As veterinarians in the twenty-first century, we have an ethical responsibility to our patients and clients to avoid, or at least to reduce significantly, pain in animals under our care. The American Animal Hospital Association and the American Association of Feline Practitioners have joined to promote an emphasis in veterinary medicine on pain management.1 Although this mandate can be stretched to cover a range from “less than appropriate” management to “unnecessary extremes” in analgesia administration, this article attempts to define a safe, practical, and yet suitable approach to management of pain in the perioperative period. Treatment for pain that approaches either extreme should be addressed by observation and refinement, because exact recipes do not suit all individuals, even animals that have undergone a similar procedure. Veterinarians must use their best judgment related to a starting point (often beginning with guidelines), monitor the patient’s response to such treatment, and adjust accordingly. Clearly, the veterinarian’s role in pain management is not complete after establishment of an analgesic plan.

ADJUNCTS TO PAIN MANAGEMENT

Usually, we think of analgesic drugs when the topic of pain management is mentioned, but it is important to keep in mind the other aspects that contribute to successful pain control. Anxiety, stress, and uncomfortable surroundings have an impact on the individual’s ability to handle pain. We recognize the comfort of our own bed in a quiet home with loving people, familiar objects nearby, and appetizing food as significant determinants in our overall feeling of well-being. Research has also shown that psychologic and physical aspects have an impact on the achievement of pain control.2 Veterinarians may be able to reduce anxiety and uncomfortable surroundings with simple actions. Noise, temperature, and light can be maintained at a more optimal level for our patients. Quiet rooms can be defined to isolate the patient to keep it from disturbing others or to provide a calmer environment for the more sensitive
animal. Nursing care that includes provision of clean bedding, comforting words, petting, cuddling, and playing with the pet should contribute significantly to the management of mild pain and supplement the pharmacologic treatment of more severe pain, as has been reported in human infants. Many practices encourage family visits during hospital stays to help reduce patient stress and gain insight on other interventions toward analgesia for the individual involved. Further information on good nursing care for surgical patients can be found in the article by Shaffron, Fagella, and Taylor elsewhere in this issue.

Nonanalgesic pharmacologic approaches can also provide calming effects that intensify the pain relief from specific analgesic drugs. This is the principle behind neuroleptanalgesia, which is able to provide better results than analgesia alone when minor surgical procedures are required. Therefore, the use of sedatives and tranquilizers is considered along with the administration of analgesic drugs, when appropriate.

ADVANCE APPLICATION OF ANALGESIA

Fentanyl patches require advance application to be effective for perioperative pain management. Animals that are admitted the night before can have a patch placed if this is an option for postoperative management. The advantage of this method is achievement of a steady-state level of analgesia in 12 hours (cats) to 24 hours (dogs) and lasting 72 hours. Fentanyl plasma concentrations vary significantly among individuals, however, and it may not be possible to guarantee achievement of good analgesic levels at the time of surgery. The impact of a fentanyl patch on inhalant requirements during surgery has been estimated by minimum alveolar concentration (MAC) measurement. A MAC reduction of 18% in cats and 37% in normothermic dogs is expected, with no significant MAC reduction in hypothermic (34.5°C) dogs. The reduction in MAC in cats is not much different than after administration of butorphanol, and because hypothermia, which is commonly expected during longer and more painful surgical procedures, reduces the impact on MAC as well, further intramuscular opioid administration in premedication should not cause concerns. If clinical signs of opioid administration are apparent in advance of premedication (eg, panting, mild sedation), one may elect to give only half of the opioid dose planned. Further opioid can be administered if needed during the operation. Many anesthetists believe that these results and the safety associated with opioid use during surgery provide little reason to reduce opioid doses significantly in the premedication period, however (Table 1). Thus, the entire dose is usually used for premedication when fentanyl patches are used.

Some nonsteroidal anti-inflammatory analgesics (NSAIAs) may also be administered in advance of premedication if there are no present or expected contraindications for use (see the article by Papich and the article by Mathews elsewhere in this issue). This preoperative use may be a reasonable option to ensure analgesia at the time of recovery if the operation is unlikely to be associated with excessive blood loss or hypotension. A complete history from the owner and careful assessment of the patient are critical to ensure that NSAIA use is actually safe, however, irrespective of time of administration. For example, owners may administer aspirin to their pet and yet not consider this when asked indirectly if the animal is on any medication. Related to considering use before surgery, not all NSAIAs can be recommended. Carprofen, meloxicam, and tepoxalin have been assessed and found to be safe in healthy dogs when given in advance of anesthesia. Recommendations on timing of NSAIA administration varies according to the route selected. If oral drugs are selected, they are usually not given with premedication but at the last meal, although oral administration can result in a rapid effect similar to that achieved with intravenous dosing.
(30–60 minutes). Research indicates that the achievement of maximum plasma concentrations is longer, and that onset of analgesia for acute synovitis is slower, after meloxicam administration when compared with other NSAIA,

The analgesic efficacy of NSAIA has been documented for several surgical procedures in dogs and cats, but this should not eliminate consideration of additional analgesic drugs. Because no significant MAC reduction results from the preoperative administration of NSAIA, the addition of opioid analgesics can provide this and other benefits, such as prevention of wind-up.

**PREMEDICATION**

Most surgical procedures performed in general practice are elective; thus, the patient is presented without pain. The ideal approach to managing pain in these patients is to prevent it, and this usually starts with the premedication analgesics. Other patients presented for surgery may have accompanying pain and have analgesia on board as discussed previously or may be receiving continuous rate infusions (CRIs; as discussed elsewhere in this article) according to the level of pain on admission to the hospital. The anesthetist or practitioner must consider any present opioid effects at time of presentation for surgery in addition to the impact of other drugs on board when deciding on premedication requirements. If the analgesic administered during the preoperative period is effective, it should never be assumed that the intraoperative and postoperative pain is going to be managed equally as well. For some surgical procedures, the pain may be less after surgery (eg, cervical disk surgery), whereas for others, the pain may be greater during and after surgery (eg, most fracture repairs, peritonitis).

Opioid analgesics are the most commonly selected drugs for perioperative pain prevention or treatment. The specific drug selection and dose should be based on the level of expected pain. Butorphanol or buprenorphine is appropriate for mild (to moderate) pain (likely that involved in an ovariohysterectomy or castration performed by an experienced veterinarian). Buprenorphine has the advantage of a 6-hour duration of effect compared with as little as 2 hours with butorphanol. Morphine or hydromorphone could be selected for a longer effect as well, but low doses (eg, 0.2–0.3 mg/kg, 0.02–0.03 mg/kg, respectively) may be more appropriate for milder pain. Occasionally the “harder to handle” patient requires use of these more profound opioids at higher doses for the additional sedating effect that they achieve; however, dysphoria and panting may be a disadvantage. It is important to keep in mind that elective surgery is not always associated with mild pain. Surgical skill (ie, inexperienced) and patient condition (eg, severe obesity) can change the expected pain level of a procedure. Onychectomy in a cat is an elective procedure associated with a greater level of pain. Good analgesia has been shown after administration of buprenorphine (0.01 mg/kg), although hydromorphone (0.05 mg/kg) could also be chosen for premedication for such procedures. When other surgical procedures are required that involve more extensive tissue trauma or take longer to perform (thus increasing inflammation from tissue handling), the μ-agonists are usually selected, and typical doses in dogs are 0.3 to 0.5 mg/kg and 0.03 to 0.05 mg/kg for morphine and hydromorphone, respectively, or fentanyl at a dose of 3 to 5 μg/kg. Extremely painful operations or those in which significant wind-up may be present may require up to 1.0 mg/kg and 0.1 mg/kg, respectively, especially when performed in smaller patients (surface area impact on drug dosing). Cats are safely
<table>
<thead>
<tr>
<th>Drug</th>
<th>Indication</th>
<th>Dose</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buprenorphine</td>
<td>Minor procedures (e.g., castration, joint tap, laceration)</td>
<td>0.003–0.005 mg/kg</td>
<td>4–8 hours</td>
</tr>
<tr>
<td></td>
<td>Mild to moderate pain (e.g., ovariohysterectomy)</td>
<td>0.005–0.1 mg/kg</td>
<td>4–8 hours</td>
</tr>
<tr>
<td>Butorphanol</td>
<td>Minor procedures (e.g., castration, joint tap, laceration)</td>
<td>0.1–0.2 mg/kg</td>
<td>3–6 hours</td>
</tr>
<tr>
<td></td>
<td>Mild to moderate pain (e.g., ovariohysterectomy)</td>
<td>0.2–0.4 mg/kg</td>
<td>2–4 hours</td>
</tr>
<tr>
<td>Fentanyl</td>
<td>Premedication or loading dose</td>
<td>2–10 μg/kg</td>
<td>15–20 minutes</td>
</tr>
<tr>
<td></td>
<td>Moderate pain associated with most orthopedic procedures (e.g., fracture repair, back surgery)</td>
<td>2–5 μg/kg/h</td>
<td>Infusion duration + 20 minutes</td>
</tr>
<tr>
<td></td>
<td>Moderate to severe pain associated with major surgery (e.g., thoracotomy, amputation)</td>
<td>3–10 μg/kg/h</td>
<td>Infusion duration + 20 minutes</td>
</tr>
<tr>
<td>Fentanyl patch</td>
<td>Painful procedures that may benefit from extended duration of effect (e.g., declawing) or from steady level of underlying analgesia (e.g., trauma surgery, orthopedic surgery) in association with other analgesic techniques</td>
<td>Cats, dogs &lt;10 kg: 25 μg/h</td>
<td>3–5 days</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10–20 kg: 50 μg/h</td>
<td>3 days</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20–30 kg: 75 μg/h</td>
<td>3 days</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;30 kg: 100 μg/h</td>
<td>3 days</td>
</tr>
<tr>
<td>Hydromorphone</td>
<td>Mild to moderate pain associated with straightforward abdominal surgery (e.g., ovariohysterectomy) or elective orthopedic surgeries (e.g., dew claw removal)</td>
<td>0.02–0.03 mg/kg</td>
<td>3–6 hours</td>
</tr>
<tr>
<td></td>
<td>Moderate pain associated with most orthopedic procedures (e.g., cruciate surgery, declawing)</td>
<td>0.03–0.05 mg/kg</td>
<td>3–4 hours</td>
</tr>
<tr>
<td></td>
<td>Moderate to severe pain associated with major surgery (e.g., thoracotomy, amputation)</td>
<td>0.05–0.1 mg/kg. (monitor for hyperthermia in cats if high doses are given)</td>
<td>3–4 hours</td>
</tr>
<tr>
<td>Ketamine</td>
<td>Used as premedication (usually in combination) for good restraint and somatic analgesia</td>
<td>Cat: 5–7 mg/kg</td>
<td>20–30 minutes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dog: 3–5 mg/kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Short-term analgesia</td>
<td>0.2–4 mg/kg</td>
<td>10–30 minutes</td>
</tr>
<tr>
<td></td>
<td>Analgesic infusion (usually with other drugs)</td>
<td>0.1–2 mg/kg/h</td>
<td>Infusion duration</td>
</tr>
<tr>
<td>Ketamine with diazepam (1:1 or 2:1)</td>
<td>Used to supplement premedication effect</td>
<td>0.03–0.04 mL/kg</td>
<td>4–6 minutes</td>
</tr>
<tr>
<td>Drug</td>
<td>Usage</td>
<td>Dose (Example)</td>
<td>Duration</td>
</tr>
<tr>
<td>--------------</td>
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<td>-------------------------------------------------------------------------------</td>
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</tr>
<tr>
<td><strong>Lidocaine</strong></td>
<td>Used in association with any induction for analgesia and MAC reduction; often given before induction and then infusion used</td>
<td>2 mg/kg ⇒ 50–200 μg/kg/min (reduce dose in 1 hour or stop 20 minutes before recovery)</td>
<td>Infusion duration</td>
</tr>
<tr>
<td></td>
<td>Used in association with any induction for antiarrhythmic effect, analgesia and MAC reduction; bolus often given before and after induction and then infusion used</td>
<td>2 mg/kg (twice in 10 minutes) + 120 μg/kg/min (reduce dose in 1 hour before recovery)</td>
<td>Infusion duration</td>
</tr>
<tr>
<td><strong>Medetomidine</strong></td>
<td>Used as premedication in healthy animals for more profound restraint and associated analgesia</td>
<td>Dog: 10–20 μg/kg Cat: 20 μg/kg</td>
<td>1–2 hours</td>
</tr>
<tr>
<td></td>
<td>Supplementation of analgesia (and sedation)</td>
<td>1–2 μg/kg/h</td>
<td>Infusion duration</td>
</tr>
<tr>
<td></td>
<td>Used immediately after surgery (in close association with extubation)</td>
<td>1–2 μg/kg</td>
<td>0.2–0.5 hour</td>
</tr>
<tr>
<td><strong>Meperidine</strong></td>
<td>Short-term mild to moderate analgesia for intramuscular use only</td>
<td>5–10 mg/kg</td>
<td>0.5–2 hours</td>
</tr>
<tr>
<td><strong>Morphine</strong></td>
<td>Mild to moderate pain associated with straightforward abdominal surgery (eg, ovariohysterectomy) or elective orthopedic operations (eg, dew claw removal)</td>
<td>Dog: 0.2–0.3 mg/kg Cat: 0.2 mg/kg</td>
<td>3–4 hours</td>
</tr>
<tr>
<td></td>
<td>Moderate pain associated with most orthopedic procedures (eg, cruciate surgery, declawing)</td>
<td>Dog: 0.3–0.5 mg/kg (not in cats)</td>
<td>3–4 hours</td>
</tr>
<tr>
<td></td>
<td>Moderate to severe pain associated with major surgery (eg, thoracotomy, amputation)</td>
<td>Dog: 0.5–1 mg/kg (not in cats)</td>
<td>3–4 hours</td>
</tr>
<tr>
<td><strong>Nonsteroidal anti-inflammatory analgesics</strong></td>
<td>Possibly alone in mild to moderately painful procedures and as supplementation of other analgesia in moderate to severe pain</td>
<td><strong>Carprofen</strong>&lt;br&gt;Cat: 4 mg/kg once&lt;br&gt;Dog: 4 mg/kg/d ⇒ 2 mg/kg/d</td>
<td>&gt;24 hours</td>
</tr>
<tr>
<td></td>
<td>Loading dose is rarely needed in elective procedures (without wind-up and less painful)</td>
<td><strong>Ketoprofen (postoperative use only)</strong>&lt;br&gt;2 mg/kg/d ⇒ 1 mg/kg/d</td>
<td>12–24 hours</td>
</tr>
<tr>
<td></td>
<td>Injectable formulations are noted as follows:</td>
<td><strong>Meloxicam</strong>&lt;br&gt;0.2 mg/kg/d ⇒ 0.1 mg/kg/d</td>
<td>24 hours</td>
</tr>
</tbody>
</table>

Range noted relates to surface area adjustment or degree of effect required. A separate cat dose is noted when needed. An extended list of drugs and more detail are found in this article and in the other article by Dyson elsewhere in this issue.
premedicated with hydromorphone for procedures associated with moderate to severe pain, using a starting dose of 0.05 mg/kg and considering that the duration of effect may be longer in cats than in dogs. Caution related to use of high doses or early repeat dosing is warranted to avoid hyperthermia (see section on preparation for recovery for more detail). Fentanyl can also be used in the cat at similar doses as used in the dog. Morphine, however, is rarely used at a dose higher than 0.2 mg/kg in the cat.

Ketamine is a somatic analgesic that may be added to the premedication. Telazol contains tiletamine, another N-methyl-D-aspartate (NMDA) antagonist with similar analgesic properties. Hyperalgesia associated with surgery in people seems to be less with ketamine, and the requirement for postoperative analgesia is reduced. Ketamine is a useful premedication in cats (5–7 mg/kg), although it is more often selected in those that are hard to handle. Although ketamine is rarely used in dogs for premedication, evidence for incorporation as an intraoperative infusion is presented elsewhere in this article.

At the time of premedication, this author often administers sedatives to reduce anxiety from the handling involved (Table 2). Acepromazine is quite effective in most cats and dogs. Even low doses can be helpful (0.01–0.02 mg/kg) when selected in the quiet or older dog. Cats typically require a minimum of 0.05 mg/kg if an effect is to be achieved by its addition to the premedication, whereas more may be required after surgery to produce an improvement in analgesia (discussed in the section on preparation for recovery). The older cat or dog may be managed without acepromazine as part of the premedication in most situations, however, with the option of adding this for recovery if necessary. Compromised patients are best managed without using acepromazine. Preliminary evidence indicates that treatment of hypotension may be more difficult when acepromazine is on board. Benzodiazepines (diazepam or midazolam at a dose of 0.2 mg/kg) can produce an anxiolytic effect and are occasionally

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Drugs (dosages listed reflect combination use) that are useful in combination with some of the analgesics in Table 1</th>
</tr>
</thead>
</table>
| Acepromazine | **Preoperative use in young healthy animals**  
| | Cat: 0.05–0.15 mg/kg  
| | Dog: 0.02–0.05 mg/kg  
| | **3–4 hours**  
| | **Preoperative use in geriatric patients**  
| | Cat: 0.02–0.05 mg/kg  
| | Dog: 0.01–0.02 mg/kg  
| | **3–4 hours**  
| | **Immediate postoperative use (in close association with extubation)**  
| | Cat: 0.02–0.05  
| | Dog: 0.01–0.02  
| | **0.5–2 hours**  
| Diazepam or midazolam | **Used with premedication**  
| | **0.2–0.5 mg/kg**  
| | **10–20 minutes**  
| | **Used intravenously in association with induction, during surgery, or with recovery**  
| | **0.2 mg/kg**  
| | **5 minutes**  
| Propofol | **Used to supplement premedication effect**  
| | **0.5–1 mg/kg**  
| | **2–3 minutes**  

These are typically used with opioids and have no analgesic properties but enable the analgesic to be more effective because of the calming effect achieved.
selected in place of acepromazine in more critical patients when an additional sedative effect beyond that of the opioid alone is desired. In most critical cases, however, it is not necessary to include a benzodiazepine, because opioid use in these patients usually is associated with a good level of sedation.

$\alpha_2$-Agonists can also be used for analgesia and sedation in healthy dogs and cats. Those animals showing any potential for cardiovascular compromise or organ dysfunction should not be given this class of drug because of its peripheral vasoconstriction effects and depression of cardiac output. Medetomidine is the most commonly used $\alpha_2$-agonist in small animals (5–20 $\mu$g/kg for dogs, 10–20 $\mu$g/kg for cats). At these doses, one can expect significant MAC reduction and analgesia for approximately 1 hour, although some animals show a more prolonged sedative effect. Low doses reduce the duration of cardiovascular depression rather than the degree. During the postoperative period, microdoses (as discussed elsewhere in this article) may be used, and such low doses (<2 $\mu$g/kg) have less effect on the cardiovascular system.

NSAIAs can be administered at this time (if not given earlier) if no contraindications exist, but it must be recognized that the full effect may not be present at the completion of short procedures. Patients need to be covered with other means of analgesia for 30 to 60 minutes before an NSAIA is effective.

**INDUCTION**

Such drugs as opioids, ketamine, $\alpha_2$-agonists, or lidocaine may be components of the induction protocol; as such, they result in analgesia at this time.

Only in critical cases do opioids facilitate induction (usually combined with diazepam at a dose of 0.2 mg/kg). The opioid dose required is at the high end (hydromorphone at 0.05–0.1 mg/kg administered intravenously, fentanyl at a dose of 10–20 $\mu$g/kg administered intravenously) and provides good analgesia, although respiratory depression and bradycardia are to be expected. Fortunately, the associated negative effects from opioids are managed easily with positive-pressure ventilation or anticholinergic administration. The higher doses suggested previously are more likely required when minimal premedication or analgesia is on board in advance. Such patients are often continued on opioid infusions (as described elsewhere in this article) to maximize MAC reduction.

For the more common situations, ketamine is frequently used for induction, combined with opioids, acepromazine, $\alpha_2$-agonists, or benzodiazepines. The dose used for intravenous administration may have a short duration of analgesia, whereas typical doses that are used intramuscularly, as often performed in cats, should provide some analgesia for the duration of surgery. Nevertheless, it must be recognized that the analgesia associated with ketamine is more somatic than visceral, so further analgesia may be required. Telatamine (in Telazol) would have similar effects.

$\alpha_2$-Agonists may be administered intramuscularly with ketamine to achieve induction. Postoperative analgesia was apparent after ovariohysterectomy in cats that received ketamine and medetomidine intramuscularly for anesthesia. Comments and concerns related to this combination are similar to those given for premedication. It is important to recognize that although good analgesia is associated with these drugs, the duration is limited to, and often less than, the sedative effect. Lidocaine is discussed in greater detail related to use in CRIIs. A single dose (2 mg/kg) should result in a short period of analgesia and MAC reduction. For this reason, it may be used as part of the induction.
Inhalants, propofol, and thiopental do not produce analgesia, although excessive depth of anesthesia may allow painful procedures to be performed. These depths are associated with significant respiratory and cardiovascular depression, however, and wind-up is unlikely to be avoided. Thus, a more balanced method of anesthesia is preferred.

Local anesthesia should be included in procedures in which a significant benefit is possible. Digital (onychectomy), dental (extractions), intercostal (thoracotomy), epidural (hind limb fractures), and brachial plexus (forelimb fractures) blockade has been used to improve intraoperative and postoperative analgesia in small animals. Readers are referred to the articles by Lemke and Valverde elsewhere in this issue for details on techniques.

Single-dose administration of any of the analgesics previously mentioned can be performed as needed during maintenance of anesthesia. If the premedication dose is waning or was poorly judged, another dose can be given to bring the level up to what may be effective. For example, one may see that the hydromorphone effect is not as good 2 hours into a procedure. At least half of the dose has been eliminated by this time, and another half-dose could be given. Repeat dosing of long-duration drugs (eg, hydromorphone) may be helpful during surgery but can create adverse effects in recovery if the dose on board is greater than required when the animal is recovering (ie, a full dose given at 2 hours may be beneficial for the surgery but results in too high a dose at recovery). For this reason and others, CRI administration has gained popularity. A CRI may be calculated as described under this topic elsewhere in this article.

Epidural administration of morphine or hydromorphone may reduce further analgesia requirements for 12 to 24 hours. The analgesia effect has been measured as far forward as the forelimbs and can be an excellent supplementation of analgesia for thoracotomy and peritonitis. More detail on this technique is found in the article by Valverde elsewhere in this issue.

Morphine has also been placed intra-articularly to affect receptors directly in joints. The evidence on its benefit is controversial, but the addition of local anesthetic is effective and the technique is simple. Morphine (0.1 mg/kg) is added to bupivacaine (approximately 0.1 mL/kg [0.5% solution]) and placed intra-articularly at time of joint closure. With this technique and epidural administration, the dose of morphine is so low that systemic side effects are not significant.

Patient monitoring is invaluable in assessing patient analgesia during surgery. Increases in respiratory rate, heart rate, or blood pressure are typically noted when further analgesia is necessary. It is necessary to ensure that ventilation is adequate, however, because an increase in $p_{CO_2}$ attributable to hypoventilation is a common confounder associated with similar physiologic changes.

CONTINUOUS RATE INFUSIONS

The following discussion covers the use of CRI analgesia administration in the preoperative, intraoperative, and postoperative situations. There are several advantages to this technique of administration in the management of pain. A steady level of analgesia is more likely to be achieved, because the mountains and peaks associated with intermittent analgesic use are avoided. A steady level is more likely to avoid significant adverse effects and is more easily titrated to achieve continuous comfort. When certain procedures or periods of time require a greater level of analgesia, it can be "dialed" to effect. Although the benefit of steady-state pain relief is difficult to
measure, preemptive analgesia achieved in various ways has been shown to reduce postoperative analgesia demand in a multitude of studies (339 papers displayed in a recent search) ranging from local anesthetic to nonsteroidal and even inhaled opioid use. Therefore, it is likely that our patients also reap such benefits with continuous analgesia control. Considering that infusions can be used during surgery, the anesthetist and the patient can gain from the impact on inhalant requirements (MAC reduction). Based on drug selection for these infusions, there may be other benefits that arise (discussed under the section on specific infusions).

Anyone can administer a CRI if he or she is capable of giving fluid therapy to a patient. A syringe pump is not required, although it is the simple way to manage infusions, especially when frequent adjustment of the dose is required. An ordinary fluid pump is usually capable of delivering drugs from a syringe, however. Test the consistency of fluid administration of the pump at hand with a saline infusion (watching the drips falling from an extension set) in advance of using this technique. If the consistency is limited to higher rates, the analgesic can be diluted in a part of, or the entire, hourly surgical or maintenance fluid to enable accurate administration. Only diazepam cannot be diluted because of concerns about precipitation. Midazolam can be used interchangeably with diazepam (same dosing recommendations would apply), and it can be diluted in fluids or mixed with other analgesics without such concerns. If neither a fluid pump nor a syringe pump is available, the use of a burette inserted within the fluid line enables drug administration in a smaller volume of surgical or maintenance fluid (add analgesic to the volume to be given in 15–60 minutes). Another alternative is to reduce the volume in a bag of fluids to that appropriate for the duration of administration (eg, 250 or 500 mL rather than 1000 mL) and to spike this remaining volume with the expected drug requirement at the fluid rate to be administered. This last recommendation is more suitable for surgical patients than for awake patients, which would be less tolerant of fluid volume adjustment. The volume during surgery would be given at 10 mL/kg/h. A surgical fluid rate adjustment from 5 to 20 mL/kg/h could be safe in most animals, however, and would allow analgesia dose modification from half to double the starting point if deemed necessary. A second bag of fluids would have to be connected should fluid requirements dictate an increase in rate, as needed for blood loss correction.

Almost any analgesic can be adjusted to be given as an hourly rate by using the following calculation: [Effective Dose (mg)/Typical Duration of Effect (h)]

The calculation can be performed using pharmacologic data. For example, a dose of morphine at 0.5 mg/kg is likely to provide 4 hours of pain relief in a dog. This provides an estimate of the dose per hour (0.125 mg/kg/h), which can usually be adjusted as the effect is observed in the individual. In some situations, one might observe that a dose of 0.5 mg/kg given to a particular dog provides only 3 hours of analgesia. The calculation can use this clinical information to define the individual patient’s infusion guideline (0.17 mg/kg/h). Because there is a possibility of a reduced drug requirement with the CRI method of administration, either calculation may result in an overestimation of the dosage and require adjustment according to the patient’s response. Similar analgesic effects were observed in dogs administered half the dose as a CRI compared with intermittent intramuscular injection of morphine. CRIs are usually limited to drugs with a duration of effect of 6 hours or less.

It must also be recognized that an hourly rate maintains analgesia that was achieved by an initial loading dose. As long as the expected duration of the loading dose is similar to that of the infusion drug, it does not have to be the same drug. Also, a short-duration drug like fentanyl can be easily used after a longer duration drug like morphine. Analgesia needs may increase over the first 4 hours (morphine’s expected
duration) if the pain involved remains constant. Careful observation of the patient should indicate if this is the case. Because surgical pain may actually lessen over the first 4 to 24 hours after surgery, changes in fentanyl infusion may not be required, may be increased for only a few hours, or may actually decrease over time.

Veterinarians have several analgesic drug options for CRIs. Typically, an opioid is chosen first (eg, morphine, hydromorphone, fentanyl) in awake patients or during surgery. When a long-lasting opioid is on board during surgery (usually part of the premedication), however, lidocaine may be the first drug selected as a CRI to improve analgesia during surgery. The reasons for this are discussed elsewhere in this article. Other infusions (eg, ketamine, medetomidine) are usually added when these options alone are ineffective. These drugs are rarely selected alone for analgesia by CRI. One analgesic cocktail (morphine, lidocaine, and ketamine [MLK]) has gained popularity for surgery and is also discussed elsewhere in this article.

Opoid Continuous Rate Infusion

There are several reports on morphine CRI in dogs. Although a rapid intravenous bolus of morphine is contraindicated because of histamine release, a slow intravenous infusion can be used without concern. The doses that have been assessed range from 0.12 mg/kg/h to 0.34 mg/kg/h. The analgesia produced varied from mild to moderate. The higher dose resulted in plasma concentrations that were greater than the previously suggested analgesia range but were not associated with significant cardiovascular or respiratory side effects in healthy awake dogs. Because sedation is apparent at the higher CRI, it should be safe to assume that in the awake animal, undesirable central nervous system (CNS) depression would accompany any respiratory depression and provide a clue to overdosage. Sedation and mild hypothermia are expected consequences of using opioids for analgesia in the awake animal. In the anesthetized dog, bradycardia and respiratory depression are obvious, but both are easily treated in this setting, as mentioned previously. A conservative dose range for a morphine CRI may fall within the range of 0.12 to 0.25 mg/kg/h (corresponding roughly to the effect from 0.5–1.0 mg/kg as an intermittent dose) for dogs. Fentanyl is preferred in cats.

There are no published studies using hydromorphone as a CRI in dogs or cats. Considering the fact that the duration of effect tends to be similar to morphine and that hydromorphone is 10 times as potent as morphine, however, one should be able to extrapolate safely from the studies using a CRI with morphine. Thus, a dose range of 0.01 to 0.03 mg/kg/h should be effective. In either case, a loading dose of morphine from 0.3 to 1.0 mg/kg or a loading dose of hydromorphone from 0.03 to 0.1 mg/kg would be given to achieve appropriate analgesia in advance of starting the CRI. Hydromorphone, in contrast to morphine, is safe given rapidly intravenously at these doses. The selected dose would vary with the procedure performed and the expected pain associated with it, in addition to the individual patient. Smaller patients would need a higher dose per kilogram than large dogs.

Fentanyl is presently the most popular opioid for CRI. The effectiveness and cardiovascular safety of this infusion in dogs have been reported. Its short duration of effect makes it suitable for administration by this method. The dose-related MAC reduction and ceiling effect (42 μg/kg/h) from fentanyl CRI were first reported in 1982. Doses of 3, 12, and 42 μg/kg/h showed a MAC reduction of 20%, 44%, and 65%, respectively. Practical intraoperative administration involves a loading dose of 3 to 5 μg/kg followed by a CRI of 10 μg/kg/h. This infusion can be halved or doubled based on the desired effect on the inhalant requirements. In rare critical cases in which isoflurane must be extremely low, fentanyl (50 μg/mL) and midazolam (5mg/mL)
(10:1 as vol/vol) have been administered at 1 mL/kg/h (45 μg/kg/h + 0.45 mg/kg/h, respectively). High intraoperative infusions of fentanyl (>5 μg/kg/h) need to be lowered in advance of recovery (approximately 20 minutes before the end of surgery). This should reduce the chance of postoperative dysphoria. Infusions used in the awake or recovering patient are usually 2 to 5 μg/kg/h, with doses as high as 10 μg/kg/h in extremely painful conditions.

Butorphanol has also been used as a CRI at 0.1 to 0.4 mg/kg/h. This infusion would be most appropriate for mild to moderate pain. A loading dose of 0.1 to 0.4 mg/kg would be appropriate.

Practical evidence for use of opioid CRIs in cats is nonexistent. Analgesia has been shown to be good after low-dose morphine administration (0.2 mg/kg), and MAC reduction has been determined as significant at high (1.0 mg/kg) but not low (0.1 mg/kg) doses. Morphine as a CRI is not likely to be suitable in cats, however, because of concerns for excitement with overdosing. If a μ-agonist is required, fentanyl would be the preferred drug because of its short duration of effect, thus reducing concerns for overdosing and excitement. Low doses of hydromorphone as a CRI can be used in the cat with assessment of effectiveness of the infusion, adjustment as needed, and monitoring for hyperthermia, however. An infusion based on a 6-hour duration of effect rather than 4 hours, unless proved otherwise by individual response, may be a practical approach in cats (0.005–0.01 mg/kg/h). In general, butorphanol selection as a CRI would be a safe alternative for mild to moderate pain.

Lidocaine Continuous Rate Infusion

Lidocaine has been shown to reduce MAC in dogs, provide analgesia, and act as an antiarrhythmic. It is an excellent choice in cases in which these benefits are of value (eg, animals presented with gastric dilation/torsion, splenic tumors, chest trauma, cardiac disease). Such critical patients can be induced with the addition of 2 mg/kg as a bolus in advance of the induction agent, a second bolus of 2 mg/kg after intubation and stabilization onto an inhalant, and a CRI started at 120 μg/kg/min (7 mg/kg/h). This recommendation achieves immediate therapeutic levels for antiarrhythmic effects and an expectation for a MAC reduction of approximately 43%. This approach is extrapolated from studies performed in normal and cardiovascular-compromised patients. Plasma levels from this method are similar to those achieved in longer than 30 minutes from a single 2-mg/kg dose followed by a 200-μg/kg/min (12 mg/kg/h) CRI. This second method would be suitable for dogs with no evidence of cardiovascular compromise, arrhythmia concern (requiring an immediate antiarrhythmic level), or possibly liver compromise (although lidocaine accumulation depends more on flow than on liver function). It is a simple method for intraoperative MAC reduction and analgesia in other cases (10 mg/kg/h simplifies calculations even more so with likely little difference), however. Before recovery or after 1 hour in long surgical procedures, the CRI should be reduced to 40 to 80 μg/kg/min (2–5 mg/kg/h) to reduce the chance of mildly toxic plasma levels. The infusion can simply be stopped if not needed for postoperative analgesia or arrhythmia management. At lower infusions, the MAC may be reduced by approximately 20%. Analgesia can be achieved with as little as 1 to 3 mg/kg/h, however. The effective loading dose for analgesia in the awake patient is similar to that during anesthesia (1–4 mg/kg).

Although MAC reduction has been measured in cats during lidocaine infusion, significant cardiovascular depression has been shown. It has been suggested as an analgesic in the awake cat at a loading dose of 0.25 to 1 mg/kg followed by a CRI at 0.5 to 2 mg/kg/h. At the Ontario Veterinary College, however, the author and her colleagues have no experience in this setting.
Ketamine Continuous Rate Infusion

Ketamine has been studied as a CRI in dogs and shown to provide an approximately 25% MAC reduction at 10 μg/kg/min (0.6 mg/kg/h).\textsuperscript{35} Intraoperative CRI administration is suggested at 2 to 10 μg/kg/min (0.1–0.6 mg/kg/h) after a loading dose provided by ketamine in the induction or 2 mg/kg administered intravenously. At these doses, MAC reduction and somatic analgesia are expected without evidence of significant sympathetic drive. Doses between 0.1 and 2 mg/kg have been used for analgesia in the postoperative setting when other analgesics alone are not effective. CNS depression, muscle rigidity, and sympathetic drive may occur with higher doses, depending on coinciding drug use.

Morphine/Lidocaine/Ketamine Continuous Rate Infusion

A single report on the use of an MLK cocktail has been published.\textsuperscript{35} Analgesia and MAC reduction are achieved with a mixture of morphine (12 mg), lidocaine (150 mg), and ketamine (30 mg) in surgical fluid (500 mL) dripped at the standard surgical fluid rate (10 mL/kg/h). This provides morphine at a rate of 4 μg/kg/min (0.24 mg/kg/h), lidocaine at 50 μg/kg/min (3 mg/kg/h), and ketamine at 10 μg/kg/min (0.6 mg/kg/h). The mixture produced the same MAC reduction (45%) and cardiovascular effects as morphine alone (same dose as in mixture). A multimodal approach to analgesia was suggested as the benefit of this cocktail. This view may not be taken by all anesthetists, however. If there is no measurable advantage, a simpler approach may be more appropriate.\textsuperscript{48} The lack of benefit with the addition of ketamine along with opioids during orthopedic surgery was similar\textsuperscript{35} to that shown in the study by Muir and colleagues. This MLK cocktail is not simpler to use and shows no clear advantage when compared with using higher lidocaine infusions or opioid infusions. Although no advantage has been shown at this point, it does not cause harm if mixed properly and inhalant adjustments are made appropriately. For severe postoperative pain, the concentrations of each drug in this mixture, and their combined potential effect, are unlikely to confer adequate analgesia.

PREPARATION FOR RECOVERY

Appropriate analgesia should be achieved in advance of recovery. This may require lowering or stopping infusions (as previously addressed), adding additional analgesics (eg, NSAIs delayed for concerns about hypotension or those only used for postoperative administration), or bringing single-dose opioid injections up to therapeutic levels based on timing of last administration. There is no reason to avoid additional opioids until after recovery if the patient is expected to require more than the level on board. Delay in recovery associated with analgesia administration is more likely attributable to poor drug or dose selection. Calculate the dose required to produce the desired effect as described in the section on repeated intraoperative dosing during maintenance, and administer just before turning off the inhalant. If the drugs on board are likely to provide adequate analgesia, however, recovery can proceed with plans to provide more analgesia only if the patient seems to need such.

Sedatives should be preemptively administered if thought to be useful in recovery. The primary concern about acepromazine relates to intraoperative hypotension; however, a low dose in the premedication prevents this. Also, administration of low doses (0.01–0.02 mg/kg) at recovery does not seem to affect blood pressure adversely at this time. In hard-to-handle or stress-sensitive patients that were given acepromazine as part of their premedication, additional dosing before recovery may be appropriate to achieve significant sedation. The dose chosen depends on the residual...
premedication dose effect expected, but 0.01 to 0.02 mg/kg in dogs and 0.02 to 0.1 mg/kg in cats are suggested. In some cases, medetomidine may be preferred (1–2 μg/kg given as the patient is extubated). This is more likely to be chosen for the extremely aggressive animal.

POSTOPERATIVE ANALGESIA

Need for further analgesia is assessed after recovery. The patient must be carefully assessed to determine if excitement, whining, or agitation is pain, dysphoria, or disorientation. When in doubt, pain should be assumed, and the response to treatment defines if this judgment was correct. When pain is suspected or clearly displayed, rapid administration of hydromorphone, fentanyl, or butorphanol, as appropriate, should be performed. Morphine must be given intramuscularly or slowly intravenously. If necessary, propofol (0.5–1-mg/kg increments) can be used to return the animal to an anesthetized state until morphine is fully effective. Diazepam (0.2 mg/kg administered intravenously) is also effective in the short term to deepen the plane of sedation in a recovering animal that is showing signs of pain and provides time for the opioid to take effect. It is important to recognize that some dogs can become quite excited after benzodiazepine administration in the fully awake animal requiring analgesia. The opioid should always be given first in this circumstance.

Low doses of acepromazine (0.01–0.02 mg/kg for dogs, 0.02–0.05 mg/kg for cats) can be given if an animal is appearing only mildly uncomfortable or mildly dysphoric. Response to treatments (acepromazine or more opioid) may be the best method of diagnosis when uncertain. Occasionally, the treatment selected may be a reversal agent. If the patient is clearly dysphoric or returns to a whining state shortly after additional opioid administration, or if suspicion exists related to the use of high doses of opioid during surgery, a slow titration of naloxone can be given to effect (4 μg/kg diluted to 10 mL and given in 1-mL increments every minute).

For the animal that is thrashing and difficult to assess, medetomidine (1–2 μg/kg) can be helpful. Some analgesia is achieved, and when recovery occurs in 15 to 20 minutes, it is usually smooth if the initial recovery behavior was disorientation. This is an excellent approach in the “husky syndrome,” wherein disorientation in this breed is associated with dramatic behavioral responses that are difficult to differentiate from pain.

After stabilization of the patient in an analgesic state at recovery, regular assessment is required to maintain this comfortable state. The patient may need no more analgesia, occasional single-dose injections of opioid, or CRI administration of one or more drugs to manage the pain.

ADVICE FOR SPECIFIC CASES

Not every case can be considered in this article, but a few special situations are discussed.

PEDiATRICS

Much evidence exists that human babies experience pain. Responses to typical analgesics are not always as expected. A study in puppies revealed that newborn pups have a reduced requirement for analgesia and that, overall, puppies may be more sensitive to opioid-associated respiratory depression. By 1 month of age, puppies have a significantly increased analgesic requirement. Based on this evidence, we must not ignore analgesia but must be cautious to monitor the effects of it.
Our primary analgesic choices for these cases include opioids and local anesthesia. Ketamine may be a consideration as well and seems to be a reasonable choice for short procedures in human infants, although neonates may be less responsive to NMDA antagonists and ketamine is thus ineffective in providing analgesia.

Opioids alone provide good restraint and sedation in addition to analgesia. In most situations, sedatives are not required in pediatric patients. The dose of opioid selected for premedication in healthy pediatric patients is often at the higher end of the range related to patient size, but redosing may be less frequent, and if profound sedation is associated with doses given, lower doses should be chosen. In sick patients or those younger than 1 month of age, low doses should be administered. The patient can be induced with propofol, diazepam/ketamine, or mask inhalant and then maintained on inhalant.

Local anesthesia is an excellent choice when possible. Eutectic mixture of local anesthetics (EMLA) cream is effective for local analgesia if given 30 minutes to penetrate the skin. The weight of the animal must be used to calculate a safe volume of injectable local anesthesia (2% lidocaine or 0.5% bupivicaine at approximately 0.4 mL/kg). Dilution to half strength with saline can be performed to allow more volume without risking toxicity. If laryngeal desensitization is performed, the use of 2% lidocaine drops rather than the 10% spray reduces the lidocaine dose by this route, allowing for a larger volume to be used in other specific local blockade.

NSAIAs are not recommended in patients younger than 8 weeks of age because of their effect on kidney development.

COMMON ELECTIVE SURGICAL PROCEDURES

Premade mixtures containing meperidine or butorphanol for premedication provide a low level of analgesia conferred by the opioid and are capable of producing a short-term mild to moderate analgesic effect. These mixtures are also dosed at the lowest end of the analgesic range, again making them most suitable for mild pain. With this in mind, further analgesia is required in many situations. NSAIAs are useful in these cases. In any elective procedure, the NSAIA loading dose (initial dose as double the maintenance dose) is usually not needed. The approved dosing of meloxicam at 0.3 mg/kg in cats (United States) is not recommended, because a dose of 0.1 or 0.2 mg/kg (orthopedic procedures) is adequate. Effective analgesia is common with use of the maintenance dose (0.1 mg/kg) for elective procedures, because wind-up is not established with any associated increased analgesic demands. If, however, the animal seems to be slightly uncomfortable later in the evening, a second dose can be given because this does not exceed label dosing.

Cat castrations are associated with mild pain and may not require more analgesia than that in the premedication period, provided that the procedure is performed within 15 to 30 minutes of administration. The administration of an NSAIA is a responsible approach to avoid any painful experience, however. Dog castrations should be managed adequately with an NSAIA, even if administered postoperatively, given the same conditions as for the cat. Ovariohysterectomies in dogs and cats may require an additional opioid dose for recovery if the NSAIA is withheld until the operation is over, however. The opioid dose should be calculated in the premedication period, and additional opioid should be added during or after surgery to achieve a total dose of butorphanol at 0.2 to 0.4 mg/kg or meperidine at 5 to 10 mg/kg. A more profound opioid dose at the lower end of the range may be selected as part of the premedication (usually given with acepromazine), however. The use of NSAIAs for 1 to 3 days is a reasonable option for postoperative analgesia in these cases. If the
NSAIA is given 30 minutes or more before recovery, additional or more profound opioid administration is less likely to be required. Onychectomy in cats is best managed with buprenorphine or hydromorphone as part of the premedication and the addition of local blocks using bupivacaine or a lidocaine-bupivacaine mixture in advance of surgery (see the article by Lemke elsewhere in this issue). Postoperative NSAIA analgesia is indicated for 2 to 3 days. This technique seems to be effective, although fentanyl patches have also been applied for pain associated with the declawing procedure. In this case, because the fentanyl patch usually is removed on discharge and the effect quickly dissipates, analgesia can be continued with an NSAIA for 1 to 2 more days.

**EMERGENCY CASES**

The reader is referred to the article by Dyson elsewhere in this issue.

**CESAREAN SECTION**

There is little concern related to the use of opioids for premedication in patients requiring a cesarean section. If puppies or kittens are sedated or have respiratory depression from the expected placental transfer of the opioid, 1 drop of naloxone (0.4 mg/mL from a 1-mL syringe) can be administered under the tongue, and repeat doses can be sent home with the owner if longer acting opioids are involved. Doxapram may be helpful during resuscitation of the newborn if the response to naloxone is poor or if no opioids were used. Because of the analgesic effect of progesterone, which is at high levels at this time in the bitch or queen, butorphanol may be adequate as a premedication. Its short duration of effect can result in mild and short-duration respiratory depression on neonates but provides short-term analgesia in the bitch at recovery. A single dose of an NSAIA is often administered after surgery. Concerns for milk transfer and the impact on the neonate’s kidney development dictate the use of one dose only, however. If low-dose butorphanol is given for the premedication, the bitch could be provided a dose of hydromorphone for discharge, which can then provide several hours of analgesia. The antagonistic effect of the butorphanol is likely to be minimal when a \( \mu \)-agonist is given approximately 1 hour after butorphanol. Although hydromorphone or morphine is suitable as a premedication in these cases, low-end doses should be given initially, with more given after removal of the puppies if deemed necessary (based on other analgesia present). There is a greater need to reverse the neonate when profound \( \mu \)-agonists are selected, even when low doses are used. Local analgesia is also a reasonable choice, especially in cases in which inhalant use must be minimized because of cardiovascular instability. A local line block is quick and easy; epidural local analgesia can provide a longer duration of effect but involves more time and expertise.

**GERIATRICS**

In general, typical doses of analgesia are selected for the geriatric patient. Because of the slower elimination, however, redosing may be required less frequently. As in the pediatric patient, if excessive sedation is associated with the dose selected, lower doses would be administered thereafter. Partial reversal by careful titration with naloxone and saline, as previously described, can also be considered if an excessive effect of the opioid is noted.
SUMMARY

Pain exists; however, we can prevent it, and we can treat it. The fallacy that pain is protective and must be allowed to avoid risk for damage after surgery needs to be eradicated. Preoperative and postoperative analgesia is directed at aching pain, whereas sharp pain associated with inappropriate movements persists. Analgesia provides much more benefit than concern. Preoperative and intraoperative analgesia reduces wind-up and postoperative demands for analgesia, and during general anesthesia, it creates a more balanced plane associated with less cardiovascular depression. The advice given in this article provides guidelines for the veterinarian that can be adjusted according to the patient’s needs and responses. Suggestions are provided from the point of admission to discharge to give a starting point for individual tailoring of an analgesic plan.

REFERENCES


