Assessment, Physiological Monitoring, and Consequences of Inadequately Treated Acute Pain

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ABSTRACT:
Postoperative pain is a major health care issue. Several factors have contributed to inadequate postoperative pain control, including a lack of understanding of preemptive pain management strategies, mistaken beliefs and expectations of patients, inconsistencies in pain assessment practices, use of as-needed analgesics that patients must request, and lack of analgesic regimens that account for interindividual differences and requirements. Untreated acute pain has the potential to produce acute neurohumoral changes, neuronal remodeling, and long-lasting psychologic and emotional distress and may lead to prolonged chronic pain states. To effectively manage postoperative pain, nurses must be able to adequately assess pain severity in diverse patient populations, understand how to monitor physiologic changes associated with pain and its treatment, be prepared to address the psychosocial experiences accompanying pain, and know the consequences of inadequate analgesia. It is important for nurses to be aware of relevant research and evidence-based guidelines that are available to guide pain assessments and patient monitoring practices.

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Postoperative pain is a major health care issue (Carr & Goudas, 1999). Several factors have contributed to inadequate postoperative pain control including a lack of understanding of preemptive pain management strategies, mistaken beliefs and expectations of patients, inconsistencies in pain assessment practices, use of as-needed analgesics that patients must request, and lack of analgesic regimens that account for inter-individual differences and requirements. Attention to pain begins before surgery and continues throughout the postoperative period (Table 1) (Krenzischek & Wilson, 2003; American Society of
### TABLE 1. Important Elements of Perioperative Patient Assessment

<table>
<thead>
<tr>
<th>Category</th>
<th>Elements</th>
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</table>
| **Preoperative Assessment**   | **Medical/surgical history**  | Cardiorespiratory status and stability  
Liver or kidney disease that might impair metabolism of various anesthetics  
Cognition and neurologic status  
Comorbidities including painful conditions that must also be addressed in the treatment plan  
Procedure and site  
Previous operations  
Obstructive sleep apnea |
|                               | **Liver or kidney disease that might impair metabolism of various anesthetics**  
Cognition and neurologic status  
Comorbidities including painful conditions that must also be addressed in the treatment plan  
Procedure and site  
Previous operations  
Obstructive sleep apnea |
|                               | **Medication/drug history**  | Substance use disorder  
Previous analgesia (drug[s], route, frequency, effectiveness, adverse events; opioid naïve or experienced)  
Medications that might influence the route and type of analgesia (e.g., anticoagulants, muscle relaxants, blood pressure medications)  
Medications whose abrupt cessation might precipitate acute withdrawal |
|                               | **Pain history**  | Preexisting pain  
Source  
Type  
Severity  
Location  
Time course  
Response to medications  
Effects on quality of life  
Experience with pain in previous instances (e.g., type of intervention, trauma, treatment received) |
|                               | **Responses to pain and discomfort**  | Sensitivity threshold  
Physical expressions related to pain (e.g., crying, agitation) |
|                               | **Preferences**  | Expectations  
Concerns |
|                               | **Education/ability to communicate**  | Barriers to learning or communication (need for an interpreter, cognitive difficulties, need for sound amplification, sign language)  
Type, location, duration of pain generally associated with the procedure  
Staff procedures for dealing with the pain  
Type of medication  
Route of administration  
Duration of action  
Use of devices such as PCA  
Assessment tools  
Importance of communicating the need for additional pain relief before pain and discomfort are intolerable  
Dispel misconceptions  
Discuss potential outcomes |
|                               | **Postoperative Assessment**  | Identify patient  
Validate orders (are pain medications prescribed PRN and with dose range)  
Review preoperative data  
Type of surgery  
Anesthetic agents  
Reversal agents |
|                               | **Analgesia history**  | Type (opioid, nonopioid, adjuvants)  
Time and amount of last dose |
|                               | **Pain assessment**  | Sedation level  
Pain assessment procedures described during postoperative assessment  
Determine quality, frequency  
Pain and comfort levels  
Arrival  
Regular intervals during PACU stay  
Before transfer to post-surgical unit or discharge home |
Anesthesiologists Task Force on Acute Pain Management, 2004). Preoperatively, nurses must take a careful history that includes the patient’s health history and any comorbid conditions, prior experiences with pain and responses to analgesic medications, current medications and past exposure to analgesics, preferences for comfort levels, concerns about pain and its treatment (e.g., fears, worries, or anxiety), and informational needs. This comprehensive preoperative assessment helps to identify potential factors that can influence the degree of pain, the patient’s response to pain, and issues that may affect the pharmacokinetics of various analgesics. Moreover, conversations with patients should focus on desired pain goals and how patients can participate in their care. This also provides an opportunity for identifying patients at risk for increased pain, educating patients and their families, and alleviating apprehensions related to pain. Kalkman et al. have demonstrated that a set of specific indicators can be used to predict the severity of postoperative pain (Kalkman, Visser, Moen, et al., 2003). These include variables such as younger age, gender, level of preoperative pain, incision size, and type of surgery, all of which independently predicted severe postoperative pain early after awakening from general anesthesia. Although this model requires further validation, it indicates that the severity of pain can be reliably predicted and anticipated before patients arrive in the postanesthesia care unit (PACU).

After surgery, the plan of care is focused on frequent assessments and reassessments of the nature and intensity of pain, aggressive pain control measures, and regular monitoring to ensure adequate pain relief, adequate management of analgesic side effects, and patient safety. It is important to:

1) Clarify the patient’s expectation for pain relief both at rest and with activity.
2) Discuss how the patient can participate in care.
3) Regularly obtain patient-reported measures of pain severity and relief and avoid making assumptions about comfort levels based solely on how patients appear or if they are sleeping.
4) Assess the degree of pain and promptly intervene with prescribed analgesics and other interventions.
5) Reevaluate pain after treatments to determine if acceptable pain relief has been achieved.
6) Monitor for complications of analgesia.

Reassessment of pain following administration of analgesics and use of nonpharmacological interventions is mandated by the Joint Commission, and should be carried out to evaluate the effectiveness of treatment strategies. It is important to time these assessments appropriately so that it is possible to determine whether or not interventions for pain provide acceptable pain relief. This requires an understanding of the optimal effects of pain therapies and their anticipated duration of effects.

### ASSESSMENT TOOLS

Several reliable and valid measures are available to assess pain. These consist of unidimensional scales measuring one component of the pain experience (e.g., pain severity and pain relief) and multidimensional pain tools that capture several aspects of pain, such as quality and character of pain, satisfaction with pain control, and impact of pain on various indicators (e.g., activity, mood, sleep, and nutrition) (Davis & Walsh, 2004; De Conno, Caraceni, Gamba, et al., 1994). Although pain has multiple dimensions, unidimensional pain scales offer an easy way for patients to rate various components of their pain and express their pain on a simple analog instrument. To measure pain intensity or severity, several scales can be used,
such as the visual analog scale (VAS), a numeric rating scale, faces rating scales, observational scales with indicators of pain, and even creative depictions of pain intensity with scales using a pain thermometer (Husband, 2001). The VAS consists of a 10 cm line with anchors of “no pain” at one end and “worst possible or unbearable pain” on the other. Patients place a mark on the line that best reflects the level of pain they are experiencing. Because it is necessary to measure the placement of the mark to obtain a pain intensity score, the VAS is rarely used in clinical practice but is often used in research studies. The numeric rating scale allows patients to rate their pain on an 11-point scale of 0 (no pain) to 10 (worst pain imaginable). The majority of patients, even older adults, can use this scale (Herr, Titler, Schilling, et al., 2004). The Faces Rating Scale–Revised consists of six depictions of adult faces corresponding to a numeric rating for pain on a scale of 0 to 10; these representations are recommended for use in adults by the American Geriatrics Society and the American Pain Society (Ware, Epps, Herr, & Packard, 2006; Herr, Spratt, Mobily, & Richardson, 2004). The thermometer scale may be useful in the elderly (Rakel & Herr, 2004). It shows a picture of a thermometer arranged on a background with a vertical word scale. Finally, categoric scales use verbal descriptors to quantify the level of pain (e.g., none, mild, moderate, or severe). Such scales have been validated and are considered to be reliable (Chapman, Casey, Dubner, et al., 1985). Furthermore, categoric scales can be more easily understood by patients with cognitive impairments.

Criteria should be established both in the PACU before discharge and on postoperative care units to determine acceptable levels of pain defined by both a minimal degree of pain, e.g., a numeric value, and an acceptable level of pain expressed by the patient. Keep in mind that the presence of sedation and other adverse effects of analgesics must be considered before pain is aggressively treated to reduce pain scores. It is also important to anticipate times when patients may be discharged from the PACU with a level of 3 (in a 0-10 scale), anticipating that transfer to the general postsurgical units may increase pain. Transfer of care between perianesthesia and postsurgical nurses should include information about comfort level, effective strategies for relieving pain, and concerns that patients may have about his or her pain. Skilled communication is important in effectively controlling pain and meeting patients’ expectations for pain relief after this transition of care.

The measurement of pain relief, a different concept, is intended to obtain an estimate of either how well pain is being managed or the effectiveness of analgesic therapies. There are many versions of pain relief scales, but the most frequently used one uses a percentage rating of 0% to 100% pain relief (Davis & Walsh, 2004). Although responses help to determine the degree of relief produced by analgesic therapy, the results can be misleading because, even though a medication has relieved some of the pain the pain may still be severe. Therefore, it is essential to examine responses to both a pain intensity and a pain relief scale. Similar to pain intensity scales, measures are available to assess multiple dimensions of pain, such as pain relief, quality and character of the pain, and the degree to which pain interferes with activity, mood, and sleep. The Brief Pain Inventory, originally developed in a population of cancer patients, is a multidimensional instrument that has recently been studied with postoperative patients (Zalon, 2006).

No single unidimensional scale provides a comprehensive measure of all aspects of the pain experience, and each must be interpreted alone and in combination with other patient data. For example, the degree of pain relief is often reported to be greater despite evidence that pain intensity may be moderate or severe. This caveat underscores the importance of comparing responses to ensure that no single measure is relied upon to confirm a favorable response to pain management. Multidimensional instruments capture several components of the pain experience. These instruments may require additional time, however, to administer, complete, score, and interpret; therefore, they are most often used in pain research. They evaluate the effects of pain on multiple domains of a patient’s life (e.g., emotional, mental, activities of daily living, relationships, and quality of sleep; Table 2). (Davis & Walsh, 2004).

**ASSESSMENT OF PAIN IN SPECIAL POPULATIONS**

The preceding section reviews elements of the assessment process in adults. However, special populations require either modification of the process or the use of additional pain assessment tools and strategies. Health care professionals must be aware of their attitudes, beliefs, and personal biases toward vulnerable populations. Here, the important components of pain assessment in the young, elderly, and patients with difficulties communicating their pain are briefly described.

Among the most vulnerable of populations experiencing pain are infants and children. Assessment of pain in infants can be difficult, because they are unable to verbally communicate the presence and severity of pain. In addition, assessment criteria differ depending
on the age of the infant. Therefore, evaluation of infant pain and responses to pain treatment must be undertaken by relying on reliable and valid criteria-based scales that incorporate physiologic parameters, ratings of behavioral observations, and overall disposition of the patients. For example, clues to the presence of acute severe pain on physical examination may include tachycardia, tachypnea, increased blood pressure, cutaneous pallor, and vomiting. Caution must be exercised when evaluating physiologic parameters, however, because they may be indicators of conditions other than pain, such as hypovolemia and shock. Above all, nurses must be cognizant of procedures that are known to evoke pain and discomfort (e.g., heel sticks, venipunctures, and insertion of tubes and drains) as well as the presence of surgical incisions, other wounds, and invasive technology. Infants experiencing acute pain may also express a variety of behavioral clues, including crying, grimaces, alterations in sleep and eating patterns, and body movements, that may indicate that they are withdrawing from an adverse stimulus. Several reliable and valid measures are available to assess pain in infants, including the Premature Infant Pain Profile (Stevens, Johnston, Petryshen, & Taddio, 1996), the Neonatal Infant Pain Scale (Lawrence, Alcock, McGrath, et al., 1993), the

**TABLE 2.**

<table>
<thead>
<tr>
<th>Scale</th>
<th>Important Features</th>
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<tr>
<td>Brief Pain Inventory</td>
<td>Developed to balance the need for information with the burden of responding to a multidimensional instrument. Four questions about intensity of pain. Seven questions about pain-related interference. Numeric scale to rate pain intensity and interference overall.</td>
</tr>
<tr>
<td>McGill Pain Questionnaire</td>
<td>Assesses the following pain-related elements: Sensory. Affective. Evaluative. Affective word scales can help to identify depression.</td>
</tr>
<tr>
<td>Memorial Pain Assessment Card</td>
<td>Assesses the following pain-related elements on a VAS: Intensity. Relief. Mood.</td>
</tr>
</tbody>
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*Multidimensional instruments are generally used in clinical trials of patients with chronic pain, not in acute perioperative pain.

Pain assessment in older adults can be challenging and very difficult in some situations (Rakel & Herr, 2004). Their mindset may reflect beliefs from earlier times when there were a limited number of medications and concerns about the potential for addiction were more prevalent. Also, some older adults may be stoic, may believe that they should tolerate unnecessary pain, or may be reluctant to ask for or self-administer analgesia until pain is more severe. Furthermore, older patients may prefer to use alternate means to express their pain through the use of word descriptors that best characterize the pain, such as “aching,” “hurting,” and “soreness” (Herr & Garand, 2001). Another complicating factor is the presence of preexisting pain (e.g., osteoarthritis). It is estimated that 25% to 50% of older adults experience some form of persistent pain (American Geriatrics Society Panel on Persistent Pain in Older Persons, 2002). In a study of pain assessment practices abstracted from 709 older adults hospitalized for hip fractures across 12 acute care hospitals and evaluations of practice reported by 172 nurses, fewer than 40% of patients had pain assessments documented every 4 h in the first 24 h of hospitalization, and much fewer (less than 6%) were assessed within 72 h of admission (Herr, Titler, Schilling, et al., 2004). Moreover, compliance with established standards for documentation of reassessment of pain 60 min after the administration of analgesics was extremely poor. In addition, deficiencies were noted for routine documentation of pain-related behaviors and opioid-induced adverse effects. Thus, the authors concluded that pain assessments and reassessments are not regularly performed in accordance with standards set by the Joint Commission and Agency for Healthcare Research and Quality (AHRQ), and that evidence-based practices for pain assessment were not fully integrated into the care of hospitalized older adults. Recent consensus reports outline evidence-based practice guidelines for assessing pain in older adults with and without cognitive impairments (American Geriatrics Society Panel on Persistent Pain in Older Persons, 2002; Hadjistavropoulos, Herr, Turk, et al., 2007; Herr, Coyne, Key, et al., 2006).

Unidimensional tools can be extremely useful when assessing pain in older adults. In fact, even in the presence of cognitive impairment, elderly patients in pain may be able to report and describe their pain. Postoperatively, acute pain may be manifested by diaphoresis and changes in vital signs; however, they may be absent in patients with significant pain. In addition, tachycardia and tachypnea can be confused with physiologic alterations from other complicating conditions (e.g., anxiety, bleeding, and venous thromboembolism).

Significant challenges occur when assessing patients who are not able to communicate verbally, in writing, or by gestures, or when they are cognitively impaired. Because there is compelling evidence to support the need for pain evaluations in this population, many nurses struggle with ways to reliably obtain pain relief outcomes. In these circumstances, it is imperative to assume that pain is present when consistent with tissue injury, procedure-induced pain, or disease-associated pathology, and treatment appropriate for the management of pain should be instituted. Initially, however, there should be an attempt to obtain a self-report. In some instances, a simple “yes” or “no” may be sufficient to initiate therapy. Surrogates (e.g., family members or significant others) can, in many instances, provide credible information. Even if patients are unable to communicate, they may exhibit a variety of pain-related behaviors, such as restlessness, agitation, rubbing, splinting or guarding painful body parts, or using facial expressions including frowning, grimacing, and/or wincing. Vocalizations such as groaning, moaning, sighing, or grunting may also be behavioral indicators of pain. Pain should also be suspected when postoperative behaviors are distinctly different from those observed in the preoperative state. Other manifestations of pain can also include withdrawal, refusal to eat, aggression, irritability, or signs of anxiety. The Checklist of Nonverbal Pain Indicators (CNPI) is an observational pain rating measure that has been validated in patients with cognitive impairment using several of the behaviors mentioned previously (Feldt, 2000). Of course, a trial of analgesics may prove to be both affirming and therapeutic if pain-related behaviors improve.

The unconscious mechanically ventilated patient presents a significant pain assessment challenge. As mentioned, behaviors may be used to assess pain when a patient is unable to provide self-report. The Critical Care Pain Observation Tool (Gelinas, Fillion, Puntillo, et al., 2006) and the Behavioral Pain Scale (Payen, Bru, Bosson, et al., 2001) have been shown to

CRIES (C-Crying; R-Requires increased oxygen administration; I-Increased vital signs; E-Expression; S-Sleeplessness) (Suracrossinongse, Kosaard, Intakong, et al., 2006), COMFORT Scale (Bear & Ward-Smith, 2006), the FLACC (Face, Legs, Activity, Cry, and Consolability) Scale (Malviya, Voeppel-Lewis, Burke, et al., 2006) and the Wisconsin Children’s Hospital Pain Scale for Preverbal and Nonverbal Children (Soetenga, Frank, & Pellino, 1999). The latter three scales have utility in measuring pain responses in preverbal and nonverbal children. For older children who are capable of providing self-reports of pain, the Wong-Baker Faces Pain Scale can be helpful (Hockenberry, Wilson, & Winkelstein, 2005).
be reliable and valid behavioral pain assessment tools in this patient population.

An important principle whenever behavioral tools are used in any patient who is unable to provide a self-report of pain is that the patient must be able to respond with the requisite behaviors listed in the tool. If a patient with potentially painful pathology is unable to respond with the requisite behaviors, the tool should not be used, the presence of pain should be assumed, and an appropriate plan of treatment should be formulated (Pasero & McCaffery, 2005). It is also important to realize that a behavioral score is not the same as a pain intensity score. Behavioral scores are useful in telling us that pain may be present. The exact intensity of the pain is unknown, however, if a patient cannot provide a self-report (Pasero & McCaffery, 2005).

**APPROPRIATE MONITORING**

Monitoring patients in the perioperative period is critical to evaluating responses to treatment and ensuring patient safety. Nurses are the first line of defense in the prevention of clinically significant opioid-induced respiratory depression. Although there are no universally accepted practice guidelines for the frequency of vital signs and other parameters, the most aggressive monitoring must take place in the first 24 h after surgery and at times when existing doses of analgesics are altered or when new analgesic modalities are introduced. In addition to vital signs, other parameters must be regularly monitored, including levels of sedation, mental status, activity, and psychologic status. The observation that patients are sedated before clinically significant opioid-induced respiratory depression warrants more vigilant monitoring of this parameter in particular and the expectation that nurses will decrease opioid doses as soon as increased sedation is detected (Pasero & McCaffery, 2002).

There are numerous guidelines that help to guide pain management practice in the perioperative setting. ASPAN Pain and Comfort Guideline discusses the responsibilities of perianesthesia nurses throughout the continuum of care (American Society of PeriAnesthesia Nurses, 2003). The American Society of Anesthesiologists (ASA) also has outlined the criteria for monitoring and documenting patient responses in the perioperative period (American Society of Anesthesiologists Task Force on Acute Pain Management, 2004). Specific to analgesia by catheter techniques, the American Society for Pain Management Nursing has a position statement that incorporates practice standards for assessing and monitoring patients (Pasero, Eksterowicz, Primeau, & Cowley, 2007). Members of the American Society of Regional Anesthesia and Pain Medicine conducted a critical appraisal of current postoperative pain practices and graded the scientific evidence to support ten practice-based statements and recommendations for practice (Rathmell, Wu, Sinatra, et al., 2005). Rathmell et al. also emphasize the need for monitoring for the purpose of medication error prevention (Rathmell, Wu, Sinatra, et al., 2005). The use of technology such as invasive or noninvasive cardiovascular and respiratory monitoring equipment provides more intensive and often continuous monitoring to augment practices for ensuring safe and efficient patient care. All of these documents are useful resources for supporting evidence-based practice and helpful in addressing patient needs, designing plans of care, and monitoring patients.

**VITAL SIGNS**

Changes in vital signs may be early indicators of the need for initial or additional analgesia and of adverse effects from systemic or neuraxial analgesia. As previously noted, acute pain is accompanied by neurohumoral responses that can lead to significant increases in heart rate, blood pressure, and respiratory rate. Alternately, bradycardia, hypotension, and bradypnea may be a sign of overmedication (sedatives or opioids). Frequent assessments of respiratory status are critical, especially in patients receiving systemic or neuraxial opioids and patients at risk for opioid-induced respiratory depression and pulmonary complications. Factors increasing this risk include older age, obesity, patients with obstructive sleep apnea or pre-existing pulmonary disease, location of incision, and duration of surgery. The pattern of respirations, including rate, depth, and regularity, should be observed and documented, and respirations should be counted for 1 full min. Overall, changes in vital signs may be the first sign of a complication directly related to the surgical procedure.

**SpO₂ by Pulse Oximetry**

Pulse oximetry provides a simple way to monitor oxygenation of the blood (SpO₂) in the perioperative setting (Soubani, 2001). The Anesthesia Patient Safety Foundation recommended in 2006 that health care professionals should give serious consideration to continuous monitoring of oxygenation (pulse oximetry) and ventilation in patients receiving patient-controlled analgesia or neuraxial opioids in the postoperative period. To date, there is little evidence to show the benefit of continuous pulse oximetry. Ochroch et al. studied 1,219 patients cardiothoracic surgery randomized to continuous pulse oximetry connected to a
central monitoring station for standard monitoring using intermittent SpO₂ readings taken with a standalone monitor to determine the effects on intensive care unit (ICU) readmissions rates (Ochroch, Russell, Hanson, et al., 2006). Although there was no difference in rates of ICU readmissions, the reasons for readmissions differed, and duration and estimated costs of the ICU stay were significantly lower for the continuously monitored group. Some believe that pulse oximetry may not accurately measure normal ventilatory functions and therefore is not capable of detecting episodes of severe CO₂ retention (Goyette, 1997). The SaO₂, which is the absolute oxygen content of the blood, is more accurate, but arterial blood gas measurements are required which are not feasible or practical in routine postoperative care. Because only a limited amount of oxygen is dissolved in the plasma, the SaO₂ essentially reflects the amount of oxygen bound to hemoglobin. The normal SaO₂ of arterial blood is ≥97%; this is equivalent to a PO₂ of 100 mm Hg (Cornell UMC). Oxygen saturations of <90% correspond to PO₂ of <59 mm Hg. The narrow gap between normal SaO₂ and hypoxia is a function of hemoglobin’s oxygen dissociation curve; because the curve is sigmoidal rather than linear, a 7% decrease in SaO₂ reflects a decrease of the PO₂ by 41 mm Hg. Limitations include failure to evaluate the small amount of oxygen that is actually dissolved in the blood and inability to sense the pulse in patients with significant peripheral vasoconstriction or dysrhythmias. Because providing supplemental oxygen decreases the sensitivity and specificity of the SaO₂, capnography provides valuable additional information on respiratory status (Table 3) (Soubani, 2001). The ramifications of such monitoring have not been fully addressed, and there is no compelling scientific evidence that this type of intensive monitoring leads to safer patient care. In one small observational study of 28 patients receiving epidural or patient-controlled analgesia and supplemental oxygen after elective major laparotomy, hypercapnia was evident even when respiratory rates and SpO₂ values were normal (Kopka, Wallace, Reilly, & Binning, 2007).

End-Tidal CO₂ by Capnography

Capnography is the process of continuously measuring the CO₂ concentration in a mixture of gases (Soubani, 2001). Similar to pulse oximetry, this procedure uses differences in light transmission by various substances to determine their concentration. The normal capnogram has three phases: Phase I is the basal state and represents anatomic dead space; phase II demonstrates a rapid rise as the CO₂ in the exhaled breath contains increasing amounts of the gas; and phase III occurs at the end of expiration and represents the alveolar CO₂, known as end-tidal CO₂ (PetCO₂). With inspiration, there is a rapid downstroke of the curve as CO₂ levels drop sharply. In normal individuals, the PetCO₂ differs from the PaCO₂ by 2 to 5 mm Hg; the difference widens with increasing amounts of dead space. Because waveform changes may be clinically significant, both the PetCO₂ and the tracing should be monitored. Applications of the PetCO₂ include monitoring alveolar ventilation, confirming endotracheal intubation, assessing cardiopulmonary resuscitation, and evaluating changes in dead space. Nasal cannula technology is available, and new technology is on the horizon for measuring PetCO₂ transcutaneously.

### CONSEQUENCES OF INADEQUATE ACUTE PAIN MANAGEMENT

#### Alterations in Physiology

Acute postoperative pain is accompanied by a neurohumoral response that can have a significant negative impact on patient outcomes. In response to the stress of trauma and/or the operative procedure, increased release of catecholamines can lead to tachycardia, elevated blood pressure, and associated myocardial oxygen use (KLiu & Gropper, 2003). This consequence may result in left ventricular dysfunction, myocardial ischemia, or myocardial infarction. Other hormones released in response to the stress of unrelieved pain include cortisol and glucagon. These hormones can lead to insulin resistance, hyperglycemia, alterations of protein and fat metabolism, and postoperative compli-

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**Table 3. Conditions Altering PetCO₂**

<table>
<thead>
<tr>
<th>Disorder</th>
<th>Change in PetCO₂</th>
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<tbody>
<tr>
<td>Increased PetCO₂</td>
<td>↑</td>
</tr>
<tr>
<td>Hypoventilation</td>
<td>↑</td>
</tr>
<tr>
<td>Increased cardiac output</td>
<td>↑</td>
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<tr>
<td>Fever</td>
<td>↑</td>
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<tr>
<td>Exogenous CO₂ (e.g., laparoscopy)</td>
<td>↑</td>
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<tr>
<td>Administration of bicarbonate</td>
<td>↑</td>
</tr>
<tr>
<td>Decreased PetCO₂</td>
<td>↓</td>
</tr>
<tr>
<td>Esophageal intubation</td>
<td>↓</td>
</tr>
<tr>
<td>Hyperventilation</td>
<td>↓</td>
</tr>
<tr>
<td>Decreased cardiac output</td>
<td>↓</td>
</tr>
<tr>
<td>Cardiac arrest</td>
<td>↓</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>↓</td>
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<tr>
<td>Hypothermia</td>
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cations (Ljungqvist, Nygren, Soop, & Thorell, 2005; Marik & Raghavan, 2004; Rosenfeld, Faraday, Campbell, et al., 1994; Turina, Miller, Tucker, & Polk, 2006). Stress associated with inadequately treated acute pain can produce hypercoagulability and impaired activity of both innate and adaptive immunity (Rosenfeld, Faraday, Campbell, et al., 1994; Turina, Miller, Tucker, & Polk, 2006; Slade, Greenberg, Yunis, & Simmons, 1974). Consequences of these complications may include venous thromboembolic disease and increased risk of postoperative infections. Early studies have demonstrated that when pain is adequately treated the magnitude of these perioperative neurohumoral and hemostatic changes is less (Swinamer, Phang, Jones, et al., 1988; Modig, Borg, Bagge, & Saldeen, 1983). Fast-track surgery using combinations of epidural or regional anesthesia and minimally invasive techniques to optimize pain control reduces the stress response and organ dysfunction, thus greatly shortening the time to recovery for patients undergoing elective surgery (Wilmore & Kehlet, 2001; Shang & Gan, 2003).

Clinical Manifestations
In addition to metabolic, hemodynamic, and hemostatic changes, inadequately treated acute pain can produce impairments that are more clinically obvious, although not necessarily more clinically significant. Postoperative pain with thoracic and abdominal splinting can impair respiratory excursions and inhibit coughing needed to clear the airway and prevent atelectasis (Watson, 2002; Desai, 1999). Furthermore, inadequately treated acute pain can delay return of normal gastrointestinal function. With increased autonomic activity, there is decreased motility of gastrointestinal smooth muscle, which can lead to gastric dilatation and may contribute to postoperative ileus in some patients (Stephens, Laskin, Pashos, et al., 2003). The same increased autonomic outflow can contribute to postoperative urinary retention. Unmanaged, acute postoperative pain can also delay mobilization, which can increase the risk of venous thromboembolic disease, produce joint stiffness, delay rehabilitation, and prolong hospitalization (Hughes, 2004). Inadequate acute pain management can also have significant psychosocial consequences and cause patients to become dissatisfied with their care. Patients with unrelieved postoperative pain can be anxious, agitated, and unable to sleep well and can experience negative emotions (Lipman, 1990).

Potential for Chronic Pain
There is a link between poorly controlled postoperative pain and the risk of developing chronic pain (Rathmell, Wu, Sinatra, et al., 2005). Interventions such as minimally invasive procedures or nerve blocks are followed by fewer instances of chronic pain (Kehlet, Jensen, & Woolf, 2006). For example, in patients undergoing a thoracotomy, epidural analgesia is accompanied by less acute pain and a lower frequency of chronic pain. Although the literature supports the association between poorly controlled postoperative and chronic pain, it is a risk factor and not necessarily causative. The mechanisms by which acute pain leads to chronic pain states are depicted in the complex cascade of events following acute injury.

that occur when tissues are initially injured (Fig. 1) (Carr & Goudas, 1999) For example, patients who experience more severe pain despite attempts to optimize analgesia may well develop chronic pain irrespective of analgesic interventions.

CONCLUSIONS

Many patients perceive that control of their acute postoperative pain is inadequate. Inadequate pain control can prolong the recovery period, increase length of stay, and increase overall health care costs (Shang & Gan, 2003). An additional consequence of poorly treated pain is a decrease in patient satisfaction; this alone is important but also can adversely affect the ability to attract patients in the current competitive health care market. Nurses are the primary group of health care professionals responsible for the ongoing assessment and monitoring of patients to ensure that pain is effectively and appropriately managed and that patients and families are informed of the consequences of acute pain (Buckley, 2000).

REFERENCES


