Atlas of Ultrasound-Guided Procedures in Interventional Pain Management

Second Edition

Samer N. Narouze
Editor

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ISBN 978-1-4939-7752-9 ISBN 978-1-4939-7754-3 (eBook)
https://doi.org/10.1007/978-1-4939-7754-3

Library of Congress Control Number: 2018941488

Printed on acid-free paper

This Springer imprint is published by the registered company Springer Science+Business Media, LLC part of Springer Nature.
The registered company address is: 233 Spring Street, New York, NY 10013, U.S.A.

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 not have completed this book.

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

Foreword

For much of the past decade, fluoroscopy held sway as the favorite imaging tool of many practitioners performing interventional pain procedures. Quite recently, ultrasound has emerged as a “challenger” to this well-established modality. The growing popularity of ultrasound application in regional anesthesia and pain medicine reflects a shift in contemporary views about imaging for nerve localization and target-specific injections. For regional anesthesia, ultrasound has already made a marked impact by transforming antiquated clinical practice into a modern science. No bedside tool ever before has allowed practitioners to visualize needle advancement in real time and observe local anesthetic spread around nerve structures. For interventional pain procedures, I believe this radiation-free, point-of-care technology will also find its unique role and utility in pain medicine and can complement some of the imaging demands not met by fluoroscopy, computed tomography, and magnetic resonance imaging. And over time, practitioners will discover new benefits of this technology, especially for dynamic assessment of musculoskeletal pain conditions and improving accuracy of needle injection for small nerves, soft tissue, tendons, and joints.

Ultrasound application for pain medicine is an evolving subspecialty area. Most conventional pain interventionists skilled in fluoroscopy will find it necessary to undertake some special learning and training to acquire a new set of cognitive and technical skills before they can optimally integrate ultrasound into their clinical practices. Although continuing medical educational events help facilitate the learning process and skill development, they are often limited in breadth, depth, and training duration. This is why the arrival of this comprehensive text, *Atlas of Ultrasound-Guided Procedures in Interventional Pain Management*, is so timely and welcome. To my knowledge, this is the first illustrative atlas of its kind that addresses the educational void for ultrasound-guided pain interventions.

Preparation of this atlas, containing 6 parts and 30 chapters and involving more than 30 authors, is indeed a huge undertaking. The broad range of ultrasound topics selected in this book provides a good, solid educational foundation and curriculum for pain practitioners both in practice and in training. Included is the current state of knowledge relating to the basic principles of ultrasound imaging and knobology, regional anatomy specific to interventional procedures, ultrasound scanning and image interpretation, and the technical considerations for needle insertion and injection. The ultrasound-guided techniques are described step-by-step in an easy-to-follow, “how to do it” manner for both acute and chronic pain interventions. The major topics include somatic and sympathetic neural blockade in the head and neck, limbs, spine, abdomen, and pelvis. Using a large library of black-and-white images and colored illustrative artwork, the authors elegantly impart scientific knowledge through the display of anatomic cadaveric dissections, sonoanatomy correlates, and schematic diagrams showing essential techniques for needle insertion and injection. The information in the last two chapters of this book is especially enlightening and unique and is not commonly found in other standard pain textbooks. One chapter describes how ultrasound can be applied as an extension of physical examination to aid pain physicians in the diagnosis of musculoskeletal pain conditions. With ultrasound as a screening tool, pain physicians now have new opportunities to become both a diagnostician and an interventionist. The last chapter discussing advanced ultrasound techniques for cervicogenic headache, stimulating lead placement, and cervical disk injection gives readers a glimpse of future exciting applications.

This book is a distinguished product carefully prepared by Dr. Samer Narouze, the editor, and his handpicked group of contributors from all over the world. The authors are all recognized opinion leaders in anesthesiology, pain medicine, anatomy, and radiology. I believe this quick reference book containing useful practical information will become a standard resource for any practitioner who seeks to learn ultrasound-guided interventional pain procedures for relief of acute, chronic noncancer, and cancer pain. I am sure the readers will find this atlas comprehensive, inspiring, practical, and easy to follow.

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Preface

Over the past decade, ultrasonography provided to be a valuable imaging modality in interventional pain practice. The interest in ultrasonography in pain medicine (USPM) has been fast growing, as evidenced by the plethora of published papers in peer-reviewed journals as well as presentations at major national and international meetings. This has prompted the creation of a special interest group on USPM within the American Society of Regional Anesthesiology and Pain Medicine, of which I am honored to be the chair.

The major advantages of ultrasonography (US) over fluoroscopy include 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 US guidance of soft tissue and joint injections brings great precision to the procedure and why ultrasound-guided pain nerve blocks improve its safety. That said, USPM is not without flaws. Its major shortcomings are the limited resolution at deep levels, especially in obese patients, and the artifacts created by bone structures.

While the evidence points to the superiority of US over fluoroscopy in peripheral nerves, soft tissue, and joint injections, it also suggests that we should not abandon fluoroscopy in favor of US in spine injections and should instead consider combining both imaging modalities to further enhance the goal of a successful and safer spine injection.

When I first started using US in pain blocks in 2005, there was no single text on the subject, and that remains true up until the first edition of this atlas in 2011. Most of my knowledge on the subject was gained from traveling overseas to learn from expert sonographers, radiologists, and anatomists. The rest was worked out by trial and error using dissected cadavers and confirming appropriate needle placement with fluoroscopy or CT scan. When I started teaching courses on USPM, the overwhelmingly enthusiastic response from students persuaded me of the need for a comprehensive and easy-to-follow atlas of US-guided pain blocks. That is how the first edition of this book – the first to cover this exciting new field – was born.

Recent research evaluating ultrasonography in interventional pain procedures, the development of new technique and applications, and the establishment of neurosonology necessitates this version of the atlas with many updated and new chapters as well as a new section on diagnostic neurosonologyNot surprisingly, an extensive learning curve is associated with US-guided pain blocks and spine injections. The main objective of this atlas is to enable physicians managing acute and chronic pain syndromes who are beginning to use US-guided pain procedures to shorten their learning curve and to make their learning experience as enjoyable as possible. Among the target groups are pain physicians, anesthesiologists, physiatrists, rheumatologists, neurologists, orthopedists, sports medicine physicians, spine specialists, and interventional radiologists.

I was fortunate to gather almost all of the international experts in US-guided pain blocks to contribute to this second edition of the book, each one writing about his or her area of subspecialty expertise, and for this reason, I am very proud of the book. Its central focus is on anatomy and sonoanatomy. The clinical section begins with a chapter devoted to anatomy and sonoanatomy of the spine written by my dear friend, Professor Dr. Moriggl, who is a world-class anatomist from Innsbruck, Austria, with special expertise in sonoanatomy. He is the only one who could have written such a chapter. Each clinical chapter follows this format: description of sonoanatomy accompanied by illustrations; detailed description of how to perform the procedure, beginning with the choice and application of the transducer, to how the needle is introduced, and finally, to how to confirm appropriate needle placement. This stepwise description of the technique is enhanced by sonograms both without labels and – to better understand the images – with labels.

The book comprises 34 chapters, organized into 7 parts, covering US-guided pain blocks in the acute perioperative and chronic pain clinic settings, US-guided MSK applications, as well as diagnostic neurosonology.

Part I reviews the imaging modalities available to perform pain procedures and the basics of ultrasound imaging. Two important clinical chapters cover the essential knobology of the ultrasound machine and how to improve needle visibility under US.

Part II is the largest and covers the sonoanatomy of the entire spine and spine injection techniques in the cervical, thoracic, lumbar, and sacral areas. All the different applications are well documented with simple illustrations and labeled sonograms to make it easy to follow the text.

Part III focuses on abdominal and pelvic blocks. It covers the now-famous transversus abdominis plane (TAP) block, celiac plexus block, and various pelvic and perineal blocks.

Part IV addresses peripheral nerve blocks and catheters in the acute perioperative period as well as peripheral applications in chronic pain medicine. Ultrasound-guided stellate and cervical sympathetic ganglion blocks are presented, as are peripheral nerve blocks commonly performed in chronic pain patients (e.g., intercostals, suprascapular, ilioinguinal, iliohypogastric, and pudendal). There is a new chapter on ultrasound-guided occipital nerve block.

Part V discusses the most common joint and bursa injections and MSK applications in pain practice. The chapters are written by world experts in the area of MSK ultrasound.Part VI is a new section on diagnostic neurosonology. This section discusses the new application of ultrasound as a diagnostic tool in the diagnosis of different peripheral nerve entrapment syndromes. There is also a chapter devoted to occipital nerve entrapment.Part VII covers advanced and new applications of ultrasound in neuromodulation and pain medicine and looks ahead to its future. Ultrasound-guided peripheral nerve stimulation, occipital stimulation, and groin stimulation are presented as innovative applications of US in the cervical spine area, namely, atlanto-axial joint injection and cervical discography. Given the multitude of vessels and other vital soft tissue structures compacted in a limited area, ultrasonography seems particularly relevant in the cervical area.

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 sonograms, 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 ultrasound technology and the range of possible clinical circumstances may give rise to other, more appropriate approaches in USPM. Until then, mastering the current approaches will take preparation, practice, and appropriate mentoring before the physician can comfortably perform the procedures independently. It is my hope that this book will encourage and stimulate all physicians interested in interventional pain management.

Akron, OH, USA Samer N. Narouze

Acknowledgments

In preparing *Atlas of Ultrasound-Guided Procedures in Interventional Pain Management*, I had the privilege of gathering highly respected international experts in the field of ultrasonography in pain medicine. I thank Dr. Chan, professor of Anesthesiology at the University of Toronto and past president of the American Society of Regional Anesthesiology and Pain Medicine (ASRA), for agreeing to contribute a chapter to this book. I also extend my sincere thanks to the founding members of the ASRA special interest group on ultrasonography in pain medicine, who are also my friends and colleagues, for contributing essential chapters in their areas of expertise: Dr. Eichenberger (Switzerland), Dr. Gofeld (Canada), Dr. Morrigl (Austria), Dr. Peng (Canada), and Dr. Shankar (Wisconsin).

My sincere thanks to Dr. Galiano and Dr. Gruber of Austria for contributing two chapters to the book – and for introducing me to ultrasound-guided pain blocks when I visited their clinic in Innsbruck in 2005. I also acknowledge my esteemed colleagues from the University of Toronto for their help and support: Dr. McCartney, Dr. Brull, Dr. Perlas, Dr. Awad, Dr. Bhatia, and Dr. Riazi.

I cannot thank enough my friends Dr. Huntoon (Mayo Clinic) and Dr. Karmakar (Hong Kong) for agreeing to contribute essential chapters despite their busy schedules. A special thank you to Dr. Ilfeld (UCSD) and Dr. Mariano (Stanford) for their help with the regional anesthesia section; Dr. Bodor (UCSF), Dr. Hurdle (Mayo Clinic), and Dr. Schaefer (CWRU) for their help with the musculoskeletal (MSK) section; and Dr. Samet (Northwestern University) for contributing the diagnostic neurosonology chapter.

I express my sincere thanks to all the Springer editorial staff for their expertise and help in editing this book and making it come to life on time.

I am very blessed that these experts agreed to contribute to my book, and I am very grateful to everyone.

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Part I

Imaging in Interventional Pain Management and Basics of Ultrasonography

Imaging in Interventional Pain Management

1

Marc A. Huntoon

Introduction

Interventional pain procedures are commonly performed either with image-guidance fluoroscopy, computed tomography (CT), or ultrasound (US) or without image guidance utilizing surface landmarks. Recently, three-dimensional rotational angiography (3D-RA) suites also known as flat detector computed tomography (FDCT) or cone beam CT (CBCT) and digital subtraction angiography (DSA) have been introduced as imaging adjuncts. These systems are indicative of a trend toward increased use of specialized visualization techniques. Pain medicine practice guidelines suggest that most procedures require image guidance to improve the accuracy, reproducibility (precision), safety, and diagnostic information derived from the procedure [1]. Historically, pain medicine practitioners were slow adopters of image-guidance techniques, largely because the most common parent specialty (anesthesiology) had a culture of using surface landmarks to aid the perioperative performance of various nerve blocks and vascular line placements [2]. Indeed, some pain medicine practitioners in the 1980s and early 1990s felt that studies advocating the inaccuracy of epidural steroid injections performed with surface landmarks [3] were published more for specialty access than to increase patient safety or improve outcomes.

Ultrasound has recently exploded in popularity for perioperative regional blockade, but utilization of other imaging modalities in the perioperative arena, e.g., fluoroscopy, has lagged behind, despite more accurate placements compared to surface landmark-driven placements [2]. Technology acquisition costs and the physician learning required to master the new technologies are significant barriers to full implementation of many advanced imaging systems. However, the increasing national focus on safety in clinical medicine may ultimately mandate the use of optimal image guidance for selected procedures. In most cases, studies are lacking to compare the various types of image guidance in terms of patient outcomes, safety, and cost value for specific procedures. This is further complicated by the fact that many procedures in pain medicine have been considered poorly validated for the conditions being treated [4–6]. Thus, it may not matter if a particular image-guidance technique improves the reliability of a given procedure, if that procedure ultimately loses favor due to poor evidence or lack of evidence. Whether high-technology imaging brings safety and/or cost savings to the performance of evidence-based pain procedures is, thus, of paramount importance. The risks of the image guidance must also be considered as part of any imaging technology that is felt to be necessary for routine use. For example, a risk/benefit ratio of CT scanning relative to an equally suitable alternative technique may force physicians to use the lesser technology in some cases. CT as a diagnostic tool has come under greater scrutiny with the recent publication of several trials depicting the meteoric rise in the annual performance of CT scans (now over 72 million per year) and the large doses of radiation received by adults and particularly children [7]. Cancer risk from CT radiation has been modeled after longitudinal studies of cancer occurrences in atomic bomb survivors [8]. Now, it seems that the risk of cancer is something that should be more actively considered when CT is utilized. Radiation risks are not trivial and likely amount to about 14,000 or more future cancer deaths as a consequence of year 2007 CT scans [7]. For those treating patients with chronic pain, one needs to merely consider how many patients with an elusive diagnosis receive advanced imaging in efforts to find the cause of that pain. Thus, repeating imaging studies with a fairly low yield may actually be harming our patients. Ultrasound guidance, the focus of this atlas, has many advocates for these same radiation safety issues [9]. The use of ultrasound, however, is limited in many obese or larger adults [10], and the cost of some

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S. N. Narouze (ed.), *Atlas of Ultrasound-Guided Procedures in Interventional Pain Management*,
https://doi.org/10.1007/978-1-4939-7754-3_1

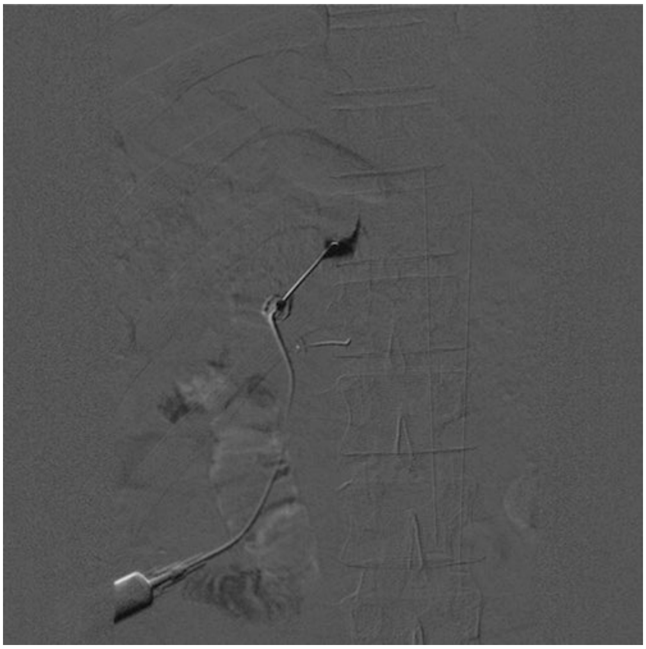

Fig. 1.1 A digital subtraction image of a thoracic dorsal root ganglion contrast injection at T11 prior to pulsed radiofrequency. Note that the contrast spreads medial to the pedicle. Below, a second needle has been placed at the pedicle of T12 just inferior to the sagittal bisector

advanced systems capable of rendering deeper structures with high clarity can surpass the cost for fluoroscopes in some cases. The use of imaging modalities such as 3D-RA and DSA is being advocated by others. While a FDCT suite is extremely expensive, DSA is actually a relatively inexpensive add-on to a conventional fluoroscope that may have a substantial role in the safe performance of transforaminal epidural steroid injections [11]. For example, when performing injections or other procedures in critical areas, such as the left T11 and T12, the territory of the great segmental medullary artery of Adamkiewicz, digital subtraction can demonstrate vascular uptake more clearly (Fig. 1.1). Chapter 2 focuses on the limited studies currently present in the literature, with suggestions for areas where one imaging modality may have certain advantages over another. Ultimately, further study will be necessary to ascertain the most safe, accurate, and cost-effective practices for image-guided procedures.

C-Arm FDCT

Most pain procedures require cross-sectional or 3D soft tissue imaging to accurately target structures in a complex anatomical landscape. Very few procedures are intended to target bony structures, with the exception of such procedures as vertebral and sacral augmentation, bone biopsies, and a few others. Yet, fluoroscopy remains the most popular imaging method, for primarily soft tissue targets, despite its limitations. Intradiscal procedures, vertebral augmentation, neuromodulation procedures, and deep abdominopelvic and head and neck blocks may be examples of some procedures where a limited CT scan capability (FDCT) would enhance the accuracy and safety of the procedure as compared to plain fluoroscopy. C-arm FDCT and C-arm CBCT utilize different gantries but are nearly synonymous terms for a modern 3D imaging system that can also integrate 2D data from fluoroscopy, sometimes US, and DSA in a single suite. Interventional radiologists and some pain physicians are using these advanced image-guidance systems to aid procedural performance in certain cases, with an expanding list of potential indications. FDCT is accomplished via a single rotation of the fluoroscope gantry, rendering a complete volumetric data set using a flat panel detector. These flat panel detectors have significantly better resolution than older image intensifiers. This is in contrast to conventional CT which uses multiple detectors and requires several rotations of the gantry, with the patient being moved into the CT scanner [12]. With FDCT, the patient is stationary through the imaging cycle. CT images do take approximately 5–20 s to be acquired; thus this is not a true real-time CT fluoroscopy procedure. Images from FDCT scanning have lower resolution due to scattered radiation, but in many cases the lower resolution images are more than adequate for the intended procedure. However, during the 200° gantry rotation of a FDCT system, experiments have shown that radiation doses are less than that for a single helical CT [12]. Carefully limiting the field of scanning will decrease radiation dose to the patient and improve image contrast. CBCT units may have significant application for intraoperative minimally invasive surgical applications. Surgeons using CBCT for minimally invasive spine procedures tended to want to utilize the higher technology of the CBCT in their cases in an escalating fashion with increasing exposure to the new technology [13].

Many creative interventionalists are adapting the FDCT capability to new procedures, such as diskography, without the need for a postprocedural standard CT (Figs. 1.2 and 1.3). In diskography, it is usual and customary to perform contrast injections into the presumed diseased disk as well as a control disk. A postprocedural delayed CT image to better quantitate annular tears and contrast leak into the spinal canal is considered standard. CBCT technology may allow these CT images to be performed in the same suite, saving time and expense. This “single-suite” concept for specific blocks can also save on radiation exposure for both the patient and the physicians.

Deep plexus blocks such as celiac or superior hypogastric plexus blocks may benefit from the ability to better quantitate the spread of injected contrast in multiple planes. Potentially, factors such as local tumor burden or lymphadenopathy that limit the spread of the contrast and neurolytic solution may be noted earlier with these advanced imaging

Fig. 1.2 A sagittal CT view of a two-level diskogram. Note an annular tear at L5/S1 with epidural extravasation

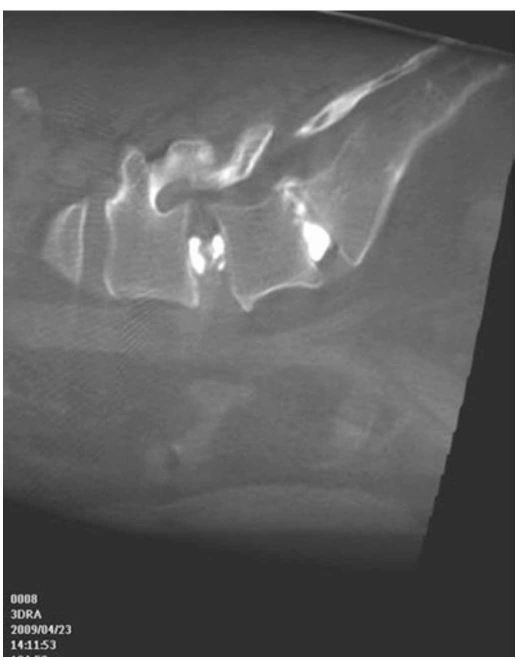

Fig. 1.3 Compare similar FDCT/3D-RA sagittal diskogram in the same patient as above. The epidural extravasation is seen again

techniques. For example, Goldschneider et al. [14] performed celiac plexus blocks in children utilizing 3D-RA to show the benefits of examining contrast spread in three dimensions. Similarly, superior hypogastric blocks (Fig. 1.4a–c) have added detail when a 3D image is rendered. In another recent report [15], Knight et al. performed vertebroplasty in a patient with a retropulsed bone fragment in the spinal canal, normally at least a relative contraindication. The authors utilized FDCT technology to visualize these areas during injection of the polymethyl methacrylate cement and avoid spinal cord injury [15]. Neuromodulation, particularly spinal cord stimulation, may be more easily targeted in some cases with FDCT technology. The anterior or lateral movement of the electrodes could more easily be seen, eliminating the need for multiple repositionings of the electrode and needle in the epidural space. The utilization of FDCT/CBCT/3D-RA technology to better treat patients seems to be limited only by one's imagination.

Ultrasound

Ultrasound has become extremely popular in acute pain block procedures, and chronic pain practitioners are slowly adopting ultrasound as both a diagnostic and image-guided block aid. Chronic pain procedures may include nerve blocks (such as the brachial or lumbar plexus) commonly performed in an acute perioperative nerve block suite but also may require image-guided injection of more distal branches of the plexus or at less common locations (proximal to sites of trauma or entrapment or neuroma formation). Blockade of various small sensory or mixed nerves, such as the ilioinguinal [16, 17], lateral femoral cutaneous [18], suprascapular [19], pudendal [20], intercostal [21], and various other sites, has been performed. In addition, many spinal procedures including epidurals, selective spinal nerve blocks [22, 23], facet joint, medial branch blocks, and third occipital nerve blocks [24, 25], as well as sympathetic blocks (stellate ganglion) [26] may be performed. Finally, a broad array of possible applications for peripheral neuromodulation electrode placement may be possible with ultrasound guidance [27] (see Chap. 26).

Intra-Articular Injections

Intra-articular injections of medications (primarily corticosteroids) are extremely common procedures performed by physicians from primary care disciplines as well as specialists. While few would dispute that these procedures are easy to do and very accurate, whether image guidance can improve the outcome of intra-articular procedures was not specifically known. A recent study of intra-articular injections suggests that these may be one area where the use of image guidance is useful [28]. The study of 148 painful joints (shoulder, knee, ankle, wrist, hip) compared the use of US guidance to a surface landmark-based injection. The authors

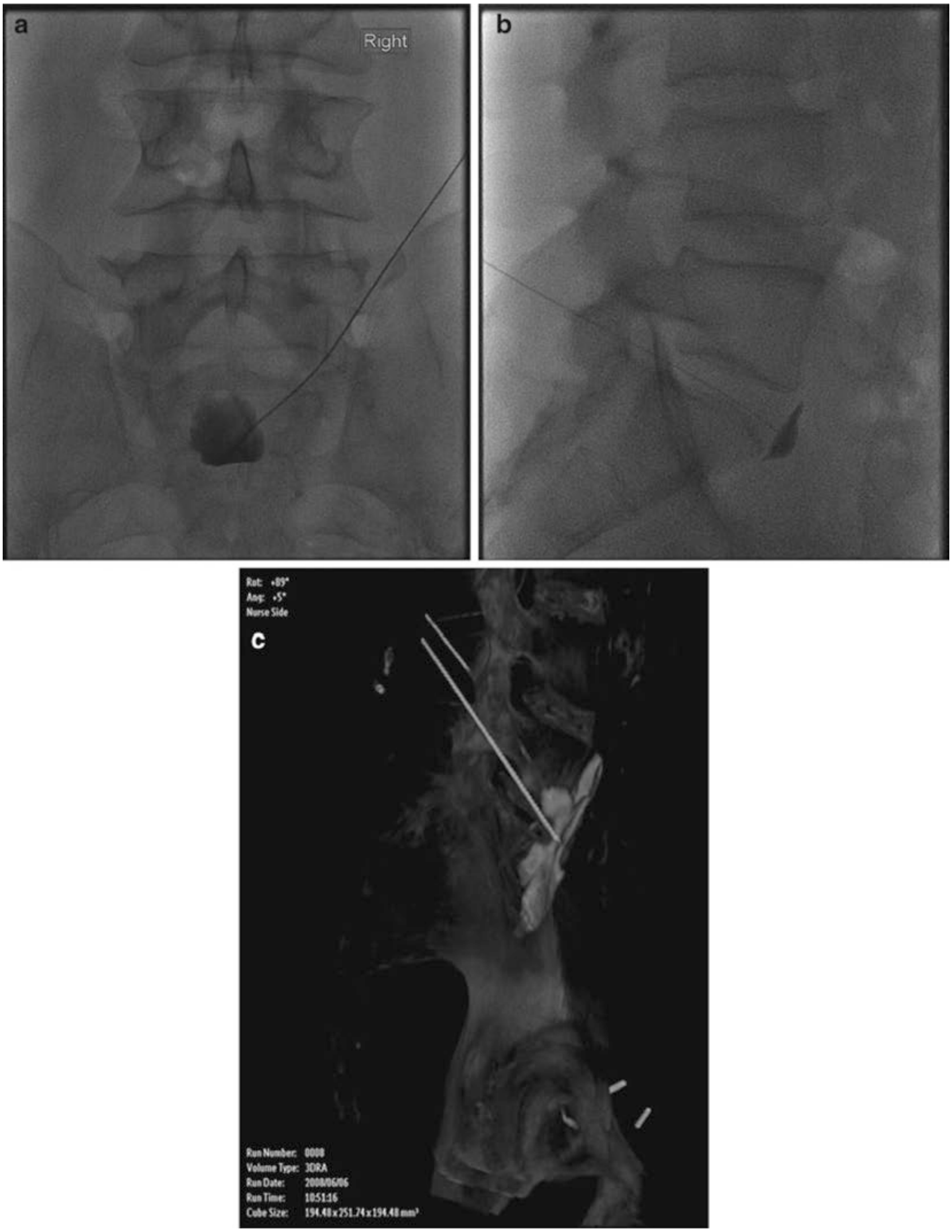

Fig. 1.4 (**a**) AP view of fluoroscopic superior hypogastric plexus block, (**b**) lateral view of superior hypogastric plexus block, and (**c**) 3D-RA view of contrast in three dimensions

found that the use of US led to a 43% decrease in procedural pain, a 25.6% increase in the rate of responders, and a 62% decrease in the nonresponder rate. Sonography also increased the rate of detection of effusion by 200% as compared to the use of surface landmarks. None would dispute that the use of image guidance would add to the cost of the actual procedures. However, health-care economics studies would be required to ascertain whether the improved outcomes would lead to better health-care value viewed through a long-term perspective.

Trigger Point and Muscular Injections

The performance of most deep muscular and trigger point injections has been relegated to a trivial office-based procedure, generating little enthusiasm from the interventional pain community. Image guidance (fluoroscopy) for these soft tissue structures was not helpful, and many physicians considered the performance of the procedures to be "the art of medicine." However, the addition of ultrasound may be changing the way one views these procedures. Certainly, it is easy to see how a target such as the piriformis muscle could be identified more accurately using US. It is likely that fluoroscopic techniques may actually mistake the gluteal or quadratus femoris muscles on occasion. In addition, the anatomic variability and proximity of neurovascular structures, including the sciatic nerve, make visualization important. US also allow the use of a diagnostic exam (hip rotation) to aid in the proper identification of the muscle (Fig. 1.5). Studies to date suggest that the piriformis muscle is easily injected using this modality [29]. Other muscular targets such as trigger points have been targeted using US guidance [30]. Pneumothorax is an all too frequent complication of thoracic area trigger points. In the 2004 ASA Closed Claims Project, 59 pneumothorax claims were filed. Of this 59, fully half (23 intercostal blocks and 1 costochondral injection) would likely have been preventable under US guidance. Additionally, 15 of the cases were trigger point muscular injections which would likely be preventable as well. Together, at least 2/3 of the pneumothorax claims (and likely even more) could be prevented with better imaging [31].

.Whether the use of US or another imaging technique is justified in all cases by the avoidance of complications may depend on a more accurate depiction of the true incidence of complications and better outcome data. Certainly, it may be true that positive responses could be more accurately replicated in some cases.

Zygapophyseal and Medial Branch Blocks

One of the better studies of ultrasound guidance in pain medicine evaluated third occipital nerve block procedures and peaked interest in US for many in the pain medicine community [24]. The third occipital nerve had been suggested as a therapeutic target for conditions, including high-cervical spondylosis and cervicogenic headaches, and as a predictor of success for radiofrequency ablative procedures. In that study, the accuracy of US guidance compared to that of fluoroscopy was good, with 23 of 28 needles demonstrating accurate radiographic positioning [24]. Fluoroscopic procedures targeting the third occipital nerve around the C2/C3 zygapophyseal joint have been performed utilizing three sequential needle placements. These fluoroscopy-guided placements have been very accurate but suffer from the inability to actually see the targeted nerve. Whether US is superior in some way to standard fluoroscopy remains to be tested.

Fig. 1.5 A dynamic exam is depicted wherein the piriformis muscle (P) is contracted

Epidural Blocks

Epidural techniques including interlaminar, caudal, and selective spinal root blocks have been studied in limited fashion utilizing ultrasound guidance. Fluoroscopy techniques are extremely easy and generally use small amounts of radiation; thus the advocates for US will need to perform comparative studies to demonstrate any particular advantages. Caudal procedures are perhaps most promising in this regard.

Caution should be exercised until mechanisms of ischemic injury during transforaminal epidural procedures are better understood. Lack of a contrast control in US in spite of "extraforaminal" vascular structure visibility is the most significant drawback. Even CT scanning is not foolproof for cervical transforaminal corticosteroid injections [11, 22, 23].

Sympathetic Blocks

Sympathetic blocks have been studied in limited fashion with ultrasound guidance. Stellate ganglion block (SGB) was performed at C6 anterior to Chassaignac's tubercle based on surface landmarks for years prior to modern fluoroscopy techniques which have become the standard of care in most regions. A recent analysis of 27 previously reported cases of retropharyngeal hematoma after SGB emphasized the potential for delayed bleeding and hematoma formation [32]. Although image-guided techniques were not described in this review, aspiration of blood was negative in all but four cases requiring needle redirection. One of the earliest papers examining US guidance was by Kapral et al. [26]. In this study, the nonultrasound group had three hematomas. The authors theorized that the vertebral artery might be more likely to be involved in left-sided injections. They and other researchers have raised the possibility of other arteries at

Table 1.1 Comparison of relative attributes of various imaging techniques

Procedure	Guidance	+Attributes	Problems
Sympathetic blocks			
Stellate ganglion	Fluoroscopy	Contrast use	Soft tissues not seen
	US	Visualize vessels, fascia/muscle	Advanced skills needed
Celiac plexus	Ct, FDCT	3D anatomy in cross section	Delayed contrast, increased radiation
	Fluoroscopy	Real-time contrast	No 3D imaging
Epidurals			
Caudal	Fluoroscopy	Lateral view	Minimal, radiation
	US	Real-time contrast	Contrast flow
		Needle visualization	
		No radiation	
Lumbar TF	Fluoroscopy	Real-time contrast	Missed vascular injection
	DSA	Vessel detection	Equipment availability
	US	No role	Obesity
			Poor visualization
Lumbar IL	Fluoroscopy	Contrast use	Minimal radiation
	US	Needle entry	Poor contrast
Cervical TF	Fluoroscopy	Real-time contrast	Miss vascular injection
	DSA	Vessel detection	Equipment availability
	US	Vessel detection	Contrast flow
	CT	3D anatomy	Radiation increased
		Vertebral artery visible	Small vessels missed
Lumbar medial branch block	Fluoroscopy	Easy, contrast use	Small
	US	Fair visual	Obese patient technically difficult
Cervical medial branch block	Fluoroscopy	Easy, contrast use	Small
	US	Fair visual	Obese, technically difficult
Lumbar facet joint	Fluoroscopy	Easy, contrast use	Small
	US	Feasible	Obesity
Cervical facet joint	Fluoroscopy	Contrast	Difficult
	US	Feasible	Advanced

CT computed tomography, *DSA* digital subtraction angiography, *FDCT* flat detector computed tomography, *US* ultrasound, TF transforaminal epidural risk, specifically, the ascending cervical branch off the inferior thyroid artery, which commonly passes over the C6 anterior tubercle [33]. No head-to-head comparison studies of ultrasound vs. CT or fluoroscopy for SGB have yet been performed. The advantages of ultrasound would seem to be avoidance of vascular or soft tissue injuries. The advantages of fluoroscopy or CT would appear to be ease of interpreting contrast spread patterns and better representation of 3D anatomy in the case of CT.

Combined US and CT/Fluoroscopy

The use of combinations of these imaging modalities has had limited study to date but may have some indications as time and experience accumulate. For example, peripheral nerve stimulation may be best accomplished with US and FDCT or US and fluoroscopy [27]. It is possible that combined imaging techniques of US-fluoroscopy, CT-fluoroscopy, and US/CT and other combined techniques may become normalized in particularly complicated procedures.

Conclusion

The future of image guidance for pain medicine interventions must balance risk to the patient and clinician from ionizing radiation, risks of procedural complications, outcomes, and relative value. Although ultrasound imaging is feasible in many instances, best practice may favor fluoroscopy or CT in some cases. Ultrasound appears to have advantages for musculoskeletal diagnosis and therapy for some joint and soft tissue conditions, procedures where the peritoneum or pleura may be punctured, deep muscle injections, most peripheral nerve procedures, possibly SGB, possibly caudal epidurals, and perhaps equivalency for sacroiliac joint and some medial branch blocks. Other uses will require ongoing comparison to other image-guidance techniques. The following table compares the relative attributes of various imaging techniques and points out areas where one image-guidance modality may have unique advantages relative to another (Table 1.1).

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