

Incentive spirometry and breath stacking: effects on the inspiratory capacity of individuals submitted to abdominal surgery

Inspirometria de incentivo e *breath stacking*: repercussões sobre a capacidade inspiratória em indivíduos submetidos à cirurgia abdominal

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Abstract

Background: Respiratory complications are the main causes of increased morbidity and mortality in individuals who undergo upper abdominal surgery. The efficacy of physical therapy procedures needs clarification, and it is necessary to know which therapeutic approaches are the best ones to implement. **Objective:** To compare the inspiratory volume during the breath stacking maneuver with the volume during incentive spirometry, in abdominal surgery patients. **Methods:** Twelve patients, on their first postoperative day, were instructed to take a deep breath through the *Voldyne*TM incentive spirometer and to make successive inspiratory efforts using a facemask that had been adapted for performing the breath stacking maneuver. Each technique was performed five times according to the randomization. Before the operation, the patients performed a spirometric test. They were also assessed and instructed about the procedures. A *Wright*SM ventilometer allowed inspiratory capacity to be recorded. **Results:** The inspiratory capacity during breath stacking was significantly higher than during incentive spirometry, both before and after the operation. There was a significant reduction in volumes after the surgical procedure, independent of the technique performed. **Conclusions:** The breath stacking technique was shown to be effective. This technique was better than incentive spirometry for generating and sustaining inspiratory volumes. Since no adverse effects have been described, this technique can probably be used safely and effectively, particularly in uncooperative patients.

Key words: pulmonary volumes and capacities; respiratory complications; physical therapy; breath stacking.

Resumo

Contextualização: As complicações respiratórias são as principais causas de aumento da morbidade e da mortalidade em indivíduos submetidos à cirurgia de andar superior do abdômen. A eficácia dos procedimentos fisioterapêuticos precisa ser melhor definida, assim como é necessário o conhecimento da melhor estratégia terapêutica a ser implementada. **Objetivo:** Comparar o volume inspiratório mobilizado durante a técnica de *breath stacking*, com o volume na inspirometria de incentivo em pacientes submetidos à cirurgia abdominal. **Materiais e métodos:** Doze pacientes, no primeiro dia de pós-operatório, foram orientados a inspirar profundamente por meio do inspirômetro de incentivo *Voldyne*[®] e a realizar esforços inspiratórios sucessivos pela máscara facial adaptada para realização da manobra de *breath stacking*. Cada técnica foi realizada cinco vezes de acordo com a randomização. No período pré-operatório, os pacientes realizaram prova espirométrica, foram avaliados e instruídos quanto à realização das técnicas. Um ventilômetro de *Wright*[®] permitiu o registro da capacidade inspiratória. **Resultados:** A capacidade inspiratória foi significativamente maior durante o *breath stacking* do que durante a inspirometria de incentivo, tanto no pré quanto no pós-operatório. Houve redução significativa dos volumes após o procedimento cirúrgico, independentemente da técnica realizada. **Conclusões:** A técnica de *breath stacking* mostrou-se eficaz e superior à inspirometria de incentivo para a geração e sustentação de volumes inspiratórios. Por não haver descrição de efeitos adversos, essa técnica pode, provavelmente, ser utilizada de forma segura e eficaz, principalmente em pacientes pouco cooperativos.

Palavras-chaves: volumes e capacidades pulmonares; complicações respiratórias; fisioterapia; *breath-stacking*.

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Introduction ::::

The associations between thoracic and abdominal surgeries and the high incidence of respiratory complications^{1,2} are already well documented in the literature and its main characteristics are: atelectasis³, pneumonia⁴, respiratory dysfunction² and pleural effusion⁵. The immediate postoperative period may evolve with hypoventilation, due to the residual effects of the anaesthetic, and deep breathing may be impaired as a function of pain from surgical incision⁶. The rate of prevalence of respiratory complications in upper abdomen surgeries ranges from 17 to 88%¹.

One of the basic mechanisms involved in respiratory disorders is the lack of adequate pulmonary insufflation that results from monotonous and superficial respiratory patterns⁷, prolonged restraint in bed⁸ and temporary diaphragmatic disfunctions⁹. The mucociliary clearance is also impaired in the postoperative period contributing to the reduction of the effectiveness of cough and increasing of risks associated with the retention of sputum¹⁰. There is a reduction in functional residual capacity (FRC), of inspiratory (IRV) and expiratory reserve volumes (ERV) and vital capacity (VC), also causing a reduction in expiratory flow, probably due to the reduced diaphragmatic activity¹¹.

All these respiratory complications can be minimized or avoided by the use of a protocol of respiratory physiotherapy, since the pulmonary atelectasis is considered the major cause of complications. This assertion is based on the observation that lung compliance and partial pressure of oxygen (PaO₂) return to their normal values after deep lung insufflations¹².

Several methods have been studied such as: intermittent positive pressure ventilation, exercises with deep breathing, incentive spirometry and conventional chest physiotherapy, nevertheless, a meta-analysis confirmed that all studied protocols and methods were equally effective in reducing the frequency of pulmonary complications after upper abdominal surgery¹³. However, the efficacy of physiotherapy in the post-operative period of abdominal surgery remains controversial. While Pasquina and colleagues suggest that the routine use of respiratory physiotherapy is not justified, since few clinical trials show its efficacy as a prophylactic feature¹⁴; Lawrence and colleagues describe that in the upper abdominal postoperative period, any technique for lung expansibility is superior than non-prophylaxis¹⁵.

The incentive spirometer is an equipment that encourages the patient, through a visual feedback, to maintain a maximum inspiration, in one attempt, as one of the most commonly used strategies in the postoperative¹⁶. In 1986, Marini and colleagues described an alternative method to estimate VC in low cooperative individuals, called breath-stacking. The method proved to

be effective for the proposed purpose and also made maximum lung expansion possible with minimum patient cooperation¹⁷.

The present study aimed to compare the effects of the technique called "Breath-Stacking" with those observed during the "Incentive Spirometry" in patients in the upper abdominal post-operative period, assessing the inspiratory capacity achieved by patients with each technique.

Methods ::::

Subjects

Twelve patients were sequentially recruited and evaluated in the pre-operative period for upper abdomen surgery admitted at the National Institute of Cancer – HC II (Instituto Nacional de Câncer – HC II), in the period of August to November 2006. The Research Ethics Committee of the National Institute of Cancer - HC II, approved this project, with the record number 31/06 in CONEP and written informed consent was obtained from all participants.

The assessment of eligibility for participation in the study followed well defined criteria: 1) **Inclusion criteria:** patients in the upper abdomen pre-operative period who agreed to participate in the study; 2) **Exclusion criteria:** cognitive impairments or lack of coordination to perform the incentive spirometry, intolerance to use the breath-stacking mask, post-operative complications that led to admission on the Intensive Treatment Center or extubation in a period exceeding 24 hours after surgery, level of consciousness in the post-operative period incompatible with the incentive spirometry realization.

Interventions description

- **Incentive Spirometry:** after placing a nasal clip, the subject was instructed to inhale deeply until total lung capacity through the mouthpiece of the *Voldyne 5000*[®] equipment (Sherwood Medical, St Louis, MO - USA) from the functional residual capacity.
- **Breath-stacking:** a siliconized mask connected to a one-way valve was adapted to the patient's face. Once the mask was set to allow only the inspiration (the expiratory branch remained occluded), the individual carried through successive inspiratory efforts for a period of 20 seconds. Then, the expiratory branch was released and patient expired freely^{17,18}.

Experimental protocol

This study consisted of a crossover clinical trial to compare the inspiratory capacity achieved by the patients through the

use of each technique on the first postoperative day after surgery. At the pre-operative evaluation, the patients had been trained for the accomplishment of the two techniques and, after learning, the registering of the mobilized volume was carried out. Additionally, the spirometric test was performed with the Pony Fx[®], COSMED[®] equipment, USA, with the patient in the sitting position. The Torrington range[®] was defined based on clinical and functional data.

On the first post-operative day, the patient executed each of the techniques with a one hour interval, a period in which there were no modification or new medicines added. The order of the techniques was randomly defined into two blocks of six individuals, which means, for each block were made up of and ordered randomly into three envelopes corresponding to each treatment order (beginning by Voldyne[®] or Breath-stacking). These envelopes were externally numbered and after the recruitment and decision of the inclusion of the individual in the study, the envelope was opened to define which technique would be first held. The drawing up and the selection of the envelopes were conducted by a person who was not involved in the recruitment and selection of patients in the study. Five repetitions of each techniques were performed and a Wright[®] ventilometer (British Oxigen Company, London, England) was connected to the circuit of each equipment to measure the inspiratory capacity²⁰. All the procedures were carried out under the guidance and supervision of the same physiotherapist,

always in the morning, and the techniques were performed with the patient in the Fowler position of 45 degrees.

Statistical analyses

The statistical analysis was done in the SigmaStat[®] program for Windows[®] (V 3.0). The normality of the data (test of Kolmogorov-Smirnov with Lilliefors correction) and the equality of variance (Median Levene test) were tested. Due to the normality of the data, One-Way Repeated Measures ANOVA test was applied, followed by the Tukey test.

To correlate the volumes mobilized with the Torrington Scale, the Spearman Correlation was used. Values were expressed by mean \pm MSE and the selected level of significance was 5% ($p < 0.05$).

Results

All assessed patients were able to perform the techniques requested without reporting any respiratory discomfort or announcing changes in heart rate and blood pressure, tolerating of the breath-stacking handling without difficulty. The anthropometric data, diagnosis, the spirometric measures' values and Torrington Scale are shown in Table 1.

Table 1. Patients' characteristics.

Patients	Sex	Age (years)	Diagnosis	BMI kg/m ²	FVC (l, %)	FEV ₁ (%)	FEV ₁ /FVC (%)	Torrington Scale
1	M	75	Gastric Neoplasm	18	2.45 73	71	72	4
2	F	45	Appendix Neoplasm	27	2.88 81	88	90	3
3	F	51	Retroperitoneal Neoplasm	19	3.07 87	86	80	2
4	M	77	Pancreatic Neoplasm	18	2.42 70	64	68	4
5	M	41	Rectum Neoplasm	22	4.97 103	113	90	2
6	M	45	Colon Neoplasm	17	3.94 80	78	80	2
7	M	71	Gastric Neoplasm	24	2.98 73	84	87	3
8	F	57	Pancreatic Neoplasm	25	3.04 102	112	88	2
9	F	69	Colon Neoplasm	20	2.27 89	89	78	3
10	M	73	Gastric Neoplasm	19	4.09 110	122	84	3
11	M	68	Colon Neoplasm	18	3.79 78	95	96	3
12	M	56	Rectum Neoplasm	28	4.28 101	103	80	2

BMI= Body Mass Index; FVC= Forced Vital Capacity; FEV₁= Forced Expiratory Volume, 1 second.

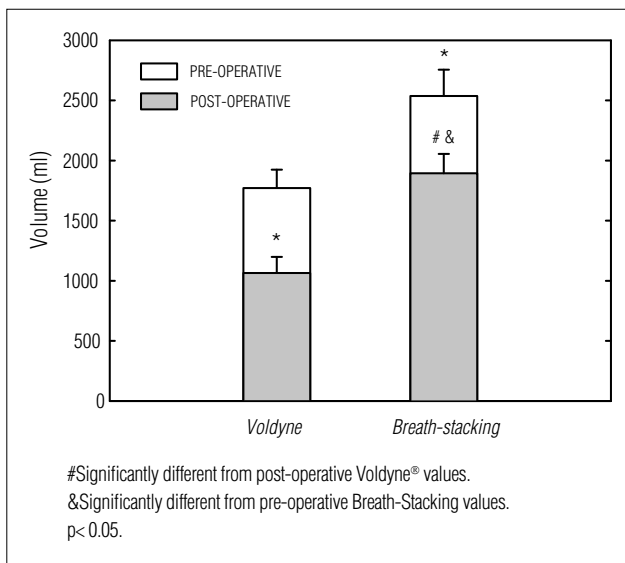


Figure 1. The values are means \pm SE of 12 patients. *Significantly different from pre-operative Voldyne® values.

The analysis by the Wright® ventilometer showed significantly higher inspiratory volumes during the breath-stacking handling compared to the incentive spirometry, both in the pre-operative as in the post-operative periods (Figure 1). Comparisons of the values of each technique reported in the post-operative period with the values obtained before surgery showed significant reductions of the inspiratory volumes both in the breath-stacking treatment and in the incentive spirometry, and there was a more pronounced reduction in the latter condition, 76 ± 4 versus 61 ± 6 , respectively. The volumes deployed in the postoperative period during the incentive spirometry were significantly correlated with the Torrington Scale (Figure 2).

Discussion

The present study showed that during the execution of the breath-stacking technique, largest mobilization of inspired volume occurred when compared to the incentive spirometry, both in the pre- as post-operative periods. There was a significant reduction in volume after the surgical procedure, whatever the selected physiotherapeutic maneuver was performed. The reduction of volumes in the post-operative period was more pronounced during the incentive spirometry when compared with the breath-stacking maneuver, with correlations between the volumes in incentive spirometry and the Torrington Scale. These correlations showed the importance of this scale as a predictor index of the risk of post-operative pulmonary complications, as well as, showing a higher dependency between

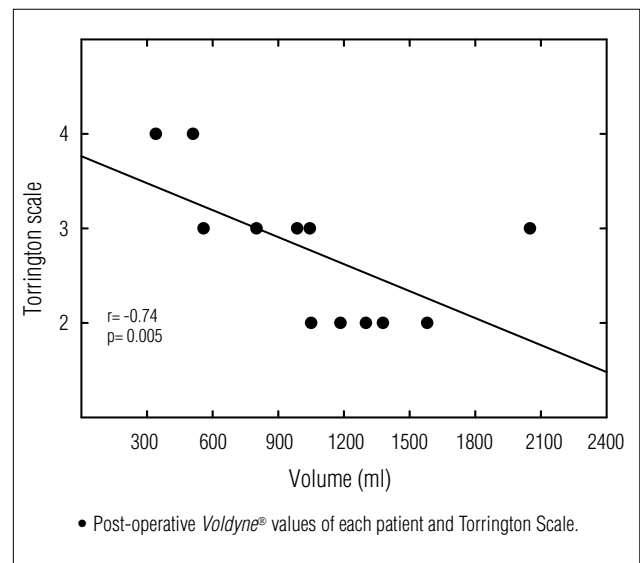


Figure 2. Spearman correlation.

the volume in incentive spirometry and the risk of post-surgical pulmonary risks.

The decrease in the inspired volume in the postoperative period observed in this study may be corroborated by previous findings that described impairments of the respiratory system functions during and after chiralurgical procedures⁴, with hypoventilation, deep breathing impairments⁶, monotonous respiratory patterns⁷ and decreases in coughing effectiveness¹⁰.

Prevention and reversion of atelectasis has shown to reduce pulmonary complications, and to this end, techniques and equipment are used to encourage patients to inspire deeply^{21,22}. The final goal is the production of a large and sustained increase in the transpulmonary pressure, which will distend the lungs and re-expand the collapsed areas. The effective treatment of the post-operative respiratory complications is still hard², and it is important to emphasize and establish the physiotherapeutic procedures for greater effectiveness.

The first study that showed the benefits of maximum inspiration in the post-operative period was made by Thoren in 1954. When analyzing 343 patients in the post-operative period after cholecystectomy, this study showed a 42% incidence of atelectasis in the group that was not submitted to the physical therapy procedures (including deep breathing) compared to 27% in the group that carried out the physical therapy treatments²³.

The ventilatory desynchronization causes differences in the spatial and temporal distributions of the inspired air in the lung regions with different time constants^{18,24}. Ward and colleagues had shown that post-operative atelectasis were more effectively reversed when the deep inspiration was maintained for a three

seconds pause post-inspiration, when compared to the deep breathing with multiple inspirations without sustenance²⁵. The accomplishment of slow and deep inspirations, followed by a post-inspiratory pause, allows the air to distribute itself in a homogeneous form, with a necessary pause of, at least, five seconds^{18,24}. The primary therapeutic goal of the incentive spirometry or any pulmonary insufflation technique is to increase the transpulmonary pressure and the functional residual capacity, reverting the alveolar collapse areas²⁶.

The incentive spirometry is used clinically as an intrinsic part of the prophylactic and therapeutic routine in the respiratory care in the post-operative period of abdominal, cardiac and thoracic surgeries. However, its efficacy is still quite debated². The success of incentive spirometry is quite variable, since patients who are weak and with dyspnea are unable to perform enough of an inspiratory effort to achieve and sustain high inspiratory volumes and, even with very cooperative and motivated patients, the ability to perform the incentive spirometry is compromised by dyspnea, muscle weakness and pain¹⁸.

In the present study, there was greater inspiratory volume during the breath-stacking execution compared to incentive spirometry. Such findings were corroborated by the study of Baker and colleagues, conducted in 1990, which reported that the breath-stacking increases the amplitude and duration of thoracic expansion¹⁸. The volume of multiple inspiratory efforts can be added through the use of a one-way valve that allows only the inspiration (the expiration is blocked), even in less cooperative patients¹⁷. During airway occlusion, the central drive increases gradually and, with the expiration blocked, the air inlet follows each inspiratory effort, consequently, increasing the thoracic volume¹⁸. Thus, air can be involuntarily trapped¹⁸, not requiring the patient's cooperation, and favoring the distribution of air in areas with different time constants²⁴. This increase of the volume tends to diminish with successive breaths, a time that the complacency of the thoracic wall diminishes and the respiratory muscles are shortened and enter in a mechanical disadvantage¹⁸. Maximum inspirations cause increases of the transpulmonary pressure and the post-inspiratory pause, with the maintenance of this raised pressure, contributes to the increases of the PaO₂, presumably through the recruitment of the collapsed alveoli.

Many patients who breath spontaneously are able to generate sufficient pressures to achieve high pulmonary volumes^{17,27}, however, the impairment of the respiratory mechanics, dyspnea and pain compromise the maintenance

of the effort long enough to achieve the maximum volumes and sustained inspiration¹⁸. Breath-stacking makes the pressure generated possible during successive inspiratory efforts to overcome the elastics (and non-resistive) forces. At the end of the stacking, small inspiratory volumes need smaller flows and cause less frictional pressure. The pressure peak is, then, available for the elastic work of the expansion of the thorax¹⁸.

To keep the lungs distended with the occlusion of the expiratory branch, this allows additional time so that the interdependent forces recruit volume, a process that is not complete in conventional spirometry¹⁸. Katz and colleagues showed that a total recruitment volume attained from gradual increases of the PEEP, is only achieved after four-five breaths (20 to 25s) after application of the PEEP, or the duration of maneuver of breath-stacking²⁸.

This study shows as one limitation, the number of patients involved, as well as the specificity of the researched population, and does not allow the generalization of the results to other clinical situations. In this context, during the time that the analgesic medication dose used by each patient was not registered, the possibility that the drug action may have influenced the volume mobilized by patients cannot be excluded. In the case that this effect may have been relevant, this does not invalidate the comparisons between the techniques, since the study was crossed and no medication was given during the interval between them.

The technique of breath-stacking could surpass the objectives of the incentive spirometry¹⁸ overall with uncooperative patients who demonstrated difficulties to generate high volumes and to sustain the inspired volume. Additionally, this technique could reveal to be efficient in patients with higher risks of pulmonary complications, since greater reduction of the volumes during the incentive spirometry were observed.

Conclusions : : : .

The breath-stacking technique was revealed to be effective and superior compared to the incentive spirometry for the generation and sustaining of inspiratory volumes. Since there are no descriptions in the literature of adverse effects that compromise its use, this technique can probably be used in a safe and efficient form, mainly with uncooperative patients.



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