ORIGINAL ARTICLE

Intermittent Positive-Pressure Breathing Effects in Patients With High Spinal Cord Injury

Isabelle Laffont, MD, PhD, Djamel Bensmail, MD, Sylvie Lortat-Jacob, MD, Line Falaize, AAS, Claudette Hutin, BSc, PT, Elisabeth Le Bomin, BSc, PT, Maria Ruquet, AAS, Pierre Denys, MD, PhD, Frédéric Lofaso, MD, PhD

ABSTRACT. Laffont I, Bensmail D, Lortat-Jacob S, Falaize L, Hutin C, Le Bomin E, Ruquet M, Denys P, Lofaso F. Intermittent positive-pressure breathing effects in patients with high spinal cord injury. Arch Phys Med Rehabil 2008;89: 1575-9.

Objective: To determine whether intermittent positive-pressure breathing (IPPB) improved lung compliance, work of breathing, and respiratory function in patients with recent high spinal cord injury (SCI).

Design: An unblinded randomized crossover trial.

Setting: Rehabilitation hospital.

Participants: Patients (N=14) with SCI caused by trauma within the last 6 months and located between C5 and T6.

Intervention: Two months of IPPB and 2 months of conventional treatment were evaluated prospectively in random order in patients with SCI.

Main Outcome Measures: Noninvasive lung function tests and arterial blood gas measurements were obtained repeatedly in all patients. Repeated measurements of dynamic lung compliance and work of breathing as measured by computing the area enclosed between the inspiratory esophageal pressure-tidal volume curve, and the theoretical chest wall static pressure-volume curve were performed in 7 patients.

Results: IPPB had no long-term effects on vital capacity (52.1%±11.3% vs 54.5%±12.5%, after conventional treatment and IPPB, respectively; $P=.27$), lung compliance (66.4±48.9mL/cmH_2O vs 70.3±38.4mL/cmH_2O; $P=.56$), or other lung function tests. IPPB did not exert short-term effects on lung compliance or work of breathing.

Conclusions: IPPB produced no immediate or long-term improvements in lung function or ventilatory mechanics in patients with recent SCI. (ClinicalTrials.gov identifier: NCT00476866.)

Key Words: Insufflation; Lung compliance; Paraplegia; Quadriplegia; Rehabilitation; Work of breathing.

ACUTE RESPIRATORY FAILURE is common immediately after SCI, and pulmonary complications are the leading cause of mortality in the first year after SCI.[1] Pulmonary complications have been reported to occur during the acute hospitalization in 84% of patients with C1-4 injury, 60% of those with C5-6 injury, and 65% of those with thoracic SCI.[2] Normative or increased abdominal excursion with paradoxical inspiratory retraction of the rib cage has been noted after cervical or thoracic SCI below C4[3,4] and ascribed to normative diaphragm motion contrasting with paralysis of rib cage and abdominal wall muscles. The result of this imbalance is a reduction in lung compliance, which may develop within 1 month after SCI.[5] Reduced lung compliance has also been reported in patients with kyphoscoliosis.[6]

In 1972, IPPB for 5 minutes to induce lung hyperinflation was reported to increase lung dynamic compliance by up to 70% for up to 3 hours in patients with kyphoscoliosis.[6] More than 30 years later, the same intervention was shown to induce a short-term, moderate but significant increase in lung compliance in patients with amyotrophic lateral sclerosis.[7] However, an earlier study of IPPB in patients with neuromuscular disorders showed no effect on lung volumes or compliance.[8] Little is known about the effects of IPPB in patients with SCI. A study of 20 minutes IPPB in 7 patients with quadriplegia and 7 with muscular dystrophy found no improvements in ventilatory mechanics.[9] However, the subjects with quadriplegia had long-standing SCI injuries, and the effect of long-term IPPB was not evaluated.

While IPPB is not a largely recognized method for the management of SCI respiratory dysfunction,[10] specialized physical medicine and rehabilitation units in France currently use this technique during acute care of patients with high tetraplegia. To our knowledge, very few complications occur with IPPB, and none is described in the current literature. IPPB is usually associated with a complete respiratory rehabilitation program including techniques to enhance clearance of secretions (suctioning, manual, or instrumental assisted cough), techniques to maintain thoracic flexibility (manual mobilizations), and motor reinforcement of respiratory muscles.[10] Binders are systematically proposed in the initial stage of rehabilitation because their efficacy is supported by other studies.[10-12] We hypothesized that IPPB may increase lung compliance and therefore may improve spirometry and may decrease the cost of breathing. Therefore, the objective of this study was to evaluate the immediate and 2-month effects of IPPB on lung compliance, WOB, and lung function in patients with recent high SCI.

List of Abbreviations

IPPB	intermittent positive-pressure breathing
SCI	spinal cord injury
VC	vital capacity
WOB	work of breathing

From the Service de Physiologie-Explorations Fonctionnelles (Falaize, Lofaso), Médecine Physique et de Réadaptation (Laffont, Bensmail, Lortat-Jacob, Hutin, Le Bomin, Denys), and Centre d'Investigation Clinique-Innovations Technologiques (Laffont, Denys, Ruquet, Lofaso), Hôpital Raymond Poincaré, University of Versailles Saint Quentin en Yvelines, Garches, France; and Inserm UMR 841, Créteil, France (Lofaso).

Supported by the Association d'Entraide des Polios et Handicapés.

No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit upon the authors or upon any organization with which the authors are associated.

Correspondence to Frédéric Lofaso, MD, PhD, Service de Physiologie-Explorations Fonctionnelles, Hôpital Raymond Poincaré, Garches, 92380, France. e-mail: *f.lofaso@rpc.ap-hop-paris.fr*. Reprints are not available from the author

Published online July 7, 2008 at *www.archives-pmr.org*.

0003-9993/08/8908-00348$34.00/0
doi:10.1016/j.apmr.2007.12.037

METHODS

Participants

The local ethics committee approved the study, and all patients gave their written informed consent before inclusion. To be included, patients had to satisfy the following criteria: (1) American Spinal Injury Association grade A or B[13] SCI caused by trauma within the last 6 months and located between C5 and T6, (2) no thoracic injury, and (3) admission to a rehabilitation unit. The study was conducted over the first 4 months in the rehabilitation unit.

Measurements

All tests were performed with the patients seated in their wheelchairs. Lung function was tested using a Vmax 229 Sensormedics System[a] according to standard guidelines.[14] Arterial blood gas levels were measured in capillary blood immediately after sampling from the radial artery with local anesthesia (topical lidocaine prilocaine [EMLA]), using a Radiometer ABL 330 analyzer.[b] Flow was measured using a Fleisch number 2 pneumotachograph[c] and esophageal pressure using a catheter-mounted pressure transducer system.[d] Appropriate placement was verified by the occlusion test.[15]

Data Analysis

Respiratory parameters were measured during the last 5 minutes of a 20-minute period of relaxed breathing. From the flow tracings, we measured inspiratory time and respiratory frequency. Tidal volume was obtained from the integrated flow signal. Dynamic lung compliance was calculated as the ratio of tidal volume over the esophageal pressure difference at the points of 0 flow corresponding to the start and end of inspiration.[16] Inspiratory WOB (in J/min) was calculated from a Campbell diagram by computing the area enclosed between the inspiratory esophageal pressure−tidal volume curve and the theoretical static pressure−volume curve of the chest wall, as previously described.[17] In addition, WOB was partitioned into its elastic and resistive components on either side of the line joining the 2 zero-flow points.

Study Protocol

All patients were studied during 2 months with and 2 months without IPPB, in random order. IPPB treatment consisted of at least 20 minutes of IPPB twice a day and 5 days a week, provided by an Alpha 200 C ventilator.[e] The patient was comfortably seated with the back of the chair inclined at 45°. Inspiratory pressure was increased gradually to either the highest tolerated value or 40cmH_2O. Respiratory rate, inspiratory flow (from 20−60L/min), and end-inspiratory trigger were set to maximize patient comfort. The patients chose between a mouthpiece[f] and a nasal mask.[g] A few leaks around the mask may occur; however, the device was always able to compensate for leaks and therefore was able to reach the pressure consign when leaks were less than 1L/s, which was always the case. During both of the 2-month treatment periods, the number of patients who required physiotherapy to clear excess secretions and the number of physiotherapy sessions a patient were recorded.

Lung function tests were performed at inclusion and at the end of each 2-month period in all patients. In addition, patients were asked whether they agreed to measurements of flow, esophageal pressure, and gastric pressure at inclusion and at the end of each period. Measurements at the end of the IPPB period were performed twice, immediately before and immediately after 20 minutes of IPPB with the catheter-mounted pressure-transducer system still in place. Each measurement period lasted about 5 minutes.

Statistical Analysis

All data are given as means ± SDs. Paired *t* tests were used for within-patient comparisons of variables between the 2 treatments. Unpaired *t* tests were used for group comparisons.

RESULTS

We included 14 patients, whose individual data are summarized in table 1. Patients 1 through 7 accepted repeated transdiaphragmatic and esophageal pressure measurements.

To evaluate the effect of time irrespective of the treatment, we compared data obtained at the end of 2 months (end of the first treatment period) and at the end of 4 months (end of the study) in the rehabilitation unit, and observed that only VC differed significantly (50.2%±12.5% vs 56.5%±10.4%; *t* test, $P=.002$), while IPPB had no long-term effects on vital capacity (52.1%±11.3% vs 54.5%±12.5%, after conventional treatment and IPPB, respectively; *t* test, $P=.27$). VC changes in individual patients are shown in figure 1. The mean parameters ± SDs

Table 1: Patient Characteristics

Subject	Sex/Age (y)	Height (cm)	Weight (kg)	Level of Injury	Time From Injury to Study (mo)	VC (L)	VC (%)	FEV_1 (%)	TLC (%)	MIP (cmH_2O)	MEP (cmH_2O)	$Paco_2$ (kPa)
1	M/19	170	55	C7	5	1.58	30	26	54	72	21	5.8
2	M/21	192	75	T5	2	4.47	69	74	90	76	50	5.4
3	M/26	178	63	C6	2	3.56	65	61	92	20	20	4.9
4	M/47	169	55	C8	6	1.89	44	43	92	30	26	NA
5	M/40	173	75	T6	3	3.15	66	65	80	72	30	5.1
6	F/35	170	59	T4	3	1.67	35	24	NA	84	36	6.3
7	M/18	172	53	C5	4	2.24	42	42	82	56	17	6.4
8	M/32	173	66	C7	1	2.53	51	50	66	90	35	6.1
9	M/38	183	80	C5	2	2.25	41	31	62	56	15	5.1
10	M/21	170	55	C7	4	3.14	61	59	82	95	26	5.9
11	M/28	180	60	C7	3	2.74	49	45	74	70	70	5.7
12	M/19	187	65	C5	4	2.48	40	42	62	47	30	5.9
13	F/16	163	43	C7	4	1.20	36	24	45	30	50	6.0
14	M/16	168	50	C6	2	2.11	41	41	59	95	30	5.7

Abbreviations: F, female; FEV_1, forced expiratory volume in 1 second; M, male; MEP, maximal expiratory pressure; MIP, maximal inspiratory pressure; NA, not available; $Paco_2$, partial pressure of carbon dioxide, arterial; TLC, total lung capacity.