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Postural Stability following Ambulatory Regional Analgesia for Labor

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Background: **The safety of mobilization following low-dose regional analgesia in parturients remains controversial. Previous studies have demonstrated preserved balance function despite clinically elicited sensory deficits. The aim of this study was to use the Balance Master 6.1, a device capable of real-time analysis of ambulation, to score the performance of basic maneuvers following initiation of low-dose combined spinal–epidural analgesia in laboring women compared with pregnant and nonpregnant controls.**

Methods: **Using the Balance Master, balance function during the performance of several simple tasks, including walking and standing up from a sitting position, was evaluated in a prospective, controlled, observational study with 50 laboring women after combined spinal–epidural analgesia compared with 50 pregnant and 50 nonpregnant controls.**

Results: **Nonpregnant women scored significantly better results in 6 of the 13 measured balance function parameters compared with both the combined spinal–epidural and pregnant control groups. Compared with the nonpregnant subjects, the pregnant groups generated less force standing up from the sitting position ($P < 0.0001$), walked more slowly ($P = 0.0067$), and took shorter steps ($P < 0.0001$). They also took longer to step up onto and over a 20-cm-high obstacle ($P < 0.0001$), and they generated less force while stepping up. Initial spinal analgesia in laboring women did not significantly affect performance in comparison to the pregnant controls. Thirty-four percent of women in the combined spinal–epidural group required supplemental epidural analgesia following the initial spinal injection (n = 17) before testing; they had significantly impaired balance function in four tests compared with those receiving a spinal injection only (n = 33).**

Conclusions: **Being pregnant at term significantly affects balance function, although initial low-dose spinal–epidural analgesia does not impair function further. Subsequent supplemental epidural analgesia may have a detrimental effect on balance, but properly designed studies are awaited to confirm this. This study supports the practice of allowing laboring women with initial low-dose spinal–epidural analgesia to ambulate, but indicates that further studies need to be conducted on the effects of subsequent epidural supplementation.**

WOMEN in labor increasingly request ambulatory or "mobile" epidural analgesia. The advantages of low-dose combinations of local anesthetic and opioids, notably preserved lower limb muscle power, are appreciated by medical staff and patients.[1–4] The added benefit of rapid onset of analgesia is conferred by the use of a combined spinal–epidural (CSE) technique.[3,5] However, the safety of mobilizing with such interventions remains a matter of debate.[6–11]

Previous investigations into this question have used clinical neurologic assessment. Using standard tests of proprioception, dorsal column sensory deficits have been detected to widely varying degrees: in 66% of subjects in the study by Buggy *et al.*,[7] but only in 7% in that of Parry *et al.*[9]

Further information comes from the computerized assessment of balance, such as Computerised Dynamic Posturography (CDP). In one CDP system, the EquiTest® machine (NeuroCom® International, Inc., Clackamas, OR), the subject stands on a hinged footplate mounted on force transducers, with a three-sided visual surround. The sensory modalities contributing to integrated balance function (somatosensory, vestibular, and visual) can be assessed individually using this system. Pickering *et al.*[12] used the EquiTest® to compare balance function in women receiving regional analgesia for labor with pregnant controls and found no functional impairment, even in cases where proprioceptive deficits had been clinically detectable.

The aim of our study was to use another computerized device, the Balance Master® (version 6.1; NeuroCom International, Inc.) to analyze balance function. The Balance Master (fig. 1), like the EquiTest, was developed for investigation of neurologic, orthopedic, and other conditions affecting balance and posture. The Balance Master system consists of two "forceplates," which are 150 × 23-cm metal footplates placed side by side, with computer-linked force transducers under each corner. The subject's center of gravity is determined by averaging the vertical and horizontal forces exerted through both feet. The Balance Master software program then uses these data to calculate, for example, the degree to which the subject sways on walking or standing up, how weight distribution occurs between both feet, or how much force is used to step over an obstruction. With the EquiTest, the subject stands passively on the platform and has to respond to sensory and motor challenges, whereas the Balance Master requires the subject to perform actively a variety of maneuvers, which the computer measures and scores. Therefore, its perceived advantage over the EquiTest is that it allows for the real-time analysis of the movements involved in activities of daily living, and the performance of basic ambulatory tasks—standing up, walking, turning, and negotiating steps—may be quantified objectively. The Balance Mas-

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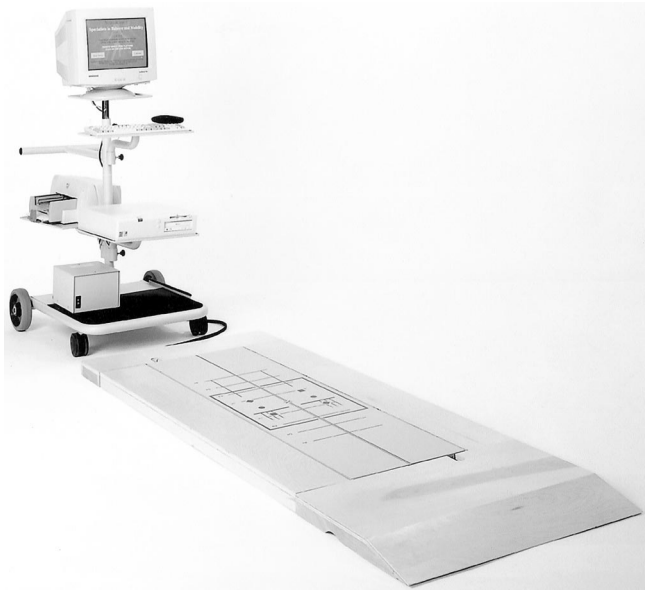

Fig. 1. Balance Master 6.1. Reprinted with permission.

ter is a relatively new CDP device for which the manufacturers are still acquiring patient data. However, age-related reference scores for the tests used in our study show a roughly 50% decrease in performance in the 70–79-yr age group compared with the 20–39-yr group (Dr. Lewis Nashner, NeuroCom Inc., personal communication). We designed a study to evaluate the performance of these tasks by women with CSE analgesia established for labor and to compare them with controls to determine the relative effects on postural stability of pregnancy and regional analgesia.

Materials and Methods

After obtaining local ethics committee approval and informed written consent, we recruited 150 women to our study. Fifty of the women were nonpregnant controls aged 18–40 yr, recruited from delivery suite staff; 50 were nonlaboring pregnant controls (PC) between 36 and 42 weeks' gestation awaiting elective cesarean section or induction of labor, and 50 were laboring women, greater than 36 weeks' gestation, who had requested regional analgesia (as our standard CSE technique) at less than 6-cm cervical dilatation. Women with a complex obstetric presentation (preeclampsia, placenta previa, multiple pregnancy) or with musculoskeletal, vestibular, or peripheral neurologic problems were excluded, as were those receiving medication (meperidine, benzodiazepines) potentially affecting balance. Otherwise, the women were recruited sequentially as they presented to the delivery suite.

The CSE group was managed according to our standard hospital protocol, as described previously.[12] This involved a needle-through-needle technique using a 16-gauge epidural needle (SIMS Portex; Hythe, Kent, United Kingdom) and a 27-gauge Whitacre spinal needle (Becton-Dickinson & Co., Franklin Lakes, NJ) with the patient in the sitting position. Initial spinal analgesia was provided with 2.5 mg bupivacaine and 5 μg fentanyl injected intrathecally and an epidural catheter left *in situ* for continued analgesia. For the first 20 min after institution of the spinal block, maternal heart rate and blood pressure was measured every 5 min, and continuous external electronic fetal heart rate monitoring was undertaken to look for signs of fetal distress.

If the initial intrathecal block provided suboptimal analgesia within 15 min of spinal injection, then 10 ml of epidural low-dose mixture (0.1% bupivacaine with 0.0002% fentanyl) was given as a single bolus through the epidural catheter according to standard hospital protocol. For all subjects, after 30 min, with analgesia established satisfactorily (either by the spinal injection or epidural supplement), consent was taken for entry into the study, and the testing protocol commenced. The first part of the protocol consisted of brief clinical tests of both motor and sensory function. Motor power was assessed using the Medical Research Council scale at hip, knee, and ankle joints. The cold sensation dermatomal height of the block was assessed using ethyl chloride spray. Joint position sense was examined first at the terminal interphalangeal joint of the big toe, then more proximally. These tests were not subsequently repeated. If there was no significant motor deficit (full lower limb motor power according to the Medical Research Council scale) then the second part of the protocol, the Balance Master testing, was begun. The patient was disconnected from the fetal heart rate monitor, invited to stand up and undertake a short supervised walk, after which they were taken to the Balance Master machine located within the delivery suite. If the patient was unable to complete posturographic testing, they were excluded from the study, and the reason for exclusion was recorded. The four individual tests thought to accurately represent real life tasks, which were used for the study protocol (Sit to Stand, Walk Test, Step and Quick Turn, Step Up and Over) are described in detail in table 1.

Instructions for each test were given verbally and simultaneously displayed on a computer screen. The more complicated tests were initially demonstrated by the assessor, after which the subject was allowed to practice the movements once to ensure compliance with the study protocol. No further assistance was given in the performance of the tests.

Statistical Analysis

The outcomes measured take the form of numerical values generated by the computer (*e.g.*, speed of walking in centimeters per second; step length and width in centimeters).

A pilot study using the Balance Master 6.1 with the same three categories of subjects had been completed

Table 1. Description of Balance Master Test

Test	Measurements	Definitions
Sit to stand	Weight transfer	Time between cue to move and arrival of centre of gravity (COG) over feet (s)
(Patient rises briskly from seated to a standing position)	Rising index	Force exerted by legs during rising (% body wt)
	COG sway velocity	COG sway during and after rising (degrees/s)
	Left–right weight symmetry	Relative amount of weight borne by each leg during and after rise (% body wt)
Walking test	Step width and length	Lateral & longitudinal distance between steps (cm)
(Patient walks along forceplate)	Walking speed	Velocity of forward progression (cm/s)
	End sway	Velocity of anteroposterior (AP) sway on stopping walk (degrees/s)
Step and quick turn test	Turn time	Time taken to complete the turn (s)
Patient takes two steps forward, quickly turns 180°, and steps back to start	Turn sway	Distance traveled by COG during the turn (degrees)
Step up and over test	Lift up index	Maximum force exerted by step-up leg (% body wt)
Patient steps onto a 20 cm high box with one foot and swings other foot over the box and down onto floor, and then steps down with first foot	Movement time	Time required to complete step-over (s)
	Impact Index	Maximum force transmitted through lagging leg as it lands on the floor (% body wt)

the previous year, the results of which were not incorporated into the current study. A power analysis performed using the speed (centimeters per second) measurement generated during the walk test in the pilot study was used to assess appropriate group sizes for the definitive study. Using these data, our study had a 90% power to detect an 8-cm/s difference in speed during the walk test between PC and nonpregnant control groups with approximately 50 subjects in each group (SD = 12 cm/s; $P < 0.05$).

Analyses were performed using Excel 97 (Microsoft Corp., Redmond, WA) and Number Crunching Statistical System 2000 (NCSS Inc., Kaysville, UT). Statistical significance was defined for an overall α error at the 0.05 level. All *P* values were two-sided.

Patient data are presented as mean (SD). Comparisons between the CSE, nonpregnant control, and PC groups were analyzed using analysis of variance with intergroup subanalysis made using a Bonferroni test. $P < 0.017$ was considered statistically significant when considering the results of multiple comparisons using the Bonferroni method. Unpaired *t* tests were used to compare the epidural supplement and spinal-only patients within the CSE group, for which a *P* value < 0.05 was considered statistically significant.

Results

A total of 155 women were recruited for the study between March 1 and August 31, 2000. Three patients belonging to the PC group were withdrawn from the study: two complained of back pain and one of dizziness during the first stage of the protocol. Two subjects from the CSE group were withdrawn with copious amounts of amniotic fluid leaking from ruptured membranes prior to testing. No subject was excluded after initial motor function or proprioceptive testing. This left a total of 50 patients in each of the three groups.

All regional blocks were sited at L2–L3 or L3–L4 and produced a loss of cold sensation to between T4 and T11 (median level, T8). The patient characteristics of the CSE and control groups are presented in table 2. Although, as expected, pregnant patients were significantly heavier than nonpregnant subjects ($P < 0.0001$), women in the PC group were significantly shorter than those in the CSE and nonpregnant control groups ($P < 0.001$). The CSE group requested analgesia during the first stage of labor at a mean (± SD) cervical dilatation of 3.5 ± 1.49 cm. No abnormalities of joint position sense or deficiencies of motor power were recorded.

The Balance Master results are presented in table 3. All significant differences were between the nonpregnant group and the two pregnant groups (CSE and PC). Compared with the nonpregnant subjects, the pregnant groups generated less force standing up from the sitting

Table 2. Patient Characteristics

	NPC (n = 50)	PC (n = 50)	CSE (n = 50)
Age (yr)	29.20 (5.87)	31.58 (6.20)	29.76 (5.31)
Height (cm)	164.08 (6.43)	159.69 (6.47)*	163.87 (6.26)
Weight (kg)	66.10 (11.32)†	77.41 (11.94)	77.02 (11.11)

All values are mean (SD); $P < 0.017$ is considered statistically significant.

* $P < 0.001$ compared with NPC and CSE groups (ANOVA with Bonferroni correction); † $P = <0.0001$ compared with PC and CSE groups (ANOVA with Bonferroni correction).

NPC = non-pregnant controls; PC = pregnant controls; CSE = pregnant women after combined spinal epidural labor analgesia; ANOVA = analysis of variance.

Table 3. Balance Master Test Results

	NPC (n = 50)	PC (n = 50)	CSE (n = 50)
Sit to Stand			
Weight transfer (s)	0.41 (0.31)	0.52 (0.27)	0.54 (0.45)
Rising index (% body weight)	21.92 (6.60)*	13.32 (6.43)	11.26 (5.11)
Sway velocity (degrees/s)	3.98 (1.27)	3.67 (1.15)	3.85 (0.94)
Left/Right symmetry (%)	9.80 (7.18)	10.04 (12.40)	11.04 (8.25)
Walk Test			
Step width (cm)	19.53 (2.43)	19.63 (2.07)	20.05 (2.82)
Step length (cm)	47.36 (8.19)*	41.90 (7.60)	40.41 (8.30)
Speed (cm/s)	63.61 (13.09)†	56.55 (15.02)	55.68 (12.29)
End sway (degrees/s)	2.48 (0.98)	2.85 (1.19)	2.51 (0.82)
Step/Quick Turn			
Turn time (s)	1.13 (0.47)	1.35 (0.78)	1.23 (0.67)
Turn sway (degrees)	31.34 (8.81)	30.91 (12.67)	28.79 (12.81)
Step Up/Over			
Lift-up index (% body weight)	42.34 (8.29)*	32.44 (6.30)	30.38 (7.80)
Movement time (s)	1.43 (0.21)*	1.82 (0.43)	1.89 (0.56)
Impact index (% body weight)	42.76 (14.11)*	29.32 (10.74)	30.51 (8.32)

All values are mean (SD); $P < 0.017$ is considered statistically significant. The Step/Quick Turn and Step Up/Over test results are composite scores combining values for the left and right legs.

* $P = <0.0001$ compared with PC and CSE groups (ANOVA with Bonferroni correction); † $P = 0.0067$ compared with PC and CSE groups (ANOVA with Bonferroni correction).

NPC = non-pregnant controls; PC = pregnant controls; CSE = pregnant women after combined spinal epidural labor analgesia; ANOVA = analysis of variance.

position ($P < 0.0001$), walked more slowly ($P = 0.0067$), and took shorter steps ($P < 0.0001$) along the platform. They also took longer to step up onto and over a 20-cm-high obstacle ($P < 0.0001$) with a reduced Lift Up Index, indicating that they generated less force while stepping up, and a reduced Impact Index, indicating that they transmitted less force through the contralateral leg as they stepped down. There were no significant differences in any test result between the PC and the CSE groups.

Seventeen of the 50 CSE patients (34%) required an additional epidural top-up of 10 ml of the low-dose mixture to achieve satisfactory analgesia before mobilizing. There were therefore two subdivisions within the CSE group: spinal only and epidural supplement. A *post hoc* analysis was performed on these two subgroups, noting that this did not form part of the original study design. There were no significant differences (mean ± SD) in height (163.85 ± 7.02 cm *vs.* 165.23 ± 5.47 cm), weight (76.48 ± 10.73 kg *vs.* 78.00 ± 12.03 kg), age (30.24 ± 5.32 yr *vs.* 28.82 ± 5.33 yr), or cervical dilatation (3.59 ± 1.74 cm *vs.* 3.35 ± 0.99 cm) between these two subgroups. However, compared with the spinal-only group, those receiving an epidural supplement were significantly slower in shifting their center of gravity on standing up (weight transfer; mean difference, 0.45 s; 95% confidence interval, 0.21–0.69; $P = 0.0005$) and in performing the Step Up and Over test (movement time; mean difference, 0.52 s; 95% confidence interval, 0.98–0.09; $P = 0.0023$) (table 4). Furthermore, they were unable to generate as much force on stepping onto the 20-cm-high box (lift-up index; mean difference, 4.87%; 95% confidence interval, 0.72–9.37; $P = 0.0448$). Their velocity of sway on standing up was lower than the spinal-only group (sit to stand, sway velocity; mean difference, 0.60 degree/s; 95% confidence interval, 0.06–1.15; $P = 0.0296$).

Discussion

This study supports previous work indicating that initial CSE analgesia in parturients does not reduce objective measures of balance function.[12] It differs from previous CDP work with the EquiTest conducted by Pickering *et al.*[12] both in the technical equipment and controls used. Whereas the EquiTest presents the passive subject with sensory and motor challenges to her balance function, the Balance Master requires the subject to perform active movements, resembling basic activities of daily living. The studies are alike in showing no evidence of functional impairment after initiating CSE analgesia. The Balance Master study, however, introduces a second control group of nonpregnant women. It

Table 4. Balance Master Results: Spinal Only *versus* Epidural Supplement

	Spinal Only (n = 33)	Supplement (n = 17)
Sit to Stand		
Weight transfer (s)	0.39 (0.21)	0.84 (0.63)*
Sway velocity (degrees/s)	4.05 (0.79)	3.45 (1.09)†
Step Up/Over		
Lift-up index (% body weight)	31.94 (7.92)	27.07 (6.62)‡
Movement time (s)	1.72 (0.31)	2.24 (0.79)§

P values < 0.05 only; Data are mean (SD).

* $P = 0.0005$; † $P = 0.0296$; ‡ $P = 0.0448$; § $P = 0.0023$.

is thus able to demonstrate that term pregnancy itself has the greatest impact on postural stability, with the CSE conferring no evident superadded effects.

The four tests (Sit to Stand, Walking Test, Step and Quick Turn, Step Up and Over) generated a total of 13 scores for each subject, for which significant differences between the groups were registered in six. All significant differences were found between the nonpregnant control group and the two pregnant groups and translate into considerable disparities in performance. The force generated by pregnant women on standing was 51% that of nonpregnant subjects. Pregnant women took 32% longer to step over a 20-cm-high obstacle, and their walking speed was reduced by 13%. Conversely, no significant differences were seen between the PC group and those who had received effective CSE analgesia.

In contrast to previous studies using clinical tests of proprioception,[7,9,13] the CDP system produces objective measurements of posture and gait. These are generated in real time and during simple physical tasks, which reflect the requirements of normal mobilization. This system has been used in a number of clinical contexts, including the assessment of orthopedic and neurologic dysfunction,[14] age-related postural deficits,[15] and the side effects of drugs.[16–20] The retest reliability of the machine was found to be good in 70 normal subjects.[21] We have used the Balance Master CDP system for the first time to assess the effect of low-dose CSE labor analgesia on postural stability and gait.

This study was of a prospective, observational design with two control groups, term pregnant and nonpregnant subjects. A crossover design, where subjects were studied before the onset of labor and again later after CSE analgesia, may have had greater power but would have been difficult to conduct and might also have introduced the element of learning. However, all groups were clinically comparable, *i.e.*, healthy women of reproductive age. As expected, the two pregnant groups were significantly heavier than the nonpregnant subjects, but unexpectedly, the PC subjects were significantly shorter in height. The relevance of this is unclear, although short stature might confer the advantage of greater postural stability because of a lower center of gravity and, therefore, could not account for the impaired performance of the PC group.

Seventeen of the 50 (34%) CSE subjects required supplementation with low-dose epidural analgesia. This proportion was higher than encountered in normal clinical practice using the same dosage. This may be a result of emphasizing to the participants that the testing protocol would take 15–20 min to complete; it is possible that a number of women felt the standard of analgesia needed to be of a higher order to complete a number of physical activities than if they remained in bed. They were thus able to choose epidural supplementation if they had any degree of discomfort following the spinal epidural, in preparation for the exertions of the testing protocol.

The patients who had been supplemented generated less force and were slower in performing the Step Up and Over test in comparison with the spinal-only patients, and they took longer transferring their weight in the Sit to Stand test. However, the significance of these findings is not clear. It should be emphasized that this subgroup comparison did not form part of the prospective study design and was performed retrospectively, prompted by the unpredicted finding of a relatively high epidural supplementation rate. As mentioned previously, the epidural supplement group was self-selecting and not randomly allocated. A prospective, adequately powered and randomized study would need to be designed to address the question of the effects of subsequent supplementation on postural stability.

Previous studies have shown that changes in posture and gait occur as pregnancy progresses.[22–25] Altered weight distribution and increase in total mass must partly account for this,[26] but other factors, such as confidence and coordination, could conceivably contribute. In this study, important differences were seen in test parameters reflecting speed of movement and force generated, which may indicate a reduced confidence in moving, but there are limited objective data on this matter. Balance function after epidural analgesia has been studied in volunteers using posturographic techniques, but this has not been extended, to our knowledge, to pregnant subjects. Zaric and coworkers[27] studied the effects of continuous epidural infusions of differing strengths of local anesthetic in healthy volunteers and found that postural control remained intact with infusions of 0.1% ropivacaine, but not with higher concentrations, when leg weakness was increased.

Our data show that being pregnant at term affects many aspects of ambulation, but that initial low-dose spinal epidural analgesia does not impair performance further. This study revealed some differences between the patients who had received a single spinal injection and those who required a supplemental epidural dose. Further investigation is required, however, to establish at what point during continued labor analgesia safe ambulation becomes compromised and which bed-side tests might reliably detect this. The relative contributions of dorsal column function, proprioception, as well as muscle strength, to overall balance function remain incompletely understood. Preservation of lower limb motor power alone with low-dose regional techniques may not be sufficient in itself to ensure safe ambulation if these sensory modalities are impaired.

Low-dose ambulatory techniques are now well publicized, and women will continue to request "mobile epidurals" for their labor analgesia. The greater maternal satisfaction associated with low-dose CSE techniques has been partly attributed to increased mobility.[3] Whether

mobilization is actually beneficial to the outcome of labor remains uncertain,[28] but it has been shown to reduce analgesic requirements and improve toleration of labor.[29] However, the potential for falling does exist,[30] and women approaching labor should be entitled to good evidence allowing them to make an informed decision as to whether to mobilize after labor analgesia.

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