RAD TECH SERIES

Rad Tech's Guide to MRI: Imaging Procedures, Patient Care, and Safety

Carolyn Kaut Roth

Blackwell Science

Rad Tech's Guide to MRI: Imaging Procedures, Patient Care, and Safety

Other books in the
RAD TECH SERIES

Rad Tech's Guide to Equipment Operation and Maintenance
Euclid Seeram

Rad Tech's Guide to Radiation Protection
Euclid Seeram

Rad Tech's Guide to MRI: Basic Physics, Instrumentation, and Quality Control
William Faulkner

Rad Tech's Guide to Mammography: Physics, Instrumentation, and Quality Control
Donald Jacobson

Rad Tech's Guide to CT: Imaging Procedures, Patient Care, and Safety
Deborah Lynn Durham

RAD TECH SERIES

Rad Tech's Guide to MRI: Imaging Procedures, Patient Care, and Safety

Carolyn Kaut Roth, RT(R), (MR), (CT), (M), (CV)
Director Technologist Continuing Education
and MRI Programs
University of Pennsylvania Medical Center
Philadelphia, Pennsylvania

Series Editor
Euclid Seeram, RTR, BSc, MSc, FCAMRT
Medical Imaging Advanced Studies
British Columbia Institute of Technology
Burnaby, British Columbia, Canada

Blackwell
Science

EDITORIAL OFFICES:
Commerce Place, 350 Main Street, Malden, Massachusetts 02148, USA
Osney Mead, Oxford OX2 0EL, England
25 John Street, London WC1N 2BS, England
23 Ainslie Place, Edinburgh EH3 6AJ, Scotland
54 University Street, Carlton, Victoria 3053, Australia

OTHER EDITORIAL OFFICES:
Blackwell Wissenschafts-Verlag GmbH, Kurfürstendamm 57, 10707 Berlin, Germany
Blackwell Science KK, MG Kodenmacho Building, 7-10 Kodenmacho Nihombashi, Chuo-ku, Tokyo 104, Japan
Iowa State University Press, A Blackwell Science Company, 2121 S. State Avenue, Ames, Iowa 50014-8300, USA

DISTRIBUTORS:
The Americas
Blackwell Publishing
c/o AIDC
P.O. Box 20
50 Winter Sport Lane
Williston, VT 05495-0020
(Telephone orders: 800-216-2522; fax orders: 802-864-7626)

Australia
Blackwell Science Pty, Ltd.
54 University Street
Carlton, Victoria 3053
(Telephone orders: 03-9347-0300; fax orders: 03-9349-3016)

Outside The Americas and Australia
Blackwell Science, Ltd.
c/o Marston Book Services, Ltd.
P.O. Box 269
Abingdon
Oxon OX14 4YN
England
(Telephone orders: 44-01235-465500; fax orders: 44-01235-465555)

Acquisitions: Beverly Copland
Development: Julia Casson
Production: GraphCom Corporation
Manufacturing: Lisa Flanagan
Marketing Manager: Toni Fournier
Cover and interior design: Dana Peick, GraphCom Corporation
Typesetting: GraphCom Corporation
9 2009

Library of Congress Cataloging-in-Publication Data

Kaut Roth, Carolyn.
Rad tech's guide to MRI : imaging procedures, patient care, and safety / by Carolyn Kaut Roth.
p. ; cm.
ISBN 978-0-632-04507-5
1. Magnetic resonance imaging—Outlines, syllabi, etc. 2. Radiologic technologists—Outlines, syllabi, etc. I. Title: Guide to MRI. II. Title.
[DNLM: 1. Magnetic Resonance Imaging—methods—Outlines. 2. Technology, Radiologic—methods—Outlines. WN 18.2 K21ra2001]
RC78.7.N83 K386 2001
616.07'548—dc21

2001025055

TABLE OF CONTENTS

SERIES EDITOR'S FOREWORD

Blackwell Science's Rad Tech Series in radiologic technology is intended to provide a clear and comprehensive coverage of a wide range of topics and prepare students to write their entry-to-practice registration examination. Additionally, this series can be used by working technologists to review essential and practical concepts and principles and to use them as tools to enhance their daily skills during the examination of patients in the radiology department.

The Rad Tech Series features short books covering the fundamental core curriculum topics for radiologic technologists at both the diploma and the specialty levels, as well as act as knowledge sources for continuing education as defined by the American Registry for Radiologic Technologists (ARRT).

The entry-to-practice series includes books on radiologic physics, equipment operation, patient care, radiographic technique, radiologic procedures, radiation protection, image production and evaluation, and quality control. This specialty series features books on computed tomography physics and instrumentation, patient care and safety, and imaging procedures; mammography; and quality management in imaging sciences.

In *Rad Tech's Guide to MRI: Imaging Procedures, Patient Care, and Safety,* Carolyn Kaut Roth, a renowned educator and director technologist of MR programs of the University of Pennsylvania Medical Center, presents clear and concise coverage of patient care and safety issues of magnetic resonance imaging (MRI), as well as MR imaging procedures. Topics include patient care and safety, imaging procedures that describe MRI of the head and neck, spine, chest, musculoskeletal system abdomen, pelvis, and vascular system.

Carolyn Kaut Roth has done an excellent job in explaining significant concepts that are mandatory for the successful per-

formance of quality MRI in clinical practice. Students, technologists, and educators alike will find this book a worthwhile addition to their libraries.

Enjoy the pages that follow; remember, your patients will benefit from your wisdom.

Euclid Seeram, RTR, BSc, MSc, FCAMRT
Series Editor
British Columbia, Canada

PREFACE

The purpose of *Rad Tech's Guide to MRI: Imaging Procedures, Patient Care, and Safety* is to provide an easy reference for the study of magnetic resonance imaging (MRI) for the technologist who is preparing for the advanced level examination in MRI. This guide can also be used as a quick overview of MRI for the practicing technologist and physician. The outline format provides easy reference for each section of the text. The subtopics and bulleted text facilitate quick reference without "over reading" the material.

MRI safety and imaging procedures with anatomy have been discussed in this guide, and the basic principles and image contrast to pulse sequences and k-space are discussed in a partner guide in the Rad Tech series. The more complicated topics have hopefully been expressed in an understandable format that will encourage the reader to explore these topics, rather than run in the opposite direction. Purists may perceive our attempt at creating a "user-friendly" text as an oversimplification. However, we believe it important to disseminate difficult information to a variety of educational levels.

Carolyn Kaut Roth

Notice: The indications and dosages of all drugs in this book have been recommended in the medical literature and conform to the practices of the general community. The medications described and treatment prescriptions suggested do not necessarily have specific approval by the Food and Drug Administration for use in the diseases and dosages for which they are recommended. The package insert for each drug should be consulted for use and dosage as approved by the FDA. Because standards for usage change, it is advisable to keep abreast of revised recommendations, particularly those concerning new drugs.

ACKNOWLEDGMENTS

First, I would like to thank God for the opportunity to be involved in this project, the wisdom to undertake it, and the determination to see it through.

Next, I gratefully acknowledge the encouragement of those individuals who have given me the support and patience to complete this guide. These include my loving husband, Scott, and the rest of my family—my mom, dad, brothers, in-laws, nieces, and nephews. I love you all.

My thanks, however, cannot end with my family. My extended "HUP" family was also instrumental in providing information and images for the text. In particular, I would like to thank Lisa Desiderio, Paula Malagoli, Tony Festa, Dave Flint, Jorge Forero, Camille Gallen, Christy Lennen, Joe Shea, Lena Inverso, Doree Schrann, Russell Boucher, Lee Cohen, Doris Caine-Edwards, Beverly Farrar, Nancy Fedullo, Jim Garrisson, Christine Harris, Dave Yost, Mike Irvin, Ralph Magee, Ray Chemiewlewslki, Ted Czwoski, and Ann Kopp, my office mate. Without your support, this project would have been virtually impossible.

—CKR

CHAPTER 1

Patient Care and Safety for Magnetic Resonance Imaging

Chapter at a glance

Introduction to Patient Care and Safety for MRI

To date, there have been virtually no long-term adverse biologic effects of extended exposure to magnetic resonance imaging (MRI) in general. However, when separate components of the MRI process are examined, several inconsequential and reversible effects of magnetic, gradient, and radio frequency (RF) fields can be observed. When MRI systems began to be used in the United States, the Food and Drug Administration (FDA) issued guidelines to hospital's Investigational Review Boards (IRBs) in "Guidelines for Evaluating Electromagnetic Exposure Risks for Trials of Clinical NMR Systems," on February 25, 1982. Follow-up was presented in December of that same year, not intending to provide limitations, but rather to evaluate the need for a risk assessment. Therefore the need to evaluate MRI for potential risks and hazards is clear and, to validly discuss long-term biologic effects of MRI, all of the components of the imaging process should be considered. These elements include not only the main magnetic field known as the static magnetic field (B_0), but also time-varying magnetic fields caused by magnetic field gradients and RF fields (B_1) created by RF transmitters and receiver coils.

The purpose of this chapter is to explore the safety aspects of MRI.

Screening Patients and Personnel

Conducting a careful screening procedure is crucial to ensure the safety of anyone who enters the area of the magnetic resonance (MR) system. Careful questioning and education of patients and personnel help to maintain this controlled environment. Patient and personnel screening is, to date, the most effective way to avoid potential health hazards to patients involved in MRI. Patients and MR personnel with questionable ferromagnetic foreign objects either in or on their bodies should be rigorously examined so as to avoid any serious health risks or accidents.

- All individuals, including patients, volunteer subjects, visitors, MR health care providers, and custodial workers, must be thoroughly screened by qualified personnel before being exposed to the MRI environment. In addition, routine preventative maintenance checks by the service engineer, as well as continuing education is also important. Therefore careful planning and diligent upkeep of the MR facility can provide a safe environment for patients, visitors, and employees.
- Most MR-related injuries have been a direct result of deficiencies in screening methods. Unfortunately, not all MR users perform a rigorous screening procedure and there is a lack of agreement on what constitutes an appropriate or necessary protocol that will ensure the safety of individuals and patients in the MR setting. One other note is warranted: *If a patient has previously had an MR examination, this is not an indication that they are safe to undergo another.*

In 1994 the safety committee of the International Society for Magnetic Resonance in Medicine (previously designated as the Society for Magnetic Resonance Imaging) published screening recommendations and a questionnaire that encompassed all of the important aforementioned issues. These recommendations were developed from a consensus from an international panel of MR experts and were intended for use as a standard of care at all MR centers. Elster and others (1994) also published a screening recommendation. This information was somewhat similar to the content of the recommendations provided by the safety committee, which is not surprising since many of the same MR clinicians and scientists were involved in the development of both documents. A comprehensive pre-MRI screening form may be downloaded from the Internet (Mrsafety.com) and used at MRI facilities. This form was recently developed in collaboration with Frank Shellock and Anne Sawyer-Glover (1999).

Pre-MRI Screening Form or Questionnaire

The initial screening process should involve completion of a questionnaire that is specifically designed to determine whether there is any reason that the individual would have an adverse reaction to the MRI environment.

- The questionnaire must include important questions concerning previous surgery, prior injury from a metallic foreign body, and whether the individual is pregnant.
- In addition, the questionnaire should contain a means of determining whether the individual has any of the various implants, materials, devices, or objects that are considered to be a contraindication or problematic in the MR environment, including any device that is electrically, magnetically, or mechanically activated.
- A diagram of the human body should be provided on the questionnaire for the individual to indicate the position of any object that would be potentially hazardous or would interfere with the interpretation of the MR procedure as a result of causing what is known as an artifact.
- The pre-MRI screening questionnaire may also be used to obtain additional pertinent information related to the safe performance of the MR procedure. For example, questions may be asked concerning previous adverse reactions to contrast media that should alert the health care provider to potential problems.
- Finally, pertinent questions should include information related to the phase of the menstrual cycle, as well as the use of contrast media and hormone treatment that are relevant to patients undergoing MRI examinations for breast abnormalities.

Pre-MRI Screening Interview

With the use of any form of written questionnaire, limitations related to incomplete or incorrect answers provided by the patient, guardian, or other individual preparing to enter the MRI environment are bound to exist. For example, there may be difficulties associated with individuals who are impaired with respect to their vision, fluency, or level of literacy. Therefore it may be necessary to have a version of the screening questionnaire in the individual's native language or to have a direct verbal interaction with individuals who may routinely have problems with written questionnaires.

- It is also recommended that the MR technologist or other trained staff member conduct an oral interview to further ensure the safety of the individual entering the

MRI environment or undergoing an MR procedure. This allows a mechanism for clarification or confirmation of the answers to the questions posed to the individual so that there is no miscommunication.

- The "oral phase" of pre-MRI screening is believed to be especially vital for establishing the reliability of the individual's answer.

Prescreening for Metallic Implants

Every MRI facility must establish a standardized policy for pre-MRI screening of patients and individuals who are suspected of having metallic foreign objects. The policy should include guidelines concerning which individuals or patients require "work-up" by radiographic procedures and the specific procedure to be performed (e.g., number and type of views, position of the anatomy). Each case must be considered on an individual basis to assess the relative risk with regard to the metal object and the MRI environment. These basic precautions should be taken with respect to any type of MR system regardless of the field strength, magnet type, and the presence or absence of magnetic shielding.

Pregnant Patients

A patient who is pregnant or suspects that she is pregnant must be identified before exposure to the MRI environment to address the risks versus the benefits of the examination for the individual. To date, there are no known biologic effects of MRI on fetuses. However, a number of mechanisms exist whereby there could be a potential for adverse effects of the interaction of electromagnetic fields with developing fetuses. Cells undergoing division, which occurs during the first trimester of pregnancy, are more susceptible to a variety of effects. For this reason, many facilities choose to delay MR imaging until after the first trimester.

The FDA guidelines indicate that the safety of MRI when used to image the fetus has not been established or proved. Therefore patients should be provided this information and should also be informed that there are presently no known deleterious effects related to the use of MR procedures during pregnancy. However, according to the recommendations pro-

vided by the safety committee of the Society for Magnetic Resonance Imaging, "MR procedures may be used for pregnant patients when other nonionizing forms of diagnostic imaging are inadequate or when the examination provides important information that would otherwise require exposure to a diagnostic procedure that requires ionizing radiation (e.g., computerized tomography, fluoroscopy)." For this reason, the American College of Gynecology and Obstetrics recommends that potential MR patients who are pregnant should be reviewed on a case-by-case basis. This policy has been adopted by the American College of Radiology and is considered to be the "standard of care" with respect to the use of MR procedures for pregnant patients.

Pregnant Employees

A recent survey revealed no increased incidence of spontaneous abortions among MR technologists and health care practitioners. (It should be noted that the incidence of spontaneous abortions makes up approximately 30% of all pregnancies.) After this survey, the following determinations were made:

- The facility from which the data was observed changed their in-house policy from one which restricts pregnant technologists from being near the magnetic field to a policy which allows pregnant technologists to be in the room to set up the patient but not to remain in the room during image acquisition.
- It has been suggested that informed workers make their own decision. For this reason, MRI facilities have established individual guidelines for pregnant employees in the MR environment. The majority of facilities have determined that pregnant employees can safely enter the scan room of superconductors or permanent magnets on which the magnetic field is contained, but must stay out while the scanner is running when the RF and gradient fields are employed.
- A policy is recommended that permits pregnant technologists and health care workers to perform MR procedures, as well as to enter the MR system room and to attend to the patient during pregnancy, regardless of the trimester.