donors were used to obtain 210 radiographs. None of the specimens showed obvious post-traumatic, arthritic, or dysplastic alterations. All specimens were from donors who died at least 70 years ago.

Image acquisition

We attached all cadaveric scapulae to a special holding device allowing selective rotation of the bone around both the horizontal and vertical axes along a 2-plane goniometer (Fig. 1). Then, we obtained images by rotating every scapula with 3° increments around either axis and assessed 30 images including 2 neutral positions with

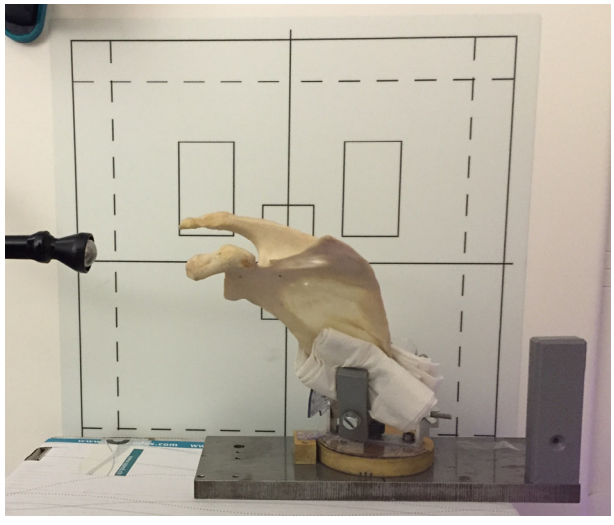

Figure 1 Holding device allowing incremental rotation of the bone around both the horizontal and vertical axes. The scapular body was centered on the digital radiograph receiver.