COMPUTERIZED DYNAMIC POSTUROGRAPHY: A NEW METHOD FOR THE EVALUATION OF POSTURAL STABILITY FOLLOWING ANAESTHESIA

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SUMMARY

Dynamic posturography, a new method to study postural stability in humans, was performed in 11 healthy volunteers before administration of midazolam 0.1 mg/kg body weight i.v., and repeated subsequently at 45, 105 and 165 min. Results indicate that balance was affected significantly (P < 0.008) up to 45 min after i.v. midazolam and did not return to control values until 105 min. The quantified version of the Romberg test performed with the eyes open or closed using the Equitest did not appear to be sensitive in detecting residual effects of midazolam on balance. We conclude that healthy, young persons should not be considered to have regained postural stability for up to 105 min after sedation with midazolam. Dynamic posturography appears to be a useful test in the objective assessment of balance disturbances.

KEY WORDS


There has been a rapid increase in the number of operations being performed on a day-case basis over the past few years [1]. Rapid recovery after anaesthesia or sedation is an important factor to be considered when choosing a safe anaesthetic for outpatient surgery. Consequently, short acting drugs such as midazolam and propofol are used commonly for sedation.

The ability to maintain postural stability is an important factor in the assessment of recovery and “street fitness”. However, standardized tests for assessment of balance are not available. Simple clinical tests (Romberg test or the ability to walk) do not seem adequate for deciding on the safe discharge of patients after outpatient surgery [2, 3]. Static posturography, or the quantitative assessment of human stability, has been used in measurement of recovery from anaesthesia [4, 5]. An instrumented force platform which measures body sway was described by Korttila [6]. This was found to be sensitive to detect balance disturbances after thiopentone, diazepam and methohexitone anaesthesia, and clinically useful, as data could be analysed immediately [7]. Computerized dynamic posturography [8, 9] is a new method for assessing human balance and posture, and has been used extensively in clinical practice for assessing and differentiating disturbances of vestibular, visual and proprioceptive functions, and central co-ordination. It has not been used, to our knowledge, for detection of balance disturbances after anaesthesia and sedation. We have used this test in assessing recovery from the effect of sedative medication in healthy volunteers.

SUBJECTS AND METHODS

The study was approved by the University Ethics Committee. Informed consent was obtained from 11 ASA I subjects aged 23–36 yr. No subject was taking any medication likely to affect postural stability. No food or drink was allowed for 6 h before the study. The subjects were asked to refrain from drinking alcohol or taking any
A cannula was inserted into a vein on the dorsum of the non-dominant hand for injecting drugs. Midazolam 0.1 mg/kg body weight was injected over 1 min and any adverse effects were recorded. The subjects were allowed to rest before further recordings were made at 45, 105 and 165 min after injection of midazolam. Variables monitored included arterial pressure, ECG, heart rate and ventilatory frequency.

Computerized dynamic posturography was performed as described by Cyr, Moore and Möller [8] and Nashner [9]. The subject stands on a dual forceplate enclosed by a visual surround. Both the forceplate and the visual surround can be made to move with the individual's antero–posterior sway or independent of sway, thus enabling programmed disturbances of equilibrium. The dual forceplate records the vertical forces between the feet and ground in addition to horizontal antero–posterior shear forces, thereby allowing estimation of the position of the swaying body and the pattern of sway in terms of hip or ankle strategy for correcting these disturbances. Vertical force transducers are located in all four quadrants of the dual forceplate. The shear force transducer is positioned in the middle of the dual forceplate.

The Equitest can be used to test two main components: sensory organization (SO) and movement co-ordination (MC), but we have tested only the former. The software for the latter is still in personal communication. The sensory portion of the test battery varies visual and proprioceptive inputs while determining the effect on equilibrium. For the effect of sensory system manipulation to be interpreted accurately, an intact motor system must be present. The SO part is divided into six separate testing conditions lasting 20 s each. SO1 is a quantified version of the Romberg test. The subject stands with eyes open and the surrounding and the support surface are stable. As all three sensory systems are operational, a high equilibrium score (defined below) should be obtained. SO2 is equal to SO1 except that the eyes are closed. Again, a high equilibrium score should be obtained because the absence of visual cues has little effect on balance in normal subjects in whom the vestibular and proprioceptive systems are functional. In SO3, performed with the eyes open, the surrounding moves in response to body sway, thus the visual cues are distorted. Under this condition, the brain is asked to ignore the inaccurate visual inputs. Because the person’s stance is fairly wide-based, equilibrium should remain fairly normal under this condition, particularly if the vestibular system is normal. In test SO4, the platform is sway referenced, and the surrounding stable. As a result, the proprioceptive input to the brain is inaccurate, and balance must be maintained by the visual and vestibular systems. In test SO5, with the eyes closed, the platform is sway referenced, and thus the proprioceptive system is compromised and the visual system is eliminated and only one of the three sensory systems is fully operational. Equilibrium and balance must then, to a great degree, be maintained by the vestibular system alone. In test SO6, both the platform and the surrounding are sway referenced. Under this condition, both vision and proprioception are compromised. Tests SO3–SO6 are repeated to get more stable values. Note that in SO3 and SO6 the subject might have some orientation information from the surrounding, as it is moving only in the antero–posterior direction and not in the lateral direction.

From each test an equilibrium score is computed by calculating the angle between the swaying body and earth vertical. The score is 100 for absolutely no sway, decreasing with increasing sway range, and zero for 12.5° sway range or in case of a fall. A strategy score is also computed, related to the amount of shear force exerted, expressing the degree of ankle or hip movements: 100 = solely ankle and no hip movements; 0 = hip movement generating approximately 110 N shear force. The subjects are secured to the apparatus by a safety harness to prevent falling.

Statistics

Paired Student’s t test was used to examine if the differences between the scores before and after the injection of midazolam were statistically significant. Baseline values were taken at 0 min and all subsequent results were compared with these values. The Bonferroni correction was applied in order to reduce the consequent increased probability of Type 1 error because of six different tests being performed at each time interval. A significant level of 0.05 was thus divided by six to yield a significance level of 0.008 \((P < 0.008)\).
COMPUTERIZED DYNAMIC POSTUROGRAPHY

TABLE I. Mean (SD) equilibrium scores (%) for the six conditions (SO1–SO6) studied, computed by calculating the angle between the swaying body and earth vertical. 100 % = absolutely no sway, decreasing with increasing sway range; 0 % = 12.5° sway range or a fall. Time 0 min = control values before the injection of midazolam; 45, 105 and 165 min = after injection of midazolam. Bonferroni correction was applied and P < 0.008 was considered statistically significant (*).

<table>
<thead>
<tr>
<th>Condition</th>
<th>0 min</th>
<th>45 min</th>
<th>105 min</th>
<th>165 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO1</td>
<td>95.8 (2.8)</td>
<td>87.5 (10.3)</td>
<td>93.5 (3.6)</td>
<td>94.9 (3.6)</td>
</tr>
<tr>
<td>SO2</td>
<td>93.2 (1.7)</td>
<td>78.2 (22.6)</td>
<td>87.6 (6.8)</td>
<td>91.1 (4.0)</td>
</tr>
<tr>
<td>SO3</td>
<td>92.0 (3.4)</td>
<td>74.8 (27.1)</td>
<td>89 (5.8)</td>
<td>91.7 (2.3)</td>
</tr>
<tr>
<td>SO4</td>
<td>90.3 (5.3)</td>
<td>69.8 (26.1)</td>
<td>86.6 (8.3)</td>
<td>90.9 (4.0)</td>
</tr>
<tr>
<td>SO5</td>
<td>72.1 (0.3)</td>
<td>41.5 (34.4)</td>
<td>66.7 (15.4)</td>
<td>68.7 (10.6)</td>
</tr>
<tr>
<td>SO6</td>
<td>72.1 (12.0)</td>
<td>48.6 (29.7)</td>
<td>66.6 (16.8)</td>
<td>68.4 (13.8)</td>
</tr>
</tbody>
</table>

Results of the study showed that all the subjects (seven male, four female) were within the normal range for the normative data representative of their age group as calculated by Neurocom International Inc.: mean age 29.2 yr (range 23–36 yr); mean weight 73.2 (SD 11.7) kg (range 57–93 kg); mean height 180.1 (SD 9.8) cm (range 170–195 cm).

Mean (SD) equilibrium scores in the sensory conditions SO5 and SO6 were significantly different 45 min after i.v. midazolam (table I). However, all the equilibrium scores had returned to control values at 105 min.

Mean (SD) of the strategy scores are shown in table II. There was no significant change in equilibrium strategy in any of the conditions tested except condition SO4 at 45 min where hip, rather than ankle strategy was used to correct body position.

One person fell on all the conditions at 45 min. Five of 11 subjects fell on condition SO5 at 45 min and three fell on condition SO6 at 45 min.

Arterial pressure, heart rate, ECG and venti-
latory frequency remained stable throughout the procedure. No person complained of nausea or vomited during the period under study and no subject complained of double vision during or after the test period.

All persons were fully awake and could answer questions accurately 105 min after the injection of midazolam. Four of the 11 subjects were slightly tired the same evening, although all of them walked or cycled home after the test period (elicited by a questionnaire sent to all the participants a few days later).

**DISCUSSION**

This study has demonstrated that midazolam 0.1 mg kg$^{-1}$ given i.v. to 11 healthy volunteers caused disorders of balance up to 45 min later, and that balance had not returned to control values until 105 min.

In order to remain in standing equilibrium, postural muscles generate acceleration forces acting upon the body segments. The cerebellum and the brainstem integrate signals from the somatosensory, visual and vestibular systems and correct equilibrium disturbances. These three systems contribute to postural control, and damage to any of them, or to the brainstem or cerebellum, influences the overall output of the postural system; this may be studied by posturography.

In clinical practice, the Romberg test is often used to assess ability to maintain balance. However, it is not objective and therefore it is very difficult, if not impossible, to grade the degree of imbalance by observation. This test appears, therefore, to be inadequate as a guideline for the safe discharge of patients after ambulatory surgery [2, 3]. Walking on a straight line suffers the same limitations as the Romberg test. Korttila used both these tests, together with other clinical tests of recovery, and compared them with psychomotor test batteries in volunteers after sedation with diazepam [10]. He observed that these tests showed no impairment of performance 30 and 150 min after injection, whereas the psychomotor tests revealed considerable impairment of reactive and co-ordinative skills.

The classical way of estimating liability to fall is that of spontaneous sway measurements on a stable platform (static posturography) in standing man [11]. Measurements in static posturography do not resemble the dynamic conditions that characterize daily life. Falls are not likely to occur in stable standing, but occur usually in situations of unexpected equilibrium disturbances, which require fast corrections of body position, demanding both muscular strength and adequate muscle co-ordination. Increased spontaneous sway is, however, not an entirely successful predictor in identifying individuals at risk of falling, particularly in the older age group [12]. Balance testing would benefit, therefore, from a more dynamic measurement situation. Dynamic posturography is a new investigation procedure that enhances measurement of spontaneous sway by exposing the subject to conditions in which the surround and the support platform can be made to follow the sway, increasing the difficulties of correcting disturbances of equilibrium. By making the visual surround and the support surface stable or sway-referenced, it is possible to test the different inputs to the postural system separately and accurately. This method has been shown previously to be very sensitive in detecting influences on balance functions during exercise in the elderly [13] and equilibrium abnormalities in acute alcoholic intoxication [14].

In this study, midazolam 0.1 mg kg$^{-1}$ i.v. resulted in significant abnormality in the sensory organization conditions SO5 and SO6 at 45 min. At 105 min, all components of this test had returned to control values. One earlier study [15] examined the problem of balance disturbances after sedation with midazolam and diazepam using the Romberg test and the ability to walk on a straight line. In that study, balance was disturbed up to 120 min after midazolam, but only up to 60 min after diazepam. This contrasts with our findings which suggest that balance had returned to normal within 105 min after i.v. midazolam. The quantitative version of the Romberg test with the eyes open and closed (conditions SO1 and SO2) at 45 min did not show any difference from control values, suggesting that it is an insensitive test for the detection of postural stability after sedation with midazolam. This difference in findings between the previous study and ours could be because the Romberg test is very subjective and hence difficult to interpret.

The plasma half-life of midazolam is approximately 120 min [16] and it has an effective duration of action varying from 90 to 240 min. This wide variation in duration of action may be a reflection of interindividual variation and of the different methods used to assess recovery.
The instrumented force platform was used by Korttila and others [6] to study static posturography after thiopentone, methohexitone and diazepam i.v. Results suggested that there was no significant body sway after methohexitone compared with normal saline. However, thiopentone was associated with increased sway up to 1 h later and diazepam up to 7 h. Closer examination of this study shows that, although patients given diazepam had returned to control sway values at 5 h, they had increased sway at 7 h. This could be because of the phenomenon of resedation, which has been described previously for midazolam [17]. Our results on dynamic posturography using midazolam did not appear to show this, although investigations were performed for only up to 165 min after i.v. injection.

Double vision, a common complication of anaesthesia, does not appear to be a problem with midazolam sedation. This is supported by the facts that, not only did none of our volunteers experience this, but also, if it were present, condition SO1 (which is a quantified version of the Romberg test with the eyes open) would also have been likely to show significant differences at 45 min.

Under normal standing conditions, most people use the ankle joint as a fixed point. This is referred to as ankle strategy. When body sway is increased beyond that which the ankle strategy can manage, the individual must incorporate corrective movements by bending at the hip. In normal healthy persons, hip strategy is considered inappropriate for the degree of body sway induced by the conditions SO1–SO4 tested here. However, because conditions SO5 and SO6 test the balance system to its extremes, hip strategy is not uncommon in these conditions alone. Thus ankle strategy is the primary strategy of corrective movement in case of body sway during simple standing conditions. Our study failed to show any significant effects of midazolam on equilibrium in adolescent idiopathic scoliosis. Acta Orthopaedica Scandinavica 1978; 49: 354-365.

In summary, the Equitest seems to be a useful advance in the study of balance disturbances after sedation. Conditions SO5 and SO6 which strain the balance system to an extreme are, perhaps, the most sensitive in the detection of postural abnormalities.

Volunteers given i.v. midazolam had returned to baseline sway values after 105 min and may be considered to possess adequate postural stability to maintain balance. Thus dynamic posturography seems to be a useful method to study balance disturbances after anaesthesia and sedation.

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REFERENCES

