Do Directed Cough Maneuvers Improve Cough Effectiveness in the Early Period After Open Heart Surgery? Effect of Thoracic Support and Maximal Inspiration on Cough Peak Expiratory Flow, Cough Expiratory Volume, and Thoracic Pain

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BACKGROUND: Directed cough maneuvers are often included in physiotherapy management aimed at preventing postoperative pulmonary complications after open heart surgery, but there is little scientific evidence of the effectiveness of directed cough maneuvers. METHODS: We conducted a randomized intra-subject crossover trial to evaluate the effect of thoracic support (patient holds his or her hands over the incision) and maximal inspiration on cough peak expiratory flow (CPEF), cough expiratory volume (CEV), and incision pain during cough in the early period after open heart surgery. Cough evaluation was undertaken on the first and second morning after surgery. On both measurement days the subject did a baseline cough (baseline cough 1) then, in a random sequence, performed 3 cough conditions: an additional baseline cough (baseline cough 2), supported cough, and supported cough preceded by maximal inspiration. In these test conditions a $P < .008$ was deemed to indicate a statistically significant difference. RESULTS: Twenty-one subjects participated. Thoracic support alone did not significantly affect CPEF or CEV (Bonferroni adjusted $P > .008$). With a maximal inspiration and thoracic support, CPEF and CPEV were significantly higher than in all other cough conditions (Bonferroni adjusted $P < .008$). Pain during cough was not influenced by the different cough conditions ($P > .05$). There was no significant difference in the cough variables or pain during the different cough conditions on the first day versus the second measurement day. CONCLUSIONS: Maximal inspiration increased CPEF and CEV, but the method of thoracic support we used did not reduce pain during cough or influence the cough values we measured. *Key words: cough, respiratory physiotherapy, cardiac surgery, respiratory complications, postoperative care, postoperative pain.* [Respir Care 2008;53(8):1027–1034. © 2008 Daedalus Enterprises]

Introduction

Respiratory complications are a leading cause of morbidity after open heart surgery, and they prolong hospital stay and increase heath care costs.[1,2] Several authors have hypothesized that retention of airway secretions after surgery is an important risk factor for atelectasis and pulmonary infections.[3-5]

Cough is the physiologic defense mechanism when mucus secretion is excessive or ciliary airway clearance is impaired.[6] After open heart surgery, especially in the early postoperative period, cough function may be impaired by difficulty in performing deep inspiration, reduced intrathoracic pressure generation, or thoracic pain.[3,4]

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Cough maneuvers to improve cough effectiveness are often included in the management of patients after open heart surgery, as part of comprehensive physiotherapy treatment aimed at preventing postoperative pulmonary complications.[7-12] Terms used in the literature to describe these maneuvers include "coughing exercises,"[9] "coughing techniques,"[12] "coughing with sternal support,"[8] and "supported cough."[11] In 1993 the American Association for Respiratory Care published a guideline that standardized the practice of cough maneuvers for different clinical situations and named the technique with the general term "directed cough maneuvers."[13] That guideline recommends that after abdominal or thoracic surgery the patient should be taught to cough following a maximal inspiration and to support the incision while coughing.[13]

Although directed cough maneuvers are frequently used in clinical practice[10] and recommended in guidelines,[13] there is little scientific evidence of the effectiveness of directed cough maneuvers in patients after open heart surgery.

We hypothesized that patients in the early period after open heart surgery would have improved cough effectiveness and less thoracic pain during cough with directed cough maneuvers. We conducted a randomized intra-subject crossover trial to test that hypothesis, and we evaluated the effect of thoracic support and maximal inspiration on cough peak expiratory flow (CPEF), cough expiratory volume (CEV), and thoracic pain during cough in post-open-heart-surgery patients.

Methods

The study was approved by our hospital ethics committee, and written informed consent was obtained from each subject before surgery.

Subjects

All patients ≥ 18 y old admitted to our university teaching hospital for elective cardiac surgery via median sternotomy were considered for inclusion. Patients were excluded before surgery if they had a history of neuromuscular or cognitive impairment that could limit their understanding and performance of the cough maneuvers. After surgery, patients were excluded if they had postoperative neuromuscular or cognitive impairment, hemodynamic instability prior to measurements (mean arterial pressure < 70 mm Hg and/or heart rate > 120 beats/min) or invasive mechanical ventilation for > 12 hours after surgery.

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Subjects were withdrawn from the study if they became hemodynamically unstable (mean arterial pressure < 70 mm Hg and/or heart rate > 120 beats/min), had signs of dyspnea (respiratory rate > 35 breaths/min and use of respiratory accessory muscles), or developed arterial oxygen saturation $< 88\%$ during the cough measurements. Subjects were also withdrawn if they were returned to invasive mechanical ventilation, used noninvasive ventilation because of respiratory failure, needed surgical reintervention, or withdrew their consent any time during the first 2 postoperative days.

Using the standard deviation ($\pm$ 21.35 L/min) obtained from pilot-study data ($n = 15$) and assuming as an appropriate effect size a difference higher than the measurement expected variation (10%) in the primary outcome CPEF, for alpha = 0.05 (2-tailed) and power of 0.80, the sample size estimate was 21 subjects. Thoracic pain was a secondary outcome of interest, so it was necessary to assure that its evaluation would not be underpowered. Considering the standard deviation obtained from the pilot study ($\pm$ 23.9%), alpha = 0.05 (2-tailed), and a difference of 33% between pain-scale values obtained in each cough condition as clinically important,[14] we calculated that 21 subjects would provide an estimated power of 0.99 for pain analysis.

Procedure

Each subject was interviewed for demographic data and underwent spirometry and respiratory muscles tests one day before surgery. Following explanations about the cough-evaluation equipment and the pain scale, the subjects practiced cough measurements. The subjects did not receive any orientation or training on directed coughing maneuvers preoperatively or any time before the first measurement day. Postoperatively, surgical data were obtained from medical reports. On the second measurement day the investigator checked for the presence of pleural and mediastinal drainage tubes, and, if the tubes were already removed, medical or nursing reports were assessed for date and time of removal. The regimen of analgesic therapy was recorded on both the first and second measurement day.

The measurements were taken by the same physiotherapist on the first and second mornings after surgery. On both measurement days the subject did a baseline cough (baseline cough 1), then, in a random sequence, performed 3 cough conditions: an additional baseline cough (baseline cough 2), supported cough, and supported cough preceded by maximal inspiration (Fig. 1). A block randomization was used to guarantee that the sequences of cough conditions were balanced among the subjects. Each of the possible cough-condition sequences were placed in sealed opaque envelopes. The evaluator was blinded to the se-

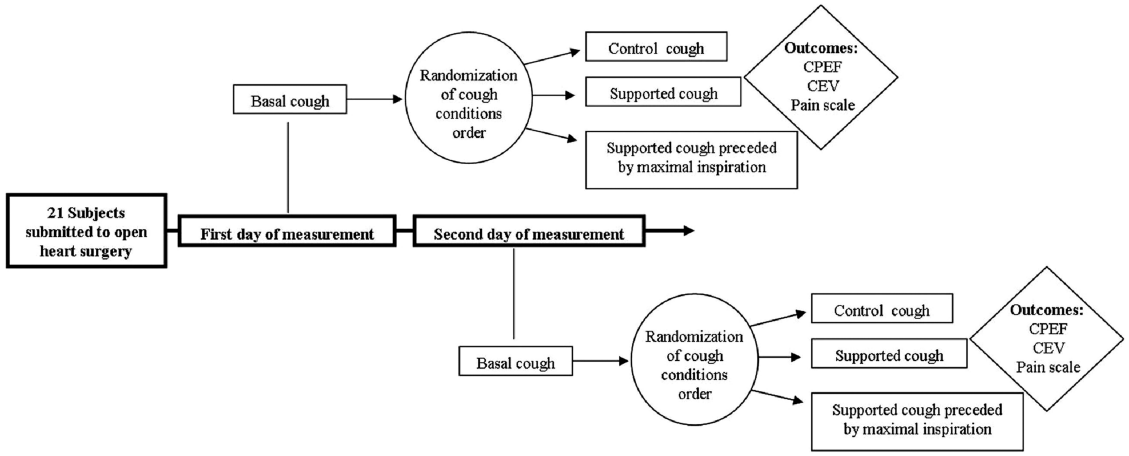

Fig. 1. Flow chart of the experimental procedure.

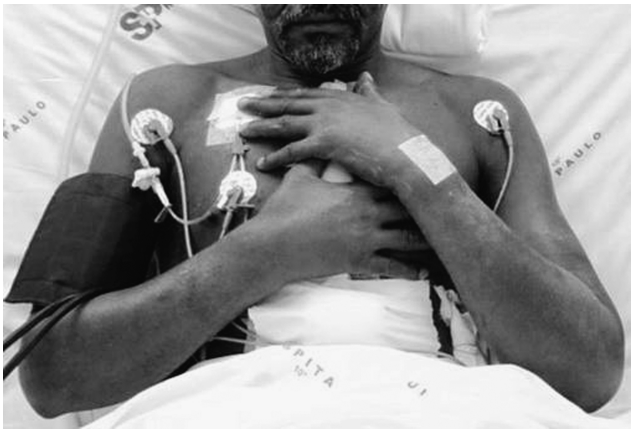

Fig. 2. Hands position during supported cough.

quence of cough conditions until the time of measurement. The same randomization process was performed independently on the first and second day with each subject.

Cough evaluation was undertaken with the patient in bed in a semirecumbent position (60°). Baseline cough 1 and baseline cough 2 both consisted of a maximal voluntary cough; the subjects were asked to "cough as strongly as possible." The performance of the 2 baseline cough measurements, one before and the other after randomization, was intended to establish a consistent baseline cough condition.

The supported cough consisted of a maximal voluntary cough with the subject's palmed hands placed firmly on the sternotomy incision. The patient was asked to put his or her hands across the chest to cover the whole incision (Fig. 2) and to use enough pressure so that the patient could feel the hand pressure over the incision without experiencing further pain due to the hand pressure. Supported cough preceded by maximal inspiration consisted of an inspiration to near total lung capacity, followed by a maximal cough, with incision support. Subjects were instructed to take the "biggest breath possible" before coughing. Five cough attempts were made in each cough condition. The subject rested for 30 seconds between each cough measurement and 5 min between each cough condition.

Cough Evaluation

CPEF and CEF were measured with a modified version of the method described by Sivasothy et al,[15] adapted for bedside assessment. CPEF and CEV were measured in each cough condition with a portable multifunction spirometer (Spirobank, Medical International Research, Rome, Italy) connected via a plastic funnel-shaped tube (6.5 cm long and 2 × 3 cm inner diameter) to a sealed oronasal mask (Adult 5, Vital Signs, Totowa, New Jersey). The Spirobank has a turbine sensor that works on the principle of infrared interruption, which can measure flows up to 960 L/min and volumes up to 10 L. The system was calibrated before each measurement day, following the manufacturer's recommendation. The PCPF and CEF values considered for analysis were the mean of the 3 highest values (with difference between each value $< 10\%$, or the next lowest) obtained from the 5 attempts in each cough condition.[16]

Reliability and Responsiveness of Cough Measurements

In a pilot study we assessed the responsiveness[17] and reliability[18] of the CPEF and CEV measurements by the Spirobank spirometer. Five baseline cough attempts were obtained from 15 patients one day before and one day after open heart surgery (Table 1).

Table 1. Reliability and Responsiveness of Cough Measurements

Responsiveness of CPEF to different cough conditions*	
Effect size	1.64
Mean difference (L/min)	255
Responsiveness of CEV to different cough conditions*	
Effect size	1.86
Mean difference (L)	1.42
CPEF inter-rater reliability†	
Intra-class correlation coefficient (model 3.5)	0.99
Standard error of measurement (L/min)	15.5
CEV inter-rater reliability†	
Intra-class correlation coefficient (model 3.5)	0.93
Standard error of measurement (L)	0.20

* Responsiveness was calculated according to Reference 17. Effect size = mean difference/standard deviation of preoperative values. An effect size > 0.8 is classified as large. Mean difference = preoperative value – postoperative value.
† Intra-rater reliability was calculated according to Reference 18, considering postoperative values. An intra-class correlation coefficient > 0.9 is classified as high. Standard error of measurement = standard deviation $\sqrt{1}$ – intra-class correlation coefficient.
CPEF = cough peak expiratory flow
CEV = cough expiratory volume

Table 2. Patient Characteristics

Patients (*n*)	21
Age (mean ± SD y)	48.86 ± 14.21
Female/male (*n*)	5/16
Body mass index (mean ± SD kg/m^2)	23.9 ± 4.8
Smoking status (*n*)	
Nonsmoker	14
Ex-smoker for > 2 mo	4
Ex-smoker for < 2 mo	1
Current smoker	2
ASA score (median, range)	2 (1–3)
Preoperative pulmonary function variables (mean ± SD)	
FEV_1 (L)	2.84 ± 0.64
FEV_1 (% predicted)*	86.9 ± 14.9
MIP (cm H_2O)	88.8 ± 23.5
MIP (% predicted)*	82.6 ± 19.6
MEP (cm H_2O)	109.0 ± 20.0
MEP (% predicted)*	100.0 ± 20.6

* The predicted values are from References 20 and 21.
ASA = American Society of Anesthesiology
FEV_1 = Forced expiratory volume in the first second
MIP = maximum inspiratory pressure
MEP = maximum expiratory pressure

Pain Analysis

Thoracic pain was measured with an 11-point box scale graduated from 0 (minimum) to 10 (maximum), applied per the method of Jensen et al.[19] Patients scored their thoracic pain before each cough condition (at rest), and after the 5 cough attempts in each cough condition, they scored the pain they felt while they were coughing.

Pain analysis was performed per the recommendations of Farrar et al,[14] with the percentage increase in pain score and considering the score values obtained before and during each cough condition (eg, a change from 4/10 to 1/10 would represent a percentage change of 75%). Farrar et al reported that when the absolute values obtained with a pain scale are converted to percentage change in pain the analysis has better accuracy in predicting adequate pain relief with a balanced sensitivity and specificity. A pain-score change of 33% was considered a clinically meaningful difference.[14]

Statistical Analysis

Statistical analysis was performed with statistics software (SPSS 13.0, SPSS, Chicago, Illinois). Analysis of kurtosis and skewness showed that the CPEF, CEV, and pain data could be treated as normally distributed. Analysis of variance for repeated measurements was used to compare the CPEF, CEV, and percentage of pain-increase values in each cough condition. When analysis of variance identified a significant difference ($P < .05$) between the cough conditions, each condition was compared with paired *t* tests with Bonferroni correction to identify pairwise differences (6 pairwise comparisons). The critical alpha derived from the Bonferroni correction was 0.008. The data obtained on the first and second days were analyzed independently.

Results

Of the 27 patients we screened for the study, 6 were excluded. One was unable to understand instructions and was excluded before surgery; the other 5 were excluded after surgery: one because of cognitive impairment, 2 had received invasive mechanical ventilation for > 12 h, one needed noninvasive mechanical ventilation because of respiratory failure, and one withdrew consent.

On the first measurement day all the subjects were in the intensive care unit, and on the second day all the subjects were on the ward. All the included subjects had their pleural and/or mediastinal drainage tubes removed on the morning of the first postoperative day. Table 2 shows the characteristics of the 21 included subjects. Table 3 shows the surgical and postoperative analgesia data. Table 4 shows the CPEF and CEV values.

There was no significant difference between the CPEF and CEV values obtained in baseline cough 1 and baseline cough 2 on either measurement day ($P > .008$).

On the first measurement day the use of thoracic support during cough did not significantly affect CPEF or CEV ($P > .008$). When, in addition to thoracic support, the subject was instructed to take a maximal inspiration before coughing, CPEF and CEV were significantly higher

Table 3. Surgical and Analgesia Data

Surgery type (*n*)	
On-pump coronary artery bypass	7
Off-pump coronary artery bypass	7
Mitral valve replacement or plasty	4
Atrial septoplasty	2
Aortic valve replacement	1
Duration of surgery (mean ± SD h)	5.00 ± 1.37
Duration of intubation (mean ± SD h)	9.54 ± 4.15
Cardiopulmonary bypass time (mean ± SD h)	1.61 ± 0.77
Drainage tubes (*n*)	
Mediastinal	11
Mediastinal and unilateral pleural (intercostal)	5
Mediastinal and bilateral pleural (intercostal)	2
Mediastinal and unilateral pleural (subxiphoid)	3
Analgesia (*n*)	
First postoperative day	
Venous sodium dipirone (2 mL every 6 h)	18
Venous tramadol hydrochloride (50 mg every 6 h)	3
Second postoperative day	
Oral sodium dipirone (1.2 mL every 6 h)	19
Oral tramadol hydrochloride (50 mg every 6 h)	2

than in all the other cough conditions ($P < .008$). On the second measurement day the cough variables during the different cough conditions were not significantly different than the first day; thoracic support did not affect CPEF or CEV ($P > .008$), but maximal inspiration significantly increased CPEF and CEV ($P < .008$).

Table 5 presents the pain-scale data. The percentage of thoracic pain increase was not different between the different cough conditions on the first or the second measurement day ($P > .05$). Our analysis of the mean difference in the percentage pain increase and its 95% confidence interval shows that the reported thoracic pain was less than the clinically meaningful difference of 33% during all the cough conditions.

Discussion

Recent evidence suggests that respiratory physiotherapy does not reduce the incidence of postoperative pulmonary complications following open heart surgery, but the studies performed to date were methodologically flawed.[22] The description of the physiotherapy treatment in the trials that compared respiratory physiotherapy to a control group was often inconsistent, although it commonly included directed cough maneuvers,[7-9,11,12] sometimes even as part of the standard postoperative care of the control group.[7,8,11,12] Although coughing may be difficult in the early period after open heart surgery,[23] patients are asked to cough according to a physiotherapist's direction, often as much as every waking hour during the early postoperative period.[8,9,11] The current literature does not allow us to evaluate whether there is any benefit from the directed cough maneuvers. To our knowledge this is the first study of the impact of directed cough maneuvers on cough physiological variables and thoracic pain after open heart surgery.

In this sample of adult patients after open heart surgery, the directed cough maneuver was safe and well tolerated. No subjects were withdrawn from the study because of hemodynamic instability, dyspnea, or low oxygen saturation during the maneuvers. Only one subject withdrew consent after surgery (no reason was given).

The performance of 2 baseline coughs was intended to ensure a consistent, stable baseline for the subsequent cough measurements, because it was possible that the first cough condition could be biased by the subject's fear of coughing, especially on the first measurement day. Other factors that may have prejudiced the baseline values were the possible learning effect of the measurement technique. However, the baseline CPEF, CEV, and pain values before and after randomization were not significantly different, so both baseline cough 1 and baseline cough 2 represented a consistent baseline condition.

The only cough condition that was associated with significant differences in CPEF and CEV was supported cough preceded by maximal inspiration. Supported cough without maximal inspiration did not affect CPEF or CEV, so we assume that asking the patient to take a maximal inspiration before coughing was the most important part of the directed cough technique. It is well described in the literature that lung volume is a major determinant of peak expiratory flow,[24,25] so it is not surprising that CPEF was higher with a maximal inhalation. The improvement of cough effectiveness with maximal inspiration is attributed to airways dilatation, greater force of expiratory muscle contraction, and greater lung recoil pressure during expiration.[26] Cough expiratory flow is enhanced when cough is started from maximum inspiratory capacity in normal subjects[27] and patients with neuromuscular disease,[15,26] but this is the first study that shows the effect of this maneuver in postoperative patients. With the equipment we used, it was not possible to measure the depth of the maximal inspiration taken. However, given that CPEF and CEV improved after the instruction to maximally inspire, we assume that a larger volume of air was inspired than before the other coughs.

Cough is described as the most painful activity after open heart surgery.[23] The purpose of supporting the wound during cough is to reduce pain by stabilizing the thoracic cage and reducing stress on the osseous, cartilaginous, and other connective tissue manipulated during surgery. Another possible effect of thoracic support is to improve the patient's confidence to cough, because the patient is supporting the wound. The thoracic support can be performed with a folded blanket, pillow, palmed hands, or other devices.[13] We evaluated the use of the simplest and most

Table 4. Cough Peak Expiratory Flow and Cough Expiratory Volume During the Different Cough Conditions on the First and Second Day of Measurement

		Cough Condition	Mean ± SD	*P**	Cough-Conditions Comparison	Mean Difference and 95% CI	*P*
First Measurement Day	CPEF (L/min)	BC1	162.9 ± 61.0	.002	BC1 vs BC2	−9.1 (−19.1 to 0.8)	.07
		BC2	172.1 ± 68.8		BC1 vs SC	−11.2 (−22.0 to −0.4)	.04
		SC	174.2 ± 71.0		BC2 vs SC	−2.0 (−9.0 to 4.9)	.54
		SCMI	200.8 ± 82.4		BC1 vs SCMI	−37.8 (−54.0 to −21.6)	< .001
					BC2 vs SCMI	−28.6 (−43.0 to −14.2)	< .001
					SC vs SCMI	−26.6 (−41.3 to −11.8)	.001
	CEV (L)	BC1	0.81 ± 0.25	.002	BC1 vs BC2	−0.02 (−0.05 to 0.01)	.23
		BC2	0.83 ± 0.27		BC1 vs SC	−0.03 (−0.08 to 0.01)	.12
		SC	0.85 ± 0.24		BC2 vs SC	−0.01 (−0.05 to 0.02)	.38
		SCMI	0.99 ± 0.29		BC1 vs SCMI	−0.17 (−0.22 to −0.12)	< .001
					BC2 vs SCMI	−0.15 (−0.20 to −0.10)	< .001
					SC vs SCMI	−0.14 (−0.18 to −0.09)	< .001
Second Measurement Day	CPEF (L/min)	BC1	162.9 ± 61.0	< .001	BC1 vs BC2	−2.6 (−11.2 to 6.0)	.07
		BC2	172.1 ± 68.8		BC1 vs SC	−5.3 (−17.6 to 7.0)	.04
		SC	174.2 ± 71.0		BC2 vs SC	−2.6 (−12.4 to 7.0)	.54
		SCMI	200.8 ± 82.4		BC1 vs SCMI	−32.2 (−50.9 to −13.5)	< .001
					BC2 vs SCMI	−29.6 (−44.9 to −14.3)	< .001
					SC vs SCMI	−26.9 (−38.2 to −15.6)	.001
	CEV (L)	BC1	0.81 ± 0.25	< .001	BC1 vs BC2	0.01 (−0.04 to 0.06)	.23
		BC2	0.83 ± 0.27		BC1 vs SC	−0.001 (−0.06 to 0.06)	.12
		SC	0.85 ± 0.24		BC2 vs SC	−0.01 (−0.05 to 0.02)	.38
		SCMI	0.99 ± 0.29		BC1 vs SCMI	−0.20 (−0.26 to −0.14)	< .001
					BC2 vs SCMI	−0.21 (−0.27 to −0.16)	< .001
					SC vs SCMI	−0.20 (−0.25 to −0.15)	< .001

* For analysis of variance, $P < 0.05$ is considered to indicate a statistically significantly difference.
‡ For within-cough-conditions comparison, $P < 0.008$ is considered to indicate a statistically significantly difference (according to Bonferroni adjustment for 6 pairwise comparisons).
CPEF = cough peak expiratory flow
BC1 = baseline cough 1
BC2 = baseline cough 2
SC = supported cough
SCMI = supported cough preceded by maximal inspiration
CEV = cough expiratory volume

clinically accessible support device: the patient's hands placed over the sternotomy incision. We expected that CPEF and CEV would be greater if thoracic support reduced pain and improved the patient's confidence to cough, but the method of thoracic support that we used did not affect any of the variables we measured. In 1998, Laurikka et al[28] studied an inflatable pneumatic vest for chest support to reduce sternotomy pain after open heart surgery. The vest covered the lower two thirds of the thorax and submitted the incision to a pressure of approximately 25 cm H_2O. Sternotomy pain was significantly lower during pulmonary function tests while wearing the vest, compared to without the vest. Although Laurikka et al did not evaluate the influence of the vest on pain during cough or measure cough variables, their findings suggest that we cannot extrapolate the results of the current study to the use of other thoracic support devices. It may be possible that support with a pillow or folded blanket (rather than hands or adding more pressure to the incision) would make the cough technique more effective.

The measurement days were chosen because most of the patients in our service have pleural and/or mediastinal drainage tubes in situ on the first morning after surgery, but the drains are removed by the second postoperative morning. We expected different responses to the cough interventions on the 2 measurements days because drainage tubes are one of the main causes of postoperative thoracic pain, and removal of the tubes often relieves pain.[23,29] The subjects may have experienced difficulty in performing deep

Table 5. Thoracic Pain Behavior During the Different Cough Conditions on the First and Second Day of Measurement

		Pain Scale Absolute Score (median, range)		Percentage of Pain Increase During Cough			
		Before Cough	During Cough	Mean ± SD %	P*	Comparison	Mean Difference and 95% CI
First Measurement Day	BC1	2 (1–7)	5 (1–9)	38.8 ± 22.8	.16	BC1 vs BC2	3.8 (−0.97 to 8.5)
	BC2	2 (1–7)	4 (1–7)	35.0 ± 24.4		BC1 vs SC	7.3 (0.25 to 14.3)
	SC	3 (1–6)	4 (1–8)	31.5 ± 22.8		BC2 vs SC	3.5 (−3.5 to 10.5)
	SCMI	3 (1–7)	4 (1–9)	32.5 ± 27.0		BC1 vs SCMI	6.3 (−1.6 to 14.2)
						BC2 vs SCMI	2.5 (−5.3 to 10.3)
						SC vs SCMI	−1.0 (−9.7 to 7.7)
Second Measurement Day	BC1	1 (1–7)	3 (1–9)	32.5 ± 29.4	.39	BC1 vs BC2	−1.0 (−2.8 to 0.7)
	BC2	1 (1–7)	3 (1–8)	33.5 ± 29.8		BC1 vs SC	−0.2 (−5.3 to 4.8)
	SC	1 (1–7)	3 (1–8)	32.7 ± 28.6		BC2 vs SC	0.8 (−4.1 to 5.7)
	SCMI	1 (1–7)	3 (1–8)	36.7 ± 27.9		BC1 vs SCMI	−4.2 (−13.1 to 4.6)
						BC2 vs SCMI	−3.2 (−12.2 to 5.8)
						SC vs SCMI	−4.0 (−11.3 to 3.3)

* For analysis of variance, $P < 0.05$ indicates a statistically significantly difference.
BC1 = baseline cough 1
BC2 = baseline cough 2
SC = supported cough
SCMI = supported cough preceded by maximal inspiration

breaths because of lung-volume reduction caused by the drainage tubes.[3] Notwithstanding that, the cough variables and pain during the different cough conditions were the same on the first and second day.

CPEF has been used for the evaluation of cough effectiveness for over 40 years.[15] Usually CPEF is measured via an oronasal or full-face mask connected to a pneumotachograph.[30] In this study we used a hand-held spirometer that allowed bedside assessment in the intensive care unit. Different from a pneumotachograph, the spirometer we used is based on a turbine sensor that works on an infrared interruption principle. This device is recommended for general use as a spirometer[31] and can adequately measure peak expiratory flow.[32] To our knowledge, this spirometer has not previously been used to evaluate cough, so our pilot study evaluated inter-rater reliability and responsiveness of its cough measurements. Both CPEF and CEV had high reliability[18] and large responsiveness[17] to the different cough conditions.

The generalizability of our findings may be restricted by some limitations. The cough variables needed to be evaluated at the moment the patient was performing the given cough condition, so neither the patient nor the investigator could be blinded to the interventions. Also, we could not standardize the analgesia regimen during data collection, and we included all types of open heart surgery, but the level of pain may partly depend on the surgical technique.[23,29] However, the analgesia was relatively similar in these patients, and, considering that each subject was evaluated as his or her own control, any bias from analgesia or surgical technique would have influenced the measurements of all cough conditions performed and not benefit one or another condition.

Conclusions

Retention of airway secretions is an important risk factor for pulmonary complications after open heart surgery, and directed cough maneuvers to facilitate airway clearance are often included in the management of these patients. Maximal inspiration before a directed cough maneuver improves CPEF and CEV, as recommended in the literature. The thoracic support method of having the patient place his or her palmed hands firmly on the sternotomy incision did not reduce pain during cough or affect CPEF or CEV. Further investigation is necessary to evaluate the effect of directed cough on postoperative outcomes and thus assess whether directed cough should be part of standard postoperative care after open heart surgery.

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