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Inhalational techniques in ambulatory anesthesia

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Ambulatory surgery continues to grow and thrive such that the vast majority (65–70%) of all surgical procedures is performed on an outpatient basis. Expeditious recovery and shorter hospital stays are necessary to improve efficiency of an ambulatory facility and reduce health care costs. One of the major factors that determine the speed of recovery from anesthesia is the choice of anesthetic technique. Although local and regional anesthesia techniques are increasingly used in the ambulatory setting because they allow a more rapid recovery [1], general anesthesia is still the most common anesthetic technique [2,3]. An ideal general anesthetic technique should provide smooth and rapid induction, optimal operating conditions, and rapid recovery with minimal or no side effects. It is also beneficial if the anesthetic technique allows for fast tracking (ie, transferring patients directly from the operating room to the phase II unit, thus bypassing the postanesthesia care unit [PACU]).

Inhalational anesthesia techniques remain the mainstay of modern anesthesia practice. The newer shorter-acting inhaled anesthetics (ie, desflurane and sevoflurane) offer the potential for rapid recovery from anesthesia. However, with the introduction of propofol and newer delivery systems (eg, target-controlled infusion), there is increased interest in total IV anesthesia (TIVA) [4]. This article reviews the advantages and disadvantages of inhalation techniques, as compared with TIVA, for the induction and maintenance of general anesthesia.

Induction of anesthesia

Because of its unique recovery profile, propofol is considered the sedative-hypnotic drug of choice for induction of anesthesia. Other potential benefits of

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propofol include its antiemetic properties and the reduced incidence of euphoria on emergence. However, the nonpungent, nonirritant properties of sevoflurane also allow smooth and rapid inhalational induction of anesthesia [5–13]. Inhalational induction may be used as an alternative to IV propofol/muscle relaxant induction if IV access is difficult, the patient is "needle phobic," or if maintenance of spontaneous ventilation is preferred (eg, in patients with an anticipated difficult airway). In addition, the use of sevoflurane for induction as well as maintenance may be less expensive than a propofol-based anesthetic [7,12,13].

The techniques for inhalation induction include progressive increases in inspired concentration (incremental induction) or use of high-inspired concentrations (vital capacity induction). Because sevoflurane is a nonirritant, it allows the use of high (up to 8%) initial inspired concentrations without the need for progressive or incremental increases in concentration. In a study in adult volunteers, induction with sevoflurane 8% rather than 3% significantly reduced the "second stage" of anesthesia without adversely affecting hemodynamic stability [6].

A study comparing induction with propofol and sevoflurane using a tidal volume breath technique reported that induction with propofol was more rapid (57 s versus 84 s), but the incidence of apnea was higher (65% versus 16%) and the time to settled respiration was longer (126 s versus 94 s) [12]. The mean arterial pressure was better maintained and the incidence of adverse respiratory events was lower with sevoflurane induction. Although both groups received sevoflurane for maintenance of anesthesia, the time to emergence (eye opening to command) was shorter in patients with sevoflurane induction (5.2 min versus 7 min) [12].

Another study comparing propofol and sevoflurane alone or with nitrous oxide (N_2O) reported that induction of anesthesia and time to jaw relaxation was shorter with propofol than that with sevoflurane [7]. However, the time to settled respiration after insertion of the laryngeal mask airway (LMA) was similar in both groups [7]. Philip et al [11] reported that single-breath vital capacity sevoflurane induction resulted in shorter induction times with more than 50% of the patients losing consciousness after the first breath, as compared with propofol induction. Spontaneous movement and hemodynamic changes occurred more often in the propofol group, while coughing occurred more often in the sevoflurane group [11].

A meta-analysis of 12 randomized, controlled studies evaluated the time to loss of consciousness, time to successful LMA insertion and success at first attempt, incidence of apnea, incidence of postoperative nausea and vomiting (PONV), and patient satisfaction with sevoflurane and propofol induction [8]. They found that sevoflurane 7% to 8% in N_2O, administered by vital capacity breathing, was as effective as propofol, but patient satisfaction was lower [8]. In addition, the incidence of PONV was higher with sevoflurane induction. These authors concluded that although sevoflurane induction may be desirable in selected patients, propofol induction might be preferred in most [8].

Several recent reports showed increased postoperative delirium and agitation with the use of sevoflurane, particularly in children [5,14]. Although the cause of this increased agitation is unknown, it is speculated that sevoflurane may be proconvulsant, as suggested by the occurrence of seizurelike activity on the

electroencephalogram and reports of tonic/clonic seizures [15,16]. Therefore, it is suggested that sevoflurane should be avoided in seizure-prone patients.

Induction of anesthesia may be improved with supplementation of hypnotic-sedative with a potent opioid [17,18]. Remifentanil is a new, ultrashort-acting opioid with a context-sensitive half-time of approximately 3 minutes and elimination half-time of about 10 minutes [19]. As with propofol, it may be desirable to combine remifentanil and sevoflurane during induction of anesthesia to facilitate tracheal intubation. Use of remifentanil (1 μg/kg IV bolus, followed by 0.25 μg/kg/min infusion) reduced the end-tidal sevoflurane concentration required for tracheal intubation from 4.5% to 2.5% [20]. Another study reported that adding remifentanil to 0.5 MAC sevoflurane in N_2O resulted in more rapid recovery of consciousness [21], and numerous studies have reported that adding a remifentanil infusion results in more rapid emergence from anesthesia [22]. However, there is a learning curve with the use of remifentanil [23]. The initially recommended doses of remifentanil may result in increased incidence of hypotension [24]. Avoidance of bolus dosing and initial infusion rate of remifentanil 0.25 μg/kg/min may be more appropriate [24].

Maintenance of anesthesia

The most important aspect of an anesthetic technique is its ability to consistently achieve rapid recovery after termination of surgery. It is believed that inhaled anesthetic technique allows rapid emergence from anesthesia, probably because of ease of titratibility, and exerts some neuromuscular blocking effect [25], which may reduce the requirements of nondepolarizing muscle relaxants [26]. The avoidance of muscle relaxants may facilitate recovery, because even a minor degree of residual blockade (usually not appreciated clinically) could cause distressing symptoms such as visual disturbances, inability to sit up without assistance, facial weakness, and generalized weakness, which may delay recovery [27].

The availability of newer shorter-acting inhaled anesthetics (eg, desflurane and sevoflurane) allows for a more rapid emergence from anesthesia compared with older inhaled anesthetics (eg, halothane and isoflurane). This should reduce the risks of early postoperative complications (eg, respiratory complications such as airway obstruction and hypoxemia) [28]. Faster emergence also allows for fast tracking (ie, bypassing the PACU).

A meta-analysis of randomized, controlled studies published before November 1994 examined the differences in recovery times (ie, emergence and home readiness) with desflurane and isoflurane (eight studies) and with desflurane and propofol (six studies) [29]. Compared with isoflurane, desflurane was associated with a faster emergence (mean difference 4.4 min). There was no difference in emergence time between desflurane and propofol [29]. Patients who received propofol were discharged to home more quickly than those who received desflurane. The authors concluded that although these differences were statistically significant, they might be of minor clinical importance [29]. The studies

included in this meta-analysis were performed before the availability of bispectral index (BIS) monitoring for titration of hypnotic sedatives. The depth of hypnosis between the groups was maintained using subjective clinical criteria [30,31].

Immediate recovery after anesthesia is faster with sevoflurane compared with propofol and isoflurane [32,33], though it does not translate into an earlier discharge from the PACU and there was no difference in the time to home readiness [32,33]. These results were confirmed by a meta-analysis of randomized, controlled studies [34].

Song et al [35] assessed the recovery times and ability to fast track with desflurane, sevoflurane, or propofol. Compared with propofol TIVA, maintenance of anesthesia with desflurane or sevoflurane resulted in shorter times to awakening, tracheal extubation, and orientation [35]. A significantly larger percentage of patients who received desflurane for maintenance were considered fast-track eligible compared with sevoflurane and propofol (90% versus 75% and 26%, respectively) [35]. There was no difference between the groups with respect to the times to oral intake and home readiness. Earlier emergence with desflurane, compared with sevoflurane and propofol, was also reported when BIS was used to titrate the anesthetic agents [31]. Use of BIS monitoring reduced the recovery times by 30% to 55%. Similar to previous studies, there were no differences in later recovery times.

Several investigations have demonstrated that early recovery (ie, emergence from anesthesia) is more rapid with desflurane compared with sevoflurane [36,31]. In contrast, a study comparing desflurane and sevoflurane anesthesia reported that recovery indices and psychomotor functions were marginally superior with sevoflurane, but this did not reach statistical significance [37].

Juvin et al [38] evaluated the recovery characteristics among morbidly obese patients receiving desflurane, isoflurane, and propofol administered according to BIS values. Immediate recovery occurred faster and was more consistent, and oxygen saturations were higher, after desflurane than after propofol or isoflurane; however, these differences persisted only in the early recovery phase (up to 2 h after surgery) [38]. The same group investigated recovery characteristics in elderly patients and found similar results [39].

A recent study in elderly patients evaluated the recovery from propofol TIVA, isoflurane, and desflurane anesthesia with 70% N_2O titrated to maintain a BIS value between 60 and 65 [40]. Patients receiving desflurane achieved a fast-track discharge score more quickly. In addition, a significantly larger percentage of patients receiving desflurane were judged to be fast-track eligible compared with those receiving either isoflurane or propofol (73% versus 43% and 44%, respectively) [40]. The need for therapeutic interventions in the PACU was significantly less with desflurane [40].

Postoperative nausea and vomiting

Several studies have reported that use of propofol TIVA is associated with a lower incidence of PONV as compared with inhaled anesthetic technique [41–44].

Similarly, Raeder et al [33] reported a greater incidence of PONV with sevoflurane-maintained patients as compared with propofol-maintained patients (32% versus 18%, respectively); however, the number of patients requiring antiemetic therapy was similar. Of note, when used as an induction agent only, propofol is not protective against PONV, probably because of its short duration of action [44].

Recen studies that have used BIS monitoring to titrate hypnotic sedatives have been unable to observe any difference in the incidence of PONV between the various general anesthetic techniques [31,38,45]. Titration of inhaled anesthetic using BIS monitoring has been shown to reduce the incidence of postoperative vomiting in the phase II area [46]. These investigators also reported that orientation and ability to drink were achieved earlier in the BIS group [46]. PONV associated with inhalational anesthesia can be further reduced with the use of prophylactic antiemetics, which are routinely administered in modern ambulatory anesthesia practice.

A large randomized study in 2010 unselected surgical patients assessed the incidence of PONV after propofol TIVA and inhaled anesthesia with isoflurane-N_2O techniques [47]. The investigators found that propofol TIVA was associated with a reduced incidence of PONV compared with isoflurane-N_2O anesthesia (29% after TIVA versus 47% after isoflurane) [47]. This effect was most pronounced only in the early postoperative period (up to 24 h). Of note, TIVA did not reduce the incidence of PONV after abdominal or laparoscopic surgery [47]. Although the duration of PACU stay in outpatients was slightly lower with TIVA (median 150 min versus 160 min after isoflurane), the recovery from inhaled anesthesia may have been shorter if newer inhaled anesthetics (ie, desflurane and sevoflurane) were used [47]. The duration of hospitalization was similar between the groups.

Nitrous oxide

N_2O is widely used as a part of a balanced anesthesia technique because of its amnestic and analgesic properties, as well as its ability to reduce the requirements of expensive inhaled and IV anesthetic drugs. Use of N_2O reduces the time to spontaneous breathing after equi-MAC (1.3 MAC) regimens of sevoflurane [48]. However, several studies have suggested that N_2O increases the incidence of PONV. In contrast, a meta-analysis of randomized controlled trials found that the emetic effect of N_2O is not significant [49]. Omitting N_2O may increase the risk of awareness [49].

A large study in women undergoing outpatient gynecological surgery compared the incidence of PONV and the time to home readiness with propofol-N_2O and propofol alone anesthetic techniques [50]. The results indicate that the use of N_2O reduced propofol requirements by 20% to 25% without increasing the incidence of adverse events or the time to home readiness [1]. Most studies evaluating the feasibility of fast tracking after outpatient surgery have used N_2O as a part of their anesthetic technique [50–52]. Thus, there is no convincing reason to avoid N_2O.

Laryngeal mask airway (LMA)

The LMA has gained popularity as a general-purpose airway device and is currently used for routine elective surgical procedures as frequently as the tracheal tube [53]. Compared with the tracheal tube, the LMA is easy to place, does not require muscle relaxation and laryngoscopy, and may prevent complications associated with tracheal intubation [53]. The LMA is tolerated at lower anesthetic concentrations than the tracheal tube and therefore allows titration of anesthetic concentrations to the surgical stimulus rather than for airway tolerance. With the patient breathing spontaneously, opioid requirements can be based on the respiratory rate and dosing requirements of hypnotic anesthetics (IV or inhaled) can be based on BIS values or recommended end-tidal concentrations of inhaled anesthetics known to prevent awareness. This allows earlier emergence from anesthesia and improved perioperative efficiency.

The LMA can be easily inserted following an IV induction with propofol or inhalation induction with sevoflurane [54]. Longer times may be necessary to reach acceptable conditions for insertion of the LMA with the use of sevoflurane. Because desflurane has irritant properties, sevoflurane is generally considered the drug of choice for patients breathing spontaneously [55,56]. Most investigations have examined the use of desflurane with controlled ventilation through a tracheal tube. However, recent studies suggest that desflurane can be safely used in patients breathing spontaneously through an LMA [57–59]. Ashworth and Smith [57] compared maintenance of anesthesia with desflurane, isoflurane, and propofol in patients breathing spontaneously through an LMA. The incidence of respiratory complications was similar between the three groups; however, purposeful movement was significantly more common with propofol compared with isoflurane or desflurane (63% versus 23% and 7%, respectively) [57].

Similarly, Tang et al [59] reported a higher incidence of transient movements to surgical stimulus (40% versus 5%) with propofol-N_2O as compared with a desflurane-N_2O anesthetic technique in patients breathing spontaneously through the LMA. However, unlike the previous study [54], the emergence from anesthesia and time to home readiness was earlier with desflurane [59]. Another study in patients breathing spontaneously by way of an LMA found that compared with sevoflurane, desflurane reduced the time to emergence, home readiness, and return to normal daily activities without an increase in airway problems [58].

Costs of anesthetic techniques

It is well recognized that propofol TIVA may be more expensive than an inhaled anesthesia technique. However, the higher drug costs associated with TIVA may be offset by the lower incidence of PONV with TIVA, which may reduce the duration of hospital stay and thus reduce overall health care costs. Smith et al [60] reported that although patients receiving sevoflurane had a higher incidence of PONV than those receiving propofol, propofol anesthesia was more

expensive. Visser et al [47] determined the costs associated with anesthetics, antiemetics, disposables, and equipment, as well as costs of duration of PACU and hospitalization in a large (n = 2010 patients) randomized study comparing propofol TIVA and isoflurane-N_2O anesthetic. The extensive cost analysis (which included direct drug costs as well as the indirect costs) showed that anesthesia costs were three times greater for propofol TIVA [47].

Summary

In the current health care environment, anesthesia practitioners are frequently required to reevaluate their practice to be more efficient and cost-effective. Although IV induction with propofol and inhalational induction with sevoflurane are both suitable techniques for outpatients, patients prefer IV induction. Maintenance of anesthesia with the newer inhaled anesthetics (ie, desflurane and sevoflurane) provide for a rapid early recovery as compared with infusion of propofol (ie, TIVA), while allowing easy titratability of anesthetic depth. Titration of hypnotic sedatives using BIS monitoring may reduce the time to awakening and thereby may facilitate fast tracking (ie, bypassing the PACU) and reduce hospital stay. Inhalational anesthesia is associated with a higher incidence of PONV, but no differences have been demonstrated with respect to late recovery (eg, PACU stay and home readiness). Although clinical differences between desflurane and sevoflurane appear to be small, desflurane may be associated with faster emergence, particularly in elderly and morbidly obese patients. Balanced anesthesia with IV propofol induction and inhalation anesthesia with N_2O for maintenance, and an LMA for airway management, may be an optimal technique for ambulatory surgery. Inhalational anesthesia may have an economic advantage over a TIVA technique.

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