Clinical Effectiveness of Incentive Spirometry for the Prevention of Postoperative Pulmonary Complications

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Incentive spirometry (IS) is commonly prescribed to reduce pulmonary complications, despite limited evidence to support its benefits and a lack of consensus on optimal protocols for its use. Although numerous studies and meta-analyses have examined the effects of IS on patient outcomes, there is no clear evidence establishing its benefit to prevent postoperative pulmonary complications. Clinical practice guidelines advise against the routine use of IS in postoperative care. Until evidence of benefit from well-designed clinical trials becomes available, the routine use of IS in postoperative care is not supported by high levels of evidence. *Key words: incentive spirometry; review of evidence; use procedure; respiratory care; postoperative care; compliance; hospital-acquired pneumonia; atelectasis.* [Respir Care 2018;63(3):347–352. © 2018 Daedalus Enterprises]

Introduction

Incentive spirometry (IS) is widely prescribed to prevent postoperative pulmonary complications. In the United States, respiratory therapists and nurses are responsible for instruction and monitoring of patients receiving IS.[1] Intermittent reassessment of patient performance after initial instruction is recommended. However, the amount of time

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that providers spend on IS-related activities has not been reported, nor have optimal use procedures been established. In this article, we review the current state of IS and question its role in the management of postoperative pulmonary complications.

History

In the 1960s, intermittent positive-pressure breathing (IPPB) was commonly used to prevent postoperative pulmonary complications. However, IPPB came under scrutiny at the Sugarloaf Conference, where it was determined that there was not sufficient evidence to support its use.[2,3] Coincidental with the criticism of IPPB, the incentive spirometer was introduced by Bartlett et al[4] after observations that yawning might generate pulmonary benefits for postoperative patients. Deciding that it was the sustained inspiration of yawning that yielded the benefit, the group constructed a device to coach patients to emulate a yawning-like sustained maximal inspiration in an effort to prevent atelectasis. The inventors' early data from postoperative patients performing sustained maximal inspiration demonstrated improvement in ventilation/perfusion mismatch and alveolar-P_{aO_2} gradient, the latter suggestive of alveolar inflation and subsequent reduction in intrapulmonary shunt. When sustained maximal inspirations were repeated each hour, P_{aO_2} levels remained near normal. These preliminary findings came to define the anticipated physiologic effects of IS.

In 1973, the Bartlett-Edwards IS device was introduced to incentivize deep breathing by providing visual light feedback when patients achieved their inspiratory target volume.[4] In 1975, the Spirocare device further enhanced the electronic IS visual feedback by putting the display lights on a scale indicating increasingly larger inspiratory volumes, attempting to gamify patient engagement and adherence.[5] These electronic IS devices were in use for many years but have been replaced by less expensive, disposable units.

Device Types

IS devices are either flow-oriented or volume-oriented. Flow-oriented IS devices consist of a chamber with 3 interconnected columns in which lightweight plastic floats are seated. The chamber is connected to a flexible tube with a mouthpiece through which the patient inhales, attempting to raise the floats through inspiratory flow created by negative intrathoracic pressure. Volume-oriented IS devices consist of a flexible tube with a mouthpiece connected to a chamber that has volume measurements displayed. When the patient inhales, a piston in the chamber rises to the maximum volume of air displaced. Clinical practice guidelines suggest that volume-oriented devices are preferable due to lower imposed work for breathing.[1]

Table 1. Variety of Clinical Approaches for Incentive Spirometry Use

Parameter	Suggestion
Frequency of sessions	Every 10 min[1]
	Every 1 h[6]
	Every 2 h[6]
	2 times/d[7]
	4 times/d[8–10]
	5 times/d[11–14]
	12 times/d[15,16]
	4 times/h[20]
	3 times/h[21]
	Every 4 h[17–19]
	10 times/h[22]
	30 times/h[23]
Target inspiratory volume	50–70% of preoperative vital capacity[24]
	1,400–1,770 mL[25]
	200–2,000 mL[26]
	Maximal inspiration above residual volume[17]
Number of breaths per session	3[19]
	3–5[14]
	5[18]
	10[16]
	15[25,27]
	20[28]
Duration of breath holds	5 s[8–11,17,18,20]
	3 s[22]
	For as long as possible[12]
Perioperative incentive spirometry use	The first 3 d after surgery[44]
	The first 4 d after surgery[45]
	Starting 4–72 h after surgery[1]
	Both preoperatively and during the first 5 postoperative days[14,16,17,19,24]
	For 3 d after surgery[31]
	For 5 d after surgery[30]
	Beginning 1 h after surgery for the next 3 d[10,29]
	Beginning 4 h after extubation[14]
Graduated use procedures	Increasing inspiratory target volume[9]
	Increasing both volume and breath-hold duration[26]
	Decreasing frequency[18]

Clinical Application

A variety of clinical approaches for IS have been suggested (Table 1). Indeed, there seems to be no standardization of approach. IS has been recommended to be performed every 10 min,[1] hourly,[6] every 2 h,[6] 2 times per day,[7] 4 times per day,[8-10] 5 times per day,[11-14] 12 times per

day,[15,16] every 4 h,[17-19] 4 times per hour,[20] 3 times per hour,[21] 10 times per hour,[22] or 30 times per hour.[23] Target inspiratory volume has been set at 50–70% of preoperative vital capacity,[24] at 1,400–1,770 mL,[25] at 200–2,000 mL,[26] or at maximal inspiration above residual volume.[17] Patients have been instructed to complete 3,[19] 3–5,[14] 5,[18] 10,[16] 15,[25,27] or 20 breaths per session.[28] The recommended duration of end-inspiratory breath-hold has been 5 s,[8-11,17,18,20] 3 s,[22] or for as long as possible.[12] IS has been prescribed for the first 3 d[44] or 4 d[45] after surgery, starting 4–72 h after surgery,[1] both preoperatively and during the first 5 postoperative days,[14,16,17,19,24] for 3 d[31] or 5 d[30] after surgery, beginning 1 h after surgery and continuing for the next 3 d,[10,29] or starting 4 h after extubation.[14] Some studies report changing the use procedure during the hospital course, including increasing inspiratory target volume,[9] increasing both volume and breath-hold duration,[26] and decreasing frequency.[18]

Systematic Reviews

Thomas and McIntosh[32] assessed the efficacy of IS, IPPB, and deep-breathing exercises in the prevention of postoperative pulmonary complications in patients undergoing upper abdominal surgery. The odds ratio for the occurrence of pulmonary complications for IS versus no physical therapy was 0.44 in favor of IS. The odds ratio for deep-breathing exercises versus no physical therapy was 0.43 in favor of deep-breathing exercises. The authors concluded that IS and deep-breathing exercises appear to be more effective than no therapy to prevent postoperative pulmonary complications, but evidence is lacking to support a significant difference between the modalities.

Overend et al[33] conducted a systematic review on the use of IS for preventing postoperative pulmonary complications. In 35 of 46 included studies, they were unable to accept the stated conclusions due to flaws in methodology. Appraisal of the 11 remaining studies found that in 10 studies there was no positive short-term effect of IS after cardiac or abdominal surgery. In the only supportive study, IS, deep breathing, and IPPB were equally more effective than no treatment in preventing postoperative pulmonary complications after abdominal surgery. They concluded that the evidence does not support the use of IS to decrease the incidence of postoperative pulmonary complications after cardiac or upper abdominal surgery.

Carvalho et al[34] conducted a systematic review of 30 studies (14 abdominal surgery, 13 cardiac surgery, and 3 thoracic surgery, including a total of 3,370 subjects). Five studies (3 abdominal surgery, 1 cardiac surgery, and 1 thoracic surgery) compared the effect of the IS with a control group of no intervention, and no difference was detected in the evaluated outcomes. The authors concluded that there was no evidence to support the use of IS in the management of surgical subjects.

A Cochrane review limited to subjects following coronary artery bypass graft included 592 subjects from 7 studies.[35] There was no evidence of a difference between groups in the incidence of pulmonary complications with IS and treatment with physical therapy, positive-pressure breathing techniques, active cycle of breathing, or preoperative patient education. Subjects treated with IS had worse pulmonary function and arterial oxygenation compared to those treated with positive-pressure breathing. There was no improvement in the muscle strength with IS. The authors concluded that there was no evidence of benefit from IS in reducing postoperative pulmonary complications and in decreasing the negative effects on pulmonary function in patients undergoing coronary artery bypass graft.

Another Cochrane review assessed the effect of IS on postoperative pulmonary complications and mortality in adults undergoing upper abdominal surgery.[36] They included 12 studies with a total of 1,834 subjects, and they were able to include data from 1,160 subjects in the meta-analysis. There were 4 trials (152 subjects) that compared the effects of IS with no respiratory treatment, with no significant difference in postoperative pulmonary complications. In 2 trials (194 subjects), IS was compared with deep-breathing exercises, with no significant effect of IS. In 2 trials (946 subjects) that compared IS with other chest physiotherapy, there was again no significant effect of IS. The authors concluded that there is low-quality evidence regarding the lack of effectiveness of incentive spirometry for prevention of postoperative pulmonary complications after upper abdominal surgery.

Agostini and Singh[37] conducted a systematic review of IS after thoracic surgery. They concluded that physiological evidence suggests IS may be appropriate for lung re-expansion after major thoracic surgery. On the basis of sparse literature, postoperative physiotherapy regimes with or without the use of IS appeared effective after thoracic surgery compared with no physiotherapy. Interestingly, the same group[30] did a later randomized, controlled trial, where they reported that IS did not improve overall recovery of lung function, frequency of postoperative pulmonary complications, or stay.

Subsequent to the publication of these systematic reviews, Cassidy et al[25] reported the result of a program designated by the acronym I COUGH, which emphasizes incentive spirometry, coughing, deep breathing, oral care (eg, brushing teeth and using mouthwash twice daily), understanding (ie, patient and family education), getting out of bed at least 3 times daily, and head of bed elevation. Implementation of this protocol resulted in a reduction in postoperative pneumonia and unplanned intubations. Unfortunately, the individual elements of

Table 2. Recommendations From the 2011 American Association for Respiratory Care Clinical Practice Guidelines on Incentive Spirometry

1. Incentive spirometry alone is not recommended for routine use in the preoperative and postoperative setting to prevent postoperative pulmonary complications.
2. It is recommended that incentive spirometry be used with deep-breathing techniques, directed coughing, early mobilization, and optimal analgesia to prevent postoperative pulmonary complications.
3. It is suggested that deep-breathing exercises provide the same benefit as incentive spirometry in the preoperative and postoperative setting to prevent postoperative pulmonary complications.
4. Routine use of incentive spirometry to prevent atelectasis in patients after upper-abdominal surgery is not recommended.
5. Routine use of incentive spirometry to prevent atelectasis after coronary artery bypass graft surgery is not recommended.
6. It is suggested that a volume-oriented device be selected as an incentive spirometry device.

From Reference 1.

the bundle were not tested alone, and thus it is not possible to know the extent to which IS contributed to the improved outcomes.

In 2017, Pantel et al[38] reported the results of a randomized clinical trial that compared the use of postoperative IS to no use of IS after bariatric surgery. Postoperative IS did not demonstrate any effect on postoperative hypoxemia or postoperative pulmonary complications. Interestingly, although IS was prescribed for use 10 times per hour, the adherence rate was much lower at about 4 times per day on the first postoperative day and 10 times per day on the second postoperative day.

Clinical Practice Guidelines

Several clinical practice guidelines from the American Association for Respiratory Care have addressed the clinical application of IS. These guidelines do not support the use of IS to prevent postoperative pulmonary complications. From the guidelines published in 2011,[1] IS alone is not recommended for routine use in the preoperative and postoperative setting to prevent postoperative pulmonary complications. Routine use of IS to prevent atelectasis in patients after upper-abdominal surgery is not recommended, and routine use of IS to prevent atelectasis after coronary artery bypass graft is not recommended (Table 2). From the guidelines published in 2015,[39] IS is not recommended for routine prophylactic use in postoperative patients. Rather, early mobility and ambulation is recommended to reduce postoperative pulmonary complications and promote airway clearance.

Why Have the Studies Been Negative?

Poor Methodology

It is important to point out that poor study methodology complicates the ability to interpret studies of IS efficacy. This has been noted in the meta-analyses.[32-37] Methodological flaws include imprecise procedure descriptions, lack of standardized outcomes, lack of appropriate control comparisons, underpowered studies, and an inability to isolate IS effects due to co-intervention. Meta-analyses of methodologically flawed data cannot resolve conflicting results.[40]

Adherence

Narayanan et al[41] suggest that a major confounder in IS trials is the scarcity of data on patient adherence. They reported that only 16.6% of IS studies included mention of adherence rates, and the reported adherence data were not comprehensible due to omitted specific datasets, aggregated population values over the whole intervention period, arbitrary classifications of good adherence, and poorly kept patient-recorded adherence logs. Without accurate adherence data, valid assessment of IS efficacy cannot occur. The results of the study by Pantel et al[38] suggest that adherence is much less than prescribed. A therapy like IS that requires a very high level of adherence may not be practical.

Perhaps IS Is Not Effective

IS might well be one of those procedures that intuitively seems that it would improve pulmonary function but, in reality, does not affect important patient outcomes. In many hospitals, there is little patient supervision of IS after initial instruction, meaning that patient adherence is likely suboptimal. It seems that IS is a procedure for which patients lack motivation. The benefits of IS might be realized with closer supervision by health care providers, such as respiratory therapists or nurses. However, this is not practical in the U.S. health care delivery system. In patients at high risk for postoperative pulmonary complications, perhaps efforts should be directed toward optimizing pain control, early mobilization, and positive-pressure techniques such as CPAP[42] or noninvasive ventilation.[43] To determine whether there are specific patients for whom IS might be of value requires additional well-designed clinical trials of patients particularly prone to de-recruitment. For the specific population after bariatric surgery, the results of the study by Pantel et al[38] suggests that IS is not effective. Physiologic studies, aiming at understanding the effects of IS, should be the key to design clinical studies

including involving the right patients with the right IS maneuver.

Summary

Given the cost of implementing IS, the low adherence rate, and the lack of reported benefit, it is worth considering whether IS should continue to be prescribed. Despite the paucity of efficacy and adherence data, physicians often prescribe IS in an effort to do something to reduce postoperative pulmonary complications without knowing what exactly is being prescribed, the effort required of the patient, and the relatively low adherence rate. Given their expertise in working to optimize patients' postoperative pulmonary outcomes, respiratory therapists can play an integral role in educating providers about the dearth of evidence supporting IS. Further study is needed to determine which specific patient groups, if any, might benefit from IS.

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