



# **The role of MRI Cartigram (T2 mapping) in Evaluation of the Articular Cartilage of the Knee Joint**

*Thesis*

*Submitted for Fulfillment of the M.Sc. Degree in  
Radio-diagnosis*

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*2019*

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

قَالَ

لَسْبَدَانِكَ لَا يَعْلَمُ لَنَا  
إِلَّا مَا عَلَّمْتَنَا إِنَّكَ أَنْتَ  
الْعَلِيمُ الْعَظِيمُ

صدق الله العظيم

سورة البقرة الآية: ٣٢

# Acknowledgment

*First and foremost, I feel always indebted to **ALLAH**, the  
Kindest and Most Merciful.*

*I'd like to express my respectful thanks and profound  
gratitude to **Assist. Prof. Amr Mahmoud Abd El  
Samad**, Assistant Professor Radiodiagnosis Faculty of  
Medicine – Ain Shams University for his keen guidance,  
kind supervision, valuable advice, and continuous  
encouragement, which made possible the completion of  
this work.*

*I am also delighted to express my deepest gratitude  
and thanks to **Dr. Ahmed Hassan Soliman**,  
Lecturer Radiodiagnosis Faculty of Medicine – Ain Shams  
University, for his kind care, continuous supervision,  
valuable instructions, constant help and great assistance  
throughout this work.*

*Ahmed Hossam Ahmed Hassan*

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## *List of Abbreviations*

Abb.	Full term
<i>3D</i> .....	<i>Three-dimensional</i>
<i>AC</i> .....	<i>Articular cartilage</i>
<i>ADC</i> .....	<i>Apparent diffusion coefficient</i>
<i>AP</i> .....	<i>Anteroposterior</i>
<i>CE</i> .....	<i>Contrast enhancement</i>
<i>CECT</i> .....	<i>Contrast-Enhanced Computed Tomography</i>
<i>CT</i> .....	<i>Computed tomography</i>
<i>DEFT</i> .....	<i>Driven equilibrium Fourier transform</i>
<i>DESS</i> .....	<i>Dual -echo steady state</i>
<i>dGEMRIC</i> .....	<i>Delayed gadolinium-enhanced MRI of cartilage</i>
<i>DTI</i> .....	<i>Diffusion tensor imaging</i>
<i>DWI</i> .....	<i>Diffusion -weighted imaging</i>
<i>ECM</i> .....	<i>Extracellular matrix</i>
<i>ECM</i> .....	<i>Extracellular matrix</i>
<i>FEMR</i> .....	<i>Fluctuating equilibrium MRI</i>
<i>FIESTA</i> .....	<i>Fast imaging employing steady -state acquisition</i>
<i>GAG</i> .....	<i>Glycosaminoglycan</i>
<i>ICRS</i> .....	<i>International Cartilage Repair Society</i>
<i>MDCT</i> .....	<i>Multidetector computed tomography</i>
<i>MRI</i> .....	<i>Magnetic resonance imaging</i>
<i>OA</i> .....	<i>Osteoarthritis</i>
<i>ORSI</i> .....	<i>Osteoarthritis Research Society International classification</i>
<i>PG</i> .....	<i>Proteoglycans</i>
<i>RF</i> .....	<i>Radio frequency</i>
<i>SNR</i> .....	<i>Signal-to-noise ratio</i>
<i>SSFP</i> .....	<i>Steady -state free precession</i>
<i>STIR</i> .....	<i>Short tau inversion recovery</i>
<i>TE</i> .....	<i>Echo time</i>
<i>true -FISP</i> .....	<i>True fast imaging with SSFP</i>

## INTRODUCTION

A primary function of articular cartilage is absorption and redistribution of biomechanical forces applied to the joint through activities of daily living (*Mosher et al., 2010*).

Osteoarthritis (OA) is a multi-tissue, multi-factorial disease and worldwide a major cause of disability resulting from reduced joint mobility and function. Progressive loss of hyaline cartilage is one of the hallmark features of osteoarthritis, initiated by a loss of proteoglycans and an increase in water content, followed by a loss of type II collagen and a change in collagen fiber orientation (*Michael et al., 2010*).

The initiation and pathogenesis of osteoarthritis can be affected by many factors including altered mechanical loading and previous knee injury. The initial stages of osteoarthritis include proteoglycan loss, increased water content, and disorganization of the collagen network. With further degeneration, cartilage tissue becomes ulcerated causing proteoglycans to diffuse into the synovial fluid, thus decreasing water content in cartilage. The intermediate stages of osteoarthritis include cartilage thinning, fibrillation, and decreased proteoglycan and water content. In the late stages of osteoarthritis, collagen, proteoglycan, and water content are further reduced, and the collagen network is severely disrupted (*Blumenkrantz et al., 2007*).

Osteoarthritis progression is usually graded based on plain radiographs, using joint space width, continuity of bony contours, and the presence and size of Osteophytes as criteria. However, these criteria do not help for the detection of early cartilage changes. As articular cartilage has only limited capability for self-repair, an early diagnosis of cartilage degeneration and a sensitive non-invasive diagnostic tool are highly desirable (*Apprich et al., 2012*).

While standard MRI techniques provide an accurate assessment of lesions of the articular cartilage as compared to arthroscopy its sensitivity to early cartilage degeneration occurring prior to morphological changes is unclear, there is great incentive to develop technologies that would allow diagnosis of osteoarthritis in its earliest stages, when articular cartilage demonstrates biochemical changes but does not yet demonstrate morphologic changes. Some studies have suggested that, when osteoarthritis is diagnosed in these very early stages, interventions such as weight-loss regimens may have the power to modify, or even reverse, the course of the disease (*Peng et al., 2016*).

Standard MR sequences for joint imaging do not allow for the quantification of early degenerative changes. Recent magnetic resonance imaging (MRI) studies have included measurements of biomechanical and biochemical properties of cartilage such as the glycosaminoglycan and water content as well as the collagen organization and content and introduced a

new technique that can quantify cartilage water content and collagen fiber orientation, which is quantitative T2 mapping.

T2 mapping is a non-invasive marker of cartilage degeneration as it is sensitive to tissue hydration and biochemical compositions, Focal increase in T2 relaxation time has been associated with cartilage matrix damage, in particular a loss of collagen integrity and an increase in water content In future, quantitative T2 mapping may aid e.g. in the diagnosis of early cartilage degeneration, as well as to demonstrate the efficacy of disease-modifying drugs or successful treatment (*Aprich et al., 2012*).

T2 mapping is based on a multi-echo pulse sequence derived from the existing FSE-XL that can create up to 8 echoes per single acquisition not more than eight echoes are acquired, due to the cartilage short T2 relaxation times. Cartigram automatically generates color-maps based on a scale of T2 values that allows visualization of changes in the composition of articular cartilage in some cases before changes in the thickness can be seen (*Soundarajan et al., 2016*).

Quantitative cartilage imaging techniques such as T2 mapping sequences are now commercially available on many MR vendor platforms and practically can be used in the detection of changes in the water and collagen content and the biochemical structure of cartilage (*Kijowski et al., 2013*).