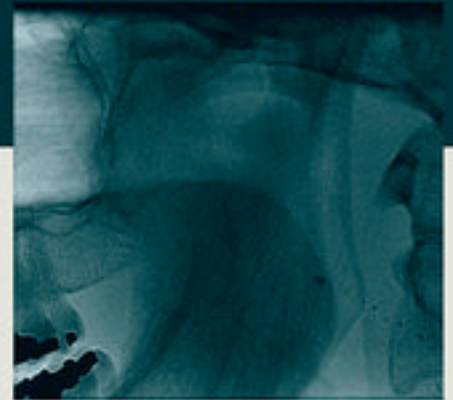
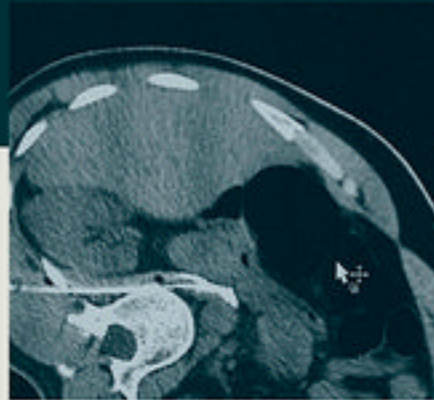
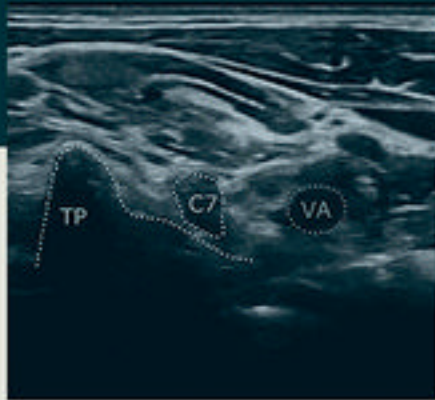


# Multimodality Imaging Guidance in Interventional Pain Management



EDITED BY

**SAMER NAROUZE**

OXFORD

---

# **Multimodality Imaging Guidance in Interventional Pain Management**



# **Multimodality Imaging Guidance in Interventional Pain Management**

Edited by

**Samer N. Narouze MD, PhD**

Clinical Professor of Anesthesiology and Pain Management

Ohio University

Clinical Professor of Neurological Surgery

Ohio State University

Chairman, Center for Pain Medicine

Western Reserve Hospital

Cuyahoga Falls, Ohio

**OXFORD**  
UNIVERSITY PRESS

Oxford University Press is a department of the University of Oxford. It furthers the University's objective of excellence in research, scholarship, and education by publishing worldwide. Oxford is a registered trade mark of Oxford University Press in the UK and certain other countries.

Published in the United States of America by Oxford University Press  
198 Madison Avenue, New York, NY 10016, United States of America.

© Oxford University Press 2017

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, without the prior permission in writing of Oxford University Press, or as expressly permitted by law, by license, or under terms agreed with the appropriate reproduction rights organization. Inquiries concerning reproduction outside the scope of the above should be sent to the Rights Department, Oxford University Press, at the address above.

You must not circulate this work in any other form  
and you must impose this same condition on any acquirer.

Library of Congress Cataloging-in-Publication Data

Names: Narouze, Samer N., editor.

Title: Multimodality imaging guidance in interventional pain management / edited by Samer Narouze.

Description: Oxford ; New York : Oxford University Press, [2016] | Includes bibliographical references and index.

Identifiers: LCCN 2015046238 (print) | LCCN 2015047052 (ebook) | ISBN 9780199908004 (hard cover : alk. paper) | ISBN 9780199908011 (e-book) | ISBN 9780199392629 (online)

Subjects: | MESH: Pain Management | Nerve Block | Ultrasonography, Interventional | Radiography, Interventional

Classification: LCC RB127 (print) | LCC RB127 (ebook) | NLM WL 704.6 | DDC 616/.0472—dc23

LC record available at <http://lcn.loc.gov/2015046238>

This material is not intended to be, and should not be considered, a substitute for medical or other professional advice. Treatment for the conditions described in this material is highly dependent on the individual circumstances. And, while this material is designed to offer accurate information with respect to the subject matter covered and to be current as of the time it was written, research and knowledge about medical and health issues is constantly evolving and dose schedules for medications are being revised continually, with new side effects recognized and accounted for regularly. Readers must therefore always check the product information and clinical procedures with the most up-to-date published product information and data sheets provided by the manufacturers and the most recent codes of conduct and safety regulation. The publisher and the authors make no representations or warranties to readers, express or implied, as to the accuracy or completeness of this material. Without limiting the foregoing, the publisher and the authors make no representations or warranties as to the accuracy or efficacy of the drug dosages mentioned in the material. The authors and the publisher do not accept, and expressly disclaim, any responsibility for any liability, loss or risk that may be claimed or incurred as a consequence of the use and/or application of any of the contents of this material.

9 8 7 6 5 4 3 2 1

Printed by Walsworth, USA

To my wife, Mira, and my children, John, Michael, and Emma—  
The true love and joy of my life. Without their continued understanding and support,  
I could have not completed this book.

This book is also dedicated to the memory of my father, who always had faith in me,  
and to my mother for her ongoing love and guidance.



---

## Contents

Foreword [xi](#)

Preface [xiii](#)

Contributors [xv](#)

### Part I: Introduction to Multimodality Imaging Guidance

1. Basics of Fluoroscopy [3](#)  
*Vikram B. Patel*
2. Basics of Ultrasound [25](#)  
*Antoun Nader, Greesh John, and Mark C. Kendall*
3. Basics of Computed Tomography [38](#)  
*Krikor Malajikian and Daniel Finelli*

### Part II: Spine Anatomy and Injections

#### Section A. Cervical Spine

4. Cervical Transforaminal/Nerve Root Injections: Fluoroscopy [75](#)  
*Jeffrey D. Petersohn*
5. Cervical Transforaminal/Nerve Root Injections: Ultrasound [96](#)  
*Samer N. Narouze*
6. Cervical Transforaminal/Nerve Root Injections: Computed Tomography [104](#)  
*Tilman Wolter*
7. Cervical Facet Nerve Block and Radio Frequency Ablation: Fluoroscopy [117](#)  
*Maarten van Eerd, Arno Lataster, and Maarten van Kleef*
8. Cervical Facet Nerve Block: Ultrasound [126](#)  
*Andreas Siegenthaler*
9. Cervical Intra-Articular Facet Injection: Computed Tomography [131](#)  
*Amaresh Vydyanathan, Karina Gritsenko, Samer N. Narouze, and Allan L. Brook*
10. Cervical Interlaminar Epidural Injections: Fluoroscopy [136](#)  
*Dmitri Souzdanitski and Samer N. Narouze*
11. Atlanto-Axial Joint Injection: Ultrasound [157](#)  
*Samer N. Narouze*



12. Atlanto-Axial Joint Injection: Computed Tomography and Fluoroscopy 163  
*Lesley Lirette and Marc A. Huntoon*

### **Section B. Thoracic Spine**

13. Thoracic Epidural and Nerve Root Injections: Fluoroscopy 171  
*Jianguo Cheng*
14. Thoracic Nerve Root and Facet Injections: Computed Tomography 183  
*Amaresh Vydyanathan, Allan L. Brook, Boleslav Kosharsky, and Samer N. Narouze*
15. Thoracic Facet Nerve Block: Fluoroscopy 189  
*Shrif Costandi, Youssef Saweris, Michael Kot, and Nagy Mekhail*

### **Section C. Lumbar Spine**

16. Lumbar Transforaminal and Nerve Root Injections: Fluoroscopy 201  
*Vahid Grami, Salim M. Hayek, and Samer N. Narouze*
17. Lumbar Transforaminal and Nerve Root Injections: Ultrasound 211  
*Michael Gofeld*
18. Lumbar Transforaminal/Nerve Root Injections: Computed Tomography 219  
*Amaresh Vydyanathan, Naum Shaparin, Allan L. Brook, and Samer N. Narouze*
19. Facet Joint Interventions: Fluoroscopy 225  
*David Jamison, Indy Wilkinson, and Steven P. Cohen*
20. Lumbar Facet Nerve Block: Ultrasound 254  
*David A. Provenzano*
21. Lumbar Epidural Injections: Fluoroscopy 265  
*Dmitri Souzdalnitski, Pavan Tankha, and Imanuel R. Lerman*
22. Central Neuraxial Blockade: Ultrasound 280  
*Ki Jimn Chin*
23. Lumbar Disc Procedures: Fluoroscopy 295  
*Leonardo Kapural*

### **Section D. Sacrum**

24. Caudal Epidural Steroid Injection: Fluoroscopy 307  
*Imanuel R. Lerman, David Hiller, and Joseph Walker*
25. Caudal Epidural Steroid Injection: Ultrasound 323  
*Imanuel R. Lerman*
26. Vertebral Augmentation: Fluoroscopy and CT 331  
*Ricardo Vallejo and Ramsin Benyamin*

## Part III: Nonspinal Injections

### Section A. Sympathetic and Visceral Blocks

27. Cervical Sympathetic Block: Fluoroscopy 351  
*Samer N. Narouze*
28. Cervical Sympathetic Block: Ultrasound 361  
*Samer N. Narouze*
29. Cervical Sympathetic Block and Neurolysis: Computed Tomography 369  
*Adrian Kastler and Bruno Kastler*
30. Lumbar Sympathetic Block: Fluoroscopy 380  
*Samer N. Narouze*
31. Lumbar Sympathetic Block and Neurolysis: Computed Tomography 389  
*Bruno Kastler and Adrian Kastler*
32. Celiac Plexus Blockade and Neurolysis: Fluoroscopy 397  
*Immanuel R. Lerman, Joseph Hung, Dmitri Souzdalnitski, Bruce Vrooman, and Mihir Kamdar*
33. Celiac Plexus Blockade and Neurolysis: Ultrasound 414  
*Samer N. Narouze*
34. Celiac Plexus Blockade and Neurolysis: Computed Tomography 420  
*Samer N. Narouze*
35. Superior Hypogastric Block and Neurolysis: Fluoroscopy, Ultrasound, Computed Tomography 426  
*Kent H. Nouri and Billy K. Huh*
36. Ganglion Impar Block: Fluoroscopy and Ultrasound 432  
*Chia Shiang (Sean) Lin*

### Section B. Peripheral Nerve Blocks

37. Peripheral Nerve Blocks in Chronic Pain 441  
*Paul Singh Tumber and Philip W. H. Peng*

## Part IV: Musculoskeletal Applications

### Section A. Joint Injections

38. Sacroiliac Joint Injections: Fluoroscopy 467  
*Dmitri Souzdalnitski, Adam Kramer, and Maged Guirguis*
39. Sacroiliac Joint Injections: Computed Tomography 474  
*Mira Herman, Amaresh Vydyanathan, and Allan L. Brook*

- 40. Hip Joint Injections: Ultrasound 481  
*Hariharan Shankar and Marina Vardanyan*
- 41. Knee Joint Injections: Ultrasound 489  
*Hariharan Shankar and Khalid Abduraheem*
- 42. Ankle and Foot Injections: Ultrasound 499  
*Marko Bodor, Sean Colio, and Andrew Toy*
- 43. Shoulder Injections: Ultrasound 515  
*Philip W. H. Peng*
- 44. Elbow Injections: Ultrasound 534  
*Jay Smith and Jacob Sellon*
- 45. Hand and Wrist Injections: Ultrasound 554  
*Marko Bodor, Sean Colio, and Christopher Bonzon*

### **Section B. Soft Tissue Injections**

- 46. Piriformis Muscle Injections: Fluoroscopy 577  
*Robert B. Bolash and Kenneth B. Chapman*
- 47. Piriformis Muscle, Psoas Muscle, and Quadratus Lumborum Muscle Injections: Ultrasound 582  
*Hariharan Shankar and Karan Johar*
- 48. Psoas and Quadratus Lumborum Muscle Injections: Fluoroscopy 594  
*Tariq Malik and Honorio T. Benzon*

Index 607

---

## Foreword

It is my honor to write the foreword for *Multimodality Imaging Guidance in Interventional Pain Management*, edited by Samer Narouze, MD, PhD. Over the past several decades, advances in imaging technology have fueled the growth of interventional pain procedures. Real time fluoroscopic, sonographic, or CT guidance allows performance of procedures that would otherwise be difficult or impossible. Documentation of needle location ensures that the practitioner can avoid vital structures and place the injectate at the intended target. Accurate needle placement has diagnostic value in confirming whether the target is in fact the pain generator and, more importantly, increases the chances of achieving the desired therapeutic benefit.

The editor and contributors of this book are some of the world's experts in the field of image-guided musculoskeletal procedures. I would certainly allow any of them to treat me! I predict that this book will be an indispensable resource to practitioners throughout the world who want to expand the breadth of their practice or refine their skills in performing one of the most important roles of a physician—the relief of pain.

Levon N. Nazarian, MD  
Professor of Radiology  
Sidney Kimmel Medical College  
at Thomas Jefferson University  
Philadelphia, PA



---

## Preface

Approximately one out of three people suffer from chronic pain in the United States. The majority of chronic pain patients do not respond well to available pharmacological treatments, whereas interventional pain management techniques have provided effective, valuable options for individuals with otherwise intractable pain. Without doubt, image-guided procedures are superior to a blind approach and are the standard of care for spinal injections. The most commonly used modalities are fluoroscopy, sonography, and computed tomography (CT).

Fluoroscopy-guided pain and spinal injections have a long history of safety and reliability. Fluoroscopy provides an easy quick visualization of bony landmarks. Contrast fluoroscopy and digital subtraction angiography (DSA) detect intravascular injections as well. However, the major limitations of this modality are radiation exposure and the inability to visualize soft tissue structures.

Computed tomographic guidance brings great precision to the procedure. However, because of the increased radiation exposure and cost, it is not routinely used to guide pain and spinal injections. In this book, we concentrate on the procedures for which CT clearly has significant advantages.

The major advantages of ultrasound over fluoroscopy and CT are the absence of radiation exposure for both patient and operator and the real-time visualization of soft tissue structures such as nerves, muscles, tendons, and vessels. The latter is why ultrasound guidance of soft tissue and joint injections, as well as pain nerve blocks, is becoming more popular. That said, sonography is not without flaws. Its major shortcomings are limited resolution at deep levels, especially in obese patients, and the artifacts created by bone structures.

There is a great need for a comprehensive yet easy-to-follow book for various image-guided pain and spinal blocks. That is how this book—the first to compare fluoroscopy, ultrasound, and CT-guided procedures—was born. I was fortunate to gather some of the national and international experts to contribute to the book, each one writing about his or her area of subspecialty expertise, and for this reason, I am very proud of the book.

The main objective of this book is to enable physicians managing acute and chronic pain to be confident using different imaging modalities and to be familiar with the advantages and limitations of each imaging modality. Among the target groups are pain physicians, anesthesiologists, physiatrists, rheumatologists, interventional radiologists, neurologists, orthopedists, sports medicine physicians, and spine specialists.

Each of the most commonly performed interventional pain procedures is described in three different chapters that focus on fluoroscopy, ultrasound, and CT guidance (if applicable). Each chapter follows a similar format that includes a description of relevant

anatomy, a detailed description of how to perform the procedure beginning with the choice and application of the transducer, and the advantages and limitations of the imaging modality. The text is enhanced by many illustrations and images to better understand the procedure.

The book comprises 48 chapters, organized into four parts that cover the basics and clinical applications of fluoroscopy, ultrasound, and CT when performing spinal, pain, and musculoskeletal (MSK) procedures. The first part reviews the foundations of various imaging modalities relative to performing interventional pain procedures. The second part, the largest in the book, contains four sections covering spinal injections in the cervical, thoracic, lumbar, and sacral areas. All the different applications are well documented with simple illustrations and labeled images to supplement the text. The third part focuses on nonspinal blocks. It covers sympathetic and visceral blocks as well as peripheral nerve blocks. The fourth part addresses MSK and soft tissue applications in pain practice. The chapters are written by *the* world experts in the area of MSK ultrasound.

A couple of notes about the book: the text has been kept to a minimum to allow for a maximal number of instructive illustrations and images, and the procedures described here are based on a review of the techniques described in the literature as well as the authors' experience.

The advancement of imaging technology and the range of possible clinical circumstances may give rise to other, more appropriate approaches. It is my hope that this book will encourage and stimulate all physicians and healthcare providers interested in interventional pain management.

Samer N. Narouze, MD, PhD  
Akron, Ohio

---

## Contributors

**Khalid Abdulraheem, MD**

Resident, Department of Anesthesiology  
Medical College of Wisconsin  
Milwaukee, Wisconsin

**Ramsin Benyamin, MD**

Clinical Assistant Professor of Surgery  
University of Illinois  
Urbana-Champaign, Illinois

**Honorio T. Benzon, MD**

Professor of Anesthesiology  
Northwestern University Feinberg  
School of Medicine  
Chicago, Illinois

**Marko Bodor, MD**

Department of Physical Medicine  
and Rehabilitation  
University of California, Davis  
Department of Neurological Surgery  
University of California, San Francisco  
San Francisco, California

**Robert B. Bolash, MD**

Staff Physician  
Department of Pain Management  
Cleveland Clinic  
Cleveland, Ohio

**Christopher Bonzon, MD**

Interventional Spine and Sports Medicine  
Napa, California

**Allan L. Brook, MD**

Professor of Clinical Radiology  
and Neurological Surgery  
Albert Einstein College of Medicine  
Montefiore Medical Center  
New York, New York

**Kenneth B. Chapman, MD**

Clinical Assistant Professor of  
Anesthesiology, Perioperative Care,  
and Pain Medicine  
NYU Langone Medical Center  
President, The Spine & Pain Institute  
of New York  
New York, New York

**Jianguo Cheng, MD, PhD**

Professor of Pain Medicine  
Program Director of Pain Medicine  
Fellowship  
Departments of Pain Management  
and Neurosciences  
Cleveland Clinic  
Cleveland, Ohio

**Ki Jinn Chin, MBBS, MMed,  
FANZCA, FRCPC**

Department of Anesthesia  
Toronto Western Hospital  
University of Toronto  
Toronto, Ontario, Canada



**Steven P. Cohen, MD**

Professor of Anesthesiology and Critical  
Care Medicine  
Johns Hopkins School of Medicine  
Walter Reed National Military  
Medical Center  
Baltimore, Maryland

**Sean Colio, MD**

Swedish Medical Group  
Seattle, Washington

**Shrif Costandi, MD**

Department of Pain Management  
Cleveland Clinic  
Cleveland, Ohio

**Daniel Finelli, MD**

Akron Radiology, Inc.  
Akron, Ohio

**Michael Gofeld, MD**

Department of Anesthesia  
St Michael's Hospital  
University of Toronto  
Toronto, Ontario, Canada

**Vahid Grami, MD, MPH**

GMC Interventional Pain Center  
Danville, Pennsylvania

**Karina Gritsenko, MD**

Assistant Professor of Anesthesiology  
Assistant Professor of Family and Social  
Medicine  
Albert Einstein College of Medicine  
Montefiore Medical Center  
New York, New York

**Maged Guirguis, MD**

Clinical Fellow  
Department of Pain Management  
Cleveland Clinic  
Cleveland, Ohio

**Salim M. Hayek, MD**

Professor of Anesthesiology  
Case Western Reserve University  
Chief, Division of Pain Medicine  
University Hospitals of Cleveland  
Cleveland, Ohio

**David Hiller, MD**

Division of Anesthesia Pain  
Management  
Scripps Health  
San Diego, California

**Billy K. Huh, MD, PhD**

Professor of Pain Medicine  
The University of Texas MD Anderson  
Cancer Center  
Houston, Texas

**Joseph Hung, MD**

Assistant Professor of Clinical  
Anesthesiology  
Weill Cornell Medical College  
Memorial Sloan Kettering  
Cancer Center  
New York, New York

**Marc A. Huntoon, MD**

Professor of Anesthesiology  
Vanderbilt University  
Nashville, Tennessee

**David Jamison, MD**

Department of Anesthesiology  
Walter Reed National Military  
Medical Center  
Bethesda, Maryland

**Karan Johar, MD**

Fellow, Pain Medicine Program  
Department of Anesthesiology  
Medical College of Wisconsin  
Milwaukee, Wisconsin

**Greesh John, MD**

Pain Medicine Fellow  
Department of Anesthesiology  
Northwestern University  
Feinberg School of Medicine  
Chicago, Illinois

**Mihir Kamdar, MD**

Instructor in Medicine  
Cancer Pain Clinic  
Massachusetts General Hospital  
Boston, Massachusetts

**Leonardo Kapural, MD, PhD**

Professor of Anesthesiology  
Wake Forest School of Medicine  
Carolinas Pain Institute and Center  
for Clinical Research  
Winston Salem, North Carolina

**Bruno Kastler, MD, PhD**

Chief of Radiology and Director  
Bioengineering Laboratory  
Besancon, France

**Mark C. Kendall, MD**

Research Assistant Professor  
Department of Anesthesiology  
Northwestern University  
Feinberg School of Medicine  
Chicago, Illinois

**Boleslav Kosharsky, MD**

Assistant Professor of Anesthesiology,  
Physical Medicine and Rehabilitation  
Albert Einstein College of Medicine  
Montefiore Medical Center  
New York, New York

**Michael Kot, MD**

Department of Pain Management  
Cleveland Clinic  
Cleveland, Ohio

**Adam Kramer, MD**

Clinical Fellow  
Department of Pain Management  
Cleveland Clinic  
Cleveland, Ohio

**Arno Lataster, MSc**

Department of Anatomy  
and Embryology  
Maastricht University  
CAPHRI School for Public Health  
and Primary Care  
Maastricht, The Netherlands

**Immanuel R. Lerman, MD, MS**

Assistant Professor of Anesthesiology  
University of California at San Diego  
La Jolla, California

**Chia Shiang (Sean) Lin, MD**

Chief Director of Pain  
Management Center  
Section Director of Pain  
Management  
Department of Anesthesiology and Pain  
Management  
Mackay Memorial Hospital  
Taipei, Taiwan

**Lesley Lirette, MD**

Ochsner Clinic  
New Orleans, Louisiana

**Krikor Malajikian, MD**

Akron Radiology, Inc.  
Akron, Ohio

**Tariq Malik, MD**

Assistant Professor of Anesthesiology  
University of Chicago Pritzker School  
of Medicine  
Chicago, Illinois

**Nagy Mekhail, MD, PhD**

Carl E. Wasmuth Endowed Chair,  
Department of Pain Management  
Director, Evidence Based Pain Medicine  
Research  
Cleveland Clinic  
Cleveland, Ohio

**Antoun Nader, MD**

Professor of Anesthesiology  
and Orthopedics  
Section Chief, Acute Pain and Regional  
Anesthesiology  
Fellowship Codirector, Adult and  
Pediatric Regional Anesthesia and  
Acute Pain Management  
Northwestern University Feinberg  
School of Medicine  
Chicago, Illinois

**Kent H. Nouri, MD**

Assistant Professor, Department of Pain  
Medicine  
Division of Anesthesiology and  
Critical Care  
The University of Texas MD Anderson  
Cancer Center  
Houston, Texas

**Vikram B. Patel, MD, FIPP, DABIPP**

President and Medical Director  
ACMI Pain Care, LLC  
Algonquin, Illinois

**Philip W. H. Peng, MBBS, FRCPC**

Professor of Anesthesiology  
University of Toronto  
Toronto Western Hospital  
Wasser Pain Management Center  
Mount Sinai Hospital  
Toronto, Ontario, Canada

**Jeffrey D. Petersohn, MD**

Advanced Spine and Orthopedic Institute  
Shore Medical Center  
Somers Point, New Jersey

**David A. Provenzano, MD**

President  
Pain Diagnostics and Interventional  
Care  
Pittsburgh, Pennsylvania

**Youssef Saweris, MD**

Department of Pain Management  
Cleveland Clinic  
Cleveland, Ohio

**Jacob Sellon, MD**

Instructor of Physical Medicine  
and Rehabilitation  
Mayo Clinic  
Rochester, Minnesota

**Hariharan Shankar, MD**

Associate Professor of Anesthesiology  
Medical College of Wisconsin  
Milwaukee, Wisconsin

**Naum Shaparin, MD**

Associate Professor of Clinical  
Anesthesiology, Family and Social  
Medicine  
Assistant Professor of Physical Medicine  
and Rehabilitation  
Albert Einstein College of Medicine  
Director of Pain Services  
Montefiore Medical Center  
New York, New York

**Andreas Siegenthaler, MD**

Chronic Pain Management Unit  
Lindenhof-Group, Lindenhof-Hospital  
Berne, Switzerland

**Jay Smith, MD**

Professor of Physical Medicine and  
Rehabilitation  
Departments of Physical Medicine &  
Rehabilitation, Radiology  
and Anatomy  
Mayo Clinic  
Rochester, Minnesota

**Dmitri Souzdalnitski, MD, PhD**

Staff Physician  
Department of Pain Management  
Cleveland Clinic  
Cleveland, Ohio

**Pavan Tankha, DO**

Chief Fellow  
Department of Pain Management  
Cleveland Clinic  
Cleveland, Ohio

**Andrew Toy, MD**

Interventional Spine and Sports Medicine  
Napa, California

**Paul Singh Tumber, MD, FRCPC**

Assistant Professor of Anesthesiology  
University of Toronto  
Toronto Western Hospital  
Wasser Pain Management Center  
Mount Sinai Hospital  
Toronto, Ontario, Canada

**Ricardo Vallejo, MD, PhD**

Director of Research  
Millennium Pain Center  
Bloomington, Illinois

**Maarten van Eerd, MD, FIPP**

Department of Anesthesiology and Pain  
Management  
University Medical Center Maastricht  
Maastricht, The Netherlands  
Department of Anesthesiology and Pain  
Management  
Amphia Hospital  
Breda, The Netherlands

**Maarten van Kleef, MD, PhD, FIPP**

Department of Anesthesiology and Pain  
Management  
University Medical Center Maastricht  
Maastricht, The Netherlands

**Marina Vardanyan, MD**

Resident  
Department of Anesthesiology  
Medical College of Wisconsin  
Milwaukee, Wisconsin

**Bruce Vrooman, MD**

Pain Management  
Cleveland Clinic  
Cleveland, Ohio

**Amaresh Vydyanathan, MD**

Assistant Professor of Anesthesiology,  
Physical Medicine, and Rehabilitation  
Albert Einstein College of Medicine  
Montefiore Medical Center  
New York, New York

**Joseph Walker, MD**

Bloomington Anesthesiologists  
Bloomington, Indiana

**Indy Wilkinson, MD**

Department of Anesthesiology  
Womack Army Medical Center  
Fort Bragg, North Carolina

**Tilman Wolter, MD**

Interdisciplinary Pain Centre  
University Hospital Freiburg  
Freiburg, Germany



# Part I

## **Introduction to Multimodality Imaging Guidance**



---

# Basics of Fluoroscopy

*Vikram B. Patel*

1

## Introduction

Interventional pain medicine is a subspecialty that is one of the newest approved specialties in medicine, with a specialty designation of 09. Although various interventions have been used to treat pain for decades, use of fluoroscopy has been more prevalent since the mid-1990s. Several studies have shown that using any form of guidance is much superior to “blind” procedures and provides better outcomes while reducing the rate of complications. Fluoroscopy is being used for most spinal interventional procedures at this time, but the use of ultrasound may be safer than fluoroscopy for certain procedures, such as joint injections or injections near and around blood vessels. Ultrasound avoids harmful radiation to the patient as well as the treating physician and his/her staff and also helps significantly by allowing the physician to visualize blood and fluid flow. Nevertheless, fluoroscopy may never be replaced for certain procedures that require full view of osseous structures as well as open but minimally invasive surgical procedures such as implantable devices and intradiscal procedures.

Radiation injuries to the physicians are less common now compared with just a decade ago, due to better awareness regarding radiation injuries and availability of low-dose radiation and pulsed modes with most modern fluoroscopy machines. This chapter attempts to educate physicians regarding the safe use of fluoroscopy and the dangers of radiation.

## Definitions

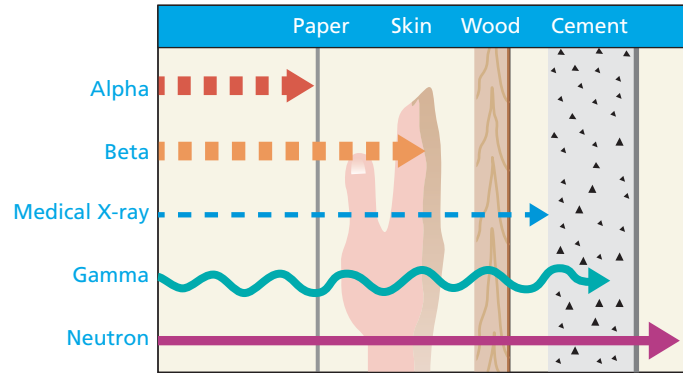
### **Radiation**

Radiation is defined as emission of energy in the form of a steady flow of “photons” generated by a given source. Radiation is either ionizing or nonionizing, depending on how it affects matter. Nonionizing radiation includes visible light, heat, radar, microwaves, and radio waves.<sup>1</sup> It deposits energy in materials it passes through. Conversely, ionizing radiation, such as x-rays and cosmic rays, is more energetic than nonionizing radiation. When ionizing radiation passes through material, enough energy is deposited to break molecular bonds and create charged particles. These charged particles can damage plant, animal, and human cells.

There are five major types of ionizing radiation (Figure 1.1)<sup>1</sup>:

1. Alpha particles: The weakest particles, they can be blocked by a sheet of paper, skin, or a few inches of air.





**Figure 1.1** Penetrating power of radiation. See United States Nuclear Regulatory Commission. Radiation Protection and the NRC. Washington, DC: United States Nuclear Regulatory Commission; 2010. <http://www.nrc.gov/reading-rm/doc-collections/nuregs/brochures/br0322/r1/br0322r1.pdf>.

2. Beta particles: Similar to electrons, these are lighter and more penetrating than alpha particles, can travel a few feet in the air, and can penetrate the skin.
3. Gamma rays: High-energy waves that can travel great distances at the speed of light and are very penetrating.
4. X-rays: Similar to gamma particles in most aspects.
5. Neutrons: Nuclear particles that are also very penetrating. Neutrons are the only particles that can make objects radioactive.

Certain terminology is important to understand along with the designated units used to define such terms.<sup>2-4</sup> The International Commission on Radiation Units has suggested conversion from the present radiation units to the International System (SI) of measurements. These new units will be phased into use and will replace the old units gradually over the years.

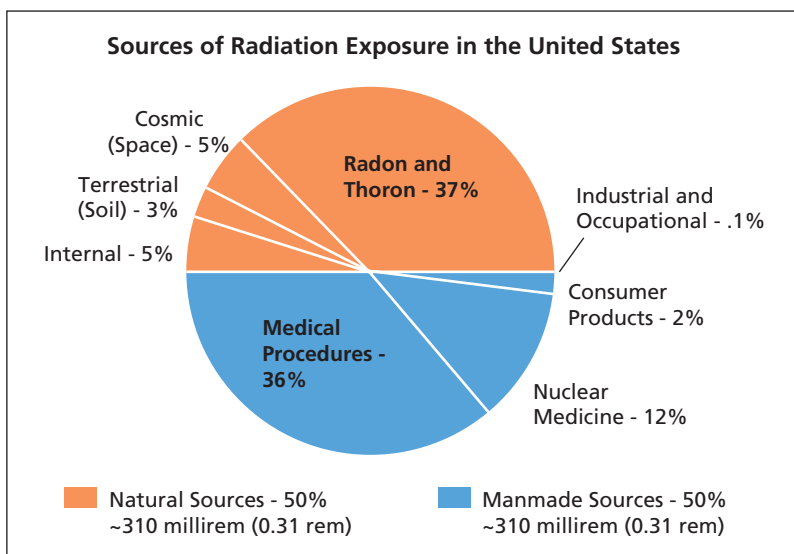
- Exposure—Quantity of radiation intensity. The Roentgen (R) is the special unit of exposure, which is the measure of the ionization produced in air by x or gamma radiation. The Roentgen characterizes a radiation field by an indirect measurement of an effect, namely, the ionization produced in air.
- Unit of measure: “R” or “Coulomb”—C/kg, an SI unit.
- Radiation Absorbed Dose—The energy actually absorbed by a sample or a biological system (depends on the matter). An absorbed dose applies to the energy deposited by any kind of radiation in any kind of material.
- Unit of measure: “rad” or Gray “Gy” (100 rad = 1 Gy), an SI unit.
- Radiation Equivalent Man—For describing the biological effects of radiation. It is affected by differences in the type of radiation or irradiation conditions.
- Unit of measure: “rem” or Sievert “Sv” (100 rem = 1 Sv), an SI unit.
- 1 R = 1 rad = 1 rem, for all practical purposes.
- Millisievert (mSv): Used to measure amount of radiation exposure and the unit measured by the dosimeters.
- Total yearly dosage in millisieverts should be less than 50 mSv.

Effects of radiation cannot be underestimated. The fact that radiation waves are invisible does not mean they do not exist! The dosage of radiation accumulates over the lifetime, and the effects are permanent in most situations. Humans are exposed to radiation every day, as there are several natural sources of radiation<sup>1</sup> such as the sun and gases such as radon (Figure 1.2). It can also be artificially produced for certain purposes including x-rays, CT scans, and so forth. For low levels of radiation exposure, the effects are so small they may not be detected, because a body can repair damage caused by such radiation.

The health effects of radiation on living cells may result in three outcomes<sup>1</sup>:

1. Injured or damaged cells repair themselves, resulting in no net damage. A yearly dose of 0.62 rem (620 millirems, or mrem) from all radiation sources has not been shown to cause humans any harm.
2. Cells die, much as millions of body cells do every day, being replaced through normal biological processes.
3. Cells incorrectly repair themselves, resulting in a physical change. The exact effect depends on the specific type and intensity of the radiation exposure.

Higher doses of radiation can lead to several biological effects, and hence a limit for such radiation has been established. It is believed that humans exposed to about 500 rem of radiation as a single dose would likely die without medical treatment. A single dose of 100 rem to a human may cause nausea or skin reddening, but recovery is likely. About 25 rem of radiation can cause temporary sterility in men. If these doses are spread out over time, instead of delivered all at once, their effects tend to be less severe.<sup>1</sup> To prevent biological damage, safety guidelines should be followed by every individual involved in



**Figure 1.2** Sources of radiation in the United States. Causing yearly human exposure on an average. See United States Nuclear Regulatory Commission. Radiation Protection and the NRC. Washington, DC: United States Nuclear Regulatory Commission; 2010. <http://www.nrc.gov/reading-rm/doc-collections/nuregs/brochures/br0322/r1/br0322r1.pdf>.

**Table 1.1:**  
**Max Permissible Radiation Dosages (MPD)—Yearly Dose**

Thyroid	50 rem
Skin	15 rem in any 1 year
Extremities	50 rem
Hands	75 rem in any 1 year (25/qtr)
Forearms	30 rem in any 1 year (10/qtr)
Lens	15 rem
Gonads	50 rem
Whole body	5 rem Annual (<50 mSv) (Prospective total)
Whole body	10-15 rem Annual (Retrospective total)
Whole body	(Age-18) × 5 rem Total long-term accumulation
Pregnant woman	0.5 rem in gestation period

United States Department of Labor. Maximum Permissible Dose Equivalent for Occupational Exposure. NCRP Publication No. 43. Washington, DC: United States Department of Labor; 1975.

the delivery of such radiation. The Nuclear Regulatory Commission (NRC) requires that its licensees limit maximum radiation exposure to individual members of the public to 100 mrem (1mSv) per year and limit occupational radiation exposure to adults working with radioactive material to 5,000 mrem (50 mSv) per year.<sup>5</sup> See Table 1.1 for the maximum permissible radiation dosages (MPD) per year<sup>6</sup> and Box 1.1 for the effects of radiation.

**Box 1.1 The effects of radiation**

- Lens - 200 rem = cataract
- Skin - 500 rem = Erythema
- Skin - 700 rem = Permanent Alopecia
- Whole body - 200-700 rem = hematopoietic failure, death Whole body - 700-5000 Rad = GI failure, death
- Whole body - 5000-10,000 rem = Cerebral edema, death
- ~6 Gray = rash
- ~14 Gray = desquamation of skin
- Typical lumbar epidural steroid with fluoroscopy
  - Fluoro from 1 m away - ~0.03 mrem (to physician)
  - 1 minute of fluoroscopy radiates up to 100 mGy
- Typical Chest x-ray: 15mRem (0.02 mSv), Abdominal x-ray: 220mRem (1.0 mSv), Lumbar-spine x-ray:250mRem (1.3 mSv), CT Abdomen: 10 mSv. These numbers differ based on the patient's size and the type of exposure. A lateral view uses more radiation than a PA or AP views due to the higher distance to travel through the human body. The bones require stronger radiation than the air in the lungs.

## **Radiation Safety**

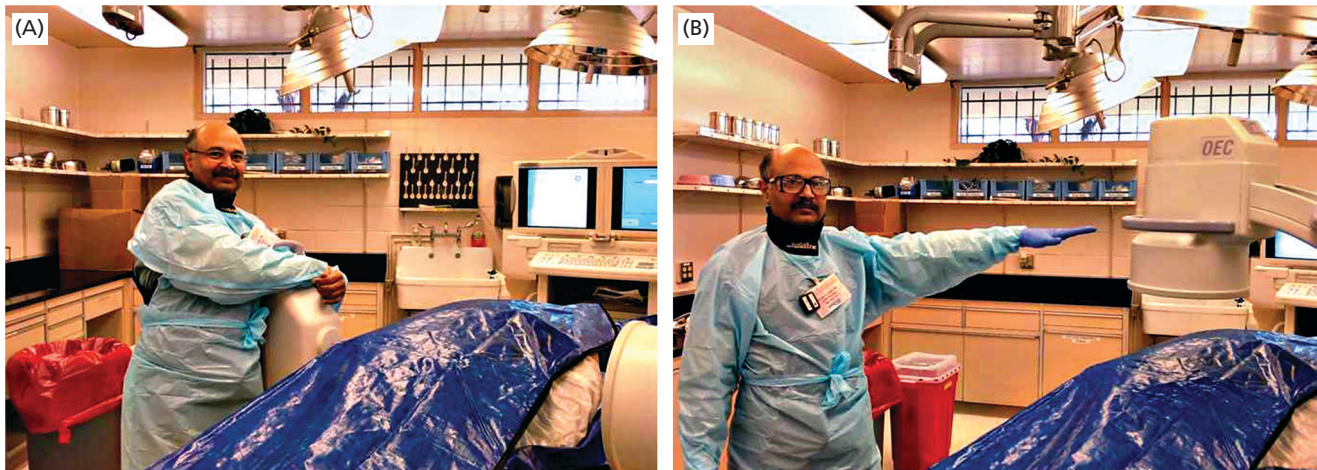
Radiation safety can be achieved with proper usage of the equipment that is properly certified. There are three most important factors involved in reducing the radiation exposure.

1. Time: Keeping the time to a minimal amount is the single most effective factor in reducing radiation exposure. A single pulse is definitely safer than continuous delivery during fluoroscopy. Also, allowing radioactive material as much time as possible to decay before exposure will minimize radiation exposure when that material needs to be handled. There are very few situations that require continuous fluoroscopy during interventions for pain procedures.
  - a. Some procedures that require continuous exposure:
    - i. Live contrast injection during a transforaminal injection
    - ii. Using an adhesiolysis catheter for epidural adhesiolysis
    - iii. Advancing a spinal cord stimulator lead
    - iv. Vertebroplasty and kyphoplasty
    - v. Minimally invasive lumbar decompression (MILD)
    - vi. Diagnostic provocation discogram
  - b. Some procedures that do not require live fluoroscopy (which is nonetheless wrongly used by several practitioners):
    - i. Finding the right entry point for placing the needle (waving the pointer under live exposure)
    - ii. Manipulating a needle while approaching the target
    - iii. Positioning the patient's head during cervical procedures
2. Distance: X-ray radiation decays very quickly over the length it has to travel; hence, maximizing the distance between the source and the target provides minimal exposure: 1 m provides reduction of up to 99% of effective radiation exposure. This may not be possible in certain situations, such as when injecting into a tight space and when there is a need for proximity to a patient while performing a procedure such as during a live contrast injection, vertebroplasty, advancing a spinal cord lead, adhesiolysis etc. However, "hugging" the fluoroscopy machine while performing a procedure is not advisable. X-rays are present even outside the field of radiation displayed on the monitor (Figures 1.3 and 1.4). A simple rule of thumb is, "If you can touch the c-arm you are too close!"
3. Protection: Protection against radiation can be effectively achieved by using barriers between the x-ray source (the tube) and the field of radiation. Several barriers are in use these days. They include static barriers, such as a leaded glass shield, and wearable barriers, such as the leaded gowns and glasses. Exposure to the thyroid can be effectively reduced with a "thyroid collar." Leaded gloves are also available for use in interventional procedures; they provide attenuation rather than blockage of x-rays, as they are made thin for flexibility, but can at least minimize the exposure several-fold. Several types of movable hard barriers are used by physicians and can be moved on wheels. Leaded glass is used for eyeglasses and is also available for prescription glasses. It is also important to shield the patient's body with such barriers to reduce the radiation exposure to the parts of the body that are not being

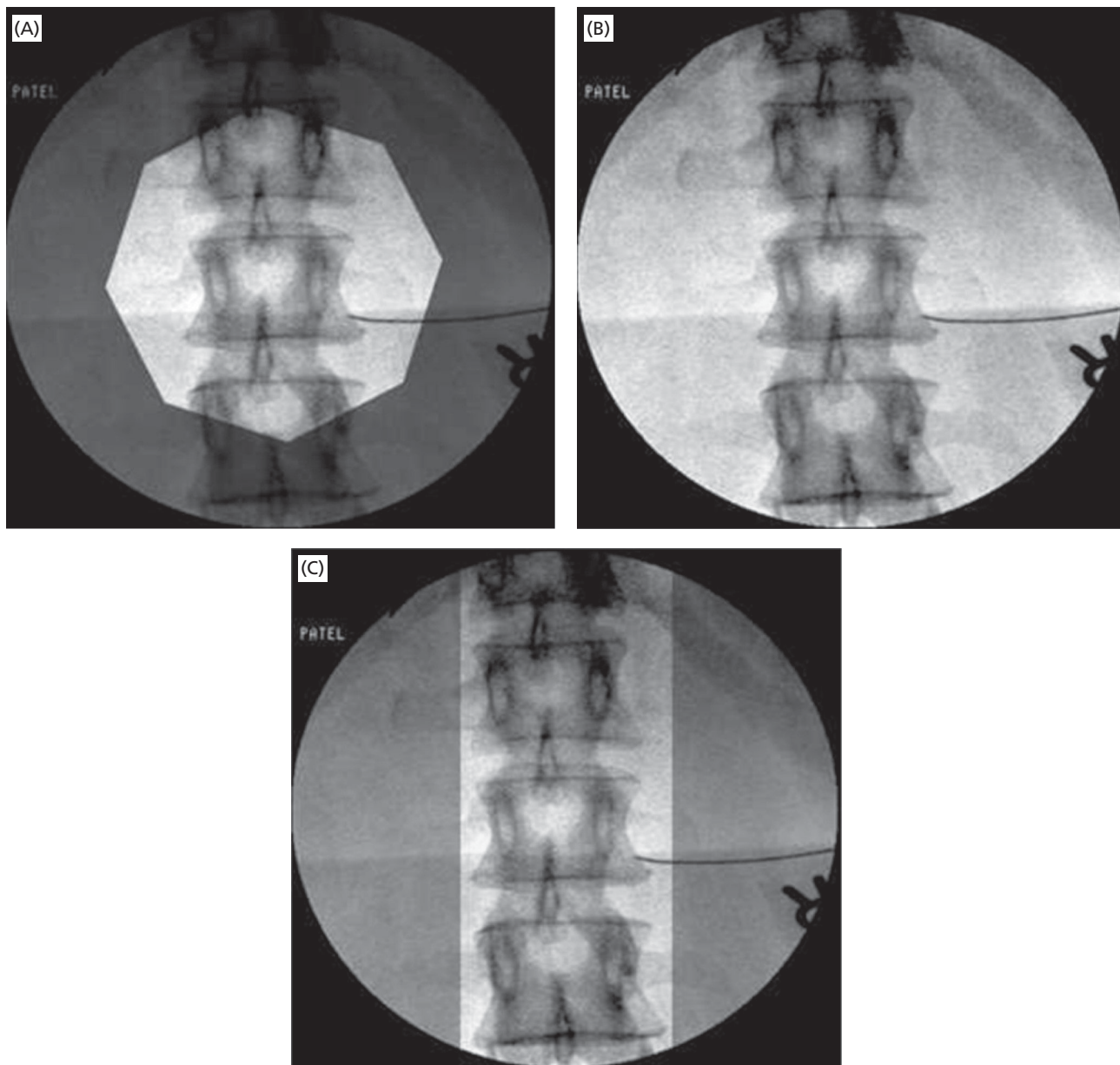


**Figure 1.3** Field of radiation around the fluoroscopy machine. The emitter is at the bottom, and the image intensifier at the top.

examined. The leaded barrier strength is measured depending on the thickness of the shielding material and denotes the lead equivalent. The attention to this very effective method for radiation exposure protection is lacking to a certain extent, and although physicians need to be aware of the dangers of excessive radiation, they do not pay enough attention to protect themselves or the patients. In a Spanish study<sup>7</sup> a nationwide survey of pain physicians who used fluoroscopy revealed that a majority (80%) did not use protective glasses and only 50% wore leaded gloves. Just under half (47%) were situated less than 0.5 meter from the patient. The majority (76%) did not inform about the radiation, nor was it mentioned in the informed consent (80%).



**Figure 1.4** “Hugging” the c-arm, especially during lateral views, exposes the physician to maximum radiation (A). Proper distance and protection (B).



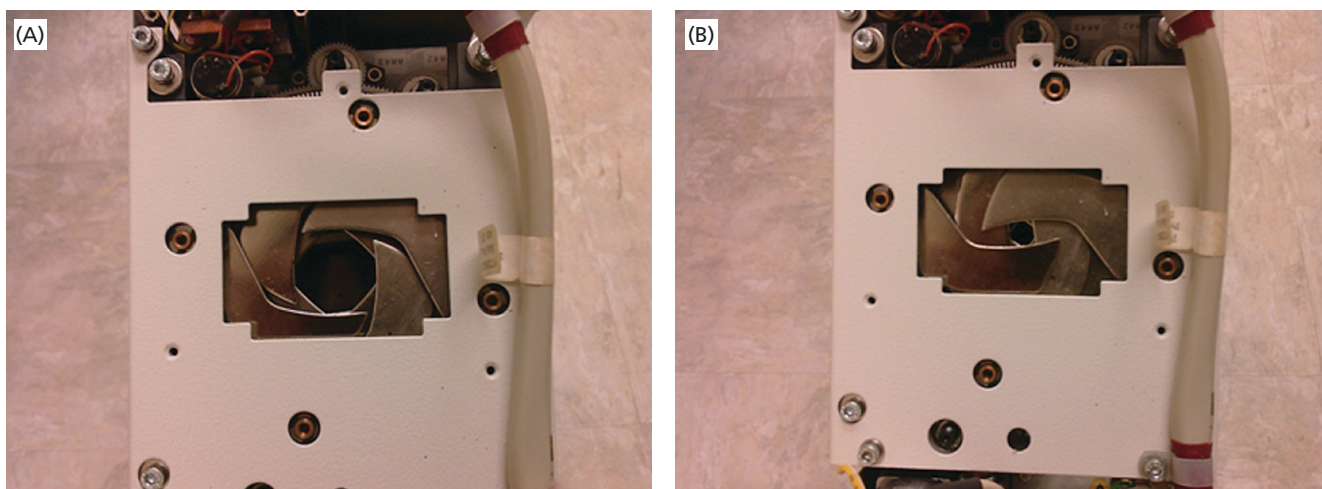
**Figure 1.5** (A) is circular collimation, (B) shows the image without collimation, (C) is linear collimation.

Besides these three main components, other factors that help reduce radiation are universally available on fluoroscopy machines, but some select modalities are available only on the most modern machines. Use of collimation is a universal modality available on even the oldest systems. This involves the use of metal plates within the emitter that are located at the exit point of the x-rays. Collimation is available in two different modes that can be used individually as well as in combination (Figure 1.5A, B, C). Circular collimation works just like a camera iris (Figure 1.6), providing a circular opening that can be adjusted for diameter from which the x-rays exit (Figure 1.7A, B). Linear collimation uses plates

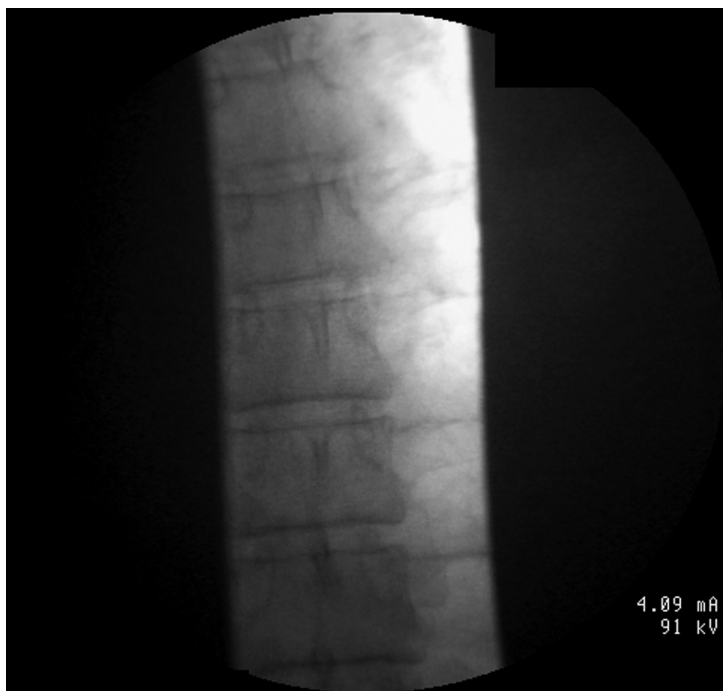


**Figure 1.6** Example of circular (iris) collimation during a transforaminal injection in an osteoporotic spine.

placed parallel to each other vertically and horizontally to provide a square or rectangular picture (Figure 1.8) (Figure 1.9A, B). Collimation not only reduces the amount of x-rays delivered to the patient but also can help enhance the image by eliminating the higher or lower brightness areas, thus normalizing the picture. The exposure interpretation of a fluoroscopy image, done digitally in most machines, works just like a digital camera and normalizes the exposure based on the visible field. For example, a thoracic fluoroscopic image will make the spine look too dark, as the image enhancements see the lung fields



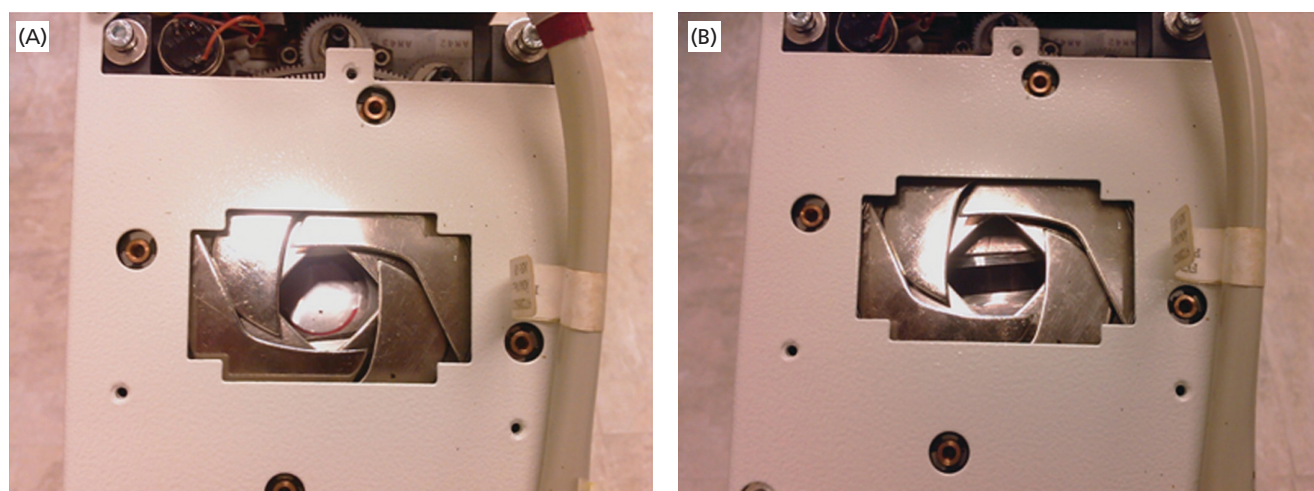
**Figure 1.7** Iris or circular collimation mechanism open (A) and closed (B).



**Figure 1.8** Example of linear collimation during a thoracic spine procedure eliminating the lung fields for a better visualization of the spine.

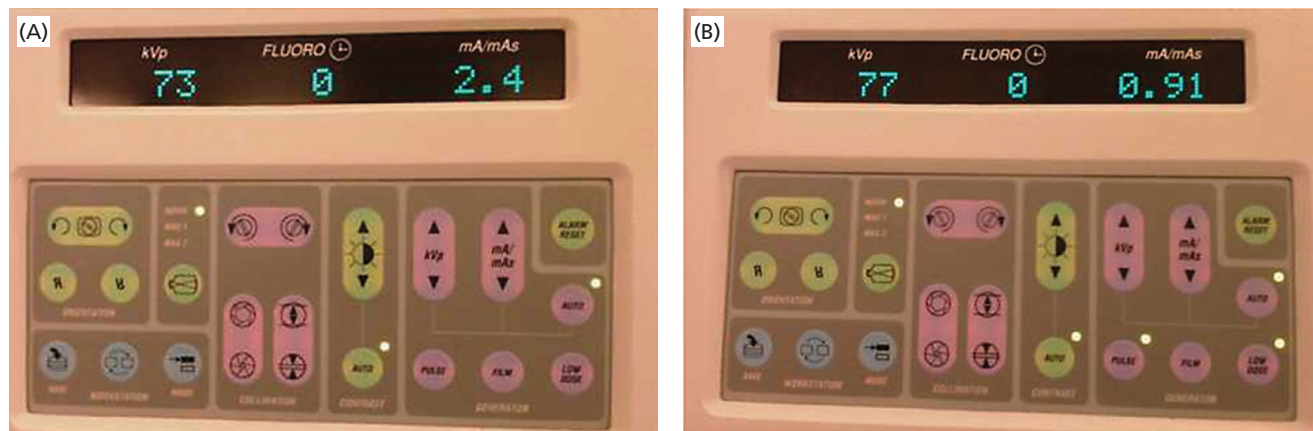
as too bright and lower the brightness. Thus, using vertical collimation, one can limit the exposure to just the spine, which then enables proper image enhancements, providing better image quality. Collimation should be used routinely in fluoroscopy.

Some newer machines are also equipped to deliver x-rays with a selectable pulse rate (pulse/s) and provide selection of a low-dose mode and a host of postimaging processing options. The pulsed delivery mode (which can be selectable on some machines) reduces the steady flow of x-rays to pulsed delivery, thereby reducing the total radiation. The



**Figure 1.9** Linear collimation open (A) and closed (B). Note the horizontal plates in B.





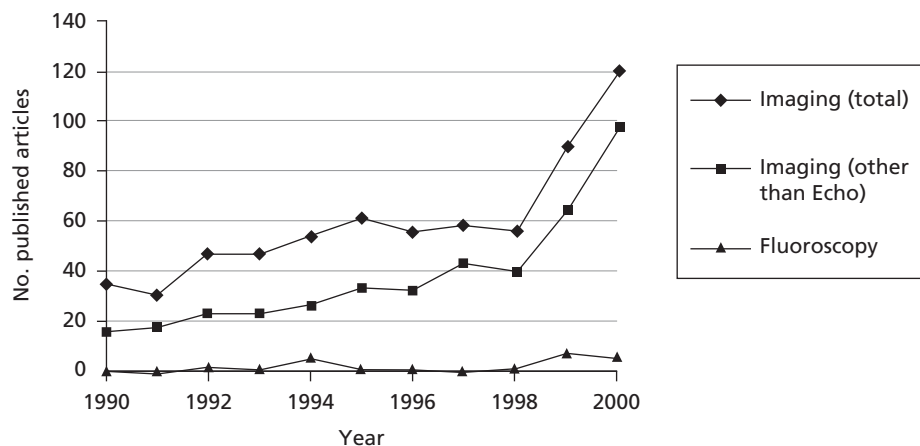
**Figure 1.10** A, B: Radiation parameters without and with the use of pulsed and low-dose modes. Note the reduction of mA to almost one-third with the use of low-dose and pulse mode while the kVp remains almost unchanged with auto selection.

advantage of using this mode is not just reduced exposure but also reduced motion blur. The slight disadvantage may be the deterioration of image quality (a grainier image), which is not as critical while performing needle localizations. Low-dose mode reduces the milliamperes of the x-rays delivered and only has minimal reduction in quality of the image. Both modes can be used simultaneously to further reduce the exposure (Figure 1.10A, B), the disadvantage being an even grainier image. Postimage zoom processing allows zooming after the image is taken thus helping reduce the exposure compared with zooming while taking the image. Other postprocessing options include adjustments to the brightness and contrast, which also help enhance the image without manipulating the automatic milliamperage and kilovolt adjustments.

Other methods to reduce exposure are listed here:

- Placing the image intensifier as close to the patient as possible—This helps reduce the scatter of x-rays to the operating personnel and provides a better image quality (most states have regulations requiring the distance between the x-ray tube and the patient to be at least 12–18 inches).
- Placing the emitter under the fluoroscopy table.
- Single shot exposure—This mode only takes one single exposure even if the operator keeps the switch pressed continuously. This can be helpful when a foot switch is used and the operator forgets to take the foot off after exposure.
- Laser guidance—This helps position the c-arm prior to exposing and provides pinpoint accuracy while performing a procedure that requires “tunnel-vision” guidance.
- 3D imaging—some newer machines provide the ability to take automatic exposures that are then unified to form a 3D image. This of course increases the patient exposure but can provide a better visualization of the needle position.

In summary, to reduce the total exposure to the patient and thus to the operating personnel, one should follow the principle of ALARA (as low as reasonably achievable) and AFAP (as far as possible) while using the fluoroscopy equipment.



**Figure 1.11** Number of pain-related articles with reference to imaging. Reprinted with permission from Rathmell JP. Imaging in regional anesthesia and pain medicine: we have much to learn. *Reg Anesth Pain Med.* 2002;27(3):240–241.

### *Radiation Safety Awareness Among Physicians*

In an editorial<sup>8</sup> in the journal *Regional Anesthesia and Pain Medicine*, Rathmell stressed the importance of proper usage of fluoroscopy in interventional pain medicine. He also noted the rise in awareness in the form of a number of pain-related articles being published with reference to imaging during the decade before this publication (Figure 1.11).

Because of serious radiographic-induced skin injuries that may have been caused by the inappropriate use of fluoroscopy during the performance of radiography-guided invasive procedures, the US Food and Drug Administration (FDA) issued an advisory in 1994 suggesting that the key to preventing such unfortunate mishaps may be physician education, training, and credentialing in the safe operation of fluoroscopic equipment.<sup>9</sup> As early as 1997 it was noted that physicians who performed radiography and fluoroscopy in the first half of the 20th century had higher rates of cancer-related deaths than any other physicians.<sup>10</sup> The American College of Radiology Guidelines suggests the following<sup>11</sup>:

The physician performing fluoroscopically guided procedures must have the following qualifications:

Certification in Radiology, Diagnostic Radiology or Radiation Oncology by the American Board of Radiology, the American Osteopathic Board of Radiology, the Royal College of Physicians and Surgeons of Canada, or the Collège des Médecins du Québec.

OR

Completion of a residency/fellowship program approved by the Accreditation Council for Graduate Medical Education (ACGME), the Royal College of Physicians and Surgeons of Canada (RCPSC), the Collège des Médecins du Québec, or the American Osteopathic Association (AOA) that includes 6 months of training in fluoroscopic imaging procedures. Documentation of the successful completion of didactic course lectures and laboratory instruction in radiation

physics, radiobiology, radiation safety, and radiation management applicable to the use of fluoroscopy, including passing a written examination in these areas.

OR

Be credentialed for specific fluoroscopically guided procedures. The following is recommended:

Physicians whose residency did not include radiation physics, radiobiology, radiation safety, and radiation management may still be considered as satisfying the qualifications if they have performed at least 10 procedures of each type for which they intend to use fluoroscopic guidance under the direction of a qualified physician who has met these standards and who certifies that the trainee meets minimum fluoroscopy safety standards. They must also have documented evidence of at least 4 hours of didactic course lectures and laboratory instruction in radiation physics, radiobiology, radiation safety, and radiation management applicable to the use of fluoroscopy, and should have satisfactorily passed an examination in these areas. Physicians who perform interventional vascular, cardiovascular, biliary tract, genitourinary tract, or neurological procedures should have at least 15 hours of didactic training in radiation physics, radiobiology, radiation safety, and radiation management applicable to the use of fluoroscopy, and have satisfactorily passed an examination in these areas.

### **Understanding Fluoroscopy and the Equipment**

Fluoroscopy is a unique imaging technology that uses x-ray radiation to visualize osseous structures with live imaging. It also uses significantly less radiation compared to regular x-rays or CT scans. It can provide live as well as still images. It has been used for decades but more recently it has been designed to be more portable in the form of a c-arm (so called due to the shape of the imaging elements in the form of a “C”). Fixed fluoroscopy had been in use for a long time and was commonly used for screening in cardiology and urology. Special fluoroscopy suites for cardiology, gastroenterology, and so forth, contain large ceiling-mounted units, sometimes in a biplanar configuration allowing live imaging in anteroposterior (AP) and lateral views of any angulation.

Portability is another advantage that allows the use of fluoroscopy in practically any location. The fluoroscopy machines have a flexible design with a c-arm that allows the unit to be positioned in nearly all configurations to obtain a biplanar image of the osseous structures. The portable units contain a command unit, which serves as the base of the machine, and a rotatable “arm” in the form of a “C” that allows quick change of the imaging position from anteroposterior (AP) to lateral or oblique views.

Newer machines with a “Super-C” can accommodate large-sized patients and can provide extreme oblique-angled views on both sides with little manipulation. Normally the units have two display monitors (usually LCD monitors in newer machines) placed on the control unit, and commonly the right-sided monitor displays the last image taken and held for comparison (LIH = last image hold). Images can be quickly sorted and displayed for comparison and are stored either on a local hard drive or a portable data storage device (USB drive, CD, DVD, etc.), or can be directly transferred to an electronic records system via Ethernet.