Pain Control in Disaster Settings: A Role for Ultrasound-Guided Nerve Blocks

Suzanne C. Lippert, MD, MS, Arun Nagdev, MD, Michael B. Stone, MD, Andrew Herring, MD, Robert Norris, MD

From the Stanford Hospitals and Clinics, Division of Emergency Medicine, Stanford, CA (Lippert, Norris); and the Alameda County Medical Center, Department of Emergency Medicine, Oakland, CA (Nagdev, Stone, Herring).

INTRODUCTION

Acute pain management for patients sustaining injuries in natural disasters and complex emergencies should be a priority for medical providers. Although there are minimal data examining the modalities and effectiveness of pain control in disaster settings, what data exist reveal practices that would be considered grossly inadequate in a typical emergency department (ED) setting.

Ultrasound-guided nerve blocks performed by emergency physicians who have undergone targeted training have the potential to positively affect pain control and safety for patients with traumatic injuries in disaster settings. Femoral, popliteal, forearm, and interscalene blocks have been used safely and successfully in the ED setting for fracture reduction and splinting, incision and drainage, and complex wound care, procedures frequently required in disaster settings. The inherent difficulties of disaster settings do raise challenges to documentation, sterile technique, and monitoring for adverse effects such as local anesthetic systemic toxicity (LAST) that will require further investigation.

Emergency physicians, already trained in procedural ultrasound skills and frequently required to perform extremity procedures in daily practice, are positioned to rapidly gain training and proficiency with nerve blocks. Once mastered, ultrasound-guided nerve blocks have the potential to greatly improve pain control in disaster settings, as well as in the general practice of emergency medicine.

Ultrasound-guided nerve blocks are being increasingly introduced into emergency medicine practice to provide pain control for patients presenting with traumatic injuries and those undergoing painful procedures. The challenges to pain control in disaster and resource-limited settings make ultrasound-guided nerve block particularly applicable in these settings as a central component of a multimodal approach to pain management. Emergency ultrasound-guided nerve blocks have proven utility in combat and disaster settings, using the deposition of local anesthetics around peripheral nerves to induce a reversible loss of sensation with minimal central nervous system and cardiovascular adverse effects. Emergency ultrasound-guided nerve blocks differ from the traditional practice of perioperative regional anesthesia, however, in having a primary goal of acute pain reduction in the setting of traumatic injury rather than complete surgical anesthesia. Using injury patterns prevalent in disaster settings and incorporating the portability of newer ultrasound technology for needle visualization and precise anesthetic deposition, focused training could be developed in specific, appropriate ultrasound-guided nerve blocks for the nonanesthesiologist provider. The primary goal of ultrasound-guided nerve blocks is pain reduction with a simple, single-injection nerve block that is safe, rapid, and easily learned.

We offer a summary of nerve blocks that have been used in the ED setting, which are invaluable as part of a multimodal approach to pain reduction in disasters. This multimodal approach uses multiple analgesic medications with different mechanisms of action and delivery method such as opioids, nonsteroidal anti-inflammatory drugs, N-methyl-D-aspartate receptor antagonists, α2 antagonists, and local anesthetics to achieve a synergistic effect improving overall pain control while minimizing adverse effects. We discuss 4 blocks based on the epidemiology of injury patterns from recent disasters, the relative complexity and risk of each block, and the time necessary to achieve pain reduction with each technique; however, this article is not intended to provide a detailed description of technique, information that can be found in multiple sites online such as http://www.usra.ca/, http://www.nysora.com, and http://www.neuraxiom.com. We discuss how the particular challenges to adequate pain control presented by disaster settings and the injury profiles of patients in those settings can be met with ultrasound-guided nerve block and how the proven utility of regional anesthesia in disaster and combat settings supports the development and use of these blocks by emergency physicians responding to disasters. Finally, we outline the potential challenges to the use of ultrasound-guided nerve blocks in disaster settings. The clear potential for the blocks to provide effective pain relief and reduce the reliance on narcotic pain medications in acute traumatic injuries supports the current momentum to expand their use in the general practice of emergency medicine.
INTRODUCTION OF ULTRASOUND-GUIDED NERVE BLOCKS

Successful use of ultrasound-guided blocks of the femoral nerve; distal sciatic nerve just proximal to the popliteal fossa (popliteal block); median, ulnar, and radial nerves (forearm block); and the interscalene brachial plexus has been described in the emergency medicine literature. Although the techniques of ultrasound-guided nerve blocks are relatively new to the ED setting, they show promise in improving pain control during procedures such as fracture reduction and splinting, incision and drainage, and complex wound care, procedures frequently required in early disaster response. We advocate the use of 4 ultrasound-guided blocks by trained emergency medicine providers. The femoral, popliteal, forearm, and interscalene brachial plexus blocks have been reported in the emergency medicine literature and offer the most utility in the disaster setting with the least risk (Table).

Femoral nerve or fascia iliaca blockade by landmark technique has previously been used for effective pain relief in the adult and pediatric ED setting for femoral neck, intertrochanteric, and more distal femur fractures; however, landmark technique carries the risk of inadvertent intravascular injection and concomitant life-threatening adverse effects such as LAST. Although limited by the small sample size, a prospective, observational, ED-based study of 13 patients with a mean age of 82 years who had sustained a femoral neck or intertrochanteric fracture reported that ultrasound-guided femoral nerve block was accomplished in a mean time of 8 minutes (range 7 to 11 minutes), required only 1 attempt, resulted in no complications, and produced a significant decrease in pain score, relative to reported baseline pain, of 44% at 15 minutes and 67% at 30 minutes, with a duration of pain relief for at least 4 hours after the procedure. Of the 2 emergency physicians administering the blocks, the one completing 7 of the 13 blocks had undergone only 30 minutes of specific, ultrasound-guided femoral nerve block training.

Similarly, the popliteal block has been studied extensively in the anesthesia and pain literature and has recently been introduced to the emergency medicine literature. Herring et al describe the successful use of ultrasound-guided popliteal block for pain control within 15 minutes of block administration in a small and therefore limited case series of 4 patients requiring procedural interventions. These cases, which required no rescue analgesia, included bilateral calcaneal fractures requiring washout and splinting, laceration of the plantar aspect of the foot requiring complex wound closure, lateral calf abscess needing incision and drainage, and trimalleolar fracture with posterior ankle dislocation requiring closed reduction and splinting.

Upper extremity nerve blocks have also been used successfully in the ED setting. In a prospective study of a small and therefore limited convenience sample of 11 adult patients with hand pathology requiring laceration repair, foreign body removal, abscess incision and drainage, or fracture or dislocation reduction, emergency physicians who had undergone a 1-hour training session on forearm nerve blocks performed a total of 22 blocks. All of the blocks were successful and rapid (median time to completion 9 minutes; interquartile range 6 minutes 30 seconds, 10 minutes 0 seconds; median 2 blocks per patient).

Table. Recommended ultrasound-guided nerve blocks for disaster settings.

<table>
<thead>
<tr>
<th>Ultrasound-Guided Nerve Block</th>
<th>Injuries</th>
<th>Difficulty</th>
<th>Challenges</th>
<th>Estimated Procedural Time, Minutes*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femoral</td>
<td>Knee</td>
<td>Basic</td>
<td>Risk of inadvertent arterial puncture; partial pain control</td>
<td>10</td>
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<tr>
<td></td>
<td>Femoral neck</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Proximal femur</td>
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<tr>
<td>Popliteal (distal sciatic nerve just proximal to the popliteal fossa)</td>
<td>Distal tibial fracture</td>
<td>Advanced</td>
<td>Excludes saphenous innervation of the medial foreleg, ankle, and foot; increased level of difficulty if patient unable to move to prone position; inadequate block without targeted anesthetic deposition</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Fibular fracture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Majority of foot and ankle injuries</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Soft tissue injuries lower leg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forearm (median, ulnar, radial nerves)</td>
<td>Isolated hand injuries</td>
<td>Basic</td>
<td>Radial nerve can be difficult to visualize in forearm</td>
<td>5</td>
</tr>
<tr>
<td>Interscalene (brachial plexus)</td>
<td>Shoulder dislocation</td>
<td>Intermediate</td>
<td>Complex anatomy in the neck. Higher risk of complications: pneumothorax, phrenic nerve paralysis</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Humerus fracture</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Elbow dislocation</td>
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</tbody>
</table>

*Estimated procedural time includes ultrasound setup, nerve identification, preparation of the injection site, and deposition of local anesthetic around the peripheral nerve identified.
none required rescue anesthesia or additional analgesia to complete the necessary procedure, median reduction in visual analog scale pain score at 15 minutes was 5.0 (interquartile range 3.0, 8.0; \(P=.003\)), and none had complications.

Landmark-guided interscalene brachial plexus block for shoulder dislocation reduction has previously been used with success in the ED.\(^{22}\) In a more recent prospective randomized trial of 42 patients presenting with shoulder dislocation, patients randomized to an ultrasound-guided emergency physician–performed interscalene nerve block compared with those undergoing procedural sedation had equivalent pain and satisfaction scores, with a significant decrease in length of stay (100.3 versus 177.3 minutes; \(P<.01\)) and a significantly shorter mean one-on-one provider time (5 versus 47.1 minutes; \(P<.01\)).\(^{5,23}\) The interscalene block will not be effective for superficial injuries in the distribution of the C8 dermatome or fractures of the elbow joint, ulna, wrist, or fifth metacarpal. Although the supraclavicular block, which has also been used in the ED setting, will cover these injuries, it fails to provide analgesia to the shoulder and proximal humerus.\(^{6}\) Ideally, practitioners will be trained to provide either interscalene or supraclavicular blocks, as the patient’s injury dictates. Because the supraclavicular block requires a more advanced technique and training, the interscalene technique should be mastered initially.

For each of the nerve blocks discussed above, the choice of local anesthetic should be predicated on the safety profile and accessibility of long- and short-acting agents. Where possible, the use of anesthetics free of methylparaben preservative is preferred to minimize the small (<1%) risk of anaphylaxis or allergic reactions. The safety profile of newer-generation local anesthetics, ropivacaine and mepivacaine, is better, making them the preferred choices when available.\(^{24}\) Nevertheless, practitioners are more likely to have access to lidocaine and bupivacaine internationally and should be familiar with their potency, duration of action, and risk profiles. The addition of vasoconstrictors, such as epinephrine, to local anesthetics can serve as an early marker of intravascular injection and can significantly slow the systemic absorption, thereby improving the safety profile and prolonging the analgesia. The potential of epinephrine to decrease the risks of systemic toxicity and enhance the duration of analgesia supports its use in disasters where patient volume and time constraints will likely preclude repeated block administration.

The duration of pain reduction is largely determined by the potential of the local anesthetic for protein binding and the use of additives such as epinephrine. The typical duration of action for the most common local anesthetics with and without epinephrine is as follows: lidocaine 30 to 60 minutes, lidocaine with epinephrine 120 to 360 minutes (2 to 6 hours), mepivacaine 45 to 90 minutes, mepivacaine with epinephrine 120 to 360 minutes (2 to 6 hours), bupivacaine 120 to 240 minutes (2 to 4 hours), bupivacaine with epinephrine 180 to 420 minutes (3 to 7 hours), and ropivacaine 120 to 360 minutes (2 to 6 hours). There are several recent randomized trials comparing single local anesthetics against combinations or additives to evaluate the duration of action when used in perioperative single-injection nerve blocks that suggest even longer duration of analgesia with these medications. In a randomized trial of 64 patients undergoing arthroscopic shoulder surgery with ultrasound-guided interscalene brachial plexus block, mean duration of analgesia with 30 mL of 1.5% mepivacaine was 4.9 hours (SD 2.4 hours); and with 30 mL of 0.5% bupivacaine, 14 hours (SD 6.2 hours).\(^{25}\) In a similar study of 93 patients undergoing arm surgery, the mean duration of sensory blockade with 1.5% mepivacaine with epinephrine was 281 minutes (4.6 hours); and with 0.5% bupivacaine, 850 minutes (14.2 hours).\(^{26}\) In a study of an ultrasound-guided medial midhigh approach to blockade of the sciatic nerve using the long-acting anesthetic 0.375% ropivacaine, mean duration of sensory blockade was 11.9 hours.\(^{27}\) The duration of action of even the short-acting local anesthetics provides sufficient time for procedural intervention in managing extremity injuries, as well as significant postprocedural pain control.

With these 4 nerve blocks—femoral, popliteal, interscalene, and forearm—physicians responding to disasters would be freed from a complete reliance on systemic, primarily narcotic, pain medication in managing the majority of extremity injuries. Because of the difficulties in pain management and the high prevalence and absolute volume of extremity injuries presented by disaster settings, physicians trained in ultrasound-guided nerve blocks and equipped with an ultrasound-guided nerve block kit (Figure) would be better equipped to efficiently provide appropriate pain control and preserve potentially scarce narcotic supplies.
**CHALLENGES TO PAIN CONTROL IN DISASTER SETTINGS**

The scale of destruction and the time and resource constraints presented by complex emergencies make adequate attention to pain reduction exceedingly difficult. Although there are minimal data examining the modalities and effectiveness of pain control in disaster settings, what data exist reveal practices that would be considered grossly inadequate in a typical ED that characterizes pain as a fifth vital sign. Médecins Sans Frontières (Doctors without Borders), one of the major nongovernmental organizations providing care in complex emergencies, investigated the use of narcotic pain medications by their practitioners. In 2004, Médecins Sans Frontières operations in 50 countries used only 10 ampules of morphine. Whether this reflects a lack of provider comfort with narcotics, barriers to narcotic access because of local regulation, prohibitive administrative time and cost in tracking narcotic medications, or simply a lack of access to sufficient quantities is unclear. It does suggest minimal use of one of the most common narcotic pain medications in the settings of health crisis where Médecins Sans Frontières works. Similarly, a survey, limited by presumed recall bias, of 848 victims who survived the Wenchuan earthquake revealed that only 1.6% received pain control at rescue, 3.9% during transfer to hospital, 19% while in the ED, and only 29% during debridement of wounds.

Inadequate pain control clearly results in needless suffering and may also lead to increased short- and long-term complications such as increased coagulation, catabolic stress response, immunosuppression, posttraumatic stress disorder, and complex regional chronic pain syndromes.

The abundant challenges to providing sufficient pain control in disaster settings can be categorized as arising from the resource-limited setting or associated with patient characteristics. Natural hazards that result in large-scale destruction disproportionately affect low- and middle-income countries, areas that already face a shortage of health care workers, inadequate medical supplies, limited access to narcotic pain medications, and poor health infrastructure.

In the wake of a disaster, hospitals are often destroyed or damaged, there are fewer providers per affected population, and those providers may be faced with a lack of monitoring equipment, oxygen, electricity, clean water, and medications. These resource constraints often result in delays in definitive care or necessitate the evacuation of patients to unaffected areas after prolonged, unmonitored transport times.

Patients with multiple traumatic injuries, dehydration, crush injury, and underlying malnutrition complicate the use of general anesthesia and narcotics in an unmonitored setting, whereas the need for patients to remain alert and capable of being active in their own care, given the potential environmental dangers, raises the need for alternatives to narcotics that do not have central nervous system effects. In addition, the predominant injury patterns of survivors are of the extremities, which invite the use of peripheral nerve blocks as an effective pain control modality. In an examination of the epidemiology of earthquake-induced injuries encountered by health care professionals, more than 75% of the total injuries were fractures, contusions, abrasions, and lacerations with trauma to the extremities as the most common injury. Missair et al. in a systematic review of 26 articles covering 14 major earthquakes and representing 29,384 patients, similarly found an average of 63% with extremity injury, more than 60% of whom had a lower extremity injury. These patient characteristics, coupled with the lack of advanced cardiorespiratory monitoring capabilities, have made regional anesthesia the method of choice for surgical interventions undertaken in early disaster response.

**PROVEN UTILITY OF REGIONAL ANESTHESIA IN DISASTER AND COMBAT SETTINGS**

As early as 1974, regional anesthesia for surgical intervention was proposed in the anesthesia literature as preferable to general anesthesia in early disaster response before establishment of fully equipped field hospitals. In those first 3 to 5 days, the lack of monitoring equipment, the appropriateness of regional pain control for the predominant injury patterns, and the prevalence of crush injury and severe infection and sepsis significantly increase the risks of general anesthesia and accentuate the applicability of regional anesthesia. Regional anesthesia also has proven utility in combat settings and has been used to provide pain control for combatants with extremity injuries requiring medical evacuation to distant centers. The parallels of disaster and combat settings are numerous, such as resource limitations, surviving patients afflicted with predominantly extremity injuries, delays in definitive management, long-distance transfers to working health centers, nonsterile conditions, and, in cases of complex humanitarian emergencies, a high prevalence of violent injuries.

**TRANSLATION TO ULTRASOUND-GUIDED NERVE BLOCKS**

The characteristics of the setting and patient population delineated above that support the use of regional anesthesia as a preferred modality for surgical intervention similarly make ultrasound-guided nerve blocks an invaluable tool for pain control during humanitarian response to disasters. As patients await definitive management or evacuation and as emergency medicine providers undertake fracture reduction, debridement, and wound management, ultrasound-guided nerve blocks can offer prolonged pain reduction without the risks of cardiorespiratory compromise or central nervous system adverse effects.

Ultrasound guidance for nerve blocks has been shown to be either equivalent to or better than other nerve localization techniques and may decrease complication rates and improve performance time and time to onset of blocks, particularly in the hands of experienced operators. Emergency medicine practitioners are proficient in diagnostic and procedural use of
ultrasound, such as central vein cannulation and foreign body identification and removal, and would be expected to require only targeted training to achieve competence and facility with ultrasound-guided peripheral nerve blocks. In addition, ultrasound guidance prevents the need for potentially painful motor stimulation of injured extremities and can be used across a language barrier.

Ultrasound technology is becoming increasingly portable and durable, with several of one manufacturer’s models containing rechargeable batteries with a 2- to 6-hour operating life, weighing between 2.7 and 3.85 kg and measuring as small as 35.8×20.8×5.8 cm. Another manufacturer has also developed a “pocket-sized” diagnostic ultrasound weighing 390 g that, although not currently appropriate for ultrasound-guided nerve blocks, reveals the potential for smaller, more portable machines. With this improved portability, ultrasound is increasingly recognized as a valuable tool in resource-limited and disaster settings for tasks as diverse as triage, surgical decisionmaking, obstetric care, and procedural efficiency, making ultrasound-guided nerve blocks one of many uses that justify the expense of transporting an ultrasound to these settings.

CHALLENGES TO THE USE OF PERIPHERAL NERVE BLOCKS

Despite the clear benefits that ultrasound-guided nerve blocks could offer, there are also several potential challenges of providing them in a disaster setting that need to be investigated before widespread adoption. Patients who have received a block will need to be identified with an unambiguous and universal system that allows clear communication between the multidisciplinary team caring for them and centers to which they may be transferred. Building from the New York School of Regional Anesthesia—recommended documentation, the indication, nerve block(s) performed, technique, approach, sedating medication used and sedation level achieved (if applicable), local anesthetic and quantity, use of epinephrine, and complications should be carefully documented. This becomes challenging in a setting in which multiple physicians working across language barriers may evaluate the patient in a given period, the basic tools of charting are difficult to procure, and patient condition may necessitate urgent transfer. At the very least, it is important to have some form of identification, such as a bracelet or surgical marking pen, that documents the date, time, and type of block at the site of the block on the patient. Detailed training protocols need to be developed for emergency physician providers to ensure proficiency and understanding of the potential complications.

The potential infectious risks of practicing ultrasound-guided nerve blocks in a nonsterile setting, as well as the possible risk of delaying the diagnosis of compartment syndrome, should be further explored, although preliminary data from military operations in Iraq and Afghanistan suggest that the benefits outweigh the risks despite these challenges. The interscalene block, in particular, presents the possibility of higher-risk complications than with femoral, popliteal, and forearm blocks, such as intravascular injection, pneumothorax, and high epidural block. The interscalene block also usually results in phrenic nerve paralysis and should not be used in patients with compromised pulmonary function.

Nerve injury, reported to occur at a 0.4% rate after peripheral nerve block, is also of concern and known to be exacerbated by high-pressure injection; however, because ultrasound guidance allows good visualization, intraneural injection is avoidable, making a rare occurrence even more unlikely. We recommend a conservative perineural technique that avoids close contact with the epineurium. All injections should be done slowly in small aliquots of 3 to 5 mL every 10 to 15 seconds in the awake patient whose symptoms may aid the clinician in recognizing direct contact with the nerve.

Teams providing blocks should be prepared to recognize and treat LAST, a rare (<0.2%) but devastating potential complication that usually occurs within minutes of injection and is most commonly associated with an inadvertent intravascular injection. LAST presents with both central nervous system and cardiovascular system effects, characterized initially as agitation, auditory changes, and metallic taste, progressing to seizures or drowsiness, coma, and respiratory arrest. The cardiovascular system effects also usually begin with excitation (tachycardia, ventricular dysrhythmia, and hypertension), which then progress to cardiovascular system depression (bradycardia, conduction block, and asystole). A 2010 review characterized the clinical presentation of LAST in the 93 cases published between 1979 and 2009, 77 of which occurred after a single injection. Isolated central nervous system symptoms were reported in 45% of the cases, combined central nervous system and cardiovascular system symptoms in 44%, and isolated cardiovascular system in only 11%. The authors reported a median time to symptom onset after single injection block of 52.5 seconds (25% to 75%; 30 to 180 seconds), with almost 50% occurring within 60 seconds, 75% occurring before 5 minutes, and 25% occurring after 10 minutes. Sixty minutes was the longest interval from injection to symptom onset reported. The American Society for Regional Anesthesia and Pain Medicine and the American Heart Association recognize 20% lipid emulsion (standard dose 1.5 mL/kg bolus over 1 minute, 15 mL/kg per hour×20-minute infusion) as an essential rescue medication, in addition to standard advanced cardiac life support resuscitation for LAST. The predominant mechanism of action of lipid emulsion is thought to be the creation of a “lipid sink,” which expands the intravascular lipid phase and absorbs excess toxin, thereby preventing it from binding to the myocardium. Intralipid should be stored above freezing and below 25°C (77°F). Ideally, because of the risk of LAST and other complications, nerve blocks would be undertaken in a controlled setting with cardiorespiratory monitoring. In a disaster setting, however, this may not be feasible. Close clinical monitoring of the patient’s mental status, with vigilance for potential symptoms of toxicity, will allow the early diagnosis of LAST in many patients.
nervous system symptoms of LAST occurred in 89% of the 93 cases reported in the 2010 review, with seizure, agitation, and loss of consciousness being the most common signs of toxicity. Monitoring the patient’s pulse rate and oxygen saturation with a pulse oximeter, particularly if epinephrine is used, during and in the immediate 30 minutes after a single injection block may also aid in the early identification of inadvertent intravascular injection or LAST, improving the safety of blocks in an austere setting.

CONCLUSION
Ultrasound-guided nerve blocks performed by emergency physicians who have undergone targeted training have the potential to substantially affect pain control and safety for patients with traumatic injuries in disaster settings. Emergency physicians, already trained in procedural ultrasound skills and frequently required to perform extremity procedures in daily practice, are positioned to rapidly gain training and proficiency with femoral, popliteal, forearm, and interscalene nerve blocks. Once mastered, these nerve blocks have the potential to greatly improve pain control in disaster settings, as well as in the general practice of emergency medicine, without sacrificing efficiency or efficacy.

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Address for correspondence: Suzanne Lippert, MD, MS, E-mail slippert@stanford.edu.

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