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The Effect of General and Spinal Anesthesia on Balance Control in Elderly Patients

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Abstract: Falls are a major problem in the elderly population, but few communications address the influence of anesthesia on balance control. This study reports how a general balanced anesthesia (GBA) and a spinal anesthesia (SA) affect balance control in the elderly. We divided into three groups, according to electronystagmography findings and type of anesthesia, 21 men older than 65 years (mean age, 72 years) who were scheduled for prostate adenectomy. One group, designated *GBN*, consisted of normal subjects who underwent surgery under GBA. In another group, designated *GBP*, were pathological subjects who had clinically compensated central vestibular disorders (CVDs) and underwent surgery under GBA. The third group, designated *SP*, contained CVD patients who underwent surgery under SA. We assessed balance control via static posturography preoperatively and 48 hours postoperatively. We observed no change in balance control parameters (center of pressure distribution area [COPa] or COP sway velocity [SV]) for those patients in the GBN group or for those in the SP group. We did observe a significant difference for the patients in the GBP group, with higher postoperative values of COPa and SV (Wilcoxon signed rank test). Our results showed that in subjects with clinically compensated underlying CVD prior to a GBA, balance control worsens after the procedure, whereas no change in balance control occurs after an SA. Balance control in subjects with normal vestibuloocular function did not change even after a GBA.

Key Words: anesthesia; balance control; elderly; postoperative; postoperative unsteadiness

Elderly patients usually present decreased performance in various neural functions as a result of normal aging of sensorimotor system components and the frequent occurrence of injuries that diminish the dynamic range of functional adjustments [1]. These can be compensated until such patients reach the limit of their physiological reserve, producing clinical or subclinical dysfunctions [2].

As the elderly population grows, so are the medical aspects that involve this particular group. Falls are one of the most important issues that affect people aged 65 years or older; reports suggest that nearly 30% of this population fall at least once a year, with multiple causes implicated in their origin [3]. In addition, the number of surgical procedures in this age group is increasing, accounting for 4.2 million hospital stays in 2002–2003 as compared to 3.4 million in 1992–1993 in the United States [4]. Anesthesia in the elderly requires special considerations in light of an elevated frequency of comorbidities that involve the type of anesthesia and surgery techniques [5,6].

Many studies reported postoperative complications, such as postoperative cognitive dysfunction (POCD), myocardial infarction, and deep venous thrombosis [7]. Furthermore, as regards POCD etiology, mental decline prior to anesthesia has been shown to be a risk factor for developing POCD [8–10]. Another factor that has been reported are the differences in resultant postoperative morbidity and mortality between general and spinal anesthesia; the spinal approach has been found to be a safer choice in some conditions to avoid such complications [11]. One aspect that has been barely studied is how anesthesia affects balance control in the aged population.

As a criterion for hospital discharge, posturography has been used to evaluate the effect of some specific anesthetic drugs on balance control after minor anesthesia [12,13]. However, at present little is known about how

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an anesthetic procedure may affect balance control in elderly patients.

The loss of accurate sensory integration is a relevant issue that produces unsteadiness and falls among the elderly, altering patients' balance strategies in demanding situations, such as walking in rich visual environments (e.g., a shopping mall). Previous studies showed how people with abnormal findings in oculomotor control recorded by electronystagmography (ENG) had altered balance control parameters measured with posturography [14,15].

The aim of this study was to evaluate how an anesthetic procedure affects balance control in elderly subjects; we also investigated the differences between patients with and without central vestibular disorders (CVDs) previous to the procedure. Furthermore, we compared pre- and postoperative balance control in groups with CVD when the procedure was either general balanced anesthesia (GBA) or spinal anesthesia (SA).

SUBJECTS AND METHODS

Population

A total of 21 patients being treated in Hospital de Clinicas (School of Medicine), Uruguay, were involved in this study after they gave approval and informed consent to the ethics committee. All were men 65 years of age or older (mean age, 72 years) who were scheduled for prostate adenectomy for benign prostate hyperplasia. This choice was made to avoid large differences in surgical procedures among subjects. The surgical team did not report any intraoperative complication during the procedure.

We evaluated all the patients through a complete medical examination and computed tomography scanning. Exclusion criteria were history of vertigo, unsteadiness (or falls), locomotor system alterations, and neurological conditions such as stroke sequela, normotensive hydrocephalus, or severe cognitive dysfunction. Vestibulo-ocular function was studied with ENG in looking for peripheral vestibular asymmetries or alterations in the oculomotor system (i.e., smooth pursuit, saccadic system, and optokinetic [OK] reflex). Those who had a normal ENG record were classified as normal patients, and those with oculomotor ENG abnormalities were classified as patients with CVDs. As the latter group had no history of vertigo, unsteadiness, or falls, we defined their condition as clinically compensated CVD. Patients were divided into three groups: One group, designated as *GBN* ($n = 6$), contained patients with normal ENG results who were scheduled for prostate adenectomy under GBA. In another group, designated *GBP* ($n = 9$), patients had clinically compensated CVDs and were scheduled for prostate adenectomy under GBA. Subjects in the third group, *SP* ($n = 6$), had clinically compensated CVDs and were scheduled for surgery under SA.

Procedure

Balance control was measured by static posturography using a force platform (AMTI, Watertown, Mass., USA) that records subjects' center of pressure (COP) during 80 seconds in two different conditions: eyes open looking at a fixed-frame reference (FFR) and eyes open inside an OK drum spinning at 60 degrees per second. The FFR condition is a low-demand situation for subjects' balance control wherein OK stimuli challenge balance control, presenting a sensory conflict situation. The parameters used as a measure of balance control were the 95% confidence ellipse (CE) of the COP distribution area (COPa) and the COP sway velocity (SV). The area was calculated according to Suárez et al. [14] as:

$$\text{Area} = 2 \times \pi \times F_{0.05[2,N-2]} \times (\sigma_x^2\,\sigma_y^2 - \sigma_{xy}^2)^{1/2}$$

The value of F for 4,000 points is well approximated by 3. SV for each period is calculated as:

$$\begin{aligned} Vxy_{i+1} = {} & [(COPx_{i+1} - COPx_i)^2 + \\ & (COPy_{i+1} - COPy_i)^2]^{1/2} \times fs \end{aligned}$$

$$i = [1 \ldots N-1]$$

$$SV = \frac{1}{N-1}\sum_j Vxy_j$$

Vxy is the speed with which the subject arrives to a point $i + 1$. According to this, the first element of the vector velocity corresponds to Vxy_2, and it is associated with the second element of the vector position because the speed with which the subject arrives at the first point is not applicable. The average of all velocities (*Vxy*) is the SV.

Posturography was conducted before and 48 hours after surgery, when there was no medical restriction against it. The anesthetic procedures were a *GBA*, defined as a combination of several anesthetics and anesthetic adjuvants, including the use of an inhalational anesthetic [16], or an *SA* [17].

Data Analysis

The values of CE and SV for the three groups were compared before and after surgery using the Wilcoxon signed rank test. The alpha level was set at 0.05.

RESULTS

The values of the COP CE and SV obtained for the three groups are shown in Tables 1 and 2. For the group of

Table 1. Values of Center of Pressure Area (in cm^2) Pre- and Postoperatively for All Groups

Patient	FFR Preop	FFR Postop	OK Preop	OK Postop
GBN	6.98	2.56	2.27	2.81
GBN	1.73	1.96	5.90	4.03
GBN	2.04	1.59	4.56	4.60
GBN	6.10	5.09	2.48	1.98
GBN	1.44	2.01	6.26	2.62
GBN	1.06	0.95	1.48	2.36
GBP	13.45	10.91	8.11	14.33
GBP	4.61	9.06	5.61	5.86
GBP	3.19	4.55	2.67	3.09
GBP	4.66	8.86	2.07	2.69
GBP	4.40	13.12	2.52	13.64
GBP	2.84	6.14	4.57	21.04
GBP	3.25	23.64	6.25	10.74
GBP	2.12	9.93	1.92	4.36
GBP	2.42	6.69	X	X
SP	2.15	1.49	4.34	1.87
SP	5.73	3.61	6.37	4.38
SP	3.12	3.30	11.89	33.36
SP	5.27	4.48	30.56	5.17
SP	1.74	5.07	1.61	1.44
SP	2.44	2.37	2.58	2.05

FFR = fixed-frame reference; GBN = normal subjects who underwent surgery under general balanced anesthesia; GBP = patients with central vestibular disorders operated under general balanced anesthesia; OK = optokinetic conditions; SP = patients with central vestibular disorders operated under spinal anesthesia; X = a fall.

Note: Values provided are in terms of the 95% confidence ellipse.

Table 2. Values of Center of Pressure Sway Velocity (in cm/sec) Pre- and Postoperatively for All Groups

Patient	FFR Preop	FFR Postop	OK Preop	OK Postop
GBN	1.67	1.17	1.52	2.02
GBN	1.95	1.76	4.38	3.42
GBN	1.39	1.42	3.64	2.16
GBN	1.17	2.23	2.16	1.74
GBN	1.47	1.33	2.77	1.78
GBN	1.40	1.32	1.77	1.75
GBP	3.36	4.19	8.49	10.24
GBP	1.92	2.16	2.41	2.35
GBP	1.67	1.74	1.64	1.56
GBP	2.06	2.11	1.67	2.59
GBP	1.61	2.15	1.92	2.73
GBP	1.35	2.71	2.26	5.73
GBP	1.68	2.09	4.72	5.84
GBP	1.39	2.08	1.55	1.70
GBP	2.29	3.88	X	X
SP	2.04	1.74	3.11	2.29
SP	4.74	3.77	5.43	5.28
SP	1.98	1.82	4.87	5.76
SP	3.02	2.39	10.32	3.20
SP	1.26	1.47	1.38	1.35
SP	1.10	1.15	1.22	1.22

FFR = fixed-frame reference; GBN = normal subjects who underwent surgery under general balanced anesthesia; GBP = patients with central vestibular disorders operated under general balanced anesthesia; OK = optokinetic conditions; SP = patients with central vestibular disorders operated under spinal anesthesia; X = a fall.

normal patients who underwent a GBN, we found no significant difference between the pre- and postoperative values of COP CE for either the FFR condition (p = .345) or the OK condition (p = .917). Neither did we find a difference in this group for the SV values in the FFR condition (p = .463) or the OK condition (p = .116), meaning that no alterations of balance control occurred after the procedure.

The group of CVD compensated patients who underwent a GBA (the GBP group), demonstrated significant differences between the pre- and postoperative values, with higher values of COP CE and SV. In the FFR condition, the CE (p = .015) and SV (p = .012) values were higher postoperatively, as they were in the OK condition for the CE (p = .008) and SV (p = .036). These outcomes indicate that balance control worsens after the anesthetic procedure.

In the SP group—CVD compensated patients who underwent an SA procedure—we noted no significant difference in pre- and postoperative balance control values. In the FFR condition, COP CE (p = .6) and SV (p = .249) values showed no significant difference. This was true also for the OK condition COP CE (p = .173) and SV (p = .345) values. These results show that no changes occurred in balance control after the procedure.

The range and median of COP CE and SV values obtained for the three groups in both conditions are shown in Figure 1: In accordance with previous reports [14,15], GBN patients (subjects without vestibulo-oculomotor abnormalities) presented balance parameters with less dispersion than in those observed in the groups with ENG abnormalities (the GBP and SP groups), in particular in SV values. (SV is claimed as a more reliable parameter [18].) Despite the absence of clinical evidence of balance dysfunction, these results demonstrate that there were not just vestibulo-oculomotor abnormalities observed on ENG in the GBP and SP groups, but also subtle dysfunctions in other components of balance control, in particular in such a challenging situation such as an OK stimulus. In CVD compensated patients, there was a larger median and a greater spread of values, with a clear increase of the median after GBA, whereas SA did not have a significant effect. Similar differences were observed in the same groups of patients when SV was assessed.

DISCUSSION

Previous damage to the central nervous system (CNS) is reported as a condition that elevates the risk of post-

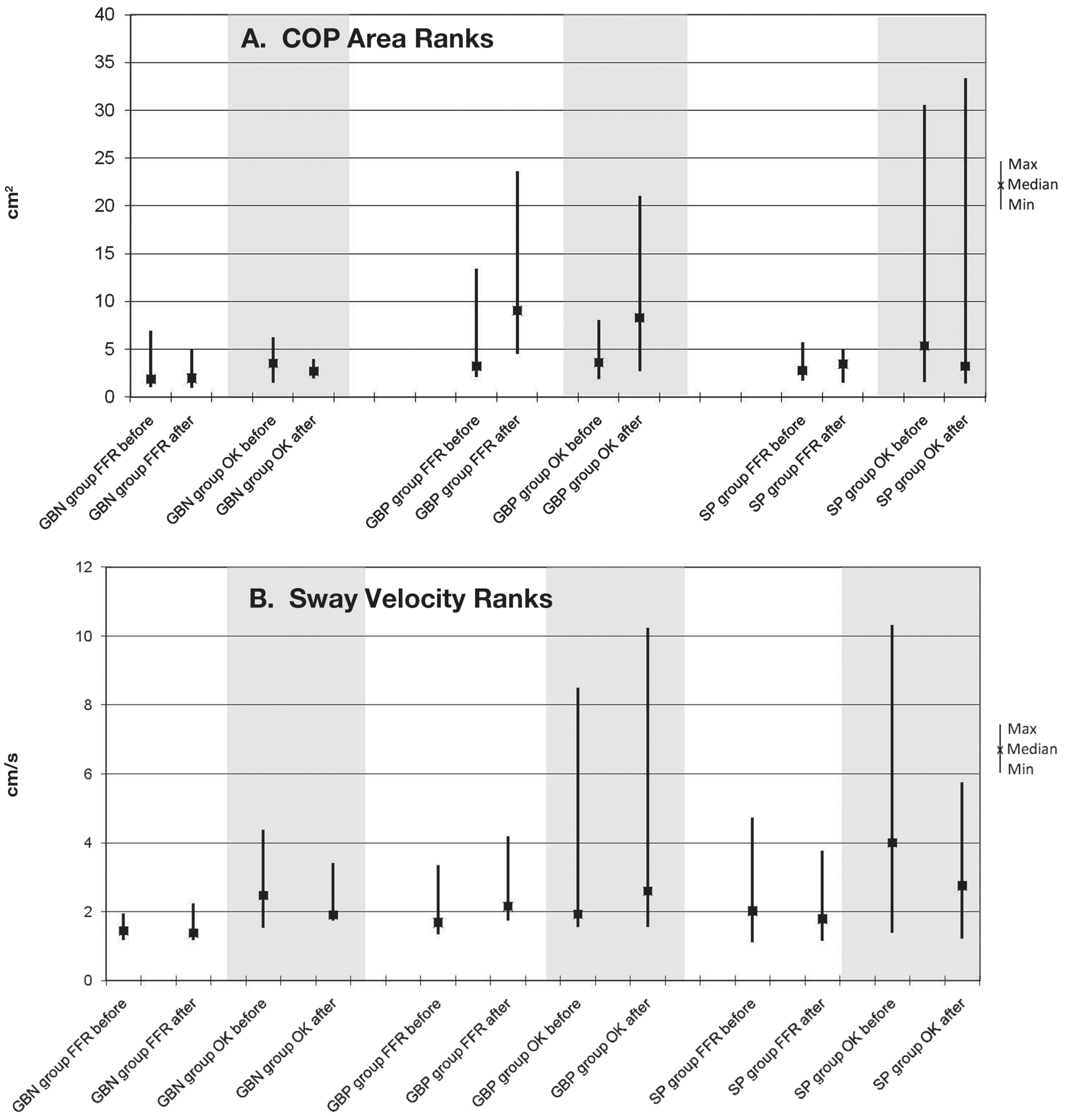

Figure 1. Range and median values (95% confidence ellipse) of (A) center of pressure area (COPa) and (B) sway velocity (SV) pre- and postoperatively for the normal group (*GBN*), the group of patients with central vestibular disorders operated under general balanced anesthesia (*GBP*), and the group of patients with central vestibular disorders operated under spinal anesthesia (*SP*). Values are provided for fixed-frame reference (*FFR;* in white background) and optokinetic conditions (*OK;* in grey background). The difference in balance control performance among the three groups can be seen: The GBN group did not show a significant difference before and after surgery. Conversely, the GBP group showed a significant increase in COPa and SV values after surgery under general anesthesia, whereas the same population operated under spinal anesthesia (SP group) demonstrated no increase in COPa or SV postoperatively.

operative CNS dysfunction, such as spatiotemporal disorientation, POCD, and even delirium [7–10]. Though little is known about delirium pathophysiology, changes in certain neurotransmitters—in particular acetylcholine and dopamine—are involved in its development [10,19]. When CNS damage occurs, some neural intrinsic properties are readjusted to compensate for the altered function. Vestibular compensation after damage is a classic paradigm of neural plasticity in which, as stated by Xerri et al. [20], some properties of the CNS organization, such as redundancy, sensory convergence, functional synergy, and sensorimotor strategies, are activated to compensate for the failure. Three different processes are activated to restore an appropriate balance control: activation of silent or secondary pathways, restitution, and substitution. These processes involve changes at different levels, such as enhanced synaptic efficacy, silent synapses activation, nerve sprouting, and synaptogenesis, among others. Vestibular compensation is a distributed process along the CNS [21], and GBA may affect the changes that occur after the process of compensation in the different sensorimotor systems involved in balance control, including the integration centers.

A comparison in our patients of the balance parameters measured by static posturography demonstrated that the group with a normal ENG record did not show any change in balance control after a GBA, whereas in the group with vestibulo-oculomotor dysfunctions, ENG revealed worsened balance control parameters, showing these patients to be at risk of falling. Moreover, when the same type of patients underwent surgery with SA, the balance control parameters did not show statistical differences postoperatively. Our results showed that previous subclinical alterations in the vestibulo-oculomotor system may be a condition for developing postoperative imbalance in the elderly population after surgery under GBA.

Vestibular function is known to decline as part of normal aging, and compensation processes occur to allow correct balance control [22,23]. These changes could be extended to other sensory systems involved in balance control. As a consequence of the administration of anesthetic drugs, an alteration of balance control occurs after a GBA but not after an SA, wherein the effect of the used drugs is restricted to a part of the CNS. We suggest that general anesthetic drugs, interfering with some neurotransmitter systems, affect the changes incurred during the compensation process to restore the function in the vestibulo-oculomotor system.

To our knowledge, no study measures balance control 48 hours after surgery. Previous reports measure balance control immediately after the surgical procedure or after administration of a specific anesthetic drug [12,13,24, 25]. We find very interesting that alteration in balance control is still present at 48 hours postoperatively. As falls are one of the most relevant health problems in the elderly population, owing to consequences to quality of life and health budget, a suitable approach may be for health care providers to think about appropriate interventions to diminish a patient's postoperative risk of fall, from a pre- and postoperative assessment of balance control such as that proposed by Fujisawa et al. [26] toward appropriate nursing care and instructions at a patient's discharge.

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