NEW TECHNIQUES IN INTERVENTIONAL MUSCULOSKELETAL RADIOLOGY

Edited by
Mark E. Schweitzer
Jean-Denis Laredo
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Mark E. Schweitzer
New York University School of Medicine
New York, New York, USA

Jean-Denis Laredo
Lariboisière Hôpital
Denis-Diderot Paris VII University
Paris, France
While thinking about this book, several thoughts came to mind. The first concerns the importance of procedures in musculoskeletal radiology. Not superficially related to this, but nonetheless important in understanding the relevance of procedures, is politics. Allow me to explain.

Several authorities have commented that radiology has many more subspecialty societies than almost any other specialty. They have suggested that this dilutes the political interests of radiology and ultimately may be the seed of its demise and the dissemination of the field into the various clinical specialties that use its services.

On the other hand, the vibrancy of these subspecialties confirms the complexity of radiology and the importance of radiology to the clinical disciplines each of us interacts with every day. This interaction is what enhances the vigor of radiology and, for the authors of this book, the vigor of musculoskeletal radiology. Being in tune to your customers, while understanding imaging technology and three dimensional anatomy, allows us to be intellectually agile.

This intellectual agility of musculoskeletal radiology has led to the rapid evolution of this field within the last decade to decade and a half. We, the editors, consider ourselves fortunate to be on the cusp of this froth and to see the rapid changes that have occurred in musculoskeletal radiology over a relatively short period of time. We have rapidly transitioned from a subspecialty that is predominantly filmed to one that is more dependent, and in some ways codependent, on advanced imaging.

Interestingly, in this rapid evolution there has been no single disruptive technology. All that we’ve done is build on what we have done in the past and our understanding of what new technologies will allow us to do. This brings us to interventional procedures. There is a confluence here: three dimensional imaging and advances in percutaneous and minimally invasive tools combined with a better understanding of the natural history of disease and medical interventions the growth of MR and ultrasound has allowed us to obtain.

As a subspecialty we have progressed in less than two decades from a field where we were mostly limited to arthrography for our musculoskeletal procedures to today, where interventional radiologic techniques and procedures form the largest component of our daily work. This is the focus of this book.

This book is an attempt, hopefully successfully, to put together many experts in different specific procedures within radiology and to allow them to describe, in detail, the when, the where, the why, and the how of these procedures. We have done this in a detailed way for a sophisticated audience. We have also tried, in the beginning of the book, to add some background information about procedures that is not readily available: the histologic evaluation of tumors, the pharmacokinetics of local anesthetics, as well as several others. Each chapter following this is devoted to a specific procedure, which is covered in detail. We have selected not only the procedures that are most commonly used, but also procedures that are less commonly used, as those procedures may be more frequently used in the future.

Each of the chapter authors has done an outstanding job in bringing together this material. The politics of whether the growth of subspecialties within radiology is good or not aside, procedures are, to a large degree, where musculoskeletal radiology is heading. Because of the dependence upon imaging both for localization as well as assessment of therapeutic outcomes, we are confident that this material will remain within the confines of radiology, and it is our hope and belief that, in the future, they will be an even more important part of the subspecialty of musculoskeletal radiology.
We are reminded of a quote by a friend of ours—“I did not become a radiologist to be a doctor”—which to some would be the way bone radiology was practiced 20 years ago. Now the specialty has turned 180 degrees towards patient care. Leaving the humor of that quote aside, this is what many of us now do. We hope that our readers enjoy this book and are able to treat patients better because of it. That would make the labor that all these chapter authors have undertaken so well all the more worthwhile.

Mark E. Schweitzer
Jean-Denis Laredo
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Contributors

Gerhard Adam  Department of Diagnostic and Interventional Radiology, University Hospital Hamburg Eppendorf, Hamburg, Germany

Ronald S. Adler  Division of Ultrasound and Body Imaging, Hospital for Special Surgery, Department of Radiology and Imaging, Weill Medical College of Cornell University, New York, New York, U.S.A.

Francesco Aparisi  University Hospital La Fe and Nueva de Octubre Valencia, Valencia, Spain

Nathalie Azoulay  Department of Bone and Joint Radiology, Lariboisière Hôpital, Assistance Publique-Hôpitaux de Paris, Paris, France

Laurence Bellaïche  Department of Bone and Joint Radiology, Lariboisière Hôpital, Assistance Publique-Hôpitaux de Paris, Paris, France

Arno Bücker  Department of Diagnostic Radiology, University of Technology, Aachen, Germany

Xavier Buy  Department of Radiology B, University Hospital of Strasbourg, Strasbourg, France

John A. Carrino  Department of Radiology and Radiological Science, Johns Hopkins University School of Medicine, Baltimore, Maryland, U.S.A.

Luc Ceugnart  Service de Radiologie, Centre Oscar Lambret, Lille, France

Pierre Champsaur  Department of Radiology, La Timone Hospital, Marseille, France

René Chapot  Department of Neuroradiology, Krupp Krankenhaus, Essen, Germany

Hélène Chiavassa  Department of Radiology, Purpan University Hospital, Place du Docteur Baylac, Toulouse, France

James J. Choi  Department of Radiology, University of Wisconsin, Madison, Wisconsin, U.S.A.

Anne Cotten  Service de Radiologie Ostéoarticulaire, Hôpital R. Salengro, Lille, France

Kirkland W. Davis  Department of Radiology, University of Wisconsin, Madison, Wisconsin, U.S.A.

Xavier Demondion  Service de Radiologie Ostéoarticulaire, Hôpital R. Salengro, Lille, France

Damian E. Dupuy  The Warren Alpert Medical School of Brown University and Rhode Island Hospital, Providence, Rhode Island, U.S.A.

Robert G. Dussault  Musculoskeletal Radiology, Laennec Radiology, Montreal, and Reso-Concorde MRI, Laval, Quebec, Canada

Odile Enjolras  Department of Neuroradiology, Lariboisière Hôpital, Assistance Publique-Hôpitaux de Paris, Paris, France

Erik Estivalezes  Department of Radiology, Purpan University Hospital, Place du Docteur Baylac, Toulouse, France
Contributors

Denise Galy  Department of Radiology, Purpan University Hospital, Place du Docteur Baylac, Toulouse, France

Afshin Gangi  Department of Radiology B, University Hospital of Strasbourg, Strasbourg, France

Bruno Grignon  Guillouz Department of Radiology, University Hospital of Nancy, Nancy, France

Rolf W. Günther  Department of Diagnostic Radiology, University of Technology, Aachen, Germany

Stephane Guth  Department of Radiology B, University Hospital of Strasbourg, Strasbourg, France

Bassam Hamzé  Department of Bone and Joint Radiology, Lariboisière Hôpital, Assistance Publique–Hopitaux de Paris, Paris, France

Jean Pierre Imbert  Department of Radiology B, University Hospital of Strasbourg, Strasbourg, France

Phoebe A. Kaplan  Musculoskeletal Radiology, Laënnec Radiology, Montreal, and Reso-Concorde MRI, Laval, Quebec, Canada

David Karasick  Department of Radiology, Thomas Jefferson University Hospital, Philadelphia, Pennsylvania, U.S.A.

Philip Lander  Department of Radiology, University of Alabama at Birmingham, Birmingham, Alabama, U.S.A.

Jean-Denis Laredo  Department of Bone and Joint Radiology, Lariboisière Hôpital, Assistance Publique–Hopitaux de Paris, Paris, France

William B. Morrison  Department of Radiology, Thomas Jefferson University Hospital, Philadelphia, Pennsylvania, U.S.A.

Jörg Neuerburg  Department of Diagnostic Radiology, University of Technology, Aachen, Germany

Brian J. O’Hara  Department of Pathology, Anatomy, and Cell Biology, Thomas Jefferson University Hospital, Philadelphia, Pennsylvania, U.S.A.


Caroline Parlier-Cuau  Department of Bone and Joint Radiology, Lariboisière Hôpital, Assistance Publique–Hopitaux de Paris, Paris, France

Jean-Jacques Railhac  Department of Radiology, Purpan University Hospital, Place du Docteur Baylac, Toulouse, France

Daniel I. Rosenthal  Division of Musculoskeletal Radiology, Department of Radiology, Massachusetts General Hospital, Boston, Massachusetts, U.S.A.

Leon Rybak  Department of Radiology, New York University/Hospital for Joint Diseases, New York, New York, U.S.A.

Nicolas Sans  Department of Radiology, Purpan University Hospital, Place du Docteur Baylac, Toulouse, France

Mark E. Schweitzer  New York University School of Medicine, New York, New York, U.S.A.

Jeff S. Silber  North Shore/LIJ Health System, New Hyde Park, New York, U.S.A.
Contributors

Pascal Swider  Department of Radiology, Purpan University Hospital, Place du Docteur Baylac, Toulouse, France

Anthony C. Toppins  Section of Musculoskeletal Radiology, Baylor University Medical Center, Dallas, Texas, U.S.A.

Martin Torriani  Division of Musculoskeletal Radiology, Department of Radiology, Massachusetts General Hospital, Boston, Massachusetts, U.S.A.

Alexander R. Vaccaro  Department of Orthopedics-Spine Division, Rothman Institute, Thomas Jefferson University, Philadelphia, Pennsylvania, U.S.A.

Michel Wassef  Department of Pathology, Lariboisière Hôpital, Assistance Publique–Hopitaux de Paris, Paris, France

Dominik Weishaupt  Institute of Diagnostic Radiology, University Hospital, Zurich, Switzerland

Lisa Wong  Department of Radiology B, University Hospital of Strasbourg, Strasbourg, France

Marc Wybier  Department of Bone and Joint Radiology, Lariboisière Hôpital, Assistance Publique–Hopitaux de Paris, Paris, France
INTRODUCTION

Adequate sedation for percutaneous musculoskeletal procedures requires a combination of patient information and reassurance, local anesthesia, and conscious sedation (1–4).

LOCAL ANESTHESIA

Local anesthetics are divided into ester- and amide-type agents. Ester agents include procaine, chloroprocaine, cocaine, and tetracaine. Amide-type agents include lidocaine, bupivacaine, mepivacaine, and etidocaine. Ester agents are hydrolyzed by plasma pseudocholinesterase. Amides undergo transformation through aromatic hydroxylation in the liver (3).

The mechanism of action of local anesthetics is by diffusion of the base form of the agent across the nerve sheath and membrane. Binding of the agent to the nerve receptor site results in inhibition of Na\(^{2+}\) transfer. The fastest-acting local anesthetics include chloroprocaine, mepivacaine, lidocaine, and etidocaine. Etidocaine is the strongest, mepivacaine is the weakest, and lidocaine is intermediate in potency. Bupivacaine is an amide agent similar to lidocaine, but lasts up to three times longer and is up to four times more potent (4).

Allergies to the local anesthetics are rare and are usually specific to ester-type agents. These allergic patients can usually be given amide-type agents because cross-reactivity between local anesthetics is rare. A true history of allergy will include the development of hives, wheezing, cardiac arrest, or shock. Most patients who claim a local allergy often have really had an adverse reaction. Symptoms of palpitations and nervousness may be a response to an additive such as Paraben or epinephrine. Patients may be describing the sequelae of inadvertent intervascular injections (4).

Lidocaine is the most commonly used amide-type agent. The maximum subcutaneous dosage of lidocaine is 7 mg/kg or less than 500 mg in a healthy adult. Two percent lidocaine contains 20 mg/mL; therefore, the maximum dose in the 70-kg adult is 25 mL of 2%, or 50 mL of 1% lidocaine. As a general rule, 2% lidocaine is preferred except when the clinical question is infection, where 1% is utilized. The lidocaine effects usually last for approximately 0.5 to 1 hour, but may be prolonged in elderly patients or those with liver failure (5).

Local anesthetics work best for soft tissue analgesia, but do not work well for intramedullary processes. The pain in the latter situation is caused by focal, local increase in intramedullary pressure. This occurs because when a needle enters the medullary cavity, it displaces local tissues. To ease this situation, a large amount of local anesthetic is given to the periosteum by scraping the local needle against the surface of the bone, as well as intravenous (IV) analgesia and patient reassurance.

Local anesthesia should be given prior to making the dermatomy. Before creating a skin wheal, anesthesia should be given a little deeper because the creation of the wheal is in itself somewhat painful. To test the adequacy of the skin anesthesia, we probe with the tip of the scalpel, touching the skin’s surface without causing bleeding.

When using local anesthetics in areas of wounds, particularly devitalized areas, the lower local tissue pH decreases the lidocaine efficacy. This should be taken into consideration when using local anesthesia for percutaneous biopsies of suspected osteomyelitis in devitalized patients (6).

One should also pay careful attention to the indication for biopsy and the potential bacteriostatic or bactericidal effect of local anesthetics. This is particularly true when the indication for a biopsy is potential infection. Although the dose causing a bactericidal effect is quite large,
and even the doses required for a bacteriostatic effect are fairly large, when doing a procedure for possible infection, IV sedation should be maximized and the use of local anesthesia should be minimized. That is also why 1% lidocaine is preferred when biopsying potential infections (7).

Epinephrine may be added to local anesthetics to cause local tissue vasoconstriction and consequently limit the uptake of the local anesthetic. Epinephrine should not be used in a patient who has a history of unstable angina pectoris and cardiac arrhythmia, or when performing a peripheral procedure on the fingers or toes.

**CONSCIOUS SEDATION**

The definition of conscious sedation is a state of depressed mentation achieved with a combination of amnesic, anxiolytic, and analgesic medications (8). Patients should retain the ability to protect their airway and respond appropriately to physical and verbal stimuli. Conscious sedation should result in mood alterations, amnesia, enhanced patient cooperation, and elevated pain thresholds. Patients should, however, maintain stable vital signs and have a rapid recovery (9,10).

Conversely, deep sedation is the controlled state of depressed consciousness with partial or complete loss of protective reflexes. Specific manifestations of deep sedation include the loss of ability to respond voluntarily to verbal or physical commands. This unconsciousness and unresponsiveness are not objectives of conscious sedation. Deep sedation may predispose a patient to respiratory depression, decreased response to fourth and a hypoxic stimulus, and cardiovascular depression (11,12).

Before giving sedation, it is important to understand four effects of IV anesthesia medications. The first is pain or analgesia relief (13). The second is amnesia, with loss of memory of the procedure. The third is sedation and relaxation (1). Part and parcel of sedation is an anxiolytic effect (14,15). Fourth and potentially fifth, there is hypotonia with loss of muscle tone and cardiorespiratory depression. The goal of conscious sedation is to maximize the first four effects, without significantly depressing cardiopulmonary function (16,17).

True conscious sedation is best achieved by a combination of narcotics, usually opiates and sedatives/hypnotics. Opiates provide analgesia by blocking the nerve response to painful stimuli, and anesthesia by causing drowsiness. Because of these effects, the shortest-acting opiates are ideal agents for percutaneous musculoskeletal procedures (18,19).

**Opiates**

Opiates are a class of drugs derived from the papaver somniferum and are used primarily for analgesia. Natural opiates contain up to 20 different alkaloids. Opiates can be natural, modified, or completely synthetic (19).

Patients with renal failure may have a prolonged ventilatory depression effect due to morphine and other opiates, particularly those excreted by the liver. As an overall rule, there are limited cardiovascular effects of opioids on occasion, but they may cause a dose-dependent bradycardia. Note should be made of the synergistic effect of benzodiazepams and opiates. There have been over 80 deaths directly attributed to these two medications in the setting of conscious sedation.

The shorter half-life opiates include morphine (about two hours), sufentanil (two to three hours), and meperidine (three to four hours). Only morphine and meperidine can be given orally. Although the agents described above have similar half-lives, the onset of action for fentanyl is much shorter than for morphine, with effects seen as early as 30 seconds after IV administration. Although fentanyl has a longer total elimination half-life, the duration of action is shorter than morphine. Fentanyl’s increased total elimination time is related to its fairly high lipid solubility.

Fentanyl has a duration of action of 0.5 to 1 hour and is more potent than morphine. It also has less negative cardiovascular and gastrointestinal effects than morphine. One hundred milligrams of fentanyl is approximately equivalent to 10 mg of morphine or 75 mg of demerol.

Fentanyl is administered intravenously and we begin with a dose of approximately 12.5 to 25 mg. Similar to other opiate-type anesthetics, fentanyl is metabolized by the liver and
should be used with care in the elderly or in patients with hepatic deficiency. Fentanyl has some respiratory depressive effects and should be used with care in those patients with borderline pulmonary status. Minor respiratory compromise can be treated by supplemental oxygen delivery. This is intended to keep blood oxygenation 95% or more. One should not continue to use this medication if it causes the blood oxygenation level to go to less than the low 90s even with oxygen supplementation.

Fentanyl is reversed with naloxone intravenously at a dose of 0.4 to 0.8 mg, with a response usually seen within five minutes. If there is no response within these five minutes, a supplemental dose of 2.4 mg can be given. Naloxone is an excellent reversal agent for fentanyl because this has a short half-life, similar to that of fentanyl.

Care should also be exercised in patients who have had prior long-term opiate use either as recreational pharmaceuticals or for pain relief. The possibility of a respiratory depressive effect in these patients at doses that are not adequate for anesthesia or analgesia is common. For these habituated patients, it is essential that the sedation be administered by an anesthesiologist, to carefully titrate medications and monitor vital functions. Also, in these patients, one should increase the dose of local anesthetic to compensate for the relative analgesic ineffectiveness of the opiates.

In a situation where there is renal or hepatic dysfunction, remifentanil may be utilized because unlike other opiates, it is broken down by nonspecific esterases in the blood rather than broken down in the liver or excreted by the kidney. This medication is 20 to 40 times more potent than fentanyl with an onset of action within one to three minutes and duration of action for only 5 to 10 minutes.

**Benzodiazepams**

Benzodiazepams are usually the best form of sedative/hypoxic agents with predominant anxiolytic and relaxation effects and no direct analgesic effects. These agents cause amnesia with loss of memory of the procedure and help to relieve patient anxiety (20,21).

Benzodiazepams cause anxiolysis, sedation, amnesia, suppression of seizure activity, and, if the dose is high enough, unconsciousness and respiratory depression. At its lowest concentrations, benzodiazepams produce only anxiolysis. High concentrations are needed for a sedative as well as an amnesic effect. The duration of retrograde amnesia is dose related. Higher doses of benzodiazepams produce unconsciousness.

Benzodiazepams affect the postsynaptic membranes of the central nervous system. At the GABA receptor complex, benzodiazepams enhance the binding of GABA to its receptor.

The three most often used benzodiazepams are diazepam, midazolam, and lorazepam.

The duration of action ranges from up to 37 hours for diazepam, 10 to 20 hours for lorazepam, and one to four hours for midazolam. The ratio of potency of these is 1:5:3, respectively (22).

Midazolam (Versid) is the most commonly used benzodiazepam. Similar to amide-type local agents and opiates, Versid is metabolized by the liver. Versid is given intravenously at doses of 1 to 3 mg, under careful titration. Similar to opiates, side effects include respiratory depression, but occasional paradoxical stimulation can be seen. Most benzodiazepams can be reversed utilizing flumazenil. The recommended dose for reversal is 0.2 mg IV over 15 seconds. If no response is seen in less than a minute, a second dose of 0.2 mg can be injected, and this can be repeated up to four times at 60-second intervals (23).

Benzodiazepams, when combined with opiates, have a synergistic effect on respiratory depression. Benzodiazepams, however, have only a minimal effect on blood pressure, cardiac output, and systemic vascular resistance.

**Other Medications**

Occasionally promethazine hydrochloride (Phenergan) is given in conjunction with analgesics to potentiate the opiate effects and to combat the nausea that is associated with these medications.

Prophylactic antibiotics are given only rarely in specific situations, mainly for diskography.
PERIPROCEDURAL ISSUES

During the procedure, a running IV line should be available. IV fluids should be administered in all conscious sedation patients in order to maintain fluid and electrolyte balance (24). Isotonic solutions (isotonic saline or lactated Ringer’s) are the preferred crystalloid IV maintenance fluid during the procedure.

Emergency medications including epinephrine and diphenhydramine should be available. Atropine should also be available in every procedure room.

Nothing by Mouth

A patient is given nothing by mouth (NPO) because of the risk of aspiration of gastric contents that may occur with as little as 25 mL content in the stomach. Although all sedation has a risk of aspiration, avoidance of deep sedation can decrease this risk, or in specific circumstances, H2 blockers can be administered, which further decreases the risk of aspiration. Even though a patient is NPO, we allow clear liquids up to two or three hours before a scheduled procedure. Also, on the morning of the procedure, patients may take their typical oral medications but with only 2 or 3 oz. of water (25–27).

Ventilation

Oxygen by nasal cannulae will increase the blood oxygen by 3% to 4% for each liter delivered. Nasal cannulae rates greater than 4 L/min may lead to irritation, bleeding, and drying of mucous membranes. A simple oxygen mask allows delivery of oxygen at 40% to 60%. A nonbreathing mask allows the use of up to 100% oxygen when a tight seal is made. In a patient who has increased pulmonary secretions, increased humidified oxygen is indicate; however, humidified action requires high flow rates because of the high viscosity.

Patient Monitoring

Pulse oximetry is a noninvasive method for measuring blood oxygenation (27). It utilizes two wavelengths of light: red at 660 nm and infrared at 140 nm. One should be aware of the oxyhemoglobin disassociation curve when evaluating pulse oximetry readings. This curve has a steep drop-off below 90%, and therefore patients with a pulse oximetry less than 90% are significantly desaturated and possibly getting inadequate oxygen to their tissues. If additional oxygen is given, it will take approximately 20 seconds for the pulse oximetry readings to increase (28).

Special Circumstances

Specific considerations in older patients are based on the increased sensitivity to pharmacological agents in elderly patients, because the greater the proportion of body fat, the lesser the skeletal muscle mass, and the lesser the volume of intracellular fluid. There are negative cardiovascular, pulmonary, and neurological effects of aging seen even in patients who have normal physical examinations and/or laboratory results (29–31). Modifications should also be made in pediatric patients. These, however, are quite complex and should be made by a pediatric anesthesiologist (11,16,32,33).

Cardiac Monitoring

Cardiovascular monitoring is provided by intermittent blood pressure readings, continuous pulse readings, and a continuous electrical demonstration of the cardiac cycle (17). The electrocardiogram reflects the electrical activity of the heart in a graphic form, with the electrodes picking up electrode signals generated by the heart’s conducting system (34). Normally electrodes are placed on four limbs and in six areas of the chest, however, standard bipolar leads used in procedural monitoring include one lead at the right arm, one at the left arm, and one at the left leg, or occasionally only one lead. The placement of these leads causes large alterations in the EKG readout and experience is necessary to understand these effects on the formal reading.
POST-PROCEDURE PAIN RELIEF

In the vast majority of cases, post-procedure pain relief is not necessary. In the small number of cases in which it is necessary, over-the-counter analgesics are suggested (35). Aspirin is to be avoided after percutaneous biopsies because of its potential anticoagulant effect. In the situations where there is inadequate pain relief with over-the-counter analgesics, consultation with the patient’s primary physician is suggested. When that physician is not available, Tylenol with codeine (one tablet with 30–60 mg of codeine is suggested) every four hours up to three doses.

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INTRODUCTION

Percutaneous selective injections including selective joint and soft-tissue injections as well as selective nerve root blocks are commonly performed by radiologists. Percutaneous selective injections are considered standard techniques in the diagnosis and treatment of various pain sources originating from the musculoskeletal system. Selective injections may be of great help in identifying the pain generator and can provide pain relief, which may maximize treatment and improve functional outcome. The rationale of these procedures is to deliver local anesthetics and/or steroids precisely within the joint cavity or to the immediate vicinity of either the nerve or the inflamed tissue. For this purpose, a needle is placed next to the presumed affected tissue target. Needle guidance may be achieved by fluoroscopy, computed tomography, or magnetic resonance imaging.

In daily practice, selective injections are most frequently performed in the management of pain affecting the lumbosacral spine. The spectrum of selective lumbosacral injections includes selective nerve root block, facet joint injection or facet joint block, and injections of the sacroiliac joint (1–7). Less frequently, patients are referred for selective injections of the cervical and thoracic spine as well as for injection into other joint cavities or injections into other nonarticular structures of the appendicular skeletal system.

This chapter is focused on biochemical and pharmacological aspects of local anesthetics and steroids that are used for selective injections. Special attention is drawn to physiological effects of these drugs to enable a rational use of these substances in clinical practice.

LOCAL ANESTHETICS

Local anesthetics are drugs that block nerve conduction when applied locally to nerve tissue in appropriate concentrations (8). They act on any part of the nervous system and on every type of nerve fiber. Thus, a local anesthetic in contact with the nerve trunk can cause both sensory and motor paralysis in the area innervated. The necessary practical advantage of the compounds that are labeled as local anesthetics is that their action is reversible, i.e., their use is followed by complete recovery of nerve function with no evidence of structural damage to nerve fiber cells (8,9).

The synthesis of procaine is considered a milestone in the development of local anesthetics. Procaine is a synthetic substitute for cocaine, and it was used as the first local anesthetic in patients. Since the synthesis of procaine in 1905 by Einhorn, several local anesthetics have been developed. The goals of these efforts were reduction of local irritation and tissue damage, minimization of systemic toxicity, shorter onset of action, and longer duration of action. Currently, lidocaine, mepivacaine, bupivacaine, and ropivacaine are most commonly used for selective infiltrations in the musculoskeletal system (1–7).

Chemistry

Figure 1 shows the chemical structure of frequently used local anesthetics for selective injections. All these drugs consist of a lipophilic group (aromatic ring) connected by an amide intermediate chain to a ionizable group (usually a tertiary amine) (8,9). The lipophilic domain determines the anesthetic potential and toxicity of the drug. Because local anesthetics can penetrate only as an uncharged (non-ionized) fraction into cells, the ionization potential of the amine group correlates