NIST Special Publication 250
NIST SP 250-100

Magnetic Resonance Imaging Biomarker Calibration Service: NMR Measurement of Isotropic Water Diffusion Coefficient

Michael A. Boss
Kathryn E. Keenan
Karl F. Stupic
Nikki S. Rentz
Cassandra M. Stoffer
Stephen E. Russek
Amanda A. Koepke
Kevin J. Coakley

This publication is available free of charge from:
https://doi.org/10.6028/NIST.SP.250-100

NIST Special Publication 250
NIST SP 250-100

Magnetic Resonance Imaging Biomarker Calibration Service: NMR Measurement of Isotropic Water Diffusion Coefficient

Michael A. Boss*
Kathryn E. Keenan
Karl F. Stupic
Cassandra M. Stoffer
Stephen E. Russek
Applied Physics Division
Physical Measurement Laboratory

Nikki S. Rentz
Boulder Safety, Health, and Environment Division
Office of Safety, Health and Environment

Amanda A. Koepke
Kevin J. Coakley
Statistical Engineering Division

**Former NIST employee; all work for this publication was done while at NIST.*

This publication is available free of charge from:
https://doi.org/10.6028/NIST.SP.250-100

March 2023

U.S. Department of Commerce
Gina M. Raimondo, Secretary

National Institute of Standards and Technology
Laurie E. Locascio, NIST Director and Under Secretary of Commerce for Standards and Technology

NIST SP 250-100
March 2023

Publication History
Approved by the NIST Editorial Review Board on 2022-11-19

How to Cite this NIST Technical Series Publication
Boss MA, Keenan KE, Stupic KF, Rentz NS, Stoffer CM, Koepke A, Coakley KJ, Russek SE (2023) Magnetic Resonance Imaging Biomarker Calibration Service: NMR Measurement of Isotropic Water Diffusion Coefficient. (National Institute of Standards and Technology, Boulder, CO), Special Publication (SP) NIST SP 250-100. https://doi.org/10.6028/NIST.SP.250-100

NIST Author ORCID iDs
M. Boss: 0000-0002-9492-767X
K. Keenan: 0000-0001-9070-5255
K. Stupic: 0000-0001-8356-1660
N. Rentz: 0000-0002-7328-5639
C Stoffer: 0000-0003-2619-546X
S. Russek: 0000-0002-8788-2442
K. Coakley: 0000-0003-3787-2577
A Koepke: 0000-0001-9515-0383

Contact Information
stephen.russek@nist.gov

Abstract

This document describes a calibration service to measure the water diffusion coefficient, or diffusivity, in reference materials and tissue mimics using nuclear magnetic resonance (NMR) techniques. This calibration is restricted to materials which exhibit isotropic Gaussian water diffusion. The measurement uses the water proton spin as a tag and standard NMR gradient techniques to measure diffusion of the proton magnetization, which, in low viscosity fluids, is largely determined by the physical motion of water molecules. The calibrated materials are meant to be used in phantoms (calibration devices) to verify the accuracy of magnetic resonance imaging (MRI)-based water diffusion measurements. The local diffusion coefficient (often referred to as the apparent diffusion coefficient in complex materials) and other associated parameters, are used as image-based biomarkers to assess the state of tissue cellular density, detect tissue anomalies, characterize tumor type, evaluate treatment efficacy, and assess neural connectivity and neural tissue degeneration. A biomarker, as defined by the U.S. Food and Drug Administration, is “a characteristic that is objectively measured and evaluated as an indicator of normal biological processes, pathogenic processes, or biological responses to a therapeutic intervention.” (1) Diffusion coefficients, which describe the rate that water protons move due to random thermal motion, are phenomenological parameters that must be carefully defined and measured to enable rigorous quantification and their use as biomarkers for clinical decision making. Diffusion parameters, in addition to being dependent on local material properties, are dependent on environmental parameters such as temperature, which must be controlled and precisely and accurately measured.

Keywords

Biomarker; magnetic resonance imaging; MRI; MRI phantoms; NMR; nuclear magnetic resonance; proton magnetization diffusion; water diffusion.

Table of Contents