

Chapter

1

Principles of pain management in trauma care

Introduction

Pain management in the trauma setting can be very challenging. There are multiple barriers to effective analgesia for trauma patients, such as the overwhelming priority of resuscitation and treatment of life- and limb-threatening injuries, fear of causing harm owing to side effects and an underestimation of a high level of pain intensity. Trauma patients are frequently unable to communicate because of the need for sedation, mechanical ventilation, etc., which can impair adequate pain assessment. Untreated pain in the injured patient is not merely a nuisance, but can increase patient fear and anxiety and have a detrimental effect on physiologic parameters, leading to significant delays in long-term physical and emotional recovery. Traumatologists are becoming better at recognizing the adverse outcomes associated with uncontrolled pain, as well as at implementing pain control solutions that are well matched to each specific patient's need.

The importance of pain management in trauma care

Acute pain represents a physical and emotional burden that can linger for long after the inciting injury heals. It is well described that under-treated acute pain can lead to the development of chronic pain syndromes (see Chapter 3), and this is as true for the trauma patient as it is for the surgical patient undergoing mastectomy or thoracotomy. Certain pain syndromes, such as complex regional pain syndrome (CRPS), are unique to trauma, and the severity and duration may be influenced with the proper and early use of pain management techniques. Inadequate analgesia has been associated with thromboembolic events, pulmonary complications, and increased ICU and hospital length of stay. Post-traumatic stress disorder (PTSD) is an affliction characterized by intrusive thoughts, nightmares and flashbacks of a past traumatic event, avoidance of reminders of trauma, hypervigilance, anxiety and sleep disturbance, all of which lead to considerable social, occupational and interpersonal dysfunction. Above all else, continued pain represents needless suffering, for which there is no valid excuse. Trauma care providers of all types (prehospital emergency medical technicians (EMTs) and paramedics, nurses and physicians) should make the evaluation and prompt, safe treatment of pain one of their prime directives.

Changing patterns of analgesia

The most common approach to pain management in trauma patients is intravenous opioids. This is true in the prehospital setting, where paramedics and EMTs administer opioids

(typically morphine) for acute pain related to injuries or medical pain; it is also true in the emergency room as well as through the perioperative period. Opioids are excellent analgesics, work quickly and are a rational choice when patients have multiple injuries. However, opioids have a wide variety of side effects that can impact patient physiology and disposition, including:

- Respiratory depression
- Nausea and vomiting
- Pruritus
- Constipation
- Vasodilation and hypotension (especially in hypovolemia)
- Immunosuppression
- Increased staffing requirement to monitor patient
- Increased length of stay in emergency department or recovery room.

Anesthesiologists have long been strong advocates for the use of multimodal analgesia in surgical patients. Its use is also well suited to the acute trauma setting, where it leads to a reduction in opioid requirements and opioid-related side effects. Common multimodal agents used in the care of trauma patients are listed in Table 1.1. While there are a multitude

Table 1.1 Parenteral multimodal agents commonly used in the trauma setting

Agent	IV/IM Dosage	Notes
Acetaminophen (paracetamol)	1 g IV/PO q 4–6 hours to a maximum of 4 g/day	Very safe profile, even in cases with traumatic liver laceration Hepatotoxicity in very large doses No antiplatelet effect
Ketorolac	30 mg, then 15–30 mg every 6 hours	↓ Bone fusion if used in large doses/ prolonged duration Gastric irritation, platelet inhibition Caution with renal insufficiency and asthma
Ketamine	250 mcg/kg loading dose, then 5–10 mcg/kg/h infusion	Potent analgesic ↑ Secretions Hallucinations (more with racemic, less with S-enantiomer) ↑ Intracranial pressure ↑ Sympathetic activity (bronchodilation, ↑ HR/ BP): good for hypotensive/hypovolemic patient
Alpha-2 agonists	Clonidine Dexmedetomidine (bolus 1 mcg/kg, followed by infusion of 0.3–0.4 mcg/kg/h)	Sedation Hypotension Bradycardia
Entonox	Inhaled 50:50 mixture of nitrous oxide and oxygen	Moderate analgesic Nausea/vomiting Contraindicated in head injury, pneumothorax

of available analgesics, for practical purposes only parenteral medications have been included, as the enteral route is often unavailable in these patients.

Regional anesthesia, particularly the use of peripheral nerve blocks, has been growing in popularity for the treatment of the acutely injured patient, both in civilian and in military medical systems. Its myriad advantages in this setting include:

- Reduction in sedative medications (especially important in avoiding respiratory depression or neurologic impairment in those with chest or head injuries)
- Reduction in other opioid-related side effects such as nausea, vomiting, pruritis, constipation and urinary retention
- Decreased risk of hypotension compared to some conscious sedation techniques, especially if the patient is hypovolemic
- Intense analgesia targeted at the injured area and nowhere else
- Decreased length of stay in the emergency room and recovery room
- Attenuated stress response to injury
- Improved safety and comfort of transport
- Decreased need for medical supervision, staffing
- Possible reduction in chronic pain syndromes and PTSD
- Decreased costs compared with conscious sedation techniques for procedural analgesia.

Not every patient is suitable for regional anesthesia techniques; similarly, the provision of regional anesthesia requires specialized training as well as a thorough understanding of the risks and benefits of performing blocks, which include nerve injury, local anesthetic systemic toxicity and inadvertent puncture of neighboring structures. Different techniques may be better suited for different phases of the patient's recovery phase – for example, a single patient might receive a femoral block in the field, intercostal blocks in the emergency department, an epidural in the operating room and a continuous paravertebral catheter in the ICU, all within a period of several days.

The widespread use of ultrasonography for diagnosis of intra-abdominal and intra-thoracic injuries makes the traumatologist, whether surgeon, anesthesiologist or emergency medicine specialist, well positioned to become facile at ultrasound-guided nerve blocks. There have been an increasing number of trials showing that ultrasound improves block success and is faster than traditional nerve stimulator or landmark methods; in addition, the incidence of inadvertent vascular puncture is decreased, just as it is when using ultrasound for jugular vein cannulation. Ultrasound is rapidly becoming, if not a standard of care, a technology that few experienced regional anesthesiologists wish to do without. For that reason, most of the techniques described in this book are of the ultrasound-guided variety, with a few exceptions.

Further reading

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Chapter

2

Acute pain, regional anesthesia and the stress response

Introduction

Trauma to the body, whether surgical or accidental, results in a barrage of noxious afferent input to the central nervous system (CNS). This in turn triggers a cascade of endocrine, metabolic and inflammatory events that, taken together, are known as the “stress response.” The stress response is an adaptive physiologic process that aids in survival by providing fuel substrates (in the form of glucose, amino acids and fatty acids), circulatory support (by promoting the renal retention of water and by the release of catecholamines) and a hypercoagulable state. In the short term, this strategy is probably protective during “fight or flight” situations, but in a medical setting, this response, if untreated, is accompanied by undesirable physiologic effects that lead to increased morbidity following trauma. This chapter will discuss the stress response and the role that regional anesthesia may play in attenuating its effects.

Metabolic response

Glucose levels are elevated following trauma, and are directly proportional to the degree of tissue injury. This is the result of the secretion of counter-regulatory hormones such as cortisol and glucagon which promote increased glucose production (gluconeogenesis and glycogenolysis), decreased glucose utilization, enhanced renal absorption of filtered glucose and resistance to insulin. Under conditions of stress, membrane proteins are expressed that allow this excessive glucose to enter cells in the endothelium, brain and liver. Intracellular glucose glycosylates proteins (e.g. immunoglobulins), rendering them ineffective. Several studies have demonstrated a direct relationship between in-hospital glucose levels and mortality, highlighting the need for strict control of this metabolic derangement.

Accelerated protein catabolism and release of amino acids occurs at the same time during stress. This can lead to a significant loss in lean muscle mass, impaired wound healing and compromised immune function. Net protein loss can exceed 200 g of nitrogen (approximately 6 kg of lean tissue) following trauma. Hepatic protein synthesis is prioritized to generate acute phase proteins such as C-reactive protein at the expense of constitutive proteins such as albumin.

Free fatty acids are released during stress owing to sympathetically mediated lipolysis. Elevated free fatty acids are a cardiovascular risk factor, having been demonstrated to depress myocardial contractility, increase myocardial oxygen consumption and to impair endothelium-dependent vasodilation.

Table 2.1 Hormonal response to stress

Hormone	Change with trauma	Effect
Adrenocorticotrophic hormone (ACTH)	↑	Release of cortisol from adrenal cortex
Growth hormone	↑	Insulin resistance, lipolysis
Antidiuretic hormone	↑	Retention of free water by kidney
Cortisol	↑	Glucose production, protein catabolism, lipolysis, anti-inflammatory
Aldosterone	↑	Sodium and water retention
Insulin	↓	Hyperglycemia
Glucagon	↑	Gluconeogenesis

These metabolic changes can be seen as a redistribution of macronutrients from reserve tissue (skeletal muscle and fat) to more active tissues (liver and bone marrow) for reasons of host defense and visceral protein synthesis (Table 2.1).

Autonomic response

Immediately following traumatic injury, the sympathetic nervous system is activated, causing an increase in plasma levels of epinephrine and norepinephrine. This leads to an increase in heart rate, contractility, arterial blood pressure, left ventricular stroke work and the incidence of arrhythmias.

Regional anesthesia and the stress response

Since the nervous system is the catalyst for initiating the stress response, it seems to be a logical target for mitigating the physiologic derangements seen with trauma. In particular, blocking the afferent nociceptive traffic from entering the CNS prevents activation of the hypothalamic–pituitary axis and the subsequent release of adrenocorticotrophic hormone (ACTH), growth hormone and antidiuretic hormone.

Of the different regional techniques, epidural blockade has been the most extensively studied. Most well-performed studies have been carried out in elective surgery and appear to agree that extensive epidural blockade that “matches” the dermatomal distribution of the incision can be effective at ameliorating the neuroendocrine response, provided that it is initiated before surgery and maintained for at least 48–72 hours postoperatively. For example, during hysterectomy, epidural blockade of levels T4 to S5 for hysterectomy effectively negated any increase in cortisol or glucose. This is more difficult to achieve with upper abdominal or thoracic surgical procedures – in a study with blocks up to C6, glycemic changes were shown to be inhibited but the rise in cortisol was not. The reasons for this are not clear, but may have to do with inadequate sympathetic blockade and the continued release of ACTH from the pituitary.

Studies investigating the role of peripheral nerve blocks in attenuating the surgical stress response have shown mixed results. These techniques appear to be effective at attenuating the

response during cataract surgery under retrobulbar block, and for thoracic surgery using paravertebral blockade. On the other hand, knee arthroplasty patients continued to experience a rise in neuroendocrine hormone levels during total knee arthroplasty using femoral and sciatic blockade. An explanation for this is that the continued neural input from the obturator and/or lateral femoral cutaneous nerves activates the hormonal cascade despite the blockade of most of the neural input.

Regional anesthetic techniques have been shown to confer beneficial effects on multiple organ systems, probably in large part because of the ability of neural blockade to control the stress response. These include reductions in pulmonary complications, deep venous thromboses, pulmonary emboli and myocardial infarction.

For the traumatically injured patient, the opportunity to place a regional block in advance of the insult is clearly lost. However, theoretically there appears to be a benefit from the abolition of the *continued* nociceptive barrage. The nature and timing of such a reduction has not yet been fully characterized. In the meantime, regional blocks in trauma patients have not been shown to be inferior in this regard and have multiple other benefits to recommend them, including superior analgesia, improved rehabilitation and the ability to avoid opioids and opioid-related side effects.

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Chapter

3

The progression from acute to chronic pain

Introduction

Acute pain is an adaptive response that is protective and serves to minimize further injury. During the process of recovery from the inciting event, a steady stream of nociceptive input is received by the spinal cord and transmitted to the higher centers in the CNS. This is prolonged by the sensitization of peripheral nerve endings to non-noxious stimulation by inflammatory mediators released as a result of the injury (peripheral sensitization). Over time, this afferent barrage causes hyperexcitation of central neurons and a decrease in the threshold required to cause a painful stimulus (central sensitization). If allowed to continue unabated, this sensitization can result in a chronic pain condition, where the original injury has healed, but the pain is maintained by the abnormally functioning nerves themselves (neuropathic pain). It is estimated that over 20% of adults in the western world experience chronic pain during their lifetime, accounting for a tremendous burden of suffering and cost to healthcare systems. Chronic pain is often defined as pain lasting greater than 3–6 months after the initial injury.

Chronic post-trauma pain

The incidence of chronic pain following severe trauma is dependent on several factors, such as the type of injury and psychological health. One study of 90 individuals that suffered severe trauma found that 44% reported accident-related pain 3 years after the accident. Those with chronic pain showed significantly more symptoms of PTSD, depression and anxiety, more disability and more days off work.

Common causes of post-traumatic pain syndromes include headache following traumatic brain injury, CRPS following injury to (usually) a distal extremity, post-traumatic abdominal pain and pain related to spinal injury (bony vertebral or spinal cord injury).

Patients suffering traumatic amputations have very specific patterns of chronic pain, including residual limb pain (stump pain), phantom limb sensation (any sensation in the missing limb except pain) and phantom limb pain. This last entity is present in up to 50–80% of amputees, and may be severe enough to interfere with a patient's work and social life. One of the factors that seems to be related to a higher risk of developing phantom limb pain is poor control of preoperative pain. In one randomized controlled study of 65 patients undergoing amputation, quality analgesia with either epidural or intravenous opioids for 48 hours prior to and 48 hours following surgery led to decreased incidence and intensity of phantom limb pain at 6 months.



Figure 3.1 Popliteal sciatic catheter being placed prior to an amputation revision.

“Pre-emptive” versus “preventive” analgesia

The idea that providing analgesia in advance of a painful stimulus might reduce pain intensity afterwards is not new. In the early 1990s the concept of “pre-emptive” analgesia was proposed; this held that a treatment initiated before a painful stimulus will prevent or reduce subsequent pain compared to an identical treatment administered after the stimulus. An example is a nerve block administered for hand surgery – when performed before the operation, the CNS does not receive the barrage of afferent input (until the block wears off); if the same block is put in *postoperatively* following a general anesthetic, the spinal cord immediately begins to receive nociceptive input and is likely to begin the process of central sensitization. Note that in this particular example, while central sensitization is (temporarily) suspended, peripheral sensitization is still occurring.

Preventive analgesia, in contrast, is based on the principle that the only way to guarantee the prevention of central sensitization (and therefore CNS neuroplastic changes that lead to chronic pain) is to maintain the analgesic treatment for the duration of the inflammatory stimulus. In the above example, this might mean placing a peripheral nerve catheter rather than performing a single injection block, and maintaining a local anesthetic infusion for days, and possibly weeks, depending on the nature of the stimulus.

The data supporting the existence of pre-emptive analgesia are limited. This is not surprising when the intensity of post-injury neural input is considered in relation to a brief delay in central sensitization. While the idea of preventive analgesia is an attractive one, a similar lack of evidence prevents strong recommendations of any kind regarding its efficacy. Notwithstanding, the provision of prolonged analgesia surrounding a surgical insult is not only theoretically appealing for any possible role in prevention of chronic pain, but it is also good medicine, as the relief of suffering is one of our primary goals.

Chronic pain and regional anesthesia

Various modalities have been employed in an attempt to invoke preventive analgesia. These include various antihyperalgesic medications such as ketamine, gabapentinoids, antidepressants and anti-inflammatory drugs. While some reports show promising results, these are primarily drugs that have shown utility for neuropathic pain of other origin (i.e. post-herpetic neuralgia, diabetic neuropathy, etc.). As such, it is difficult to expect these relatively mild therapies to have an effect on an acute pain process that is severe, unrelenting and can last weeks following the moment of injury.

Although the ultimate solution to this problem will likely involve multimodal therapy, many anesthesiologists feel that continuous neural blockade is the closest thing possible to a preventive “magic bullet.” In the trauma setting, it can be initiated as close to the time of injury as is practical, and maintained throughout the period of convalescence. Much of the evidence for safety and tolerability of long-term perineural catheter techniques has come following the military experience in Iraq and Afghanistan. Several authors have reported large series of wounded soldiers who have been instrumented with peripheral catheters and portable infusion pumps, then transported thousands of miles to regional medical centers or definitive care hospitals in their home country in comfort and safety (see Chapter 9). The safety record for these catheters, some of which have remained in place for weeks, is excellent, with low complication rates. What remains to be seen is the effect that these prolonged interventions will have on the incidence of chronic pain in this population. The vast majority of these patients have suffered extremity injury, and many are amputees. As the global war on terror continues, we are certain to accumulate evidence on this topic that will be of use to providers of acute pain services in the civilian arena.

Further reading

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