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Correlation between precise and simple tests in recovery of dynamic balance function after intravenous sedation with midazolam in the elderly

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Abstract
Purpose. Assessing the recovery of dynamic balance after intravenous sedation in the elderly is important for ensuring their safe discharge, especially when they are walking. A reliable, simple dynamic balance test would be useful in daily clinical practice. We observed the recovery of balance after intravenous sedation with midazolam, using computerized dynamic posturography (CDP), and we evaluated the correlation between the CDP result and the results of simple dynamic balance tests.
Methods. Midazolam was administered in divided doses, until the Wilson sedation score reached 3, in 18 elderly male volunteers. The dynamic balance test using CDP with perturbation stimuli was performed before and after sedation. As simple dynamic balance tests, the usual-speed walking (USW) and maximum-speed walking (MSW) tests and a modified timed "up and go" (TUG) test (subjects stand up from a chair, walk 5 m forward and return to the chair with MSW, and sit down again) were performed.
Results. The recovery times (defined as the time until the significant difference between the value at each time point and the baseline value disappeared) in the dynamic balance test (CDP), USW test, MSW test, and TUG test, were 80, 40, 80, 80 min, respectively. There was a significant, strong positive correlation between the result of the dynamic balance test (CDP) and the TUG test ($P < 0.01$; $r = 0.70$).
Conclusion. The TUG test is a useful simple dynamic balance/motor test that can be used in daily clinical practice in the elderly.

Key words Conscious sedation · Midazolam · Aged · Recovery of dynamic balance

Introduction

Intravenous sedation is sometimes used to relieve stress during surgery for elderly patients [1–3]. Assessing the recovery of dynamic balance function after intravenous sedation in the elderly is important for ensuring their safe discharge, especially when walking. Evaluation by means of computerized dynamic posturography (CDP) with unpredictable perturbation stimuli may be rational and objective for preventing falls [4,5]; however, such assessment may be difficult in daily clinical practice, owing to economic considerations and the duration of the test. Therefore, simple dynamic balance tests that are well correlated with CDP would be useful in daily clinical practice.

We observed the recovery process of postural control ability after intravenous sedation with midazolam, using CDP with perturbation stimuli and simple dynamic balance tests, and we evaluated the possible correlation between the precise test (CDP) and simple balance tests in elderly male volunteers.

Subjects and methods

After informed consent and the approval of the ethics committee of our institution were obtained, 18 elderly male volunteers were enrolled in this study. Hypertension was observed in 7 subjects, arrhythmia in 2, and diabetes mellitus and asthma in 1 each (more than 1 complication in some subjects). Long-term benzodiazepine users and those who suffered from liver, renal, or neuromuscular disorders were excluded from the study. Midazolam was administered in small, divided doses over 4 to 5 min until the Wilson sedation score reached 3 (the eyes are closed, but the subject responds to one or two calls) [6]. After the designated depth of sedation was achieved, no additional sedatives were administered. As an objective index of the sedation level, the

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bispectral index (BIS) was determined with a BIS monitor (A1050; Aspect Medical Systems, Newton, MA, USA) during sedation.

The precise balance test and three simple dynamic balance tests were performed before (baseline) and 40, 60, 80, 100, and 120 min after the administration of midazolam. As the precise test, a dynamic balance test, using CDP with unpredictable perturbation stimuli (a Stability System; Biodex Medical, Shirley, NY, USA), was performed as described previously [5]. Briefly, in the dynamic balance test, an unstable platform tilts in all directions according to changes in body weight applied to the tips of the toes and the heels. On the basis of the results of our preliminary tests, we set the platform stability; at "level 7", as a moderate and safe level for the elderly. The subjects were asked to keep the platform horizontal for 20 s. The degree of platform tilt from the horizontal line in all directions during the test was expressed as the stability index. As simple dynamic balance tests, the usual-speed walking (USW) and maximum-speed walking (MSW)tests, in which the times required to walk 10 m at the usual and maximum speeds, respectively, were measured, and the modified timed "up and go" (TUG) test [7] were performed. In the TUG test, the subject sat on a metal chair with his back in contact with the back of the chair, stood up, walked to a marker 5 m in front of the chair and returned to the chair at maximum walking speed, sat on the chair, and moved his back to the back of the chair. The time needed to complete these actions was measured with a stopwatch.

To assess psychomotor function, the digit symbol substitution test (DSST) and the Trieger dot test (TDT) were performed before (baseline) and 50, 70, 90, 110, and 130 min after midazolam administration. The DSST was performed for 90 s, using the Japanese version of the manual for the Wechsler Adult Intelligence Scale-Revised. In the TDT, a geometric figure was drawn by connecting a series of dots with a ballpoint pen.

This study was designed to have 80% power for detecting a difference of 0.48° (this value was equivalent to 20% of the baseline value in a preliminary study) in the stability index of the dynamic balance test between the baseline value and the value at each time point. The recovery time was defined as the time until the significant difference between the mean value at each time point and the mean baseline value disappeared. The recovery time was analyzed with Friedman's test, and subsequent multiple comparisons were performed with the Wilcoxon *t*-test with Bonferroni correction.

The relationship between CDP and the three simple dynamic balance tests with the change from the baseline value was assessed with Spearman's rank correlation coefficient. Differences with a P level of less than 0.05 were considered significant. Values are expressed as means ± SD.

Results

The mean age, height, body weight, and body mass index of the subjects were 68.2 ± 3.44 years (range, 61–72 years), 166.7 ± 4.8 cm (range, 156–175 cm), 65.6 ± 8.2 kg (range, 50–80 kg), and 23.7 ± 3.1 $kg \cdot m^{-2}$ (range, 19.5–29.6 $kg \cdot m^{-2}$), respectively. The mean dose of midazolam was 0.042 ± 0.0085 $mg \cdot kg^{-1}$ (range, 0.028–0.053 $mg \cdot kg^{-1}$). At the end of administration (time of optimal sedation) the BIS was 74.5 ± 3.9, and following slight arousal stimulation 5, 15, 25, and 35 min after the administration of midazolam, the BIS was 80.4 ± 4.6, 84.1 ± 5.5, 87.2 ± 5.4, and 93.1 ± 5.0, respectively.

Serial changes in the values of the balance tests and psychomotor function tests are shown in Tables 1 and 2, respectively. The recovery times in the dynamic balance test, USW test, MSW test, TUG test, and simple psychomotor function tests were 80, 40, 80, 80, and 70 min, respectively.

There was a significant positive correlation between the results of the dynamic balance test and the simple dynamic balance tests ($P < 0.01$; $r = 0.70$ in the TUG test, and $r = 0.59$ in the MSW test, and $r = 0.34$ in the USW test; Fig. 1).

Discussion

Monitored anesthesia care (MAC) is recognized by anesthesiologists as a useful anesthetic management method [8,9]. During MAC, the anesthesiologist provides a number of specific services, including the administration of sedatives, analgesics, hypnotics, and anesthetic agents as necessary to ensure patient safety and comfort [8]. Intravenous sedation with midazolam is sometimes used in MAC for day-stay surgery with regional anesthesia to relieve stress during surgery in elderly patients [1–3]. However, an increased risk of falls has been reported after the administration of sedatives [10]. In the elderly, falls often cause fracture, associated inability to walk, and a decrease in the activities of daily living. Therefore, precise evaluation of balance function after intravenous sedation is needed for these patients, safe discharge, particularly when walking. As the elderly tend to fall as a result of stumbling, the CDP method with unpredictable perturbation stimuli used in the present study is an ideal method for the evaluation of balance [11]. This method has previously been proven to be sensitive and reliable for evaluating the balance-inhibiting effects of sedatives [5]. However, such assessment with CDP may be difficult in daily

Table 1. Serial changes in values of CDP and simple dynamic balance tests after administration of midazolam

Test	Measurement (units)	Baseline	40 Min after	60 Min after	80 Min after	100 Min after	120 Min after	Recovery time (min)
CDP								
Dynamic balance test	Stability index (°)	2.44 ± 0.60	3.61 ± 0.89**	2.74 ± 0.65**	2.62 ± 0.74	2.46 ± 0.55	2.45 ± 0.56	80
Simple dynamic balance tests								
TUG test	Time (s)	9.66 ± 0.90	13.47 ± 3.02**	10.62 ± 1.49**	9.80 ± 1.22	9.66 ± 1.02	9.59 ± 0.91	80
MSW test	Time (s)	5.19 ± 0.48	5.89 ± 0.83**	5.48 ± 0.58**	5.28 ± 0.55	5.23 ± 0.51	5.20 ± 0.50	80
USW test	Time (s)	6.71 ± 0.73	6.89 ± 1.04	6.62 ± 0.84	6.38 ± 0.89**	6.37 ± 0.86**	6.36 ± 0.86**	40

* $P < 0.05$; ** $P < 0.01$ (vs baseline)
Values are means ± SD; $n = 18$ CDP, computerized dynamic posturography; TUG, timed "up and go"; MSW, maximum-speed walking; USW, usual-speed walking

Table 2. Serial changes in values of simple psychomotor function tests after administration of midazolam

Test	Measurement	Baseline	50 Min after	70 Min after	90 Min after	110 Min after	130 Min after	Recovery time (min)
DSST	Number of correct answers	49.4 ± 10.7	45.1 ± 9.0*	50.2 ± 9.9	51.9 ± 10.8	53.1 ± 11.1	52.4 ± 10.6	70
TDT	Number of dots left outside the drawn line	8.2 ± 4.7	10.6 ± 4.5*	8.0 ± 4.0	7.7 ± 4.2	7.8 ± 4.2	7.9 ± 3.9	70

* $P < 0.05$ (vs baseline)
Values are means ± SD; $n = 18$ DSST, digit symbol substitution test; TDT, Trieger dot test

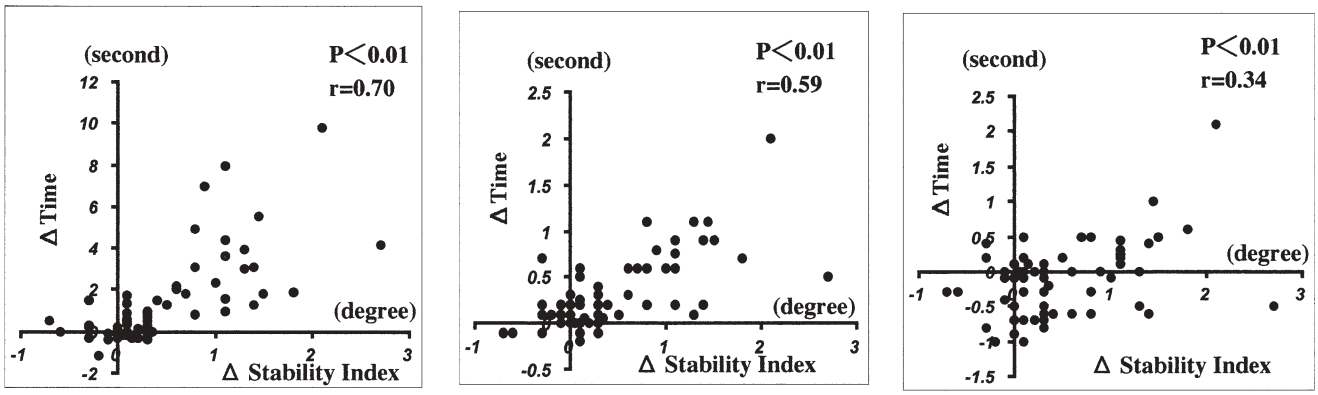

Fig. 1. Correlation between the dynamic balance test (computerized dynamic posturography; CDP), and three simple dynamic balance tests. *TUG*, timed "up and go"; *MSW*, maximum-speed walking; *USW*, usual-speed walking. There was a relatively strong correlation between the dynamic balance test and the TUG test ($r = 0.70$). Δ, the value at each time point minus the baseline value

clinical practice, owing to economic considerations and the duration of the test. Therefore, simple dynamic balance tests that are well correlated with CDP would be useful in daily clinical practice. Of the three simple dynamic balance tests used in the present study, the TUG test had results most strongly correlated with those of CDP with perturbation stimuli. The TUG test is a modified version of the "get-up and go" test, developed by Mathias et al. [12] as a simple balance function test to predict falls in the elderly. In this original method, the subject stands up from an armchair, walks forward 3 m, returns to the chair at a comfortable pace, and sits down again. These actions are recorded on videotape, and the risk of falls is evaluated by medical professionals, using a five-grade scale, with a score of 1 = normal to 5 = severely abnormal. Podsiadlo et al. [13] quantified this method by measuring the time required to complete the actions. Shumway-Cook et al. [14] used the MSW instead of the USW. Shimada et al. [7] used the MSW and extended the distance to 5 m, and we used 5 m in the present study. The TUG test used in the present study possesses all the advantages of the MSW test, as described previously [5], such as proven correlation with balance function [13–15], being a quantitative assessment, and having good reproducibility [12–14,16], short measurement time, and low cost. Furthermore, this test shows proven differences between fall and non-fall groups [7,14–16], has high sensitivity and specificity [14–16], has applicability to the elderly [7,12–16], and has no requirement for a large space. In addition, this test requires rapid acceleration and deceleration, a turn during high-speed walking, and rapid sitting down with a turn, and, therefore, seems to be more suitable for assessing comprehensive motor function more closely associated with balance function than the MSW test.

There are no exact criteria showing which percentage recovery of the baseline value of the TUG test guarantees the recovery of balance. However, the criteria of attaining 90% or more recovery of the baseline value that were used in this study may be relatively strict criteria. The test with MSW indicates the probability of falling. However, if a patient does not recover sufficiently, he or she will decrease walking speed intentionally. It may be safer to perform this test after recognizing recovery with Romberg's test, which is less reliable but safer than the dynamic balance test [17]. The good correlation we found between the results of the TUG test and the CDP test does not necessarily indicate that the reliability of the TUG test for detecting the suppression of balance is close to that of the CDP. It is also risky to presume that complete evaluation can be done with one test type alone. However, the TUG test is still useful for evaluating the balance function because of its relative reliability and ease of performance.

Unlike general anesthesia, the intravenous overdose of a sedative, even if it is slight, can lead to serious complications endangering life. Excessive sedation, airway obstruction, and respiratory failure may occur in elderly patients when the same dose of a benzodiazepine sedative as that needed for younger patients is administered, because the pharmacodynamics and/or pharmacokinetics of these drugs are different for elderly and younger persons [18,19]. Therefore, careful titration is needed to achieve an optimal sedation level of intravenous sedation, especially for the elderly [20,21]. In sedation with midazolam or propofol, the

BIS is reported to be 75 to 89 at a sedation level that does not induce airway obstruction and allows responses to verbal commands [22,23]. The BIS values during sedation in the present study were from 74.5 to 93.1, which suggests that recovery of dynamic balance from an adequate level of sedation could be evaluated here.

Before patients are discharged, the recovery of balance and psychomotor functions should be confirmed. To assess psychomotor function after general anesthesia or intravenous sedation, the DSST and TDT are frequently used [24,25]. In the present study with the DSST and TDT, the recovery time of psychomotor function was 70 min. Thus, discharge may be permitted 80 min after the administration of midazolam in the elderly, even when they return home on foot or by public transportation. This result was similar to that shown in young adults in our previous study of dynamic balance recovery [5]. However, the interpretation of recovery time agreement is tricky. We must consider, first, the same sedation level, not the same dosage; and second, the amount of change, not the actual measurement value. An age-related decrease in dynamic balance function has been reported even without sedatives [26,27]. A third consideration is platform stability; at "level 7" used in the present study, the platform was more stable than that previously reported in younger subjects [5]. In the evaluation of recovery of balance from intravenous sedation, more careful attention is needed for the aged than for younger patients.

In the present study, the recovery time of the USW test was faster than that of the CDP with perturbation stimuli, and the correlation coefficient between the two tests was low. Therefore, there is no guarantee that a patient can safely walk outside, where unpredictable perturbation stimuli occur, only because he or she can walk straight at normal speed in the hospital. In Japan, the number of medical institutes establishing a system of day stay anesthesia has been increasing [28,29]. In MAC or general anesthesia for day surgery, some patients may need to have sufficient recovery of balance function confirmed before discharge, depending on the method they will use to return home, such as by walking, and depending on physiological factors such as their age. The TUG test can contribute to safe postanesthetic management for such patients.

In conclusion, the TUG test is strongly correlated with reliable CDP with perturbation stimuli and can be used in daily clinical practice for the assessment of recovery of dynamic balance from sedation in the elderly.

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