reviews

The Effect of Incentive Spirometry on Postoperative Pulmonary Complications*

A Systematic Review

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Objective: To systematically review the evidence examining the use of incentive spirometry (IS) for the prevention of postoperative pulmonary complications (PPCs).

Methods: We searched MEDLINE, CINAHL, HealthSTAR, and Current Contents databases from their inception until June 2000. Key terms included "incentive spirometry," "breathing exercises," "chest physical therapy," and "pulmonary complications." Articles were limited to human studies in English. A secondary search of the reference lists of all identified articles also was conducted. A critical appraisal form was developed to extract and assess information. Each study was reviewed independently by one of three pairs of group members. The pair then met to reach consensus before presenting the report to the entire review group for final agreement.

Results: The search yielded 85 articles. Studies dealing with the use of IS for preventing PPCs (n = 46) were accepted for systematic review. In 35 of these studies, we were unable to accept the stated conclusions due to flaws in methodology. Critical appraisal of the 11 remaining studies indicated 10 studies in which there was no positive short-term effect or treatment effect of IS following cardiac or abdominal surgery. The only supportive study reported that IS, deep breathing, and intermittent positive-pressure breathing were equally more effective than no treatment in preventing PPCs following abdominal surgery.

Conclusions: Presently, the evidence does not support the use of IS for decreasing the incidence of PPCs following cardiac or upper abdominal surgery. *(CHEST 2001; 120:971–978)*

Key words: critical appraisal; incentive spirometry; pulmonary complications; systematic review

Abbreviations: CABG = coronary artery bypass graft; CAF = critical appraisal form; CPAP = continuous positive airway pressure; DB = deep breathing; DBC = deep breathing and coughing; FRC = functional residual capacity; IPPB = intermittent positive-pressure breathing; IS = incentive spirometry; $P(A-a)O_2$ = alveolar-arterial oxygen pressure difference; PAP = positive airway pressure; PEP = positive expiratory pressure; PPC = postoperative pulmonary complication

C ardiac and upper abdominal surgical procedures are associated with a high incidence of postoperative pulmonary complications (PPCs), which are

defined as pulmonary abnormalities occurring in the postoperative period producing clinically significant, indentifiable disease or dysfunction that adversely affects the clinical course.[1] The incidence rate depends on the surgical site, the presence of risk factors, and the criteria used to define a PPC.[1–5] Reported incidence rates for upper abdominal surgery range from 17 to 88%.[2,6,7] The basic mechanism of PPCs is a lack of lung inflation that occurs because of a change in breathing to a shallow, monotonous breathing pattern without periodic sighs,[8,9] pro-

longed recumbent positioning,[10] and temporary diaphragmatic dysfunction.[11,12] Mucociliary clearance also is impaired postoperatively,[13,14] which, along with the decreased cough effectiveness, increases risks associated with retained pulmonary secretions.

Ward et al[15] showed that postoperative atelectasis is better reduced by taking a deep breath and holding it for 3 s than by taking multiple deep breaths or not holding a deep breath. The first reports[16] on the use of such sustained maximal inspirations for the treatment of postsurgical patients originated in Great Britain. The first major study showing the benefits of postoperative maximal inspiration was carried out by Thoren[17] in 343 patients who were undergoing cholecystectomy. Thoren documented an incidence of atelectasis (detected via radiograph) of 42% in control subjects vs 27% in patients treated postoperatively with physical therapy including deep-breathing (DB) exercises. The incidence rate declined further, to 12%, in patients who received additional preoperative instruction in the breathing exercises.

An incentive spirometer is a device that encourages, through visual and/or audio feedback, the performance of reproducible, sustained maximal inspiration.[18,19] Incentive spirometry (IS) is the treatment technique utilizing incentive spirometers. Bartlett et al[18] developed an incentive spirometer that both provided visual feedback to the patient and recorded the number of successful breathing maneuvers. This unit, the Bartlett-Edwards incentive spirometer, remained the standard for many years, although it has since been replaced by less expensive, single-use units. The first specific report of IS as a treatment technique appears to be that of Van de Water et al,[20] who compared IS to intermittent positive-pressure breathing (IPPB) in 30 patients after they had undergone abdominal bilateral adrenalectomy. No statistical difference was reported in the incidence of pulmonary complications between treatment groups.

IS remains a widely used technique for the prophylaxis and treatment of respiratory complications in postsurgical patients. O'Donohue[21] surveyed its use in the United States and reported that 95% of hospitals in which cardiothoracic and abdominal surgery was performed used IS in postoperative care. Jenkins and Soutar[22] reported a usage rate of 44% in hospitals in which coronary artery bypass graft (CABG) surgery was carried out in the United Kingdom. More recently, Wattie[23] repeated this survey and found that the usage rate had increased to 71%, despite recent publications that have cast doubt on both the need for IS in patients undergoing CABG surgery and the effectiveness of IS in this population.[24–26]

A previous meta-analysis assessed the literature concerning the efficacy of IS, IPPB, and DB exercises in preventing PPCs following upper abdominal surgery.[27] While this study provided a valuable contribution to the literature, its limited scope with respect to surgery and the number of studies involving IS left it unable to answer our research question. In addition, as pointed out by Dean,[28] meta-analyses based on methodologically flawed studies cannot provide resolution to conflicting results. In view of the widespread use of IS, and the recent reports suggesting that IS may not always be an effective technique, there is a need to reassess the available literature to determine whether such reliance on IS is justified. Thus, the purpose of this study was to systematically review the literature examining the use of IS for preventing PPCs.

MATERIALS AND METHODS

Search Strategy

The search strategy included primary and secondary searches. For the primary search, computerized databases (MEDLINE, CINAHL, HealthSTAR, and Current Contents) were searched from their inception until June 2000. Key terms for the search included "incentive spirometry," "breathing exercises," "chest physical therapy," and "pulmonary complications." The secondary search involved scanning all reference lists from the studies identified in the primary search. Both searches were limited to human studies that were performed in English.

Search Results

The primary computer database search yielded 83 articles. The secondary search provided two additional articles for a total of 85. Articles were accepted for systematic review if their purpose(s) included the use of IS for preventing PPC. Articles were excluded from systematic review (n = 37) if they fell into one of the following categories: (1) reviews; (2) commentaries, cost-analyses, surveys, patient monographs, letters, and guidelines; (3) the use of IS for other purposes, such as for inspiratory muscle training and bronchodilator administration, or as a monitoring tool; and (4) use of IS in nonsurgical populations.

Forty-eight articles thus were accepted for systematic review. However, this number represented only 46 discrete studies as 2 studies were each reported in two different journals.[24,29–31] Only the first report of each of these studies was reviewed. The 46 discrete studies thus included 26 randomized controlled trials, 9 quasi-randomized controlled trials, 4 cross-over designs, 4 case series, 1 prospective cohort study, 1 retrospective case series, and 1 meta-analysis. All studies dealt with adult patients with one exception.[32]

Systematic Review Process

The review team consisted of clinical, research, and academic physical therapists. A critical appraisal form (CAF) was developed

to extract and assess information from the studies, because no existing tool met our needs for appraising this body of literature. As a pilot study, the CAF was used on several articles to refine the appraisal items and information required. Key areas on the CAF included information on study purpose, subject characteristics (ie, age, surgery type, and inclusion/exclusion criteria), study design (ie, type, sample size, treatment groups, randomization, treatment protocol, blinding, and statistical analysis), and results (ie, drop-outs, outcome measures, and statistical significance). Additional information was gathered on methodologic issues such as bias, contamination, and cointervention, as well as any other reliability or validity issues affecting the results and conclusions.

Each study was critically appraised by one of three pairs of team members. A CAF was independently completed by each member of the pair. The pair then met to reach a consensus regarding study quality and validity of the results. Each study then was presented to the entire review team for discussion and group agreement on the validity of the conclusions of the study. Due to the wide heterogeneity of patient populations and the variety of outcome measures, study results were not pooled.

RESULTS

The review team reached a consensus on each of the 46 studies that were systematically reviewed. We were unable to accept the stated conclusions in 35 papers because of multiple methodologic problems (Table 1), which were identified through critical appraisal, including the following:

1. Study design unable to answer research question: in some studies, it was not possible to isolate the effect of IS from that of other treatments, thus no valid conclusions could be drawn about the effect of IS;

2. Compliance with treatment not known: in some studies, compliance with IS or other treatments was not documented, thus making it difficult to validly assess the effect of IS or to compare effects between treatments;

3. Possibility of bias; concerns included nonrandomized treatment allocation, nonblinded outcome measure assessment, and biases stated by investigators in favor of or against a treatment;

4. Cointervention: in some studies, additional therapeutic procedures were applied to either or both of the experimental and control groups, thus making it difficult to assess the "pure" effect of the experimental intervention;

5. Contamination: in some studies, there was an inadvertent application of the experimental procedure to the control group or a failure to apply the procedure to the experimental group;

6. Invalid outcome measures: the definitions of PPC varied widely between studies and included some criteria not generally accepted as indicative of a PPC;

7. Study population not appropriate: in some studies, the population was inappropriate (ie, patients who had undergone lower abdominal surgery or peripheral surgery) with respect to the incidence of PPC; and

8. Statistical analysis not appropriate: concerns included missing statistical analysis, analysis inappropriate for the type of research design (eg, multiple t tests instead of analysis of variance tests), failure to control for baseline differences between groups, high numbers of dropouts, and comparison of data on different days with different numbers of subjects.

Complete lists of the articles not accepted for critical appraisal, as well as the articles from which the stated conclusions were not accepted, are available from the authors on request.

Of the 11 remaining studies, 3 dealt with the short-term physiologic effects of IS (Table 2),[30,33,34] and 8 dealt with the effects of a program of treatment with IS (Table 3).[35–42] We reviewed articles dealing with short-term physiologic effects because they were thought to be germane to the central question of whether or not IS is effective. None of the three studies of short-term effects supported the proposed theoretical benefits of IS. The critical appraisal of the eight articles on treatment effects indicated seven nonsupportive studies[35–41] and one supportive study.[42] The supportive study reported that IS, DB, and IPPB all were more effective than no treatment.[42]

DISCUSSION

This systematic review of the literature indicated that the balance of evidence does not support the use

Table 1—Summary of Methodologic Flaws Found in the 35 Studies From Which Stated Conclusions Were Not Accepted

Methodologic Flaw	Studies With This Flaw, No.
Study design unable to isolate effect of IS	11
Compliance with treatment not documented	17
Possibility of bias	
Treatment allocation not randomized	12
Outcome assessment not blinded	10
Stated bias by author(s)	4
Cointervention	7
Contamination	11
Outcome measures not valid	18
Study population not appropriate for PPC	3
Statistical analysis not appropriate	20

Table 2—Summary of the Studies Looking at Short-term Effects of IS*

Study/yr	Study Type	Population	Protocol	Primary Result
Chuter et al[30]/1988	CS	Post-UASx (n = 8 women)	IS, 8 breaths	IS failed to increase diaphragmatic movement (abdominal contribution to VT)
Gale and Sanders[33]/1977	CS	Post-cardiac Sx (n = 34)	IS, 20 min, qid	IS increased VC in 2 Rxs on POD 1; no effect on PaO$_2$
Paul and Downs[34]/1981	CO	Post-CABG surgery (n = 8 men)	IS, IPPB, and PEEP; 10-min Rx	IS had little or no effect on end-expiratory transpulmonary pressure (marker for FRC)

*CO = cross-over study; CS = case study; PEEP = positive end-expiratory pressure; POD = postoperative day; rep = repetitions; Rx = treatment; Sx = surgery; UASx = upper abdominal surgery; VC = vital capacity; VT, tidal volume.

of IS for preventing PPCs following cardiac or upper abdominal surgery. Our results may have implications for the current postoperative care of these two patient populations.

In our review, we minimized bias by using an extensive search strategy, including both computer-based and hand searches. Our objective was to identify the best clinical evidence available to answer our research question. Two reviewers independently assessed the validity of each study using a standardized CAF and well-established criteria. Consensus on the validity of each study was reached by the entire review team.

For a wide variety of methodologic reasons (see Table 1), we did not accept conclusions from 35 articles that we critically appraised. Of these articles,

18 were inconclusive with respect to any positive effect of IS, 7 were supportive of IS, and 10 were nonsupportive of IS. Thus, we do not think that our rigorous methodologic review substantially altered the conclusion that we may have reached by including all identified articles in a less-stringent review process.

We did not use conclusions from studies in which compliance with the IS protocol was not objectively measured. The issue of monitoring compliance deserves special mention as it is not possible to accurately assess the effect of IS (or any treatment) without critical information regarding the extent of compliance with the treatment protocol. One of the proposed benefits for IS is that patients can assume responsibility for their own treatment, thus reducing

Table 3—Summary of the Studies Investigating Effects of Treatment With IS*

Study/Year	Study Type	Population	Groups/Protocol	Primary Result
Gale and Sanders[35]/1980	RCT	Post-cardiac Sx (n = 109)	IS (n = 52); IPPB (n = 57)/20 min, qid	Use of IS qid is no better than IPPB in preventing atelectasis
Dull and Dull[36]/1983	RCT	Post-cardiac Sx (n = 49)	EM (n = 16); EM + IS (n = 17); EM + DB (n = 16)/10 reps, qid	IS or DB, in conjunction with EM, offers no advantage over EM alone for preventing PPCs or returning lung volumes to preoperative values
Stock et al[37]/1984	RCT	Post-median sternotomy (n = 38)	IS (n = 12); CPAP (n = 13); DBC (n = 13)/15 min, q2h	No difference between treatment groups in PFT result postsurgery (FVC, FEV$_1$, FEV$_1$/FVC, and FRC)
Matte et al[38]/2000	RCT	Post-cardiac Sx (n = 90)	IS + PT (n = 30)/20 reps/2 h CPAP + PT (n = 30); bilevel PAP + PT (n = 30)/both 1 h/3 h	Bilevel PAP and CPAP are better than IS for changes from POD 1 to POD 2 in VC, FEV$_1$, and venous admixture
Celli et al[42]/1984	RCT	U & L AbSx (n = 172)	IS (n = 42); IPPB (n = 45); DB (n = 41); No Rx (n = 44)/15 min, qid	IS, DB, and IPPB are all more effective than no treatment for preventing PPCs
Stock et al[39]/1985	RCT	Post-UASx (n = 65)	IS (n = 22); CPAP (n = 23); DBC (n = 20)/15 min, q2h	IS is no different from DBC, and CPAP is better than DBC in PFTs postsurgery
Schwieger et al[40]/1986	RCT	Post-UASx (n = 40)	IS (n = 20); No Rx (n = 20)/150–200 times/d	IS is no better than no treatment for incidence of PPC
Ricksten et al[41]/1986	RCT	Post-UASx (n = 43)	IS + PT (n = 15); PEP + PT (n = 15); CPAP + PT (n = 13)/30 breaths, q1h	CPAP and PEP are superior to IS for gas exchange (P[A-a]O$_2$), preservation of lung volumes, and development of atelectasis

*EM = early mobilization; PT = physical therapy; PFT = pulmonary function test; RCT = randomized controlled trial; U & L AbSx = upper and lower abdominal surgery. See Table 2 for other abbreviations not used in text.

the amount of direct patient contact time with the therapist. However, if a therapist must administer the IS treatment to ensure compliance, such benefits (and their cost implications) disappear. In this regard, it is instructive that even in articles in which compliance was measured objectively by means of direct therapist administration,[35–42] only one supported the use of IS.[42]

We found three acceptable studies that investigated the effects of a single IS treatment.[30,33,34] We included these articles in our review in an attempt to validate the purported "short-term" physiologic effects of IS. However, these studies failed to show any benefit of IS on diaphragm function (measured by the abdominal contribution to tidal volume) following upper abdominal surgery,[30] or either PaO_2 [33,34] or end-expiratory transpulmonary pressure (a marker for functional residual capacity [FRC])[34] following cardiac surgery. Thus, it appears that at least some of the theoretical physiologic rationale for IS is not supported by the available clinical literature.

We identified eight acceptable studies that investigated the effects of an IS treatment program, either as a stand-alone treatment[35,37,39,40,42] or as adjunct treatment.[36,38,41] Seven of the eight studies failed to support any positive effect of IS.[35–41] Four of the eight studies dealt with cardiac surgery and are discussed below in chronologic order. Gale and Sanders[35] compared the effect of 20 min (qid) of IS or IPPB on atelectasis in patients who have undergone cardiac surgery and reported no difference in the incidence rates between groups. Dull and Dull[36] investigated the effects of early mobilization alone (qid) compared to early mobilization plus 10 breaths of either IS or DB in patients who have undergone cardiac surgery. There were no differences among the three treatment programs in improving lung volumes or preventing PPCs. This is one of the few studies to include a control group in the research design. Stock et al[37] compared the effects of 15 min (q2h) of IS, continuous positive airway pressure (CPAP), or DB and coughing (DBC) on pulmonary function in patients who have undergone median sternotomy for a variety of cardiac surgeries. Stock et al[37] were unable to find any differences between treatment groups for FVC, FEV_1, FEV_1/FVC ratio, or FRC, but they did suggest that CPAP was less painful and hence may be preferable to either IS or DBC. However, with no control group in this study, it was not possible to determine whether any of the three treatments were more effective than no treatment. The final study using cardiac surgery patients compared the effects of IS to CPAP and bilevel positive airway pressure (PAP).[38] All patients also received standard chest physiotherapy. On postoperative day 2, both CPAP and bilevel PAP reduced venous admixture and improved vital capacity, FEV_1, and PaO_2 to a significantly greater extent than did IS.

A summary of these four studies indicates one study in which IS produced a worse effect than other treatments,[38] two studies (without control groups) in which IS was equivalent to other treatment options,[35,37] and one study in which IS plus a control treatment was no better than a control treatment alone.[36] Thus, following cardiac surgery, there is little evidence to support the use of supervised IS when it is used either as stand-alone therapy or adjunct therapy.

The four remaining studies involved abdominal surgery, and three of these indicated no support for the use of IS. Stock et al[39] compared the effects of 15 min (q2h) of IS, CPAP, and DBC on the incidence of PPCs and on pulmonary function test results in patients who have undergone upper abdominal surgery. No difference was found between treatment groups for FVC, FEV_1, or incidence of atelectasis; however, there was no control group in this study. Schwieger et al[40] compared IS to a no-treatment control group and reported no difference between groups on either postoperative day 2 or day 4 with respect to PaO_2, pulmonary function test results, or the incidence of PPCs. This is a noteworthy result given the presence of a true control group in this design. Finally, Ricksten et al[41] compared the effects of 3 days of hourly (30 breaths) IS, CPAP, and positive expiratory pressure (PEP) on gas exchange, lung volumes, and development of atelectasis. All patients also received standard postoperative chest physiotherapy. Both CPAP and PEP were superior to IS for alveolar-arterial oxygen pressure difference $(P[A-a]O_2)$, FVC, and the incidence of atelectatic consolidation.

Only one article provided support for the use of IS. Celli et al[42] compared a no-treatment control group to groups receiving 15 min (q2h) of IS, IPPB, or DB in patients who had undergone both upper and lower abdominal surgery. Compared to no treatment, the three treatment techniques were equally more effective in preventing PPCs. The authors suggested that IS may be preferable following upper abdominal surgery because it appeared to shorten the patient's length of stay. Two points should be noted from this study. The first is that both upper and lower abdominal surgical procedures were included, and lower abdominal surgical procedures are not associated with high rates of PPCs. The second point is that the study was conducted > 16 years ago, when hospital length of stay following abdominal surgery (9 to 13 days) was considerably longer than it is at present. A summary of the four studies involving abdominal surgery indicates one study in which IS

was less effective than other treatments,[41] one study in which IS was equally more effective than no treatment,[42] one study (with no control group) in which IS was equivalent to other treatments,[39] and one study in which IS was no better than a no-treatment control condition.[40] Thus, as for cardiac surgery, the balance of evidence does not support the use of IS following abdominal surgery.

We were not able to extend our conclusion to thoracic surgery. We found only two relevant articles[43,44] dealing with IS and thoracic surgery. Both were in the pool of articles from which we could not accept the authors' conclusions due to methodologic problems. However, neither of these studies provided any support for either short-term effects[43] or treatment effects[44] of IS following thoracic surgery. Additional, properly conducted studies are required in this area as postoperative complication rates are generally higher in thoracic surgery compared with cardiac or upper abdominal surgery.

Two articles have highlighted changes in surgical practice that may have a greater effect on the incidence of PPCs than the effect of any treatment. Hall and colleagues[45] compared the incidence of PPCs after laparoscopic cholecystectomy (n = 37) and after open cholecystectomy (n = 58) in a generally well-designed and described study. All patients were encouraged to use an incentive spirometer at least 10 times per hour while awake. Risk factors for PPCs were equitably dispersed between the groups. There was a significant difference in the incidence of PPCs between the laparoscopic group (2.7%) and the open-surgery group (17.2%).

A second study evaluated whether chest physiotherapy affected the postoperative course in a consecutive series of laparoscopic abdominal surgery patients (fundoplication group, 40 patients; vertical banded gastroplasty group, 40 patients).[46] Half of each surgical group was randomly assigned to a no-treatment control group that received no information or training. Chest physiotherapy for all treatment patients included preoperative information regarding breathing exercises, huffing and coughing, and the importance of early mobilization. Fundoplication patients performed breathing exercises using the pursed-lip technique, while the vertical banded gastroplasty group used PEP masks. The protocol for both treatment groups was 30 deep breaths with huffing and coughing between every 10th breath, repeated every 2 h under nursing staff and physiotherapist supervision. Compliance was stated to be satisfactory. There was no difference between the treatment group and the control group for either type of surgery, indicating that routine chest physiotherapy is not necessary in patients undergoing these laparoscopic procedures.

Two other studies provided intriguing results for other patient populations and modified IS equipment. Tan[47] reported a positive effect of adjunct IS on postoperative FVC and $P(A-a)O_2$ in 15 patients who had undergone major head and neck surgery. There were eight control (standard postoperative physical therapy) subjects. The IS was connected to a Shiley tracheostomy tube using anesthesia tubing. Tan noted that poor compliance with the protocol (10 times per hour for a minimum of 8 h/d) was an initial concern, but extensive encouragement by the health-care team and family members enabled all 15 subjects to complete the protocol. Although this study reported a positive effect, it should be noted that the chest wall was intact in these patients and that much of the upper airway was bypassed by the technique of connecting the IS directly to the tracheostomy tube. In addition, it is not clear how the randomization process resulted in a treatment group twice as large as the control group. A follow-up study is needed to confirm these interesting results in this very specific patient population.

Baker et al[48] used a one-way valve to permit breath stacking in 26 patients who were recovering from surgery, trauma, or critical illness. Patients breathed from a spirometer filled with 100% oxygen. The breath-stacking maneuver increased the inspired volume by 15 to 20% over the standard inspiratory capacity procedure, suggesting that one-way valving helps to achieve and maintain deep inspiration even in patients with poor inspiratory efforts, thus potentially improving collateral ventilation. The measurement of regional excursion of the chest and abdomen would be required to assess the possibility of altered gas distribution, and a randomized clinical trial would be necessary to assess any treatment benefit related to this short-term effect.

This systematic review was limited by the following factors. First, we retrieved articles written in English only; thus we may not have reviewed all relevant studies. However, we do not think that it is likely that the balance of evidence would have been affected by incorporating articles written in other languages, and many of the articles we selected were written by researchers in countries where English is not the first language. Second, we did not search supplements of relevant journals for abstracts not published as peer-reviewed articles. Third, we did not attempt to contact all authors to clarify or seek out information not clearly available in their articles. The effect of this on our conclusions is not known. It was our feeling that the absence of important information regarding methodologic concerns was suggestive that such concerns had not been addressed in the study.

If the balance of evidence from the best available studies fails to support the use of IS for decreasing the incidence of PPCs following cardiac or upper abdominal surgery, should IS continue to be used in the treatment of these patients? We did not deal with the financial aspects of this question as the costs of IS are affected by many factors, including the type of spirometer and the method of use (*ie*, single use vs reuse following sterilization). It should also be pointed out that we found no evidence that the use of IS was associated with any harmful side effects in any of the 46 studies that were critically appraised. However, given the need for clinical practice to be responsive to the evidence base, we believe that the results of this systematic review indicate that IS should not be used following cardiac or abdominal surgery.

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