CLINICAL STUDY

Three-Dimensional Quantitative Assessment of Uterine Fibroid Response after Uterine Artery Embolization Using Contrast-Enhanced MR Imaging

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ABSTRACT

Purpose: To evaluate the clinical feasibility and diagnostic accuracy of three-dimensional (3D) quantitative magnetic resonance (MR) imaging for the assessment of total lesion volume (TLV) and enhancing lesion volume (ELV) before and after uterine artery embolization (UAE).

Materials and Methods: This retrospective study included 25 patients with uterine fibroids who underwent UAE and received contrast-enhanced MR imaging before and after the procedure. TLV was calculated using a semiautomated 3D segmentation of the dominant lesion on contrast-enhanced MR imaging, and ELV was defined as voxels within TLV where the enhancement exceeded the value of a region of interest placed in hypoenhancing soft tissue (left psoas muscle). ELV was expressed in relative (% of TLV) and absolute (in cm^3) metrics. Results were compared with manual measurements and correlated with symptomatic outcome using a linear regression model.

Results: Although 3D quantitative measurements of TLV demonstrated a strong correlation with the manual technique ($R^2 = 0.93$), measurements of ELV after UAE showed significant disagreement between techniques ($R^2 = 0.72$; residual standard error, 15.8). Six patients (24%) remained symptomatic and were classified as nonresponders. When stratified according to response, no difference in % ELV between responders and nonresponders was observed. When assessed using cm^3 ELV, responders showed a significantly lower mean ELV compared with nonresponders (4.1 cm^3 [range, 0.3–19.8 cm^3] vs 77 cm^3 [range, 11.91–296 cm^3]; $P < .01$).

Conclusions: The use of segmentation-based 3D quantification of lesion enhancement is feasible and diagnostically accurate and could be considered as an MR imaging response marker for clinical outcome after UAE.

ABBREVIATIONS

ELV = enhancing lesion volume, ROI = region of interest, 3D = three-dimensional, TLV = total lesion volume, UAE = uterine artery embolization

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Appendix A and **Figure E1** are available online at *www.jvir.org*.

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Over the past 15 years, the role of uterine artery embolization (UAE) has evolved as a well-accepted, safe, and effective alternative to surgical treatment in the management of uterine fibroids (1–5). UAE causes irreversible ischemic injury to fibroids, while maintaining endometrial perfusion, which is known to return to normal within 4 months after treatment (6,7). Ideally, this selective infarction leads to complete fibroid necrosis and, over time, to a reduction of fibroid volume (8). The extent of necrosis has been shown to correlate with symptomatic relief (9), and multiple studies have demonstrated that incomplete infarction may be the cause for poor clinical response, requiring repeat embolization (10–13).

Although clinical improvement remains the ultimate goal of treatment and represents the most powerful endpoint in most clinical trials, magnetic resonance (MR) imaging may be an important surrogate and predictive marker for treatment success (9,14). The radiologic evaluation of treatment response to UAE usually relies on individual anatomic measurements of fibroid volume by using the formula for a prolate ellipse (13). In addition, visual assessment of contrast enhancement on T1-weighted follow-up images serves as a measure of fibroid perfusion and viability (9,13). These methods rely on the assumption that fibroid growth or response to UAE occurs in a symmetric, spherical manner and can be reliably measured by subjective, visual assessment. However, little is known about the reliability and reproducibility of these methods, and more recent data questioned the predictive value of these subjective assessment techniques (15).

The present study evaluated the clinical feasibility and diagnostic accuracy of a semiautomated, three-dimensional (3D) quantitative MR imaging technique to assess uterine fibroid response after UAE by measuring total lesion volume (TLV) and enhancing lesion volume (ELV) on contrast-enhanced MR imaging.

MATERIALS AND METHODS

Study Cohort and Clinical Evaluation

This retrospective single-institution study was conducted in compliance with the Health Insurance Portability and Accountability Act, approved by the institutional review board, and designed in agreement with the Standards for Reporting of Diagnostic Accuracy (16). A retrospective review was performed of 91 consecutive patients with symptomatic uterine fibroids who underwent their first UAE procedure between December 2010 and December 2012. Patients without follow-up MR imaging (n = 52), patients who were treated with myomectomy after UAE (n = 11), and patients with significant motion artifacts on MR imaging (n = 3) were excluded from the final cohort, which consisted of 25 patients.

All included patients underwent baseline assessment by a referring gynecologist and an interventional radiologist. The patients were assessed regarding clinical symptoms based on the Uterine Fibroid Symptom and Quality-of-Life Questionnaire (17). Patients presenting with menorrhagia or bulk-related symptoms (including pelvic pressure and pain, leg and back pain, heaviness or discomfort, urinary frequency or incontinence, abdominal bloating, constipation, and dyspareunia) were included in the analysis. After the procedure, all included patients presented for a clinical follow-up evaluation at 1 month and then at 6–8 months after treatment. The severity of symptoms was characterized as worsened, unchanged, improved, or resolved. Based on the clinical severity of symptoms recorded during the second follow-up visit, patients were classified as responders or nonresponders.

Embolization Procedure

An interventional radiologist with 10 years of experience in interventional radiology (K.H.) performed all embolization procedures. Briefly, a unilateral femoral access was achieved, and multiple angiographic steps were performed to define the uterine arterial anatomy. Consecutive direct selective catheterization of both uterine arteries was performed in all cases during the same procedure. First, the main uterine artery was engaged on one side using a Roberts uterine catheter (Cook, Inc, Bloomington, Indiana). Embolization of the uterine fibroids was performed through a coaxially advanced microcatheter (Renegade HI-FLO microcatheter; Boston Scientific, Marlborough, Massachusetts) using 500–900 μm microspheres (Embosphere; Merit Medical Systems, Inc, South Jordan, Utah). The angiographic endpoint was devascularization of the fibroid (complete lack of angiographic contrast material uptake) while preserving antegrade flow in the main uterine artery. The same technique was used to treat the contralateral side.

MR Imaging Technique

All patients included in the study underwent a standardized MR imaging protocol before and after UAE. Baseline MR imaging was acquired within 3 months before intraarterial therapy, and follow-up MR imaging was performed within a median of 6 months (range, 5–8 mo) after the procedure. MR imaging was performed on a 1.5-tesla scanner (CV/i; General Electric Medical Systems, Milwaukee, Wisconsin) using a phased array surface coil. The imaging protocol consisted of T2-weighted fast spin echo images (matrix, 256 × 256; slice thickness, 8 mm; intersection gap, 2 mm; repetition time/echo time, 5,000 ms/100 ms; receiver bandwidth, 32 kHz) and breath-hold unenhanced and contrast-enhanced (0.1 mmol/kg intravenous gadodiamide [Omniscan; GE Healthcare Bio-Sciences Corp, Piscataway, New Jersey]) T1-weighted 3D fat-suppressed spoiled gradient echo images (matrix, 192 × 160; slice thickness, 4–6 mm; receiver bandwidth, 64 kHz; flip