Burns & Trauma, 2021, 9, tkab015
https://doi.org/10.1093/burnst/tkab015
Review

Review

Techniques and strategies for regional anesthesia in acute burn care—a narrative review

Clifford C. Sheckter[1], Barclay T. Stewart[1,2], Christopher Barnes[3], Andrew Walters[3], Paul I. Bhalla[2,3] and Tam N. Pham[1,*]

[1]Department of Surgery, UW Medicine Regional Burn Center at Harborview Medical Center, University of Washington, 325 9th Ave. Seattle, WA 98104, USA, [2]Harborview Injury Prevention and Research Center, University of Washington, 401 Broadway. Seattle, WA 98122, USA and [3]Department of Anesthesia and Pain Medicine, Harborview Medical Center. University of Washington, 325 9th Ave. Seattle, WA 98104, USA

*Correspondence. Email: tpham94@uw.edu

Received 25 January 2021; Revised 3 March 2021; Editorial decision 30 March 2021

Abstract

Burn injuries and their treatments result in severe pain. Unlike traumatic injuries that are characterized by a discrete episode of pain followed by recovery, burn-injured patients endure pain for a prolonged period that lasts through wound closure (e.g. background pain, procedural pain, breakthrough pain, neuropathic pain and itch). Regional anesthesia, including peripheral nerve blocks and neuraxial/epidural anesthesia, offers significant benefits to a multimodal approach in pain treatment. A 'regional-first' approach to pain management can be incorporated into the workflow of burn centers through engaging regional anesthesiologists and pain medicine practitioners in the care of burn patients. A detailed understanding of peripheral nerve anatomy frames the burn clinician's perspective when considering a peripheral nerve block/catheter. The infra/supraclavicular nerve block provides excellent coverage for the upper extremity, while the trunk can be covered with a variety of blocks including erector spinae plane and quadratus lumborum plane blocks. The lower extremity is targeted with fascia iliaca plane and sciatic nerve blocks for both donor and recipient sites. Burn centers that adopt regional anesthesia should be aware of potential complications and contraindications to prevent adverse events, including management of local anesthetic toxicity and epidural infections. Management of anticoagulation around regional anesthesia placement is crucial to prevent hematoma and nerve damage. Ultimately, regional anesthesia can facilitate a better patient experience and allow for early therapy and mobility goals that are hallmarks of burn care and rehabilitation.

Key words: Burn, Regional anesthesia, Nerve block, Epidural, Nerve catheter, Pain

Highlights

- Regional anesthesia includes peripheral nerve and neuraxial/epidural analgesia. Regional anesthetic can be delivered through single-shot injections or infusion catheters.
- Regional anesthesia can safely be incorporated into the daily workflow of a burn center.
- A conceptional understanding of the different anatomical nerve blocks/injections facilitates discussion between burn care and regional anesthesia providers.
- Burn care providers should be aware of contraindications and complications when using regional anesthesia in acute burn care.

© The Author(s) 2021. Published by Oxford University Press.
This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (http://creativecommons.org/licenses/by-nc/4.0/), which permits non-commercial re-use, distribution, and reproduction in any medium, provided the original work is properly cited. For commercial re-use, please contact journals.permissions@oup.com

Downloaded from https://academic.oup.com/burnstrauma/article/doi/10.1093/burnst/tkab015/6323209 by guest on 12 June 2022

Background

Burn injuries and their treatments result in severe pain [1]. Unlike traumatic injuries that are characterized by a discrete episode of pain followed by recovery, burn-injured patients endure pain for a prolonged period that lasts through wound closure (e.g. background pain, procedural pain, breakthrough pain, neuropathic pain and itch). Furthermore, many patients—especially those with larger burns—undergo multiple, consecutive operations that precludes a period of pain recovery. In addition to the injured site, wound closure requires harvesting of skin from donor sites, which causes additional pain in the first 3–5 postoperative days.

The current standard of care in pain management involves a multimodal strategy using pharmacological and non-pharmacological medications and techniques [2, 3]. Since the onset of the opioid crisis, many clinicians, health systems and regulatory agencies have sought to limit opioid use and dependency [4]. Although multimodal pain management strategies have demonstrated a reduction in opioid use, burn-injured patients still require significant amounts of oral and intravenous opioids to achieve satisfactory pain levels and regain the ability to participate in care and daily functions [5].

In addition to the initial pain response, proinflammatory cytokines generated from injured soft tissues may contribute to sensitization—a process whereby both the peripheral and central nervous systems become increasingly sensitive to stimuli [6, 7]. The subsequent phenomena of hyperalgesia and allodynia can manifest as intense and disconcerting pain caused by even minimal wound or scar manipulation. These effects may be exacerbated by the paradoxical effect of opioid medications, termed opioid-induced hyperalgesia [8]. There is evidence that early and effective pain management, particularly with sodium channel–blocking agents (e.g. local anesthetic medications) can reduce sensitization and the risks of developing chronic pain [9].

Regional anesthesia can limit or extinguish pain by blocking peripheral sensory nerve transmission [10]. Local anesthetic agents (i.e. those also used for regional analgesia) reversibly bind to sodium channels along peripheral nerve axons to prevent depolarization, which inhibits pain transmission to the central nervous system. Thus, while opioids and other systemic analgesic medications can reduce nociception, regional anesthetics can bock peripheral nociception altogether to reduce pain in a more targeted manner. Regional anesthesia has gained popularity over the past 2 decades, particularly with extremity surgery where operations are limited to discrete nerve distributions [11]. For example, knee replacements and complex hand operations are commonly performed under regional anesthesia without the need for general anesthesia. Even when general anesthesia is used, regional nerve blocks can reduce the amount of opioids required intraoperatively and postoperatively and may reduce the risk of chronic pain in the long term [12, 13].

Commonly used regional anesthetic agents include amino esters (e.g. procaine) and amino amides (e.g. lidocaine, bupivacaine, ropivacaine). Agent choice depends on patient allergies, targeted duration of action and availability. Depending on the agent, the volume of injection can be balanced with the concentration of the agent to provide the patient some level of analgesia with minimal sensory deficit and motor weakness [14]. This balance is paramount in burn-injured patients, where early mobility is associated with improved outcomes and range of motion therapy assists in preventing contractures. Anesthetic agents can be administered as single-shot aliquots or delivered through continuous-infusion catheters. These blocks can target the peripheral nervous system (i.e. regional) or the central nervous system (i.e. neuraxial/epidural).

Review

Indications and contraindications

Our regional burn center has adopted a 'regional-first' strategy. The burn team defaults to evaluating patients for regional anesthesia options early after admission, in anticipation of serial dressing changes and range of motion therapy, and before each operation. The majority of burn patients admitted have an injury that is less than 15% total body surface area (TBSA), which is ideal for regional anesthesia. There is often not a feasible way to provide regional anesthesia to all injured areas. Additionally, local anesthetic agents have weight-based dose limits that may be exceeded if more than 2–3 areas are targeted simultaneously (e.g. fascia iliaca block for thigh and supraclavicular block for arm). In terms of depth, partial thickness injuries are often more painful for patients, given preserved dermal nerve fibers [2]. In these injuries, we recommend regional anesthesia prior to surgery. When patients have clear eschar (i.e. full thickness burn), dressing changes are often tolerable without considerable pain; thus, we delay block placement until the time of surgical management.

Large burn injuries usually undergo excision and reconstruction in a staged manner, which provides the opportunity to use regional analgesia serially in different locations to target the most symptomatic areas. For example, if a 45% TBSA injury requires surgical treatment of both arms, a lower extremity and the abdomen, regional anesthesia can target the extremity(ies) in earlier operative interventions, whereas the abdomen could be targeted at a subsequent operation. Our experience has demonstrated the feasibility of this approach for inpatient, perioperative and outpatient burn care.

There are few absolute contraindications to regional anesthesia in burn patients. Those with an active cutaneous infection at the site of needle entry are not candidates for a regional block because of the risk of seeding the cutaneous infection into deeper tissues. Similarly, we do not typically place a regional anesthesia catheter through eschar or burned skin.

Downloaded from https://academic.oup.com/burnstrauma/article/doi/10.1093/burnst/tkab015/6323209 by guest on 12 June 2022

However, single-shot blocks can be placed through burned skin once it is sterilely prepared. Use of therapeutic anticoagulation is a relative contraindication for regional analgesia due to the small but significant risk of perineural hematoma causing neural ischemia.

Workflow of regional anesthesia in the burn center

Cutaneous burns often occur in anatomical distributions. Upon evaluation, the admitting burn clinician evaluates the pattern of injury in the context of dermatomal and peripheral nerve distributions (Figures 1–3). While anesthesiologists trained in regional techniques automatically think through this lens, burn clinicians may need to refresh their knowledge of the anatomy of the peripheral nervous system. Our workflow (Figure 4) utilizes a Health Insurance Portability and Accountability Act–compliant team messaging application that allows all burn surgeons, bedside and charge nurses, therapists and regional anesthesiologists to communicate together prior, during and after regional anesthesia placement. For patients who might benefit from regional anesthesia, the burn team captures encrypted photographs of the patient and shares them with this messaging group. This evaluation and communication also occurs the day prior to a planned operation, which allows our anesthesiology teammates to plan their regional anesthesia procedure and broader anesthesia approach before the actual operation. If a catheter is placed (versus a single-shot block), anesthesia providers examine and assess the patient daily to manage the catheter and regional agent administration during the inpatient admission, including dose titrations, troubleshooting, optimizing the balance between pain and strength and catheter removal. Prior to anesthetic injection or placement of any catheter, the benefits and risks of regional analgesia are discussed with patients in order that they may provide informed consent.

Single-shot block versus indwelling catheter

Delivery of local anesthetic to a target nerve bundle may occur via a single injection or continuously through an indwelling catheter [15, 16]. Single-shot injections are highly effective and straightforward procedures that require few resources. However, the duration of analgesia after a single injection rarely lasts more than 12–18 hours, which may not match the duration of post-procedural pain. Additionally, pain after block resolution may be compounded by 'rebound pain', a state of hyperalgesia disproportionate to the original insult, causing confusion and distress to both the patient and unfamiliar clinicians. Rebound pain is mitigated by setting clear patient expectations and ramping up systemic pain management while the block effect wanes.

Catheter placement at the time of nerve block, though more resource intensive, both during placement and for continued evaluation and monitoring, allows for longer duration of pain control with the ability to titrate the balance of sensory versus motor blockade to individual patient needs. Catheters may be bolused around wound care activities or repeat procedures, and then weaned to improve motor function and allow for exercises with physical and occupational therapy. Particularly for wound care, this approach allows for more aggressive bedside debridement than would otherwise be tolerable with intravenous and oral pain medications. Engaged patients can often titrate their own level of pain control, with patient-controlled bolusing options available with many infusion pumps. Our program typically limits the duration of catheter placement to a maximum of 5–7 days to prevent infection, with daily reviews for efficacy and safety.

Timing of regional anesthesia

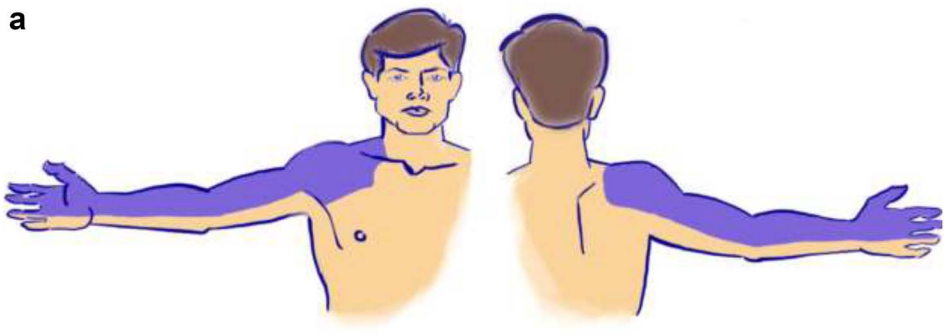
For patients undergoing regional anesthesia for wound care purposes, the catheter is placed when the patient is either in the burn unit or the perioperative care area. It is generally accepted that peripheral nerve blocks are safer in awake patients as they can give real-time feedback about paresthesia that may suggest needle-to-nerve contact; nonetheless, nerve blocks are frequently placed in sedated or anesthetized patients from special populations, such as children and ventilator-dependent patients. Nerve blocks are usually placed prior to surgery in order to minimize the risk of central sensitization during the operation [12]. However, the block may be placed after the operation if the precise requirement or required coverage for the block is unclear prior to surgery.

Local anesthetics and adjuvants

Multiple local anesthetic concentrations and adjuvants are used to produce varying duration and depth of neural blockade. Long-acting local anesthetics such as bupivacaine, L-bupivacaine or ropivacaine provide pain relief for 10–16 hours when given as a single bolus. Ropivacaine and L-bupivacaine have improved cardiac safety profiles and are commonly used despite their extra cost. Alternatively, shorter acting agents such as lidocaine and mepivacaine last for 4–6 hours. In cases where dense blockade followed by rapid resolution is needed (e.g. outpatient procedures on lower leg where sciatic block creates a fall risk), 2-chloroprocaine provides 1–2 hours of effect.

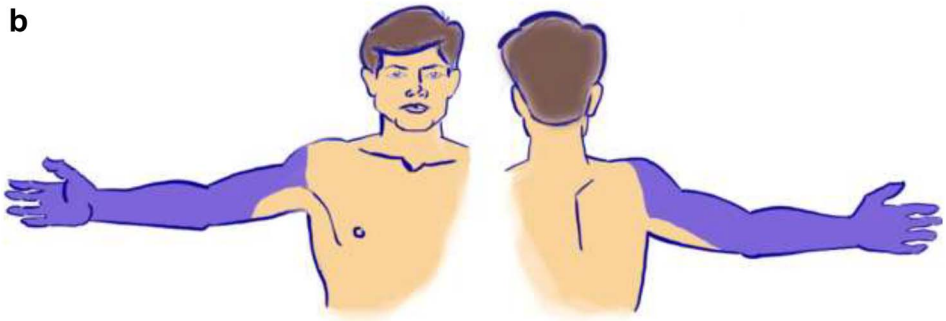
Adjuvants are often added to single-shot blocks to increase their duration. Common adjuvants include epinephrine (which may also be used as a marker of unintentional vascular access), dexamethasone, clonidine and dexmedetomidine. At our institution, both dexamethasone and dexmedetomidine are commonly used. Dexamethasone is usually delivered intravenously, as the effects of perineural delivery are not superior to intravenous delivery. Dexamethasone has been shown to prolong nerve block duration by 3–4 hours [17, 18], whether administered intravenously or perineurally. The optimal dose is debatable, with studied doses ranging from 2–8 mg. For dexmedetomidine, we have found that perineural delivery is especially useful prior to procedural blocks (e.g. dressing changes, bromelain application, etc.) as it speeds onset of the block, prolongs the duration of

Downloaded from https://academic.oup.com/burnstrauma/article/doi/10.1093/burnst/tkab015/6323209 by guest on 12 June 2022



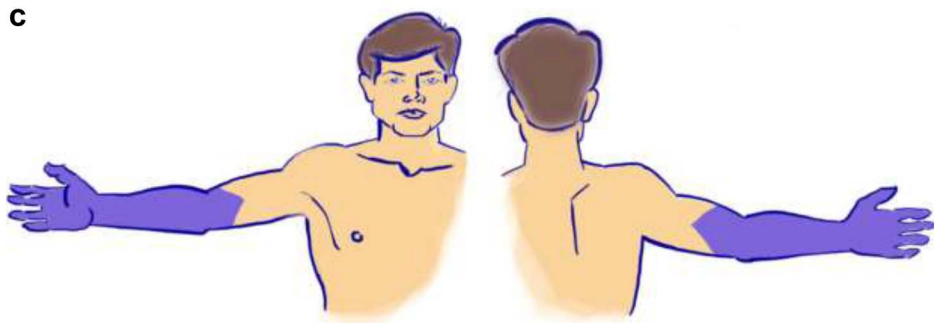
Notes

- Excellent coverage of the upper arm including shoulder. Comes at the expense of poor ulnar coverage, especially with catheter placement
- Risk of phrenic nerve block, causing shortness of breath
- Horner's syndrome is common



Notes:

- Coverage of the entire arm with the exception of the axilla (need intercostobrachial or pectoral II for axillary coverage)
- Blocks at the supraclavicular and infraclavicular provide similar analgesia, with the former providing better shoulder coverage
- More common to leave a catheter in the infraclavicular location as pectoralis muscles help prevent migration
- Lower risk of Horner syndrome or phrenic involvement with infraclavicular block



Notes:

- Suitable for procedures below the elbow, less reliable above
- Safest brachial plexus block due to easy compression of axillary vessels, and distance from phrenic nerve

Figure 1. Anatomical blocks of the upper extremity used in burn care. (a) Interscalene brachial plexus, (b) supraclaclavicular/infraclavicular brachial plexus, (c) axillary brachial plexus

the block and produces a modest amount of sedation. A recent meta-analysis [19] concluded that the addition of dexmedetomidine prolongs peripheral nerve blocks by 4.8 hours. The optimal dose is not known, but the range is 25–100 μg. At our institution, we have found that higher doses were associated with excess sedation and reversible bradycardia (we tend to use a dose of 25–50 μg). Even at lower doses, dexmedetomidine may cause delayed

Downloaded from https://academic.oup.com/burnstrauma/article/doi/10.1093/burnst/tkab015/6323209 by guest on 12 June 2022

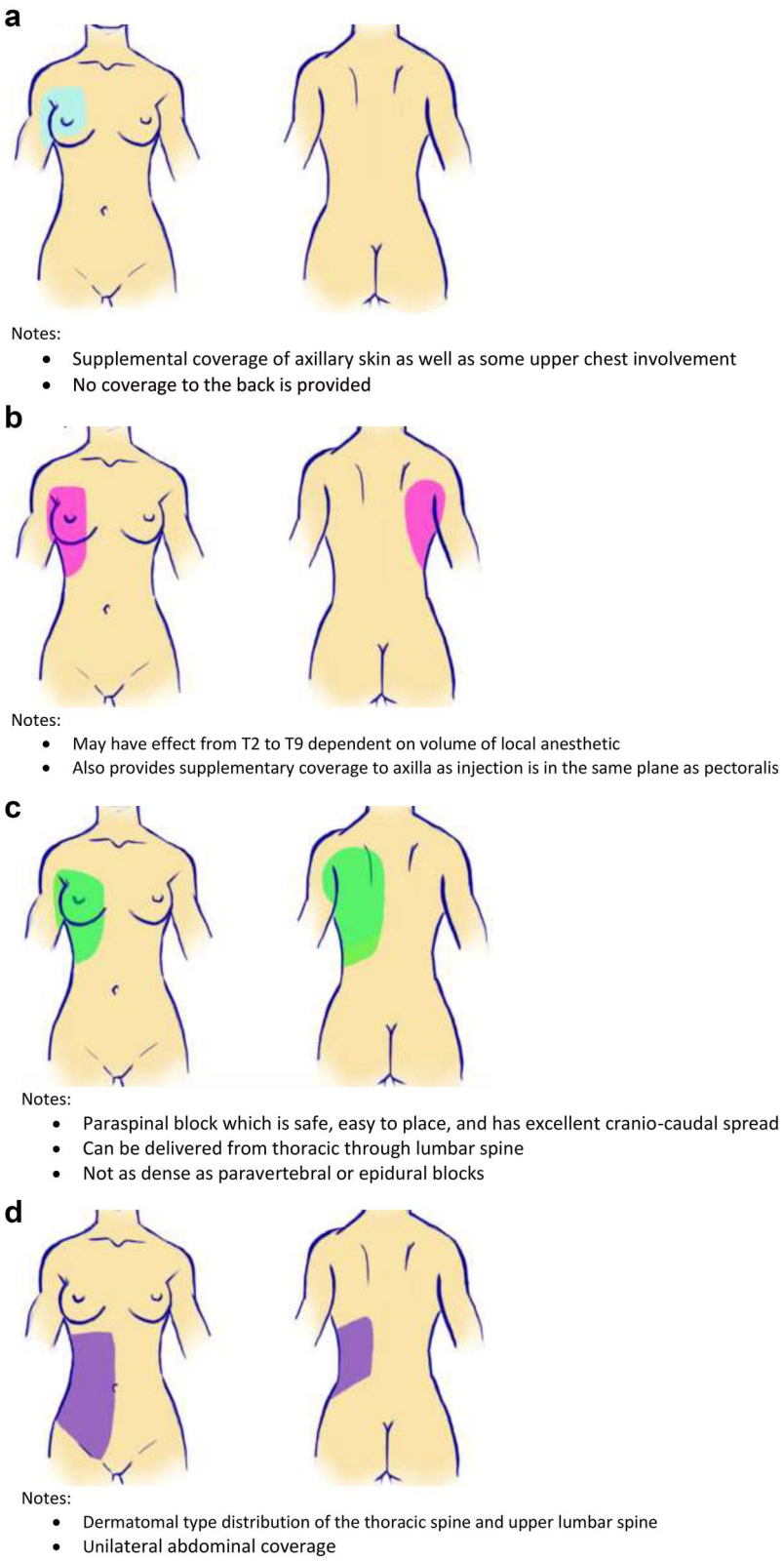


Figure 2. Anatomical blocks of the trunk used in burn care. (a) Pectoralis nerve block, (b) serratus anterior block, (c) erector spinae plane block, (d) quadratus lumborum plane block

bradycardia and/or hypotension and care team members should be aware of these risks after the patient leaves the procedural area.

Volumes of local anesthetic injected with single-shot blocks vary according to the nerve or nerve bundle being targeted and the sequalae of spread to surrounding structures.

Downloaded from https://academic.oup.com/burnstrauma/article/doi/10.1093/burnst/tkab015/6323209 by guest on 12 June 2022

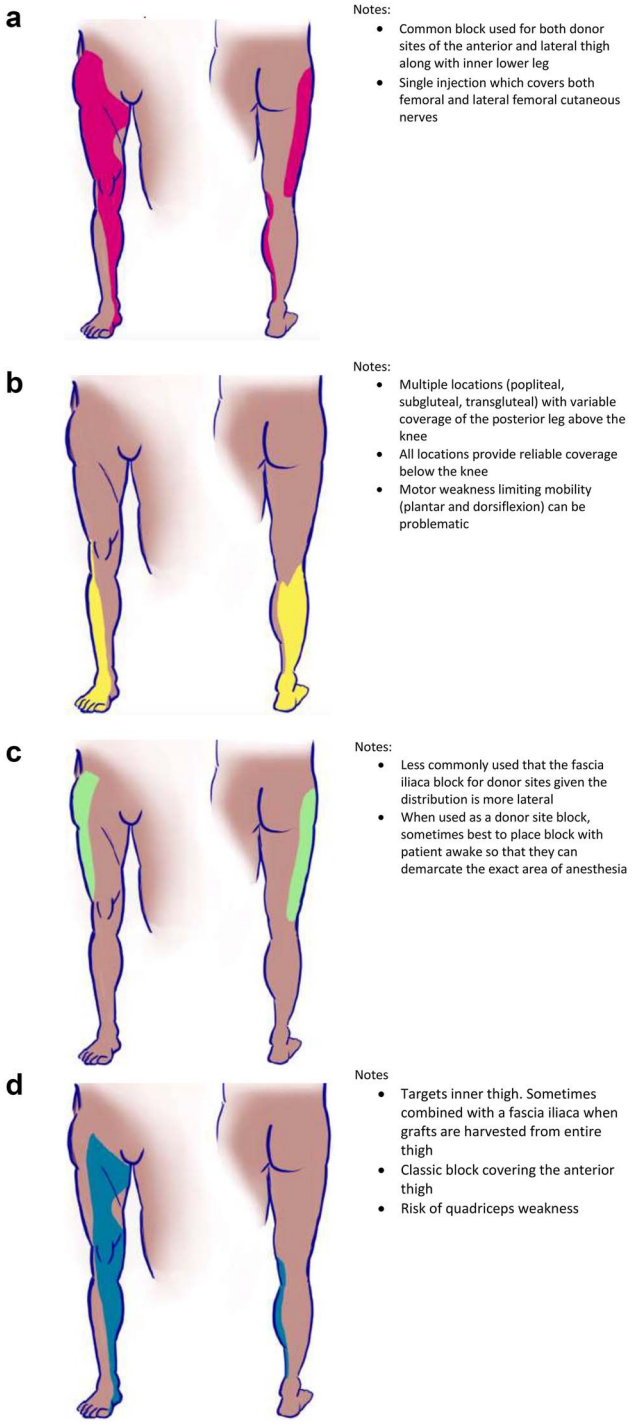


Figure 3. Anatomical blocks of the lower extremity used in burn care. (a) Fascia iliaca plane block, (b) sciatic (popliteal) nerve block, (c) lateral femoral cutaneous nerve, (d) femoral nerve

Most blocks are conducted with volumes of 20–30 mL, which provides adequate spread to surrounding bundles and travel through fascial planes. The notable exception is interscalene blocks where low volumes (5–10 mL) decrease complications such as shortness of breath due to phrenic nerve involvement and Horner's syndrome (i.e. ptosis, myosis, flushing) due to sympathetic cervical chain involvement.

After catheter placement, infusions of long-acting local anesthetics (ropivacaine, bupivacaine, L-bupivacaine) generally start at rates of 6–8 mL/hour and concentrations of 0.2–0.25%. Increasing the rate of the infusion increases the spread of local anesthetic and may be required with plane blocks (i.e. erector spinae blocks) or when the catheter is suspected to have migrated away from its target area. Once adequate coverage of the nerve is achieved, the concentration of local anesthetic may be increased to improve pain control or decreased to allow motor function. Boluses of 50–100% of the hourly rate may be infused off the pump or by hand for pain crises or anticipation of a painful care process (e.g. wound care, range of motion therapy). Our institution limits the total hourly rate of 0.2–0.25% ropivacaine or bupivacaine to 20 mL/hour through all catheters, with adjustments made for higher or lower concentrations.

Other uses of local anesthetics have been described both topically (e.g. lidocaine 2–5%) and systemically (e.g. intravenous lidocaine infusion). Topical lidocaine has been discussed in the treatment of pain in first degree burns such as sunburn; however, experimental evidence had demonstrated little efficacy [20]. Intravenous lidocaine infusions have been trialed in larger burns and a recent randomized controlled trial [21] demonstrated a 25% reduction in opioid use in acute burns. Our institution has this therapy available, although it is not frequently used because we lean on regional anesthetic practices instead. Local anesthetic toxicity is of great concern and regional blocks frequently approach local maximums, which precludes the use of additional intravenous infusions. For very large burns, where regional anesthesia is not an option, intravenous lidocaine infusion appears to be a reasonable treatment alternative.

Outpatient peripheral nerve infusion catheters

Outpatient peripheral nerve infusions are well established methods for pain control in orthopedic and hand surgery [22] that allow for continuous infusions lasting 3–5 days before the patient removes the catheter themselves at home. The pumps used for infusion are disposable, reliable and inexpensive elastomeric or battery-powered devices. Burn care has increasingly transitioned toward outpatient treatment when possible [23]. Hence, for operative burns limited to an extremity, it is safe and feasible to perform surgical debridement/reconstruction and then discharge the patient home for dressing takedown in the clinic setting. This patient is ideally treated with a peripheral nerve catheter that can be removed either at home or when they return to clinic for takedown. As for all injured patients, the feasibility of this outpatient strategy depends on patient adherence to postoperative instructions (including catheter-related precautions), access to transportation should an adverse event occur and their social support system.

Downloaded from https://academic.oup.com/burnstrauma/article/doi/10.1093/burnst/tkab015/6323209 by guest on 12 June 2022

Multimodal treatment

Regional anesthesia does not preclude or eliminate the need for systemic pain medications and/or non-pharmacological pain management strategies and should be viewed as one tool in the armory of pain management for burn patients. Our burn team works closely with pharmacists and pain medicine specialists to devise tailored pain management plans that achieve healing and mobility with the least amount of pain possible. We have found it feasible for the burn team to continue titrating systemic multimodal pain management while the pain relief service concurrently titrates the regional infusion catheter with deliberate communications.

Analgesia for enzymatic debridement of the burn wound

Bromelain is an enzymatic eschar debrider derived from pineapple extract that quickly and effectively debrides partial and full thickness burns [24]. As one of the burn centers currently trialing bromelain for eschar debridement as part of multi-institutional, multi-national trials, our center has leveraged regional anesthesia to feasibly accomplish enzymatic debridement without the need for general anesthesia or high doses of systemic pain medication. Given that the enzymatic product requires 4 hours to debride and causes pain during application, we have incorporated regional strategies for prolonged pain management [25, 26]. In our experience, intravenous and oral pain medication—even if multimodal—are insufficient to treat the pain associated with enzymatic debridement. Therefore, regional anesthesia is the primary means by which patients comfortably tolerate this treatment. The patients receive a regional catheter or single-shot block prior to the application of bromelain. After debridement has finished, the wound is considered for reconstruction. Use of a dermal template or skin grafting is sometimes indicated soon after debridement, so the catheter is left in place to bridge for a wound closure operation in the ensuing days.

Complications and pitfalls

Infection Burn-injured patients are known to have some of the highest rates of nosocomial infections due to prolonged hospitalization, large open wounds, dysregulated immunoinflammatory response and frequent manipulation of the skin [27]. Given that peripheral catheters are placed through the skin, there is the potential for catheter-associated infection, which has been reported to occur in 0–3% of cases [28]. Epidural analgesia carries the risk of epidural abscess, which is reported in up to 0.12% of cases in the non-burn literature [29]. At our institution, we have encountered 1 case of epidural abscess associated with an epidural infusion catheter. In that particular case, the patient had persistent lower back pain weeks after the epidural had been removed. There were no burns adjacent to the catheter insertion site and the catheter had remained in place for the standard 4 days after placement. Initial workup with magnetic resonance imaging of the lower spine was unrevealing; however, the patient subsequently developed lower extremity weakness 4 weeks later that prompted additional magnetic resonance imaging which showed infection of the adjacent spine. The patient underwent imaging-guided biopsy for culture and was treated with a 6-week course of intravenous antibiotics for *Pseudomonas aeruginosa*. Due to persistent weakness and pain after the course of intravenous antibiotics, he underwent surgical debridement with posterior spinal instrumentation and fusion of thoracic vertebrae 10 through lumbar vertebrae 3. He fully recovered neurologic function and remains on suppressive antibiotics.

Best practices for mitigating infection include: (1) sterile catheter placement regardless of setting; (2) covering catheters with sterile occlusive dressings akin to those used in central venous catheters; (3) placing catheters through healthy, non-burned tissue; (4) never placing catheters adjacent to cellulitis or through an eschar undergoing autolysis; (5) daily monitoring of catheter insertion sites; (6) removal of the catheter with any new erythema at the insertion site; and (7) timely removal when no longer needed.

Hematoma Bleeding is a risk with any procedure. However, even a small hematoma in an enclosed space (e.g. nerve sheath, epidural space) can exert enough pressure to cause nerve ischemia that can result in temporary or permanent weakness or paralysis. Burn-injured patients are at increased risk for venothromboembolism (VTE), thus the standard of care is pharmacologic VTE prophylaxis. Our burn center uses 30 mg enoxaparin every 12 hours for $\geq$20% TBSA open wounds and 40 mg enoxaparin daily for <20% TBSA open wounds. The most recent national guidelines from the American Society of Regional Anesthesia no longer comment on specific guidelines for regional anesthesia in the context of VTE prophylaxis, due to the paucity of evidence, and suggest a risk–benefit decision based on vascularity and compressibility of the site [30]. Therefore, institutional protocols guide our VTE chemoprophylaxis for peripheral nerve and neuraxial anesthesia (Table 1).

Nerve injury Direct trauma to the nerve from the block needle can have variable long-term effects on sensorimotor function, ranging from transient numbness and weakness to permanent paralysis. For that reason, we strongly believe that only formally trained and experienced practitioners of ultrasound-guided regional anesthesia [31] should place blocks/catheters. The overall incidence of nerve injury is quoted at 0.3%, with the majority of patients experiencing full recovery. There are no differences in nerve complications when comparing single-shot blocks to infusion catheters [32].

Limb ischemia monitoring Nerve blocks decrease sensory perception, which may mask pain as a sign of limb ischemia or compartment syndrome. Although ischemic limb pain should theoretically break through the sensory block of regional analgesia, any patient with circumferential deep burns or an

Downloaded from https://academic.oup.com/burnstrauma/article/doi/10.1093/burnst/tkab015/6323209 by guest on 12 June 2022

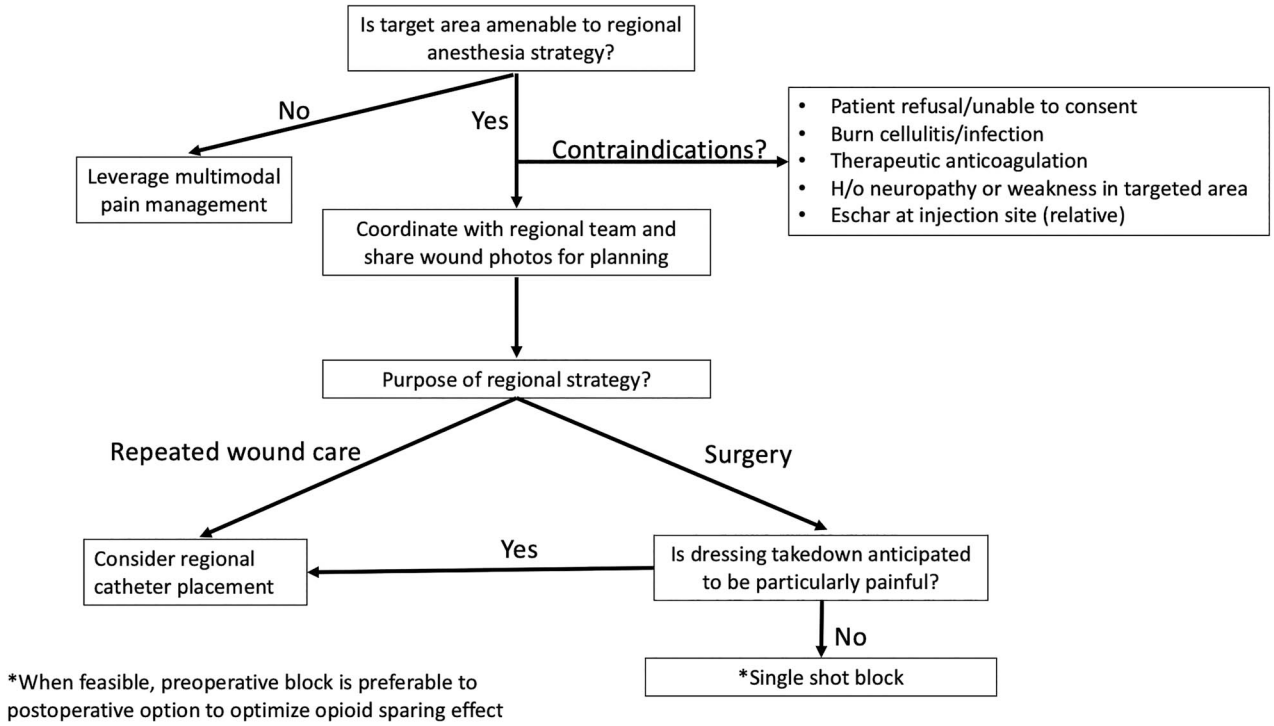


Figure 4. Workflow of regional anesthesia in the burn center. The location of the burn is evaluated in light of the nerve distributions that innervate the burned skin. If no contraindications are present and the patient is in agreement, the case is reviewed with the regional anesthesia team. If the purpose of regional anesthesia is wound care without definitive plans for surgery, then an infusing catheter is placed at the next opportunity. If definitive surgery is planned (e.g. excision and grafting) and/or dressing takedown is remote from surgery, then a single injection of anesthetic is delivered to the targeted nerve prior to surgery. If surgery is less definitive (e.g. debridement/temporizing operation with ongoing wound care), then an infusing catheter is placed prior to surgery. When skin grafts are harvested from the lower extremities, a single injection agent is delivered to the targeted areas. All injections and catheter placements are performed under ultrasound guidance. H/o, history of

Table 1. Management of venothromboembolic prophylactic medications with regional and neuraxial analgesia

Venothromboembolism prophylaxis	Hours to hold anticoagulant prior to injection/catheter placement	Safe to give anticoagulant while catheter in place?	After injection/catheter removal, hours to wait before giving anticoagulant
Heparin 5000 units SQ Q8H or Q12H	No restriction	Yes, no time restriction	No restriction
Enoxaparin 40 mg SQ QDay	12 hours if CrCl >29 mL/min 12 hours if CrCl <30 mL/min	Yes, 8 hours after injection	4 hours
Enoxaparin 30 mg Q12H	12 hours if CrCl >29 mL/min 12 hours if CrCl <30 mL/min	Never	4 hours
Apixaban 2.5 mg BID or rivaroxaban 10 mg QDay	48 hours if CrCl >49 mL/min 72 hours if CrCl 30–50 mL/min Not recommended if CrCl <30	Yes, 8 hours after injection	6 hours

These recommendations reflect the opinions of the Department of Anesthesiology of the University of Washington.
SQ subcutaneous, *Q8H* every 8 hours, *Q12H* every 12 hours, *QDay* once daily, *CrCl* creatinine clearance, *BID* twice daily

electrical injury should not receive a regional block if there is risk of or concern for limb ischemia, as the presence of a nerve block may delay diagnosis and treatment. In addition, even in patients without concern for limb ischemia, circumferential dressings or casting should not be too tight, given that patients will not be able to sense external tourniquets or areas of pressure [33].

Local anesthetic systemic toxicity (LAST) All local anesthetics have weight- or dose-based toxicity limits that should be observed. When using weight-based dosing, clinicians need to calculate allowed maximum volumes and be diligent about adhering to them, particularly in burn patients where multiple blocks may be used (e.g. simultaneous upper and lower extremities), given that doses are additive. This can be particularly challenging when local anesthetic agents are used in clysis solutions or when multiple agents are used at different sites. Prompt recognition of LAST, which may not be familiar to nursing and medical staff in burn units, is

Downloaded from https://academic.oup.com/burnstrauma/article/doi/10.1093/burnst/tkab015/6323209 by guest on 12 June 2022

Table 2. Checklist for treatment of local anesthetic systemic toxicity*

Stop the infusion
Patient stabilization
Secure airway and ventilate with 100% oxygen
If seizing, benzodiazepine preferred (avoid propofol)
Consider cardiopulmonary bypass if refractory to below treatments
Management of cardiac arrhythmia
Follow advanced cardiac life support
Avoid vasopressin, calcium channel blockers, beta blockers
Reduce epinephrine doses to no more than 1 μg/kg
Lipid emulsion (20%) for a standard 70 kg patient
Bolus 1.5 mL/kg over 60 seconds (100 mL) and then run infusion at 0.25 mL/kg/min
Repeat bolus as needed for persistent cardiovascular collapse
Double infusion rate to 0.50 mL/kg/min for persistent hypotension
Run infusion for at least 10 minutes after regaining normal circulation
Limit lipid emulsion to no more than 10 mL/kg per 30-minute interval

*From the American Society of Regional Anesthesia and Pain Medicine [14, 33, 34]

imperative as mortality is high without prompt discontinuation of local anesthetic agents and administration of intralipid rescue (Table 2). Early signs of LAST include oral numbness, a metallic taste and auditory changes (e.g. tinnitus, muffled sounds); these can progress to seizures and then cardiovascular collapse [34]. We follow the American Society of Regional Anesthesia and Pain Medicine checklist for managing LAST [14].

Hypotension and neuraxial anesthesia Epidural anesthesia carries the risk of hypotension as block of sympathetic fibers with local anesthetic leads to loss of vascular tone [35]. Prompt recognition of epidural-related hypotension is important to avoid hypoperfusion to vital organs. Treatment includes crystalloid fluid infusions to achieve normovolemia and/or infusions of alpha-1 adrenergic medications such as phenylephrine. Along with assessment of the patient for other causes of hypotension, the epidural infusion should be paused or decreased if initial treatment fails and recommenced after blood pressure becomes stabilized. Switching to a lower concentration of local anesthetic may also be considered.

Inability to achieve burn rehabilitation goals Decades of research have demonstrated the benefits of early splinting followed by aggressive mobility and range of motion therapy for healed burns/grafts near joints [36]. Recent literature indicates that early mobilization after grafting to the lower extremities and the hand is not associated with a significant increase in graft shear/graft loss [37]. Therefore, while peripheral nerve blocks in the extremities have the ability to completely anesthetize the area, this needs to be weighed against early mobility/therapy goals. When peripheral nerve catheters are used, the flow rate and/or concentration of the drug can be titrated. This titration allows the block to become denser for wound care and dressing takedown and lighter for therapy sessions. An ideal peripheral nerve catheter infusion should be dense enough to provide analgesia but not so dense that it eliminates motor function; achieving this, however, may require some trial and error [38].

Patient engagement is the foundation of recovery and rehabilitation in people living with burn injuries. This includes independent wound care, performing activities of daily living, increasing mobility, working on joint range of motion and scar massage. While regional analgesia offers the opportunity to significantly reduce and sometimes eliminate pain, it should not impede or interfere with recovery goals that are fundamental in burn care and rehabilitation.

Conclusions

A 'regional-first' approach to pain management can be incorporated into the workflow of burn centers. Working closely with regional anesthesiologists and pain medicine practitioners provides the opportunity to give patients another modality in pain control. Although burns may occur in multiple noncontiguous parts of the body, a tailored approach can assist in pain control for almost any anatomic location. Regional analgesia can prevent surgical pain and help significantly with wound care. Burn centers that adopt regional anesthesia should be aware of potential complications and contraindications to prevent adverse events. Ultimately, regional anesthesia can facilitate a better patient experience and allow for early therapy and mobility goals that are hallmarks of burn care and rehabilitation.

Abbreviations

LAST: local anesthetic systemic toxicity; TBSA: total body surface area; VTE: venothromboembolism.

Conflicts of interest

The authors report no financial disclosures or financial conflicts of interest regarding this manuscript.

References

1. Wiechman Askay S, Patterson DR, Sharar SR, Mason S, Faber B. Pain management in patients with burn injuries. *Int Rev Psychiatry*. 2009;21:522–30.
2. James DL, Jowza M. Principles of burn pain management. *Clin Plast Surg*. 2017;44:737–47.
3. Anderson TA, Fuzaylov G. Perioperative anesthesia management of the burn patient. *Surg Clin North Am*. 2014;94:851–61.
4. Tully A, Anderson L, Adams W, Mosier MJ. Opioid creep in burn center discharge regimens: doubled amounts and complexity of narcotic prescriptions over seven years. *Burns*. 2019;45:328–34.
5. Kim DE, Pruskowski KA, Ainsworth CR, Linsenbardt HR, Rizzo JA, Cancio LC. A review of adjunctive therapies for burn injury pain during the opioid crisis. *J Burn Care Res*. 2019;40:983–95.

Downloaded from https://academic.oup.com/burnstrauma/article/doi/10.1093/burnst/tkab015/6323209 by guest on 12 June 2022

6. Yardeni IZ, Beilin B, Mayburd E, Levinson Y, Bessler H. The effect of perioperative intravenous lidocaine on postoperative pain and immune function. *Anesth Analg*. 2009;109:1464–9.
7. Kawamata M, Takahashi T, Kozuka Y, Nawa Y, Nishikawa K, Narimatsu E, *et al*. Experimental incision-induced pain in human skin: effects of systemic lidocaine on flare formation and hyperalgesia. *Pain*. 2002;100:77–89.
8. Holtman JR, Jellish WS. Opioid-induced hyperalgesia and burn pain. *J Burn Care Res*. 2012;33:692–701.
9. Carroll I, Hah J, Mackey S, Ottestad E, Kong JT, Lahidji S, *et al*. Perioperative interventions to reduce chronic postsurgical pain. *J Reconstr Microsurg*. 2013;29:213–22.
10. Marhofer P, Willschke H, Kettner S. Current concepts and future trends in ultrasound-guided regional anesthesia. *Curr Opin Anaesthesiol*. 2010;23:632–6.
11. O'Donnell BD, Iohom G. Regional anesthesia techniques for ambulatory orthopedic surgery. *Curr Opin Anaesthesiol*. 2008;21:723–8.
12. Town CJ, Johnson J, Van Zundert A, Strand H. Exploring the role of regional anesthesia in the treatment of the burn-injured patient: a narrative review of current literature. *Clin J Pain*. 2019;35:368–74.
13. Fuzaylov G, Kelly TL, Bline C, Dunaev A, Dylewski ML, Driscoll DN. Post-operative pain control for burn reconstructive surgery in a resource-restricted country with subcutaneous infusion of local anesthetics through a soaker catheter to the surgical site: preliminary results. *Burns*. 2015;41:1811–5.
14. Farag E, Frca MD, Mounir-Soliman L. *Brown's Atlas of Regional Anesthesia (e-book)*. Philadelphia: Elsevier, 2020.
15. Shank ES, Martyn JA, Donelan MB, Perrone A, Firth PG, Driscoll DN. Ultrasound-guided regional anesthesia for pediatric burn reconstructive surgery: a prospective study. *J Burn Care Res*. 2016;37:e213–7.
16. Cuignet O, Mbuyamba J, Pirson J. The long-term analgesic efficacy of a single-shot fascia iliaca compartment block in burn patients undergoing skin-grafting procedures. *J Burn Care Rehabil*. 2005;26:409–15.
17. Baeriswyl M, Kirkham KR, Jacot-Guillarmod A, Albrecht E. Efficacy of perineural vs systemic dexamethasone to prolong analgesia after peripheral nerve block: a systematic review and meta-analysis. *Br J Anaesth*. 2017;119:183–91.
18. Pehora C, Pearson AM, Kaushal A, Crawford MW, Johnston B. Dexamethasone as an adjuvant to peripheral nerve block. *Cochrane Database Syst Rev*. 2017;11(11):CD011770. doi: 10.1002/14651858.CD011770.pub2.
19. Schnabel A, Reichl SU, Weibel S, Kranke P, Zahn PK, Pogatzki-Zahn EM, *et al*. Efficacy and safety of dexmedetomidine in peripheral nerve blocks: a meta-analysis and trial sequential analysis. *Eur J Anaesthesiol*. 2018;35:745–58.
20. Dalili H, Adriani J. The efficacy of local anesthetics in blocking the sensations of itch, burning, and pain in normal and "sunburned" skin. *Clin Pharmacol Ther*. 1971;12:913–9.
21. Abdelrahman I, Steinvall I, Elmasry M, Sjoberg F. Lidocaine infusion has a 25% opioid-sparing effect on background pain after burns: a prospective, randomised, double-blind, controlled trial. *Burns*. 2020;46:465–71.
22. Ilfeld BM, Morey TE, Enneking FK. Continuous infraclavicular brachial plexus block for postoperative pain control at home: a randomized, double-blinded, placebo-controlled study. *Anesthesiology*. 2002;96:1297–304.
23. Sheckter CC, Kiwanuka H, Maan Z, Pirrotta E, Curtin C, Wang NE. Increasing ambulatory treatment of pediatric minor burns-the emerging paradigm for burn care in children. *Burns*. 2019;45:165–72.
24. Hofmaenner DA, Steiger P, Schuepbach RA, Klinzing S, Waldner M, Klein H, *et al*. Safety of enzymatic debridement in extensive burns larger than 15% total body surface area. *Burns*. 2020;S0305-4179(20)30560-X. doi: 10.1016/j.burns.2020.10.012. Epub ahead of print.
25. Cordts T, Horter J, Vogelpohl J, Kremer T, Kneser U, Hernekamp J-F. Enzymatic debridement for the treatment of severely burned upper extremities - early single center experiences. *BMC Dermatol*. 2016;16(1):8.
26. Schulz A, Perbix W, Shoham Y, Daali S, Charalampaki C, Fuchs PC, *et al*. Our initial learning curve in the enzymatic debridement of severely burned hands-management and pit falls of initial treatments and our development of a post debridement wound treatment algorithm. *Burns*. 2017;43:326–36.
27. Wibbenmeyer L, Danks R, Faucher L, Amelon M, Latenser B, Kealey GP, *et al*. Prospective analysis of nosocomial infection rates, antibiotic use, and patterns of resistance in a burn population. *J Burn Care Res*. 2006;27:152–60.
28. Capdevila X, Bringuier S, Borgeat A. Infectious risk of continuous peripheral nerve blocks. *Anesthesiology*. 2009;110:182–8.
29. Phillips JMG, Stedeford JC, Hartsilver E, Roberts C. Epidural abscess complicating insertion of epidural catheters. *Br J Anaesth*. 2002;89:778–82.
30. Horlocker TT, Vandermeuelen E, Kopp SL, Gogarten W, Leffert LR, Benzon HT. Regional anesthesia in the patient receiving antithrombotic or thrombolytic therapy: American Society of Regional Anesthesia and Pain Medicine evidence-based guidelines. *Obstet Anesth Dig*. 2019;39:28–9.
31. Shteynberg A, Riina LH, Glickman LT, Meringolo JN, Simpson RL. Ultrasound guided lateral femoral cutaneous nerve (LFCN) block: safe and simple anesthesia for harvesting skin grafts. *Burns*. 2013;39:146–9.
32. Brull R, McCartney CJ, Chan VW, El-Beheiry H. Neurological complications after regional anesthesia: contemporary estimates of risk. *Anesth Analg*. 2007;104:965–74.
33. Grant S. Continuous nerve blocks: perineural local anesthetic infusion. *Complications in Anesthesia*. Philadelphia: WB Saunders; 2007, 282–284.
34. Fleisher LA, Rosenbaum SH. *Complications in Anesthesia (e-book)*. Elsevier Health Sciences, 2017.
35. Holte K, Foss NB, Svensén C, Lund C, Madsen JL, Kehlet H. Epidural anesthesia, hypotension, and changes in intravascular volume. *Anesthesiology*. 2004;100:281–6.
36. Richard R, Santos-Lozada AR. Burn patient acuity demographics, scar contractures, and rehabilitation treatment time related to patient outcomes: the ACT study. *J Burn Care Res*. 2017;38:230–42.
37. Dewey WS, Cunningham KB, Shingleton SK, Pruskowski KA, Welsh A, Rizzo JA. Safety of early postoperative range of motion in burn patients with newly placed hand autografts: a pilot study. *J Burn Care Res*. 2020;41:809–13.
38. Jones L, Othman M, Dowswell T, Alfirevic Z, Gates S, Newburn M, *et al*. Pain management for women in labour: an overview of systematic reviews. *Cochrane Database Syst Rev*. 2012. https://doi.org/10.1002/14651858.CD009234.pub2.

Downloaded from https://academic.oup.com/burnstrauma/article/doi/10.1093/burnst/tkab015/6323209 by guest on 12 June 2022