Anesthesia for Carotid Endarterectomy: The Third Option. Patient Cooperation During General Anesthesia

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BACKGROUND: Carotid endarterectomy is typically performed using either regional or general anesthesia techniques, which exhibit several differences, especially regarding the intraoperative neurological monitoring of patients. In this study, we introduce a technique of general anesthesia (cooperative patient general anesthesia), which allows neurological monitoring of the awake patient during surgery.
METHODS: We prospectively enrolled 181 consecutive adult patients scheduled for carotid endarterectomy. Patients were anesthetized with a total IV anesthesia technique. During carotid clamping, anesthesia was reduced and maintained only with high-dose remifentanil, such that the patient was able to respond to verbal statements and neurological monitoring could be performed. The technique is described in detail. Patient neurological and cardiac outcomes were investigated. Patient and surgeon satisfaction with the technique were also evaluated.
RESULTS: General anesthesia with a cooperative patient was achieved in 179 patients. No postoperative neurological events were observed. Two (1.1%) nonfatal myocardial infarctions occurred in the early postoperative period in two patients. Eighty-one percent of patients described the operation duration as brief, whereas 19.3% accurately perceived the time they were conscious. Both patients and surgeons were highly satisfied with the technique.
CONCLUSIONS: In our series, cooperative patient general anesthesia proved to be a safe and satisfactory anesthetic technique for both the patient and surgeon. The technique was characterized by hemodynamic stability, excellent control of ventilatory pattern, continuous neurological monitoring, and immediate and safe conversion to general anesthesia whenever required. Further studies are needed to highlight the advantages of this technique compared with standard general and local anesthesia.
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Carotid endarterectomy (CEA), one of the most common procedures in vascular surgery,[1–3] is typically performed in patients who are at risk of embolic stroke from atheromatous plaque of the carotid bifurcation. The two most feared major perioperative complications of CEA are stroke and myocardial infarction.[4,5]

CEA may be performed under regional or general anesthesia. The impact of the choice of anesthesia on the outcome of this operation is currently under evaluation in a large-scale study of general anesthesia versus local anesthesia. In the real world, anesthesiologists usually choose the anesthesia they are most comfortable with, despite several differences between the two techniques, especially regarding intraoperative patient neurological monitoring. Local anesthesia has the advantage of direct neurological monitoring of the conscious patient; however, patients and surgeons may find CEA under regional anesthesia stressful. In contrast, when the patient is under general anesthesia, it may be more difficult to decide whether or not to insert a temporary carotid shunt.[6] A number of techniques and monitors are available to detect cerebral ischemia and to assist in this decision, but none are totally effective.[7]

In the present study, we introduced a technique of general anesthesia for CEA, which allows clinical monitoring of neurological function during carotid clamping by reducing the hypnotic component of anesthesia although maintaining the analgesic one. This type of anesthesia, that we have named Cooperative patient general anesthesia (Co.PA.Ge.A.), shares with local anesthesia the advantage of continuous clinical monitoring of the patient and with general anesthesia the definitive airway control guaranteed by intubation of the trachea.

We applied this technique to 181 consecutive patients undergoing CEA from September 2006 to 2007. The aim of the present investigation was to assess the

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Table 1. Basal Characteristics of Patients ($n = 181$)

Age, mean (SD), yr	73.5 (8.13)
Male, *n* (%)	132 (72.93)
Ce = effector site concentration	
Height, mean (SD), cm	166.79 (6.98)
Weight, mean (SD), kg	72 (12.65)
ASA physical status, *n* (%)	
ASA I–II	30 (16.57)
ASA III	145 (80.11)
ASA IV	6 (3.31)
Previous neurological symptoms, *n* (%)	54 (29.83)
Occlusion of the opposite carotid artery	9 (4.97)
Reoperations	8 (4.42)
Urgent surgery, *n* (%)	1 (0.55)
Dyslipidemia, *n* (%)	70 (38.67)
Hypertension, *n* (%)	128 (70.72)
Diabetes, *n* (%)	38 (20.99)
Coronary artery disease, *n* (%)	40 (22.10)
Previous myocardial infarction, *n* (%)	26 (14.36)

feasibility and safety of Co.Pa.Ge.A. and its acceptance by patients and surgeons. Patient neurological and cardiac outcomes were also analyzed.

METHODS

Patients

In this prospective study, performed in a single center (Vascular Surgery Unit of a teaching hospital, Heart and Vessel Department, Azienda Ospedaliera Universitaria Careggi), we enrolled 181 consecutive patients who underwent CEA from September 2006 to 2007 for high-grade carotid artery stenoses (>70%) documented by preoperative carotid duplex examination. During the preoperative evaluation, all patients were carefully informed about the details of the available types of anesthesia technique and the operation. The study protocol was approved by the local Ethics Committee and all patients agreed to participate.

The mean patient age was 73.50 ± 8.13 yr (range, 51–87 yr). Approximately one-third of patients (29.83%) had prior neurological symptoms and 4.97% had occlusion of the controlateral carotid artery. Urgent surgery was performed in one patient (0.55%). Most patients (70.72%) were hypertensive, and 36.46% had ischemic heart disease (Table 1).

Anesthesia Technique

Premedication with oral diazepam 0.05 mg/kg is given 20–30 min before admission to the operating room (Table 2). Two peripheral venous cannulae are inserted: one for propofol and remifentanil infusions and the other for infusion of fluids and other drugs. Standard monitoring is used throughout the operation, including invasive arterial blood pressure, electrocardiography (heart rate and ST analysis), oxygen saturation, inspired oxygen fraction, end-tidal carbon dioxide, and respiratory variables.[8]

Before induction of anesthesia, remifentanil infusion is initiated using a target-controlled infusion device (Alaris Asena PK, Alaris Medical Systems, San Diego, CA). The aim is to detect, for each patient, the target remifentanil effector site concentration (Ce) corresponding to the target analgesic level, which is defined as the level of anesthesia characterized by the deepest level of analgesia still associated with the patient's ability to tighten his hands when requested. For this purpose, the pump is initially set to a target plasma concentration of 8 ng/mL. The plasmatic concentration of remifentanil is typically reached in several seconds, whereas the target Ce increases gradually until equilibrium is reached in a few minutes.[9,10] The built-in software calculates in real-time the actual remifentanil Ce and continuously displays it on the device monitor. During this phase, while administering oxygen, the depth of anesthesia is repeatedly assessed. Consciousness is evaluated by asking the patient to squeeze a plastic toy in the hand opposite to the side of surgery. Onset of adequate analgesia is appraised by evaluating the response of

Table 2. Anesthesia Protocol

T_0	Premedication with oral diazepam 0.05 mg/kg
T_1	Insertion of venous and arterial cannulas
T_2	Admission to the operating room: standard monitoring
T_3	Administration of oxygen: Start the infusion of remifentanil as to achieve 8 ng/ml cp Check vital signs (heart rate, arterial blood pressure, respiratory rate) Check ocular signs (winking, myosis, nystagmus) Check analgesia until lack of response to pain occurs When satisfactory anesthesia plan is achieved identify the corresponding Ce showed on the pump display
T_4	Induction: Propofol 1.5 mg/kg bolus + 2 $mg \cdot kg^{-1} \cdot h^{-1}$ infusion Set remifentanil pump as to maintain the achieved Ce Topical anesthesia of the trachea (lidocaine 2% 5 mL) Intubation without muscle relaxants
T_5	Local anesthesia of the neck (ropivacaine 1%–10 mL)
T_6	Start of surgery
T_7	Propofol interruption (at least 20 min before carotid clamping)
T_8	When consciousness has been recovered: Call the patient aloud and check his response Check his ability to squeeze the toy in his hand and to respond with a nod of the head to simple questions
T_9	Carotid artery clamping time: Repeat the test every minute for the first 3 min and then at 3-min intervals to exclude brain hypoperfusion (insert the shunt if needed) Repeat the test after the reopening of the artery
T_{10}	Carotid reopening: Start again propofol infusion at 2 $mg \cdot kg^{-1} \cdot h^{-1}$
T_{11}	End of surgery: Stop infusions of remifentanil and propofol
T_{12}	Patient awakening

Ce = effector site concentration.

the patient to noxious pinches delivered on the trapezium muscle. Standard monitoring of arterial blood pressure, heart rate, and respiratory rate as well as ocular signs are also examined.

Patients usually achieve the target analgesic level before the remifentanil concentration at the effector site reaches equilibrium with the plasma concentration. If a remifentanil Ce higher than 8 ng/mL is needed to obtain the adequate level of anesthesia, the target plasma concentration is increased by 2 ng/mL increments until a satisfactory balance between lack of response to pain and maintenance of consciousness is achieved. When the target analgesic level is reached, the corresponding target remifentanil Ce level specific for each patient may be easily identified by reading the Ce value on the pump display. The plasma remifentanil concentration is then set at the value of the identified target remifentanil Ce to maintain it throughout the procedure.

Hypnosis is subsequently induced with a bolus of propofol of 1.5 mg/kg. Laryngoscopy is performed without muscle relaxants[11] after topical anesthesia of the trachea is achieved by spraying lidocaine (2%, 5 mL) through a laryngo-tracheal cannula.[12]

The trachea is intubated with a high-volume, low-pressure cuffed tracheal tube of the appropriate size. After tracheal intubation, anesthesia is maintained with propofol 2 $mg \cdot kg^{-1} \cdot h^{-1}$ and remifentanil at the determined target Ce.

Local infiltration of the skin of the anterior border of the sternocleidomastoid muscle with ropivacaine 1% (10 mL) is also performed before surgery.[13]

Propofol infusion is then interrupted 20 min before the expected carotid cross-clamping so that patients spontaneously regain the target analgesic level of anesthesia when the surgeon is ready to clamp the carotid artery. Neurological monitoring is started by asking the patient to open his eyes, to answer with a nod of the head to simple questions and to squeeze a toy held in his hand. After patient cooperation is obtained, the target remifentanil Ce is carefully optimized on the basis of the quality of patient response to requests (too strong or too weak a response). The target remifentanil Ce is then adjusted by slight and delayed increments or reductions of 0.5 ng/mL until an appropriate patient response to stimulation is achieved.

After carotid clamping, close monitoring of the patient's neurological function is performed every minute for the first 3 min and then at 3-min intervals. When a neurological deficit is detected and is not reversed by increasing the arterial blood pressure[14] and/or F_{IO_2},[15] the surgeon proceeds to place a temporary carotid shunt.[16]

After carotid artery unclamping, the neurological test is repeated and anesthesia is deepened. Propofol infusion is then started again at 2 $mg \cdot kg^{-1} \cdot h^{-1}$ until the end of surgery when both propofol and remifentanil infusions are suspended. After recovery of consciousness, once spontaneous breathing is confirmed, the tracheal tube is removed and the patient is discharged to the recovery room. The neurological examination is repeated at the end of operation by the anesthesiologist and postoperatively by an experienced neurologist before discharge from the hospital. A questionnaire of explicit awareness[17] (Fig. 1) and the satisfaction score analysis are performed the day after surgery.[18] The score is composed of four levels of satisfaction regarding anesthesia (very satisfied = 4; satisfied = 3; unsatisfied = 2; very unsatisfied = 1). Surgeons are also asked to complete the satisfaction score.

Statistical Analysis

Data were analyzed with the statistics software GraphPad (version Prism 4.0; GraphPad Software, San Diego, CA). Data were tested for normality using the Kolmogorv-Smirnov test. Parametric data were expressed as mean (Standard Deviation, SD). Nonnormally distributed variables were presented as median and interquartile range. The relationship between variables was investigated by calculating the Spearman rank correlation coefficient (ρ). Differences between groups were tested with Mann-Whitney *U*-test. A P value <0.05 was considered statistically significant.[19]

RESULTS

Co.Pa.Ge.A. was successfully performed in all but two patients (1.1%) who needed conversion to general anesthesia during the clamping time because of anxiety and agitation. A carotid shunt was placed in these two patients. The median target remifentanil Ce at the carotid clamping time was 7.7 ng/mL (25th–75th percentiles 6.3–10 ng/mL) corresponding to a median infusion dose of 0.24 $\mu g \cdot kg^{-1} \cdot min^{-1}$ (25th–75th percentiles 0.185–0.295 $\mu g \cdot kg^{-1} \cdot min^{-1}$). The lowest target remifentanil Ce was achieved in an 84-yr-old woman (1.9 ng/mL) although the highest one was recorded in a 66-yr-old-woman (20 ng/mL). Patients ≥75-yr-of-age required a lower median infusion dose (0.26 vs 0.21 $\mu g \cdot kg^{-1} \cdot min^{-1}$; $P < 0.05$) and target remifentanil Ce (8.2 vs 7.5 ng/mL; $P < 0.0001$) than patients younger than age 75.

However, age itself correlated poorly with both the target remifentanil Ce ($\rho = -0.2175$) and the corresponding remifentanil infusion dose ($\rho = -0.3670$, Fig. 2).

During the phase that preceded the induction of anesthesia, although remifentanil Ce was increased, patients usually experienced, at first, respiratory depression but they could breathe on command. Afterward, they showed a slight decrease in heart rate and arterial blood pressure. We observed that the target analgesic concentration of remifentanil was often preceded by three ocular signs in succession: frequent winking of the eyelids, myosis, and then vertical nystagmus. Vertical nystagmus usually preceded the achievement of an

Surname……Name……Operation……Date……

1. Can You describe your perception during anesthesia?

2. Answer to the following questions about those sensations felt during the operation:
   - a. AUDITORY:
     - i. Do you remember noises or voices? Yes No
     - ii. If Yes, loud or weak? Yes No
     - iii. If Yes, far or near? Yes No
     - iv. Did you realized from what direction sounds were coming? Yes No
     - v. Did you recognized sounds? Yes No
     - vi. Did you recognized voices? Yes No
     - vii. Can you remember conversations, other than commands? Yes No
     - viii. If Yes, could you understand the meaning of them? Yes No
   - b. VISUAL:
     - i. Do you remember lights? Yes No
     - ii. Do you remember darkness? Yes No
     - iii. Do you remember shadows? Yes No
     - iv. Do you remember to have seen figures? Yes No
     - v. How can you define your recalls, clear or foggy? Yes No
     - vi. Could you recognize objects? Yes No
     - vii. Could you identify people? Yes No
     - viii. Are your recalls isolated or pertained to the operation? Yes No
   - c. TACTILE:
     - i. Do you remember to have been touched? Yes No
     - ii. If Yes, in which part of the body? Yes No
     - iii. Can you remember the quality of that sensation? Yes No
   - d. PARALYSIS:
     - i. Do you remember to have been paralyzed? Yes No
     - ii. Do you remember to be unable to move:
       1. Arms Yes No
       2. Legs Yes No
       3. Head Yes No
       4. Vocal cords Yes No
       5. Respiratory muscles Yes No
   - e. PAIN:
     - i. Did you feel pain:
       1. NO
       2. Yes mildly
       3. Yes much
     - ii. Can you remember where in the body? Yes No

3. FEELINGS:
   - a. Do you remember to have been helplessness? No mildly much
   - b. Did you feel fear? No mildly much
   - c. Did you feel panic? No mildly much
   - d. Did you feel weakness? No mildly much

4. THOUGHT:
   - a. Can you remember it as reality or as a dream?
   - b. Can you tell how long you have been awake?
     - i. few minutes
     - ii. much
     - iii. too much

5. EFFECTS:
   - a. Did you have nightmares? No mildly much
   - b. Did you feel anxious? No mildly much
   - c. Did you feel afraid? No mildly much
   - d. Are you afraid to be anesthetized again? No mildly much

Figure 1. Questionnaire on intraoperative awareness.

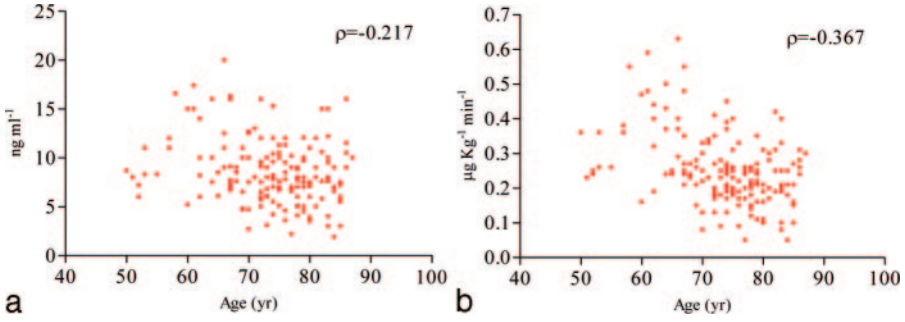

Figure 2. Correlation between age and remifentanil Ce (a) and between age and remifentanil infusion dose (b) at the target level of analgesia.

adequate depth of anesthesia that was easily assessed by the lack of response to nociceptive stimulations (noxious pinches on the trapezium muscle) while the patient was still awake or easily arousable.

Some patients, at near analgesic doses, showed increased muscular tone, though none exhibited muscle rigidity so severe as to make ventilation difficult or impossible.

Table 3. Characteristics of the Surgical Procedures ($n = 181$)

Duration of anesthesia, mean (SD), min	107 (21.3)
Duration of surgery, mean (SD), min	85 (14.7)
Carotid clamping time, mean (SD), min	32 (8.7)
Shunt insertion, *n* (%)	22 (12.15)
Repair with patch, *n* (%)	163 (90.05)
Conversion to general anesthesia (due to):	
Patient discomfort, *n* (%)	2 (1.1)
Neurological symptoms, *n* (%)	4 (2.21)
Hemodynamics during carotid clamping:	
Heart rate, mean (SD), bpm	48 (21)
Mean arterial blood pressure, mean (SD), mm Hg	98 (12)

Table 4. Outcome and Acceptance of the Technique ($n = 181$)

Neurological complications within 30 d:	
Any stroke, *n* (%)	0
Neuropsychological injury, *n* (%)	0
Death, *n* (%)	0
Cardiac complications within 30 days:	
Myocardial infarction, *n* (%)	2 (1.1)
Arrhythmias, *n* (%)	2 (1.1)[a]
Death, *n* (%)	0
Questionnaire on awareness:	
Auditory recalls, *n* (%)	172 (95.02)
Visual recalls, *n* (%)	3 (1.66)
Tactile recalls, *n* (%)	173 (95.58)
Recall of muscular paralysis, *n* (%)	0
Recall of vocal cord paralysis, *n* (%)	139 (76.79)
Any recall of pain, *n* (%)	1 (0.55)
Any recall of bad feelings, *n* (%)	2 (1.1)
Perception of real length of surgery, *n* (%)	35 (19.34)
Experienced as a dream, *n* (%)	106 (58.56)
Patients' satisfaction score, *n* (%):	
Very satisfied	112 (61.87)
Satisfied	67 (37.01)
Unsatisfied	2 (1.1)
Very unsatisfied	0
Surgeons' satisfaction score, *n* (%):	
Very satisfied	170 (93.92)
Satisfied	11 (6.08)
Unsatisfied	0
Very unsatisfied	0

[a] Atrial fibrillation.

Laryngoscopy and orotracheal intubation were easily performed through open vocal cords and no difficult intubation was recorded.

Anesthesia at target remifentanil Ce allowed continuous neurological monitoring during the clamping time in the presence of patient comfort. Table 3 shows the characteristics of the surgical procedures performed in our population.

None of the asymptomatic patients had any neurological deficit after recovery from anesthesia and none of those with preoperative stable neurological deficits showed any worsening of their symptoms. The late neurological examination performed by neurologists confirmed those perioperative findings (Table 4).

Intraoperative Complications

Apart from the two patients in whom conversion to general anesthesia was needed and in whom a routine shunt strategy was chosen, all the other shunts were inserted on the basis of the neurological monitoring. The total number of shunts inserted was 22 (12.15%). In four patients (2.21%), neurological deficit due to carotid cross-clamping did not reverse completely after the insertion of the shunt, and therefore conversion to general anesthesia was performed. In these patients, a neuroprotective anesthesia strategy was chosen. Remifentanil infusion was stopped and sevoflurane two minimum alveolar concentration end-tidal anesthetic concentration started. Norepinephrine ($0.05–0.2\ \mu g \cdot kg^{-1} \cdot min^{-1}$) was required to maintain the systolic arterial blood pressure 10%–15% higher than the preoperative values and gaseous anesthesia was maintained until the end of surgery. None of the shunted patients, as well as the nonshunted, showed persistent neurological deficit upon awakening.

In-Hospital Follow-Up

No patients died during the hospital stay (Table 4). Two (1.1%) myocardial infarctions occurred in two patients both in the early postoperative period. One patient experienced a non-ST elevation myocardial infarction in the second postoperative day, treated with medical therapy (peak troponin [Tn] I 20 ng/mL). The other patient had an ST elevation myocardial infarction in the first postoperative day and was successfully treated with primary percutaneous coronary intervention; a stent was implanted in the left anterior descending coronary artery (peak Tn I, 15 ng/mL). None of the two cardiac events was fatal and both patients were discharged from the hospital in good clinical condition. Two patients (1.1%) showed transient, hemodynamically stable atrial fibrillation, effectively treated with medical therapy.

Questionnaire of Awareness and Satisfaction Score

Two patients (1.1%) reported feeling uncomfortable during the operation (Table 4). All others (98.8%) described the experience as either nonstressful or even pleasant. Most patients (76.79%) realized they were unable to speak, but none reported being uncomfortable for that reason and, moreover, none experienced muscle paralysis. In one patient, incomplete pain suppression was reported (0.55%).

The operation duration was described as brief by 80.66% of patients, whereas 19.34% had the perception of time passing during the awake period. The experience was described as "a dream" by 58.56% of patients and as a "vivid recollection" by the remainder (41.44%).

Overall, 98.8% of patients felt "very satisfied or satisfied" with their anesthesia (Table 4). Similarly, the majority of surgeons felt very satisfied about the operative setting allowed by Co.Pa.Ge.A. (Table 4).

DISCUSSION

The Technique Itself

The idea of Co.Pa.Ge.A. was born out of our daily clinical practice because of the need to arrange an anesthesia plan incorporating the major advantage of local anesthesia (neurological monitoring) and the main benefits of general anesthesia (optimal tolerance for patients and definitive and safe control of airways). Therefore, we uncoupled the analgesic and hypnotic components of anesthesia to reach, by means of a dynamic interplay between these two elements, the depth of anesthesia that allowed neurological monitoring of patients during carotid clamping time, in the presence of hemodynamic stability and complete analgesia. In this setting, brain hypoperfusion can be diagnosed early and, if necessary, it can be managed by rapidly converting to general anesthesia.

Remifentanil has been our opiate of choice because of its short half-life, duration of effect, remarkable ability to produce analgesia easily adaptable to surgical needs[20] and its metabolism via nonspecific tissue and plasma esterases.[21]

The procedure by which we detect the appropriate target remifentanil dose before the induction of hypnosis overcame the wide variability of target levels among patients. The remifentanil Ce required for patient cooperation cannot be predicted on the basis of patient age.

At the target Ce, the patient was still able to respond to auditory stimulation although showing a full suppression of the response to pain. The main disadvantage of remifentanil, that is, respiratory depression or apnea due to the high dose needed to suppress pain, was overcome in Co.Pa.Ge.A. by orotracheal intubation.

Coppi et al.[13] described a similar technique based on remifentanil for CEA. In contrast to Co.Pa.Ge.A, neurological monitoring was performed initially by Bispectral Index and afterwards by clinical assessment. Tracheal intubation was performed by the standard technique (using succinylcholine). The main difference with Co.Pa.Ge.A. is that the propofol infusion (i.e., the hypnotic component of anesthesia) was maintained and remifentanil infusion was gradually reduced until the patient's response was elicitable. In Co.Pa.Ge.A. propofol infusion is stopped, although remifentanil infusion is maintained at a target analgesic level previously identified with the aid of a target-control infusion pump, thus facilitating the patient's neurological evaluation. Similar to our investigation, Coppi et al.[13] observed that remifentanil infusion was associated with hemodynamic stability and patient satisfaction.

The rate of conversion from local to general anesthesia because of patient intolerance to local or locoregional techiniques has been reported to be 1%–1.67%.[22,23] In our investigation, the rate of conversion from Co.Pa.Ge.A. to general anesthesia was 2.21%. This mild discrepancy may be because of different patient selection criteria in previous reports. It has been reported that some patients are usually considered incompatible with local anesthesia because of their inability to communicate or when their physiological situation is more complex and challenging.[24] Up to 10% of patients may refuse local anesthesia.[25] We did not exclude from our study patients with "difficult necks" and none of the patients refused our technique.

The two most feared major perioperative complications of CEA are cerebrovascular accidents and myocardial infarction. The incidence of perioperative stroke during CEA is approximately 3.4% for asymptomatic patients and 5.6% for symptomatic patients.[26,27] To reduce this incidence, a number of techniques and devices have been developed to detect cerebral ischemia but none have a 100% sensitivity.[7] Awake testing under local anesthesia is considered the most reliable specific technique to monitor neurological function, although not all patients may be suitable (i.e., those with a prior stroke and permanent deficits).

In our population, no strokes or new neurological deficits were observed in the perioperative period. The following factors characterizing Co.Pa.Ge.A. may account for these results: (a) hemodynamic stability which plays a pivotal role in preventing cerebral hypoperfusion[14,16]; (b) absolute control of ventilatory pattern which permits maintenance of optimal $Paco_2$ and Pao_2[13]; (c) continuous clinical neurological monitoring which allows early and specific detection of newly developed brain deficit, similarly to local anesthesia[24]; and (d) the easy, prompt, and safe conversion to general anesthesia whenever required, particularly in those cases in which shunt positioning does not reverse symptoms.

The incidence of perioperative myocardial infarction in patients undergoing CEA ranges from 0% to 4%.[27] In our case series, we found a 1.1% occurrence of acute myocardial ischemia in the early postoperative period, in agreement with previous data.[28] The two adverse cardiac events occurring in our series were not fatal; they were treated according to guidelines[29] and were associated with good early and long-term outcome. It is possible that the hemodynamic stability achieved by means of Co.Pa.Ge.A. during surgery may have contributed to the low incidence of perioperative myocardial ischemia in our investigation.

The acceptance of the technique was good in our series, considering that patients were enrolled consecutively. Awareness during general anesthesia has been described by many patients as a rather frightening experience, which may ultimately cause serious emotional or posttraumatic stress disorders. Patients who have experienced awareness during anesthesia commonly describe auditory perceptions, the sensation of paralysis, anxiety, helplessness, and panic.[30] None of our patients noted such negative feelings and the high satisfaction score they reported may have

arisen from the detailed information about the technique given before the operation by the anesthesiologist, as well as from the complete analgesia achieved by remifentanil and the lack of muscle paralysis during the awake period. Most patients remembered only the voice asking them to squeeze the toy and described this experience as not stressful and brief. None of them felt panic or helpless. Only two patients found the technique uncomfortable.

Surgeons appeared highly satisfied with Co.Pa.Ge.A. because this technique allowed accurate neurological monitoring during carotid clamping with a patient who was intubated, calm and without pain even in challenging and technically difficult cases.

Study Limitations

A possible limitation of the study could be the lack of comparison between Co.Pa.Ge.A. and general and locoregional anesthesia. The high acceptance of our technique by patients and surgeons resulted, in our daily practice, in a complete switch from locoregional anesthesia to Co.Pa.Ge.A.

However, a multicenter investigation is continuing to compare Co.Pa.Ge.A. with standard general and local anesthesia techniques.

Another possible limitation is represented by the small number of patients enrolled in our study. Though our patients are consecutive, further studies are needed to assess the feasibility and acceptance of the technique as well as the incidence of complications in a larger series.

CONCLUSIONS

Co.Pa.Ge.A is a remifentanil-based technique that has been demonstrated to be safe and satisfactory with a low rate of conversion to general anesthesia. This technique of anesthesia is characterized by hemodynamic stability and absolute control of ventilatory pattern. Continuous clinical neurological monitoring is achieved allowing early and specific detection of cerebral hypoperfusion and the easy, prompt and safe conversion to general anesthesia whenever required, particularly in those cases in which carotid shunt placement does not reverse neurological symptoms.

In our series, no neurological deficit occurred and the incidence of major cardiac complications was comparable to that previously reported in the literature.

Further studies are needed to assess the feasibility and acceptance of Co.Pa.Ge.A. as well as the incidence of complications in a larger cohort of patients.

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