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Effect of Combined Spinal–Epidural Ambulatory Labor Analgesia on Balance

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Background: **Low-dose combined spinal–epidural analgesia in labor has proved popular with women because lower-limb motor power is preserved, allowing ambulation. However, there has been debate about the safety of allowing women to walk following low-dose regional analgesia because of somatosensory impairment. The authors undertook a prospective controlled observational study using computerized dynamic posturography to examine balance function in pregnant women after combined spinal–epidural analgesia.**

Methods: **The authors performed posturographic testing on 44 women in labor after institution of regional analgesia and compared them with a control group of 44 pregnant women. A separate group of six women were tested both before and after combined spinal–epidural analgesia.**

Results: **Neurologic examination after regional analgesia showed two parturients (4%) to have motor weakness (excluded from posturography). Four women (9%) had clinical dorsal column sensory loss; these women all completed posturography. The spinal–epidural analgesia group showed a small, statistically significant reduction in one of six posturographic sensory-organization tests; however, this difference was functionally minor. There were no other differences in posturography between the control and spinal–epidural groups. Similar results were found in the paired study, in which there was minimal change in balance function after spinal–epidural analgesia.**

Conclusions: **This is the first study to objectively examine the effect of spinal–epidural analgesia on balance function. Using computerized dynamic posturography, the authors were unable to find any functional impairment of balance function after spinal–epidural ambulatory analgesia in women in labor who had no clinical evidence of motor block. (Key words: Dorsal column function; equilibrium; proprioception.)**

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EPIDURAL analgesia during labor is popular with both mothers and medical staff on labor wards. This popularity has been enhanced by the introduction of low-dose epidural analgesic techniques, in which a low dose of local anesthetic is supplemented with an opioid to provide analgesia with minimal motor block.[1-4] This technique has been further refined using combined spinal-epidural analgesia,[5,6] which offers the benefits of rapid onset of analgesia, reliable initial block, and the ability to ambulate during labor. Such low-dose spinal-epidural analgesia techniques have been shown to be preferred by mothers[7] and may be associated with lower rates of instrumental delivery.[8]

However, caution has been expressed regarding the safety and benefit of allowing parturients to ambulate during epidural analgesia.[9] One report has suggested that as many as 66% of parturients receiving low-dose epidural analgesia have clinically detectable dorsal-column sensory deficits.[10] These authors have therefore suggested that it is imprudent to allow women to walk during epidural analgesia. There has also been a report of a woman who fell while participating in a trial of ambulatory epidural analgesia.[4] In our hospital we previously demonstrated clinical dorsal column sensory deficits in 7% of women with low-dose ambulatory epidural analgesia.[11]

The functional impact of low-dose epidural analgesia on balance in labor has not been assessed. We therefore have designed a study to assess the effect of combined spinal-epidural analgesia on balance using computerized dynamic posturography. This technique has been extensively clinically evaluated in balance disorders and allows the investigator to assess the contribution to balance of visual, vestibular, and somatosensory inputs.[12,13]

A similar posturographic technique has previously been used to assess balance function in volunteers receiving continuous epidural infusions of local anesthetic.[14]

Materials and Methods

After obtaining local ethics committee approval for the study, we recruited 88 pregnant women between 36 and 42 weeks' gestation into control and spinal-epidural analgesia groups (44 in each). In addition, a separate group of six women were recruited who had posturography both before and after spinal-epidural analgesia. All women gave informed consent to participate in the study.

The combined spinal-epidural group consisted of women requesting analgesia during uncomplicated first-stage labor. Any parturient with a preexisting balance disorder, a neurologic or orthopedic condition, or diabetes or receiving medication (*e.g.*, meperidine, benzodiazepines, or antihistamines) likely to affect balance was excluded. A control population of pregnant women of similar gestation without combined spinal-epidural analgesia (and not in labor) was recruited by testing women attending the delivery suite for induction of labor or elective cesarean section.

The spinal-epidural analgesia group were managed according to our usual hospital protocol for ambulatory labor analgesia as follows: An intravenous preload of 500 ml 0.9% sodium chloride was given before location of the epidural space between L2 and L4 with a 16G Tuohy needle (SIMS Portex, Hythe, Kent, United Kingdom) using an aseptic technique with the parturient in the sitting position. A 119-mm, 27-G Whitacre spinal needle (Becton Dickinson & Co, Franklin Lakes, NJ) was passed through the epidural needle and 2.5 mg plain bupivacaine plus 5 μg fentanyl was injected intrathecally. The spinal needle was removed and an epidural catheter placed 3 cm into the epidural space. For the first 20 min after institution of the spinal block, maternal heart rate and blood pressure were measured every 5 min, and continuous external electronic fetal heart rate monitoring was undertaken to look for signs of fetal distress.

If the parturient was eligible for the study, then consent was sought once satisfactory analgesia had been achieved. Before ambulation, each parturient underwent tests of both motor and sensory function. Motor power was assessed using the Medical Research Council scale (0 = no movement; 1 = flicker of movement; 2 = movement, but not against gravity; 3= movement against gravity; 4 = movement against resistance; 5 = full power present) 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. Vibration sense was tested using a tuning fork (128 Hz) at wrist, knee, ankle, and first metatarsal joints. If there was no significant motor deficit, the patient was disconnected from the fetal heart rate monitor and invited to stand up, and the Romberg test was performed. After a short supervised walk the patient was taken for balance testing. If the patient was unable to complete the posturography, she was excluded from the study and the reason for discontinuation recorded.

Posturography commenced within 40 min of spinal insertion. In nine parturients an epidural bolus was requested during testing (10–12 ml 0.1% bupivacaine plus 2 μg/ml fentanyl). The patient's balance function was assessed using the EquiTest Computerized Dynamic Posturography system (NeuroCom International, Clackamas, OR; see fig. 1). The patient stands on a hinged dual forceplate with sensitive force and shear transducers, surrounded by a three-sided visual screen, and is placed in a harness for safety. Both the forceplate and the visual surround can be rotated in an anteroposterior axis around the ankle joint by the computer that controls the balance testing.

Dynamic posturography involves sensory organization tests (SOTs) and motor coordination tests (MCTs). There are six SOTs, which assess the contribution of each of the somatosensory, visual, and vestibular modalities to integrated balance function. Each individual SOT lasts 20 s and is repeated three times to give an average. For each test the patient is asked to stand still while the movement of her center of gravity is monitored *via* the transducers in the forceplate. A maximum angle of sway is calculated for each test and compared with the 12.5-degree sway that has been found to be the maximum compatible with stability. The machine derives an equilibrium score (percentage) for each test: A small sway produces a large equilibrium score (close to 100%), and a fall produces a score of 0%. For each test the equilibrium score is compared with a normative population dataset, and results below the fifth percentile are considered abnormal. The computer also calculates an overall SOT composite score, which is a mean of all the individual SOT scores and indicates whether balance function is abnormal.

The first test (SOT1) requires the patient to stand still

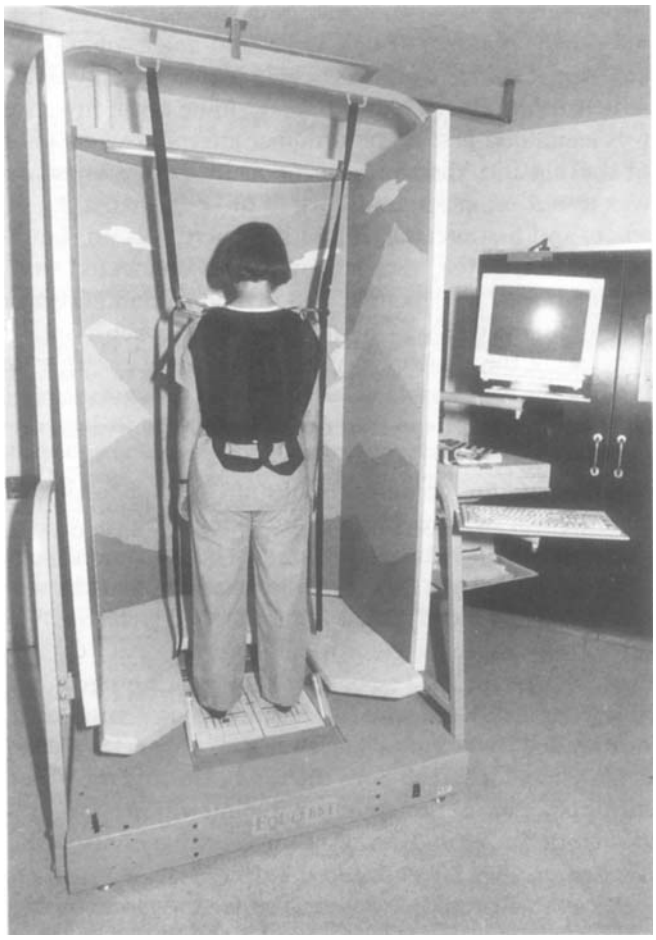

Fig. 1. The computerized dynamic posturography system (EquiTest; NeuroCom International, Clackamas, OR). The subject is seen standing on the hinged footplate facing into the three-sided visual surround ready for testing.

with a fixed forceplate and visual surround (see fig. 2 for a schematic of tests). SOT2 is a quantified Romberg test identical to SOT1 except with the patient's eyes closed. For SOT3 the visual surround is moved in phase with the patient's movement (sway-referenced) as she attempts to stand still with eyes open. The sway-referenced visual surround provides a confusing visual horizon and exaggerates the patient's sway. In SOT4 the visual surround remains fixed but the forceplate is sway-referenced, thereby depriving the patient of accurate somatosensory input. SOT5 is identical to SOT4 but with eyes closed, leaving the patient dependent upon vestibular information. In SOT6 the patient stands, eyes open, while both the forceplate and the visual surround are sway-referenced. This provides inaccurate visual and somatosensory information, leaving the patient dependent on vestibular inputs. By calculating ratios between the individual SOT results, the machine also gives an indication of which modality is deficient in the subject.

In the MCT, the forceplate is translated in a sharp step either forward or backward. This evokes an automatic postural compensatory response in the patient, and the machine measures the latency and force of this response. The latency scores from the tests are averaged to provide a MCT composite figure, which reflects both somatosensory and motor function.

Statistical Analysis

Previous clinical studies have reported an incidence of between 7% and 66% of dorsal column sensory deficit after epidural ambulatory labor analgesia.[10,11] There were no preexisting posturographic data from a pregnant population upon which to base a power estimation. Therefore, we estimated (based on the clinical studies mentioned previously) that 20% of the subjects in the spinal-epidural analgesia group (and none of the control group) would have balance deficits detectable by posturography. To achieve a power of 80% to detect a difference in balance function between the groups with a P value of 0.05, calculations indicated that 44 patients were needed in each group. The posturographic data were analyzed using unpaired or paired Student t tests as appropriate (with a Bonferroni correction for the analysis of the individual SOTs 1-6). Statistical analysis was performed using Statview 4.5 (Abacus Concepts, Berkeley, CA).

Results

A total of 99 women consented to entry into the study (between February and June 1997). Three women in the spinal-epidural group were excluded from posturography after the initial clinical examination; two of these women had transient unilateral leg weakness, and one felt unable to stand despite normal clinical testing. A further two women in this group withdrew during posturography, one with fatigue and one because she felt that her membranes were rupturing. Six of the women recruited had posturography both before and after spinal-epidural analgesia and therefore were analyzed separately. This left a total of 44 patients in each of the control and spinal-epidural groups.

There was no significant difference in age (31.1 ± 4.2 *vs.* 31.0 ± 4.5 yr) or height (165 ± 7 *vs.* 165 ± 6 cm) between the control and spinal-epidural groups

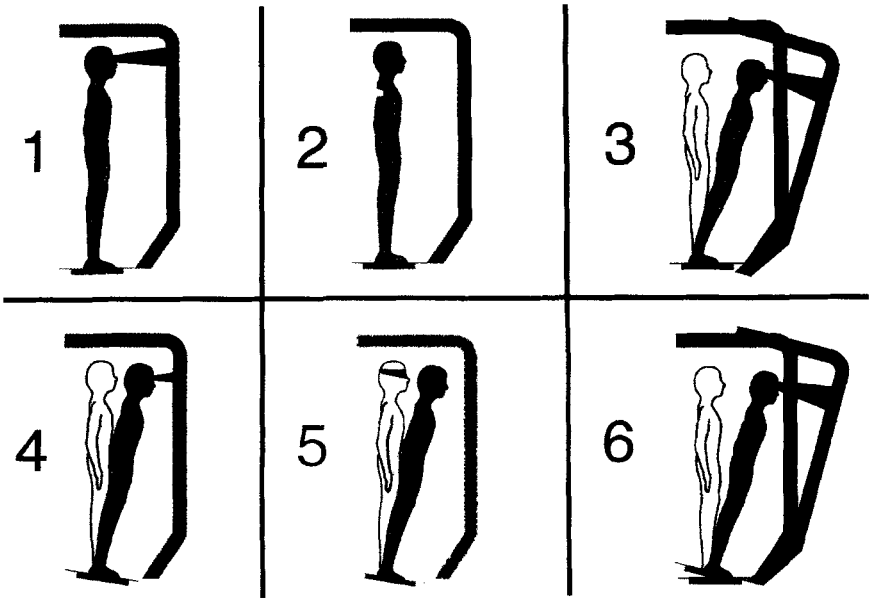

Fig. 2. Schematic of the sensory organization tests. For the first three tests the forceplate remains fixed while the visual conditions are varied (eyes open, eyes closed, and sway-referenced visual surround) to examine the effect of loss of accurate visual orientation clues. In tests 4–6 the forceplate is sway-referenced, providing misleading somatosensory feedback, while the visual conditions are varied. In tests 3 and 6 the visual surround is sway-referenced.

(means ± SD). There were more nulliparous women in the spinal-epidural group than the control group (68% *vs.* 55%, respectively). The spinal-epidural group requested analgesia during first-stage labor at a cervical dilation of 3.7 ± 1.4 cm. The majority of spinal-epidural blocks were sited at L2–L3 or L3–L4 (42 of 44) and produced a loss of cold sensation to between T4 and T11 (median level T8). In all cases satisfactory analgesia was produced within 5 min of the spinal injection and typically lasted 40–100 min. After spinal-epidural analgesia, three women had a positive Romberg sign and one had diminished vibration sense. These four women with dorsal-column sensory signs had normal posturography scores and in particular had normal SOT2 scores (SOT2 is a quantified Romberg test).

The results of posturography are shown in table 1 for the unpaired control and spinal-epidural groups. There was no significant difference in either SOT (73.8% *vs.* 72.0%; $P = 0.29$) or MCT (124 ms *vs.* 126 ms; $P = 0.40$) composite values between the control and spinal-epidural groups, respectively. The number of parturients exceeding their limits of stability during posturographic testing was the same in each group ($n = 13$). Detailed analysis of the individual SOTs showed a difference between the control and combined spinal-epidural groups in only SOT1 (93.3% *vs.* 91.9%; $P = 0.005$). However, although there was a small difference between the groups for SOT1, the absolute values were within the normal range for this test (normative population data supplied by NeuroCom International). Examination of the somatosensory, visual, and vestibular ratios showed no differences between the groups.

The paired study data for posturography performed on

Table 1. Posturographic Results of Spinal–Epidural Group Compared with Controls

Test	Control (n = 44)	CSE (n = 44)	Significance (*P*)
SOT1*	93.3 (1.7)	91.9 (2.7)	0.005*
SOT2	90.6 (2.4)	89.4 (3.4)	0.053
SOT3	89.5 (3.1)	87.6 (4.3)	0.017
SOT4	79.3 (10.6)	77.3 (10.6)	0.41
SOT5	61.8 (12.3)	62.1 (10.2)	0.92
SOT6	58.4 (15.8)	53.8 (15.6)	0.17

Data are mean % (SD). Significance tested with unpaired *t* test with Bonferroni correction.

SOT = Sensory organization test; CSE = combined spinal–epidural.

* $P < 0.008$.

Table 2. Posturography Data for Six Women Tested before and after Regional Analgesia

Test	Control	CSE	Significance (*P*)
SOT1	94.0 (2.4)	92.0 (4.5)	0.45
SOT2	92.3 (2.4)	91.0 (3.2)	0.37
SOT3	90.8 (3.7)	91.0 (1.6)	0.93
SOT4	83.7 (5.7)	86.8 (3.0)	0.08
SOT5	66.2 (7.7)	70.3 (11.1)	0.07
SOT6	62.0 (8.6)	57.5 (29.7)	0.71

Data are mean % (SD). Significance tested using paired *t* test with Bonferroni correction.

SOT = Sensory organization test; CSE = combined spinal–epidural.

parturients before and after spinal-epidural analgesia is shown in table 2. A small, significant improvement in SOT composite score followed spinal-epidural analgesia (76.8% *vs.* 79.3%; $P = 0.02$). There was no significant difference in any of the individual SOT scores after spinal-epidural analgesia. Subjectively only one of these parturients felt that her performance had been impaired by spinal-epidural analgesia.

Discussion

The objective of this study was to examine the effect of low-dose combined spinal-epidural analgesia on the ability of parturients to balance while ambulating. Previous work has suggested that mothers prefer low-dose epidural regimes and particularly value the ability to ambulate.[7] There have also been recent suggestions that low-dose regional analgesia may reduce the instrumental delivery rate.[8] In addition, the use of lower doses of local anesthetic makes toxicity less likely from inadvertent intravenous or intrathecal injection.

However, the report of a surprisingly high incidence (66%) of dorsal column sensory deficits[10] and the occurrence of a fall in an ambulating parturient[4] must be taken seriously. Although this high incidence of sensory deficit has been disputed,[15,16] and studies at our own hospital have produced a figure of only 7%,[11] this still represents a significant number of women who are at increased risk of falling if such sensory deficits translate into functional balance disorders. Any such risk is particularly important because to date no controlled randomized trials have demonstrated ambulation to be associated with improved labor outcome.

In seeking to obtain a functional measure of the significance of any dorsal column deficit, we have used computerized dynamic posturography. This technique has been extensively evaluated in a range of subjects with both normal and disordered balance function, including patients with vestibular disorders,[17] astronauts after experiencing weightlessness,[18] the elderly,[19] patients who are intoxicated with alcohol,[20] and also patients who received day-case anesthesia.[21] Of particular interest has been the use of posturography to assess balance function in a group of volunteers having epidural infusions of ropivacaine and bupivacaine.[14] In this study posturography proved to be a sensitive index of balance function, demonstrating marked differences in balance function between the different infusion regimes.

In our study posturography was straightforward to perform and was well tolerated by our subjects. Our control population of pregnant women at 36-42 weeks' gestation produced posturographic test scores that were comparable to the normative population data supplied by NeuroCom International. Our unpaired spinal-epidural study showed no difference between groups in either SOT or MCT composite scores, and only a small, functionally minor reduction in the SOT1 score. There was no posturographic evidence of a specific somatosensory deficit, not even in those subjects who had clinical dorsal column sensory signs. The fact that the three parturients with a positive clinical Romberg sign had normal SOT2 scores illustrates the subjective nature of this neurologic sign.

The findings from the paired study also failed to show any decrease in posturographic scores following spinal-epidural analgesia; rather, there was a small improvement in SOT composite score. This finding may be explained by the parturients' familiarity with the machine. A similar phenomenon has been noted previously on repeated posturographic testing and accounts for up to a 5% improvement in SOT composite score.[13]

Considering the lack of difference in balance function after ambulatory labor analgesia, it is important to consider the power of the study.[22] Our initial power calculation was an estimate based on comparable clinical studies,[10,11] but no previous studies had used posturography to examine balance function in pregnant women. However, using retrospective power analysis, we find that this study had a 90% power to demonstrate a 5.4% difference in SOT composite score between the two groups (with 44 subjects in each group and a SOT composite SD of 7.9%). Clinically this is a small change in SOT composite score and is of similar magnitude to the improvement in SOT scores observed on repeat posturographic testing, as mentioned previously. This retrospective analysis suggests that our study had sufficient power to detect a clinically relevant deterioration in balance function in our subjects.

The findings of this study agree with our previous data, indicating that a minority of women have a clinical dorsal column sensory deficit after low-dose combined spinal-epidural analgesia.[11] We are able to further conclude that balance function is preserved based on posturographic testing, even in the presence of the mild sensory deficits noted in this study.

We did not allow the two parturients with transient motor weakness to walk because we thought it inappro-

priate, and we are therefore unable to comment on how balance function might have been affected in these parturients. Using computerized dynamic posturography, we did not find any functional impairment of balance function after spinal-epidural ambulatory analgesia in women who had no clinical evidence of motor block.

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