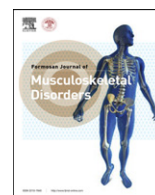




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Original Article

Calculation of osteonecrotic volume using two-dimensional projections: Comparison between the current volumetric measurement methods

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A B S T R A C T

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The prognosis of osteonecrosis of the femoral head is highly dependent on the grading of the lesion size. A small lesion (< 15% of involvement) is less likely to progress, a medium lesion (15%–30%) is at moderate risk, and a large lesion (> 30%) is doomed to collapse if left untreated. To calculate the necrosis volume, the most accurate method is to use three-dimensional magnetic resonance imaging (MRI) segmentation method. However, in clinical practice, the commonly used methods are to multiply the area percent of involvement or to use proxy, such as the necrotic index, by multiplying the angles of necrosis on two-dimensional (2D) images. The aim of this work was to find the relationship between the angular measurement proxy and the true necrosis volume. Results from different methods were compared with those of the MRI segmentation method in 29 hips. It was found that the area percent method tended to underestimate the volume and disagreed with 48% of the hips on the grading by the MRI segmentation method. As a contrast, the agreement could be improved to 90% of the hips by an index that was deduced from the original necrotic index. This study found that to estimate the necrosis volume by 2D projections is at the expense of inaccuracy but is still satisfying for clinical use. This study also found that the angular measurement proxy could be used to extrapolate the necrosis volume, whereas the bias of the measurement and grading could be decreased.

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1. Introduction

Osteonecrosis of the hip is a debilitating disease that commonly affects young adults in their third to fifth decade of life. It is also the most common reason for total hip replacement in many regions especially in Asian countries.^{1–3} The prognosis of osteonecrosis is highly related to the extent and location of the lesion involving the femoral head.^{4–6} When the lesions involve more than 30% of the

femoral head or in the weight-bearing zone, most of the hips will progress to collapsing if left untreated.^{7–9} However, if the extent of the lesions is small, many of them will remain asymptomatic and some of them may resolve as demonstrated by magnetic resonance (MR) image analysis.^{10–14} It is therefore important to estimate the extent of involvement accurately in order to identify those who need to be treated and those who need to be observed. Current staging systems integrate these concepts and stratify the extent and location of the osteonecrosis into three categories: (1) less than 15% of head involvement, (2) 15%–30% of head involvement, and (3) more than 30% of head involvement.^{15,16} Ideally, these systems can make the staging more consistent and help the comparison

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between studies more reliable. However, in the study by Plakseychuk et al,¹⁷ the reliability and reproducibility of the current staging systems were demonstrated to be poor and with high intraobserver and interobserver variations. The variations mostly come from the different results of necrosis volume calculation by different methods.

As proxies, other methods were used to assess the extent of involvement. The reliability and reproducibility of these proxies were high because the definitions were restrained and the methods of measurements were stringent.^{18,19} In addition, these proxies were found highly predictable for the clinical outcomes. For example, in the studies by Ha et al²⁰ and Kerboul et al,²¹ poor prognosis was found in cases that had a combined necrotic arc (adding the necrotic arc in two planes) greater than 200°. Similarly, an index of necrosis (calculated by multiplying the necrotic arc measured from coronal and sagittal MR images) was also found to be the prognostically significant predictor of subchondral fracture.^{18,19} Although reliable and reproducible, the current staging systems do not use these proxies for the categorization because they do not equal the necrotic volume.

To investigate the relationship of necrotic volume and their proxies (here, the necrotic index) and calculate the

necrotic volume according to the methods described in the literature,^{16,22–25} MR images of osteonecrotic hips were collected for the measurement of necrotic volumes in this study. Because the volume estimation proxy (the necrotic index) is the product of two arcs measured in two perpendicular planes, the two arcs can be used to define a cone circumscribing the necrotic lesion. The volume of circular or elliptical cones circumscribing the necrotic lesions is calculated. Finally, the relationship between the necrotic index, cone volume ratio, and necrotic volume ratio calculated by different methods was analyzed.

2. Method

Twenty-nine osteonecrotic hips with MR imaging (MRI) were used for the calculation of necrotic volumes. The methods analyzed in this study can be classified as simplified method,^{24,25} MRI-based volumetric calculation method,^{22,23,26} and proxies for volumetric measurement (the necrotic index).^{18,19} Because the necrotic index used the necrotic arcs in two perpendicular two-dimensional (2D) projections for the calculation, the volume of the cone formed by the necrotic arcs was calculated to analyze the relationships between them.



Fig. 1. The measurement of area percent of necrosis and the angular measurement of the necrotic arc on two-dimensional projections.

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