Anesthetic Pump Techniques Versus the Intermittent Bolus

What the Oral Surgeon Needs to Know

Richard C. Robert, DDS, MS*, Chirag M. Patel, DMD, MD

KEYWORDS

• Rapid redistribution • GABAA receptor • Context-sensitive half-time • Infusion pump
• Hybrid analog-digital • Smart technology

KEY POINTS

- Most of the agents currently in use for office-based anesthesia have rapid onset and offset and exert their effects through binding to receptor sites on ligand-activated ion channels in the central nervous system.
- To sustain a "smooth" anesthetic effect, anesthetic receptor sites require a steady source of agent molecules from the bloodstream.
- Although the incremental bolus approach to anesthetic delivery has served oral and maxillofacial surgeons well for decades, infusion pumps may offer advantages that should be considered.
- Although no longer in production, the hybrid analog-digital infusion pump introduced by Bard and Baxter over two decades ago continues to be popular in hospitals, outpatient surgery centers, and oral and maxillofacial surgeons' offices.
- New digital infusion pumps have "smart technology" that enables verification of the syringe, confirmation of drug dosing, and computer interfacing.

INTRODUCTION AND HISTORY

Since the seminal work of Wells and Morton in the 1840s,[1] the specialty of oral and maxillofacial surgery has been on a quest to find the ideal anesthetic for office-based oral and maxillofacial surgery. This quest has progressed from nitrous oxide to a number of intravenous agents including ultrashort-acting barbiturates, benzodiazepines, opioids, the dissociative anesthetic ketamine, and most recently the alkylated phenol propofol.[2] The quest of our specialty somewhat parallels that seen in anesthesia for ambulatory surgery. By the end of the previous century, far more procedures were performed on an ambulatory basis as opposed to protracted hospitalizations. This transition was largely fueled by the availability of such agents as propofol, ketamine, and remifentanil, which provided more rapid recovery with less likelihood of postoperative nausea and vomiting or respiratory depression. For delivery of these agents, oral and maxillofacial surgeons (OMSs) have relied on small, incremental boluses to sustain the anesthetic effect. However, many anesthesiologists have found that infusion pumps can provide a smoother anesthetic course, and now most prefer this approach.[3] The reasons that anesthesiologists overcame their initial reluctance to use infusion pumps and the potential advantages for OMSs is explored.

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Department of Oral and Maxillofacial Surgery, University of California at San Francisco School of Dentistry, Box 0440, 533 Parnassus Avenue, UB 10, San Francisco, CA 94143, USA
* Corresponding author.
E-mail address: rcr2400@aol.com

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The Nature of Current Anesthetic Agents Used for Office-Based Anesthesia

Propofol[4] and other currently popular agents such as ketamine and remifentanil[5] owe that popularity to their rapid onset and short duration. It has been found that the agents with these characteristics are often associated with less postoperative headache, nausea, and vomiting as compared with their predecessors such as methohexital[6] and fentanyl.[7] In addition, some of these agents can be used in combination to capitalize on the desirable effects of both. For example, Mortero and colleagues[8] found that the coadministration of low-dose ketamine attenuates propofol-induced hypoventilation and may lead to earlier return of cognition postoperatively as well. As the advantages of the newer agents became more widely appreciated, both anesthesiologists and OMSs began to incorporate them into their practices.

After decades of success with methohexital delivered by an incremental bolus technique, most OMSs adopted the same approach to the delivery of propofol and ketamine. In the meantime, anesthesiologists worked with equipment engineers to develop infusion pumps, which they felt would take better advantage of the pharmacologic attributes of the new agents.[9] Even in the case of medically compromised patients, they found that the latter approach could provide hemodynamic stability as well as simplicity of delivery.[10] Like OMSs, they had originally used an incremental bolus approach, but they ultimately found that infusion pumps could better serve their needs. They concluded that the optimal delivery of the new agents would be best accomplished with the steady infusion provided by an infusion pump.[11] This steady infusion could then also make it possible for the anesthesiologist to use intravenous agents to maintain a continuous level of anesthesia comparable with that which heretofore had only been possible with halogenated inhalation agents. The next section explores the rationale for anesthesiologist adoption of infusion pumps as their preferred means of delivery for intravenous anesthesia.

The Rationale for the Use of Infusion Pumps

The rationale for anesthesiologists' adopting infusion pumps as their primary mode of delivery of intravenous (IV) anesthetic agents is based on studies in the 1980s and 1990s on the dissipation of drug effect.[12] It was determined that the decrease in the plasma concentration of lipophilic anesthetic drugs after administration is due more to redistribution than actual metabolism or elimination. After passage through the blood–brain barrier, these IV anesthetic molecules bind to their respective receptor sites on ligand-activated ion channels in the central nervous system, but only briefly. They then return to central circulation and are rapidly distributed to the other tissues of the body.[13] For the activity of these agents to be continued for the duration of the anesthetic, new anesthetic molecules must be constantly available from the central circulation to again bind with the receptor site. **Fig. 1** illustrates this dynamic interaction between propofol and the gamma-amino butyric acid-A receptor.[14]

Once the anesthetic molecules have left the receptor sites, they are not distributed to all of the body's tissues equally, largely owing to differences in local blood flow. Physiologists have empirically divided the tissues into 3 groups or "compartments" based on vascularity. The first of these is the "vessel-rich group," consisting of the brain, heart, kidneys, and other highly vascularized tissues. The second or "intermediate group" consists of less well-perfused tissues such as muscle and skin. The third or "vessel-poor" compartment includes poorly perfused tissues such as bone and fat. After the infusion has been discontinued, the anesthetic molecules return from the latter compartments and reenter the central circulation. They are transported to the liver, where they are biotransformed and then excreted through the kidneys. It should be pointed out that the compartments are not anatomic entities, but theoretic ones based on mathematical calculations.

As these lipophilic anesthetic molecules pass through the central and peripheral compartments, the effect site requires new anesthetic molecules if the anesthetic effect is to be maintained. Then, once the infusion has been discontinued, there is a rapid decrease in the serum concentration depending on the drug under consideration. The parameter that most accurately captures this dynamic relationship is the context-sensitive half-time, that is, the time required for a 50% reduction in serum concentration after discontinuation of the infusion.[15] In **Fig. 2**, the plots for propofol and ketamine are compared with those of their predecessors sodium thiopental and methohexital. The low, relatively flat plots of propofol and ketamine are consistent with their clinical attribute of being associated with earlier discharge times as compared with many other agents. The plot for remifentanil is even lower and flatter than those of propofol and ketamine. This shape is a reflection of its rapid metabolism by esterases throughout the body, as opposed to hepatic biotransformation.[16]