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Spinal Anesthesia

Functional Balance Is Impaired after Clinical Recovery

Charles O. Imarengiaye, F.W.A.C.S., Dajun Song, M.D., Ph.D.,† Atul J. Prabhu, F.R.C.A.,* Frances Chung, F.R.C.P.C.‡*

Background: **The ability of patients to walk without assistance after spinal anesthesia is a determining factor in the time to discharge following ambulatory surgery. The authors compared clinical markers of gross motor recovery with objective data of functional balance after spinal anesthesia.**

Methods: **Twenty-two male patients with American Society of Anesthesiology physical status I or II who were scheduled for perineal surgery were studied during recovery from spinal anesthesia to compare the predictive accuracy of clinical markers of ambulatory readiness (*e.g.*, full knee flexion and extension) with that of an objective method of measurement focused on functional balance. Lumbar puncture was performed at the L2–L3 or L3–L4 interspace using a 25-gauge Whitacre needle, with patients in the sitting position. A 3-ml mixture of 5 mg bupivacaine (heavy) and 10 μg fentanyl was injected. Block regression and restoration of motor function were assessed and recorded. Functional balance was measured using a computerized force platform method.**

Results: **The majority of patients maintained motor function and proprioception sensation at the onset of surgical anesthesia, as indicated by performance on clinical tests of function: 96% were able to perform the straight leg increase; 82, 77, and 91%, respectively, were able to perform full knee flexion and extension, perform heel-to-shin maneuvers, and identify joint position in the supine position. Postoperatively, clinical return of motor function occurred much earlier than recovery of functional balance. At 60 min after onset of spinal anesthesia, 22 patients (100%) had recovered sensory and gross motor function, but only 36% could stand, and 8% could walk without assistance ($P < 0.01$). At 150–180 min after onset, 96–100% of patients achieved the levels of functional balance that permitted adequate ambulation.**

Conclusions: **The results suggest that the recovery time to unassisted ambulation is longer than has been assumed, and that the standard clinical markers of gross motor function are poor predictors of functional balance following ambulatory surgery.**

RECENTLY, it was suggested that spinal anesthesia with lidocaine allows patients to walk from the operating room following ambulatory surgery.[1,2] However, all measures of ambulatory readiness in these cases were clinical, *i.e.*, the Romberg test and patient performance of various maneuvers indicative of adequate motor function, including the straight leg increase, deep knee bend, and heel-to-shin touch. Evaluation of these indicators is subjective, potentially resulting in variable definitions of return of motor function, which may make it difficult to predict full recovery. Moreover, the underlying assumption is that resumption of motor function signifies ambulatory readiness, which may not be accurate.

Balance Master (NeuroCom International Inc., Clackamas, OR), a computerized force platform, has been reported to be useful in objective assessment of postoperative balance function following general anesthesia and sedation.[3–6] We hypothesized that functional balance (*i.e.*, balance when ambulating) parameters measured using Balance Master could directly identify ambulatory ability of a patient following ambulatory procedures under spinal anesthesia and would not correlate with clinical markers indicating functional motor recovery (*e.g.*, the deep knee bend, *etc.*). The common clinical markers would not be reliably predictive for a patient's time to ambulation or discharge.

Lidocaine used in spinal anesthesia has been reported to cause postoperative transient neurologic symptoms in 0–40% of patients, which is unrelated to anesthetic concentration and baricity.[7–11] To avoid risk of such complications, we chose low-dose, saline-diluted bupivacaine combined with fentanyl for spinal anesthesia in our study.[12]

Materials and Methods

Following institutional review board approval (University of Toronto, Toronto, Ontario, Canada), 22 male outpatients aged 18–65 yr with American Society of Anesthesiologists physical status I or II who were scheduled for elective ambulatory perineal surgery were asked to participate in this prospective study. Informed consent was obtained. Patients with a history of allergy to the study medications, previous or current psychiatric illness, medical conditions affecting balance and coordination, neurologic or vestibular disease, or morbid obesity were excluded from study.

Anesthetic Technique

In the operating room, intravenous access was established in one of the forearms. Following initial vital signs, the patients were placed in the sitting position for administration of spinal anesthesia. The L2–L3 or L3–L4 intervertebral space was then infiltrated with 2% lidocaine, and the subarachnoid space was identified *via* the midline using a 25-gauge Whitacre needle. On reflux of clear cerebrospinal fluid, a 3-ml mixture of 5 mg heavy bupivacaine (7.5%), 10 μg fentanyl, and 0.9% N saline was injected slowly into the subarachnoid space. The

* Clinical Fellow, † Research Fellow, ‡ Professor of Anesthesia.

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Address reprint requests to Dr. Chung: Department of Anesthesia, Toronto Western Hospital, 399 Bathurst Street, Toronto, Ontario, Canada M5T 2S8. Address electronic mail to: frances.chung@uhn.on.ca. Individual article reprints may be purchased through the Journal Web site, www.anesthesiology.org.

patient was then placed in the supine position to achieve sensory blockade to T10–T12 within 10 min. Analgesia was supplemented intraoperatively (on patient request) by intravenous administration of 25–50 μg fentanyl.

Clinical Assessment of Sensory and Motor Function

Motor function of the lower extremities of each patient was assessed using straight leg raises (measured approximately every 15° from 0° to 90° in the supine position), deep knee bends (full knee flexion and extension in the supine position), heel-to-shin maneuvers (touching the shins with the opposing heels in the supine position), and modified Bromage scores (1 = unable to move the feet or knee; 2 = able to move only the feet; 3 = just able to move the knee; 4 = full flexion of the knee with weakness; 5 = full flexion of the knee without weakness). These tests were performed 30–60 min before anesthesia (baseline), 5 min after spinal injection (before skin preparation), 60 min after spinal injection (time of first postoperative assessment), and every 30 min following the first postoperative assessment, until the patient was discharged home. The level of sensory blockade was determined at the same intervals (except baseline) by testing responses to pin-prick stimulation using a 23-gauge needle bilaterally in the midclavicular lines.

Evaluation of Functional Balance Using Balance Master

The Balance Master system (model 6.1) is a computerized force platform in which the patient's feet are placed on two foot plates, each resting on a transducer that transmits movement-generated signals to a computer. The computer calculates and tracks the force and movement of the patient's center of gravity and displays the value on a monitor. The data can also be stored or printed out by the computer.

The functional balance tests chosen for this study were as follows:

1. Sit-to-stand test: Patients were asked to rise quickly from a seated to a standing position, during which data on weight transfer (time of center of gravity moving from sitting to standing position, in seconds), rising index (percentage of body weight exerted to rise [the higher the better]), and end sway (center of gravity movement immediately after standing, in degrees per second) were obtained.

2. Step-up/-over test: Patients were asked to step quickly onto a 8-in curb using one foot and swing over and step down with the other foot on the force platform to allow determination of rising index (percentage of body weight exerted to rise to the curb), impact index (percentage of body weight to step down to the force plate), and movement time (from start to end of the movement, in seconds).

3. Tandem walk: Patients were asked to walk, heel to toe, from one end of the force plate to the other, to determine individual step width, speed, and end point center of gravity sway (degrees per second).

All balance tests were performed 30–60 min before anesthesia (with instruction and proper practice), 60 min after spinal injection (first postoperative assessment), and then at 30-min intervals until patients were discharged home. Prior to each balance test, motor function and ability to ambulate were assessed clinically. Patients did not proceed to postoperative balance evaluation until they were able to perform a 90° leg increase, a deep knee bend, and a heel-to-shin maneuver and had achieved modified Bromage scores of 4 or greater. Ambulatory readiness and candidacy for discharge were defined by the patients' ability to walk steadily without assistance.

Temporal Measurements

The time to onset of spinal anesthesia, the duration of anesthesia and surgery, and the times to return of motor and sensory function, recovery to ambulatory readiness, postanesthetic care unit discharge, and discharge home were recorded.

Data Analysis

Parametric data obtained from balance and motor function testing before and after spinal anesthesia were compared using the paired *t* test. Nonparametric data from these tests were analyzed using the chi-square test. A *P* value of less than 0.05 was considered statistically significant.

Results

All 22 male outpatients completed the study, and all of them achieved satisfactory surgical anesthesia to T11–T12. None required supplemental intraoperative analgesia. Table 1 provides patient demographics, types of surgical procedures, and recovery times.

Five minutes after spinal injection, the level of sensory blockade determined by response to pin-prick stimulation averaged T11 (table 2). Most patients maintained motor function and proprioception sensation: 96% were able to achieve the straight leg increase (averaging a 69° angle lift), 82% were able to perform deep knee bends, 77% were able to perform heel-to-shin maneuvers, and 91% were able to identify joint positions.

At 60 min after spinal injection (first postoperative assessment), the level of sensory blockade averaged T12 (T3–L3). All patients were able to achieve the straight leg increase (averaging a 79° lift), and the percentage of those able to perform the deep knee bend, perform the heel-to-shin touch, and identify joint position was the same as that at the time of 5 min after spinal injection

Table 1. Patient Demographics, Surgical Procedures, and Perioperative Time Variables

Demographics	
Age, yr	45 ± 12
Height, cm	171 ± 6
Weight, kg	76 ± 12
ASA physical status (I/II), n	17/5
Surgical procedures, n	
Hydrocelectomy	7
Fissurectomy	5
Varicocelectomy	4
Hemorrhoidectomy	4
Circumcision	1
Orchidopexy	1
Perioperative time variables, min	
Duration of surgery	23 ± 16
Injection to PACU discharge	126 ± 46
Injection to voiding	175 ± 47
Injection to home discharge	193 ± 46

Values are expressed as number or mean ± SD.

Table 2. Change of Sensory and Motor Functions

Sensory/Motor Function	Number	Percentage	Degree/ Score
Leg Raising			
Preanesthesia	22	100	90 ± 0
5 min after spinal injection	21	96	69 ± 32*
60 min after spinal injection	22	100	79 ± 18*
90 min after spinal injection	22	100	88 ± 6
Deep knee bend			
Preanesthesia	22	100	NA
5 min after spinal injection	18	82	NA
60 min after spinal injection	18	82	NA
90 min after spinal injection	22	100	NA
Heel–shin touch			
Preanesthesia	22	100	NA
5 min after spinal injection	17	77	NA
60 min after spinal injection	17	77	NA
90 min after spinal injection	22	100	NA
Joint position			
Preanesthesia	22	100	NA
5 min after spinal injection	20	91	NA
60 min after spinal injection	21	96	NA
90 min after spinal injection	22	100	NA
Bromage score			
Preanesthesia	NA	NA	5 (0)
5 min after spinal injection	NA	NA	4 (3–5)
60 min after spinal injection	NA	NA	4 (3–5)
90 min after spinal injection	NA	NA	5 (4–5)

Values are expressed as number, percentage, mean ± SD, or median (range).

* $P < 0.05$ compared to the preanesthesia value.

NA= not applicable.

(table 2). In contrast, functional balance tests demonstrated that only 36% of patients (8 of 22; $P < 0.01$) could actually stand, and even fewer, 18% (4 of 22; $P < 0.01$), could complete the Balance Master assessment (table 3). Those who completed the Balance Master assessment had significantly ($P < 0.05$) lower rising indexes compared to their preanesthesia baselines (table 3).

At 90 min after spinal injection, the level of sensory blockade averaged L2 (T3–S2). All patients could achieve the straight leg increase (averaging an 88° lift), and all could perform deep knee bends, perform heel-to-shin maneuvers, and identify joint positions. The percentage able to stand increased to 73% (16 of 22; $P > 0.05$), and 55% (12 of 22; $P < 0.01$) fulfilled functional balance tests (table 3).

At 150 min after spinal injection, 96% of patients (21 of 22) had fully recovered the ability to walk steadily without assistance, and their balance scores achieved the preanesthesia values (within ±20% ranges). Only 1 patient obtained full ambulatory recovery at 180 min. The median level of blockade at the time patients achieved preanesthesia balance scores was L2, with a range from T10 to S2.

Table 3. Change of Functional Balance Parameters

Functional Balance Parameter	Preanesthesia	60 min After Spinal Injection	90 min After Spinal Injection	120 min After Spinal Injection
Sit to stand, n	22	8*	16*	22
Weight transfer, s	0.63 ± 0.25	1.16 ± 0.69*	0.64 ± 0.39	0.61 ± 0.19
Rising index, % weight	23.9 ± 8.59	16.38 ± 8.77*	17.33 ± 8.11*	19.9 ± 4.16
End sway, degree/s	2.38 ± 0.96	2.70 ± 1.13	2.90 ± 1.57	2.77 ± 1.04
Step up/over, n	22	4*	12*	21
Left leg				
Rising index, % weight	31.8 ± 6.7	25.1 ± 5.13*	29.5 ± 6.3	31.38 ± 5.51
Impact index, % weight	33.1 ± 11.3	32.0 ± 12.5	30.9 ± 11.0	32.0 ± 9.85
Movement time, s	1.75 ± 0.36	2.12 ± 0.69	1.96 ± 0.6	1.95 ± 0.50
Right leg				
Rising index, % weight	35.4 ± 6.0	28.3 ± 7.20*	32.9 ± 8.10	31.7 ± 8.39
Impact index, % weight	33.6 ± 9.11	27.0 ± 13.8	31.3 ± 11.7	30.4 ± 6.60
Movement time, s	1.67 ± 0.30	2.01 ± 0.82	2.11 ± 0.70	1.95 ± 0.50
Tandem walk, n	22	4*	12*	21
Step width, cm	6.87 ± 2.89	7.49 ± 1.81	7.9 ± 2.69	7.9 ± 1.13
Speed, cm/s	27.8 ± 10.6	27.3 ± 12.1	25.9 ± 6.94	27.0 ± 8.12
End sway, degree/s	3.25 ± 1.48	3.85 ± 2.01	3.51 ± 1.59	3.89 ± 2.24

Values are expressed as number or mean ± SD.

* $P < 0.05$ compared to the preanesthesia values.

Discussion

An essential component of early patient discharge following outpatient surgery using spinal anesthesia is the ability to walk steadily without assistance. To date, outpatient ambulatory readiness has been assumed when clinical indicators, such as return of motor function and adequate Romberg test results, are present. Positive performances on tests, such as the straight leg increase and deep knee bend, have been considered a marker of ambulatory capacity and were used to suggest that patients could walk unassisted from the operating room following spinal anesthesia.[1–2] The results of the present, prospective study suggest otherwise.

We found a disparity between the time to recovery of motor function and the time to achieve the postural control and balance essential for safe ambulation. Walking balance remained impaired long after (90–120 min) clinical criteria for functional recovery from spinal anesthesia were met. Specifically, all patients had clinically fully recovered motor function at 90 min after induction of anesthesia, whereas only 55% were able to walk without assistance and achieved their preanesthesia balance function parameters.

The relation among motor function, balance, and postural stability is complicated. They are determined by the integration of visual, somatosensory, and vestibular inputs by the brainstem and cerebellum. Ideally, the ability to walk should be determined independently of motor function, by testing the several complex components of balance and posture. The Balance Master is such a tool that could objectively measure certain sensitive balance parameters when patients perform real-life movement. The results could provide an immediate and accessible evaluation of patients' ability to walk after ambulatory surgeries.

The literature on objective assessment of postural functions after spinal anesthesia is limited. Previous studies with a force platform have consistently showed impairment of stability and balance after sedation or anesthesia.[3–6] The influences of general anesthesia and spinal anesthesia on posture and balance are different. Although there is no residual cortical depression after spinal anesthesia, maintenance of equilibrium for the tasks of daily living depends on a well-integrated musculoskeletal system. In disturbances of equilibrium, there is liability to fall. Such circumstances demand prompt corrections of body position, which require adequate muscle tone and coordination. It is possible that the ability of the patients to initiate an appropriate response to disturbed equilibrium in the immediate postoperative period may still be impaired. Thus, ambulation without assistance should still remain a major factor in determining home readiness of the ambulatory surgical patient.

To produce spinal anesthesia, we used a low-dose (5-mg), dilute solution of bupivacaine combined with 10 μg fentanyl. Our goal was to produce satisfactory surgical anesthesia while reducing the likelihood of residual postoperative motor block, thereby minimizing the time to adequate motor function, ambulation, and discharge. Saline dilution of low-dose spinal bupivacaine appropriately decreased this agent's characteristically long duration of action,[12] making it useful in our outpatient time frame, and use of a small dose enabled some control of the dose-dependent magnitude of motor block.[13,14] The addition of fentanyl improved the quality of the spinal anesthesia without prolonging recovery.[15] We achieved an early return of motor function (60 min after induction of anesthesia), but did not improve recovery time to ambulation and discharge beyond that previously reported by other investigators (150–180 min after induction).

The limitation to the use of the Balance Master as a clinical tool is that repetitive testing is required to determine satisfactory recovery. This process is both time-consuming and cumbersome. However, the use of such a system as a research tool can provide insight into the problem of functional balance after anesthesia.

In conclusion, we found a disparity between the time to return of gross motor function and the time to recovery of functional balance after spinal anesthesia with low-dose bupivacaine. The functional balance remained impaired long after (90–120 min) the motor function recovery was judged adequate using clinical indicators. Tests of gross motor function are inadequate as indicators of the ability to ambulate in readiness to discharge. These results suggest that the ability to walk without assistance after spinal anesthesia requires a longer recovery period than predicted solely by gross motor recovery, making its return inadequate as a sole marker of ambulatory ability and readiness for discharge. Supporting this finding is our use of an objective method of determining postoperative ambulatory ability, *i.e.*, a computerized force platform system that quantifies the patient center of gravity and measures multiple aspects of postural control and balance during repetitive testing.

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