RESPIRATORY CARE Paper in Press. Published on August 25, 2020 as DOI: 10.4187/respcare.07972

Incentive Spirometry for Prevention of Postoperative Pulmonary Complications After Thoracic Surgery

Prasanti A Kotta and Jason M Ali

Incentive spirometry is frequently used after thoracic surgery as an adjunct to physiotherapy. Despite its widespread use, it has remained challenging to demonstrate a clinical benefit in terms of either incidence of postoperative pulmonary complications or hospital stay. In this literature review, we have observed that, although there is no study supporting clinical benefit in the thoracic surgical patient population generally, there is now emerging evidence of benefit in higher-risk patient populations such as those with COPD. There is an indication that incentive spirometry can lead to a reduction in the incidence of postoperative pulmonary complications in these patients. The problem with studies published to date is that there are many limitations, not least of which is the challenge of achieving patient adherence with performing incentive spirometry as prescribed. Despite the lack of evidence, there remains an appetite for persevering with incentive spirometry in the postoperative thoracic surgical patient because it is a relatively inexpensive intervention that motivates many patients to perform regular breathing exercises long after the therapist has moved on to the next patient. *Key words: incentive spirometry; physiotherapy; thoracic surgery; pulmonary complications.* [Respir Care 0;0(0):1–●. © 0 Daedalus Enterprises]

Introduction

Postoperative pulmonary complications (PPCs) are the most common complication seen after thoracic surgery.[1] The incidence of PPCs after thoracic surgery has been reported to be between 19% and 59%.[2] It is recognized that there is a high incidence of atelectasis in patients undergoing any general anesthesia due to the high oxygen concentration used and reduced muscle tone, and that this can persist for several days.[3] Atelectasis leads to secretion retention and regional hypoventilation, both of which can contribute to the development of PPCs. In thoracic surgery, this can be even more pronounced due to postoperative chest wall pain that, if not well controlled, leads to hypoventilation and impairs the resolution of atelectasis.

Sustained deep breathing is thought to recruit collapsed alveoli and restore preoperative pulmonary function in thoracic surgical patients.[4] Physiotherapy plays an essential role in the recovery of thoracic surgical patients. In particular, airway clearance techniques, such as teaching patients breathing exercises to reduce the impact of the atelectasis,

Ms Kotta is affiliated with the School of Clinical Medicine, University of Cambridge, Cambridge, United Kingdom. Dr Ali is affiliated with the Department of Cardiothoracic Surgery, Royal Papworth Hospital, Cambridge, United Kingdom.

The authors have disclosed no conflicts of interest.

Correspondence: Jason M Ali PhD, Department of Cardiothoracic Surgery, Royal Papworth Hospital, Cambridge, CB2 0AY, United Kingdom. E-mail: ja297@cam.ac.uk.

DOI: 10.4187/respcare.07972

RESPIRATORY CARE Paper in Press. Published on August 25, 2020 as DOI: 10.4187/respcare.07972

have been shown to have a positive impact on reducing the incidence of PPCs.[5] Incentive spirometry (IS) is a technique that allows patients to perform deep breathing exercises independently with visual feedback of inspiratory effort. This technique is thought to increase the accuracy of deep breathing techniques and to encourage patients to perform deep breathing exercises.[6] Given this physiological theory, there has been increasing use of IS over recent years with the belief that it can enhance a patient's recovery after surgery and reduce the risk of PPCs.[7] However, there is much debate about the true clinical effectiveness of IS.[8]

IS Devices and Theory

Atelectasis management involves removal of retained secretions and stretching the lung tissue sufficiently to achieve parenchymal re-expansion.[9] The "ideal" deep-breathing technique to re-expand collapsed alveoli was originally described by Bartlett et al,[6] who reported that a long, slow inspiration with an inspiratory hold for several seconds is required to achieve optimal re-expansion. IS was designed to allow patients to perform this breathing technique more accurately and enthusiastically by providing them with visual feedback of their inspiratory effort.

There are 2 types of IS devices: flow-oriented and volume-oriented. Flow-oriented IS devices typically consist of 3 interconnected columns, each containing a lightweight plastic float that acts as a marker. The columns are connected to a mouthpiece through which the patient inhales. The deep-breathing exercise with this device involves the patient attempting to lift the float, through inspiratory flow, to a certain point in the columns for a certain amount of time. The volume-oriented device consists of a mouthpiece connected to a chamber with a visible scale. The deep-breathing exercise with this device involves the patient attempting to lift a marker as high as possible. Clinical practice guidelines recommend the volume-oriented devices to be used postoperatively because they are considered to impose lower work of breathing, pain, and fatigue.[10,11]

Outcomes in Thoracic Surgery

In 2009, Agostini and Singh[12] reviewed 3 randomized controlled trials (RCTs), 1 cross-sectional study with historical control, and 1 systematic review comparing the effects of postoperative physiotherapy and IS in subjects who underwent thoracic surgery. The authors reported that there is little evidence of benefit of IS after thoracic surgery. They concluded that studies looking into the clinical effectiveness of IS after thoracic surgery were sparse in number, not adequately powered, and incomparable due to different outcome measures studied. They identified a need for more adequately powered studies with well-defined outcome measures to better evaluate the treatment benefit of IS in thoracic surgery patients. Since the publication of this review, there have been 4 further studies[13-16] with 8,166 subjects investigating the clinical effectiveness of IS in the postoperative management of thoracic surgery patients. Three were RCTs, and one was a population-based observational study (Table 1). T1,AQ:E

Liu et al[13] performed a retrospective, population-based observational study utilizing Taiwan's Longitudinal Health Insurance Database for Catastrophic Illness Patients. They identified 7,549 subjects with lung cancer who underwent surgical lung resection by video-assisted thoracoscopic surgery (VATS) or thoracotomy between 2000 and 2008. Subjects in the experimental arm were prescribed IS for 7 d after admission, and the control group included subjects who were not prescribed IS postoperatively. The experimental group had a lower prevalence of asthma and a higher proportion of subjects who had received neoadjuvant therapy ($P < .05$). They found that subjects in the experimental group had lower hospitalization costs in both the VATS and thoracotomy cohorts ($P < .05$). Subjects who underwent VATS and received postoperative IS had a lower incidence of pneumonia (3.09% vs 5.46%, $P < .05$), but a statistically significant reduction in pneumonia incidence was not observed in the cohort of subjects who underwent thoracotomy (5.56% vs 6.19%, $P > .05$). The authors concluded that there may be selective benefit conferred by IS in patients undergoing VATS with the reduced hospitalization cost and reduced incidence of pneumonia.

Malik et al[14] performed an RCT with 387 subjects undergoing lung resection in Canada between 2014 and 2017. They investigated whether any incremental benefit was conferred by the addition of IS to standard physiotherapy. They confirmed similar patient demographics in both groups. Subjects in the experimental arm received IS in addition to standard physiotherapy, whereas subjects in the control arm received only standard physiotherapy. Subjects in both groups had a similar incidence of PPCs (12.3% vs 13.0%, $P = .88$). Examining individual complications also revealed no significant differences: pneumonia ($P = .21$), atelectasis ($P > .99$), requirement for bronchoscopy ($P = .64$), and requirement for mechanical ventilation ($P = .69$). The addition of IS also had no impact on length of hospital stay, with both groups showing a median length of stay of 4 d ($P = .34$). In a subgroup analysis of subjects undergoing minimally invasive or open thoracic surgery, the authors observed similar findings. The incidence of PPCs were reduced in the subgroup of subjects with COPD receiving IS, although this did not reach statistical significance (9.3% vs 16.4%, $P = .39$). The authors concluded that their findings did not support the addition of IS to the postoperative care of patients who underwent pulmonary resection. However, it is worth emphasizing that the authors were attempting to show an incremental benefit above physiotherapy, and despite this

RESPIRATORY CARE Paper in Press. Published on August 25, 2020 as DOI: 10.4187/respcare.07972

Table 1. Summary of Studies Examining Incentive Spirometry After Thoracic Surgery

Study	Study Location	Study Type	Level of Evidence	Subjects	Outcomes	Key Results	*P*
Liu et al[13]	Taiwan	Population-based observational study	2c	7,549 subjects with lung cancer who underwent surgical resection by VATS (1,440) or thoracotomy (6,145) from the LHID-CIP (2000–2008)	Hospitalization cost		
					VATS non-IS group	$5,536.50	< .05
					VATS IS group	$5,295.50	
					Thoracotomy non-IS group	$4,904.60	< .001
					Thoracotomy IS group	$4,864.60	
				Control (non-IS group): 659 subjects who underwent VATS and 1,940 subjects who underwent thoracotomy and were not prescribed IS	Pneumonia, %		
					VATS non-IS group	5.46	< .05
					VATS IS group	3.09	
					Thoracotomy non-IS group	6.19	> .05
					Thoracotomy IS group	5.56	
				Experimental (IS group): 745 subjects who underwent VATS and 4,205 who underwent thoracotomy and were prescribed IS for the first 7 d of admission	Mean stay, d		
					VATS non-IS group	18.3	> .05
					VATS IS group	19.3	
					Thoracotomy non-IS group	23.3	> .05
					Thoracotomy IS group	19.5	
Malik et al[14]	Canada	Prospective RCT	1b	387 subjects undergoing lung resection (2014–2017)	PPC, %		
					Control	13.0	.88
					Experimental	12.3	
				Control: 192 subjects who received standard physiotherapy	Pneumonia, %		
					Control	7.8	.21
					Experimental	4.6	
				Experimental: 195 subjects who received IS in addition to standard physiotherapy	Atelectasis, %		
					Control	4.2	>.99
					Experimental	4.6	
					Median length of hospital stay, d		
					Control	4	.34
					Experimental	4	
					Readmission within 30 d , %		
					Control	9.9	>.99
					Experimental	10.3	

(Continued)

RESPIRATORY CARE Paper in Press. Published on August 25, 2020 as DOI: 10.4187/respcare.07972

Table 1. Continued

Study	Study Location	Study Type	Level of Evidence	Subjects	Outcomes	Key Results	P
Gunay et al[15]	Turkey	Prospective RCT	1b	50 subjects who underwent thoracoscopic pleural effusion drainage and pleural biopsy (March 2013 to March 2014)	Increase in FEV_1, L		
					Control	0.35 ± 0.2	< .001
					Experimental	0.2 ± 0.17	
					Increase in FVC, L		
					Control	0.16 ± 0.09	.39
					Experimental	0.13 ± 0.13	
				Control: 25 subjects who received physiotherapy supervised or carried out by physiotherapist	Increase in P_{aO_2}, mm Hg		
					Control	18.40 ± 9.7	.51
					Experimental	216.64 ± 9.12	
				Experimental: 25 subjects who received physiotherapy with IS	In-patient stay, d		
					Control	8.63 ± 3.86	< .001
					Experimental	10.12 ± 3.34	
Agostini et al[16]	United Kingdom	Prospective RCT	1b	180 subjects undergoing thoracotomy and lung resection (October 2008 to October 2010)	Mean ± SD drop in FEV_1 on postoperative day 4, %		
					Control	41 ±14	.82
					Experimental	40 ±16	
					PPC, %		
					Control	15.0	.80
					Experimental	12.5	
					PPC in high-risk patients, %		
				Control: 88 subjects who underwent thoracic expansion exercises with physiotherapist	Control	23%	.41
					Experimental	14%	
					Median (IQR) hospital stay, d		
					Control	6 (3)	.004
					Experimental	5 (3)	
					Median (IQR) HDU stay, d		
					Control	2 (1)	.21
				Experimental: 92 subjects who underwent thoracic expansion exercises with IS	Experimental	2 (1)	

RCT = randomized controlled trial; VATS = video-assisted thoracoscopic surgery; LHID-CIP = Longitudinal Health Insurance Database for Catastrophic Illness Patients; IS = incentive spirometry; PPC = postoperative pulmonary complications; HDU, high dependency unit

RESPIRATORY CARE Paper in Press. Published on August 25, 2020 as DOI: 10.4187/respcare.07972

challenge, there was suggestion of benefit for subjects with COPD.

Gunay et al[15] performed an RCT with 50 subjects who underwent thoracoscopy and pleural biopsy for pleural effusion in Turkey between 2013 and 2014. They compared the outcomes of respiratory physiotherapy with IS alone in the intervention group with the outcomes of physiotherapist-guided physiotherapy in the control group. The authors reported that subjects undergoing physiotherapy had a significantly greater improvement (mean ± SD) in FEV_1 after surgery (0.35 ± 0.2 L vs 0.2 ± 0.17 L, $P < .001$). However, improvements in FVC ($P = .39$), P_{aO_2} ($P = .51$) and S_{aO_2} ($P = .45$) were not significantly different between the groups. There was, however, a significantly reduced length of hospital stay (mean ± SD) in subjects receiving physiotherapy (8.63 ± 3.86 vs 10.12 ± 3.34 d, $P < .001$). The authors concluded that exercises performed under the supervision of a physiotherapist were more effective than IS alone in the postoperative recovery period; however, the authors did not comment on PPCs.

Agostini et al[16] performed an RCT with 180 subjects undergoing thoracotomy and lung resection in the United Kingdom between 2008 and 2010. They aimed to investigate the effectiveness of IS compared with a control group who performed thoracic expansion with deep breathing exercises. There was a notable increase in age ($P < .01$) and American Society of Anaesthesiologists (ASA) grade ($P = .04$) for subjects in the control group. The incidence of PPCs was similar between the groups (12.5% vs 15.0% in the control group, $P = .80$). The authors also performed subgroup analysis on a group of high-risk patients who included subjects over the age 75 y, ASA grade ≥ 3, subjects with COPD, current/recent ex-smokers, or body mass index ≥ 30 kg/m^2. In this high-risk group, they found a reduced incidence of PPCs than in the experimental group (14% vs 23%, $P = .41$) but this did not reach statistical significance due to the small number of subjects. The difference in frequency of PPC, although nonsignificant, was relatively large in subjects with COPD at 19% and current smokers/ex-smokers of ≤ 6 weeks at 15%, with 95% CIs that indicated improved outcomes in those subjects receiving IS. The authors found no significant difference in postoperative lung function, frequency of PPCs, or length of stay between the 2 groups and concluded that their data did not support the hypothesis that IS improves recovery of lung function or reduces the incidence of PPCs. However, they identified that it is difficult to rule out the benefit of IS in high-risk patients.

Outcomes of IS in Other Surgical Specialties

IS use is not restricted to thoracic surgery, and its use is widely documented in other surgical specialties. Odor et al[17] conducted a systematic review and meta-analysis of 95 RCTs with 18,062 subjects that looked at perioperative interventions including IS for prevention of PPCs in noncardiac surgery patients. They concluded that there is evidence of moderate quality that IS offers no benefit in preventing PPCs compared to standard medical care (risk ratio 1.06, 95% CI 0.85–1.34).

A Cochrane review from 2012 investigated the use of IS compared to physical therapy, positive-pressure breathing techniques (including CPAP, bi-level positive airway pressure, intermittent positive-pressure breathing, and active cycle of breathing techniques), or preoperative patient education for preventing PPCs after coronary artery bypass graft surgery.[18] That review included 7 studies with 592 subjects. The authors found no difference between the groups in the rates of PPCs. Subjects treated with IS had worse pulmonary function and arterial oxygenation compared with the positive-pressure breathing group. The authors concluded that there was no evidence that IS reduced PPCs or improved pulmonary function after coronary artery bypass graft surgery.

A Cochrane review published in 2014 investigated the use of IS for preventing PPCs after upper abdominal surgery.[19] The authors included 12 studies with 1,834 subjects. Four studies (152 subjects) compared IS with no respiratory treatment and reported no statistically significant difference between the 2 groups for clinical complications (relative risk 0.59, 95% CI 0.30–1.18). Two studies (194 subjects) compared IS with deep breathing exercise and found no statistically significant differences between the 2 groups in the meta-analysis for respiratory failure (relative risk 0.67, 95% CI 0.04–10.50). Two other studies (964 subjects) compared IS and other chest physiotherapy and found that there was no statistically significant difference between the 2 groups in terms of the risk of developing PPCs. The authors concluded there was no evidence that IS is effective in preventing PPCs.

The other area of surgery in which IS is commonly reported is bariatric surgery.[20] Pantel et al[20] conducted an RCT comparing IS with no IS after bariatric surgery. They found no significant effect of IS in preventing PPCs. However, they identified a low adherence rate for IS use, with IS use at about 4 times per day on postoperative day 1 and 10 times per day on postoperative day 2 compared to the prescribed 10 times per hour.

Should We Persevere With IS in Postoperative Patients?

Considering these data together, there is little evidence supporting the widespread routine use of IS in all patients after thoracic surgery. However, several studies hint at a treatment benefit conferred by IS in high-risk patients, such as those with COPD.[14,16,21] Despite these generally neutral results, IS remains widely used, which suggests that thoracic surgical teams have some confidence in their ability to encourage patients to undertake breathing exercises. It is possible that trials struggle to demonstrate a benefit because subjects within these trials receive enhanced physiotherapy compared to what is normally available outside of a trial setting, perhaps due to the Hawthorne effect.[22]

It is worth noting that there are significant limitations within trials on the use of IS. For example, there is a lack of standardization on the prescription and use of IS between studies, difficulties in achieving blinding with the use of IS devices, lack of appropriate control comparisons, and an inability to isolate IS effects due to co-intervention.[8] These trials may also be underpowered to show differences for the higher-risk groups, which has been suggested in several trials.[11,17] It is also widely recognized that there is significant heterogeneity in the definition of PPCs in the published literature and that this term is used loosely.[23] It is therefore likely that the definition of a chest infection differs significantly between the studies.

Furthermore, in a study that examined patient use of IS in postoperative subjects, 26.2% were not using the device correctly, and 38.1% denied using the device at all.[24] In a similar study that surveyed care providers on their thoughts on IS use in clinical practice, 86% of respondents believed adherence was poor due to patients forgetting to use IS devices, not using them correctly, and not using them frequently enough.[25] Although this may be true, the clinical reality is that providing more patient training and encouraging more frequent use will come at a cost, in addition to the cost of the devices, which may become difficult to justify in the context of numerous studies questioning the clinical benefit of IS. Eltorai et al[26] evaluated the financial impact of implementing IS using prospective questionnaires to evaluate the time spent by health professionals doing IS-related activities and national survey work load data. The authors estimated that the total annual cost of implementing postoperative IS to be $1.04 billion (95% CI $949.4 million to $1.13 billion). One strategy that may be useful in improving adherence and technique is educating patients in the use of the device preoperatively rather than introducing them to the device after surgery, when they are potentially in pain and may not be able to concentrate as easily.[7]

It should be considered that these studies attempt to demonstrate equivalence or superiority of IS over physiotherapy. However, these should not be considered as independent entities, and it is likely that the maximum clinical benefit could in fact come from the use of IS as an adjunct to physiotherapy. In support of this suggestion, IS was included as a component of the multidisciplinary I-COUGH patient care program, which was demonstrated to result in almost halving the incidence of postoperative pneumonia.[27] It should also be considered that correct use of IS may be particularly beneficial for patients after discharge when motivated patients will continue to perform IS at home when physiotherapy is no longer available. The stay following thoracic surgical procedures is typically on the order of a few days, so the true benefit of IS in reducing complications may in fact occur after discharge and may explain why it has been difficult to demonstrate benefit in studies typically focusing on in-hospital outcomes.

Summary

For patients undergoing thoracic surgery, there is limited evidence of clinical benefit in widespread routine use of IS. There is a suggestion of potential benefit for patients at higher risk for the development of PPCs, such as those with COPD, which needs to be investigated further. Despite various studies questioning the efficacy of IS, it continues to be relatively widely used. This may reflect belief that when used effectively, IS can act as a significant motivator to patients to continue performing breathing exercises and contribute to reducing the incidence of PPCs. However, this remains difficult to prove in clinical trials. It may be that, with appropriate preoperative training, and its use as a component of a multidisciplinary package of care, IS can be an effective intervention with benefits lasting long beyond the hospital stay.

REFERENCES

1. Lawrence VA, Cornell JE, Smetana GW, American College of Physicians. Strategies to reduce postoperative pulmonary complications after noncardiothoracic surgery: systematic review for the American College of Physicians. Ann Intern Med 2006;144(8):596-608.
2. Spencer R, McIndoe AK. Preoperative assessment. Anaesth Intensive Care Med 2003;4(10):319-323.
3. Hedenstierna G, Edmark L. Mechanisms of atelectasis in the perioperative period. Best Pract Res Clin Anaesthesiol 2010;24(2):157-169.
4. Bakow ED. Sustained maximal inspiration–a rationale for its use. Respir Care 1977;22(4):379-382.
5. Boden I, Skinner EH, Browning L, Reeve J, Anderson L, Hill C, et al. Preoperative physiotherapy for the prevention of respiratory complications after upper abdominal surgery: pragmatic, double blinded, multicentre randomised controlled trial. BMJ 2018;24(360):j5916.
6. Bartlett RH, Gazzaniga AB, Geraghty TR. Respiratory maneuvers to prevent postoperative pulmonary complications: a critical review. JAMA 1973;224(7):1017-1021.
7. Lumb AB. Pre-operative respiratory optimisation: an expert review. Anaesthesia 2019;74:43-48.
8. Eltorai AEM, Szabo AL, Antoci V, Ventetuolo CE, Elias JA, Daniels AH, et al. Clinical effectiveness of incentive spirometry for the prevention of postoperative pulmonary complications. Respir Care 2018;63(3):347-352.
9. Marini JJ. Postoperative atelectasis: pathophysiology, clinical importance, and principles of management. Respir Care 1984;29:516-528.
10. Restrepo RD, Wettstein R, Wittnebel L, Tracy M. Incentive spirometry: 2011. Respir Care 2011;56(10):1600-1604.
11. Parreira VF, Tomich GM, Britto RR, Sampaio RF. Assessment of tidal volume and thoracoabdominal motion using volume and flow-oriented incentive spirometers in healthy subjects. Braz J Med Biol Res 2005;38(7):1105-1112.
12. Agostini P, Singh S. Incentive spirometry following thoracic surgery: what should we be doing? Physiotherapy 2009;95(2):76-82.

RESPIRATORY CARE Paper in Press. Published on August 25, 2020 as DOI: 10.4187/respcare.07972

13. Liu CJ, Tsai WC, Chu CC, Muo CH, Chung WS. Is incentive spirometry beneficial for patients with lung cancer receiving video-assisted thoracic surgery? BMC Pulm Med 2019;19(1):121.
14. Malik PRA, Fahim C, Vernon J, Thomas P, Schieman C, Finley CJ, et al. Incentive spirometry after lung resection: a randomized controlled trial. Ann Thorac Surg 2018;106(2):340-345.
15. Gunay S, Eser I, Ozbey M, Agar M, Koruk I, Kurkcuoglu IC. Evaluation of two different respiratory physiotherapy methods after thoracoscopy with regard to arterial blood gas, respiratory function test, number of days until discharge, cost analysis, comfort and pain control. Niger J Clin Pract 2016;19(3):353-358.
16. Agostini P, Naidu B, Cieslik H, Steyn R, Rajesh PB, Bishay E, et al. Effectiveness of incentive spirometry in patients following thoracotomy and lung resection including those at high risk for developing pulmonary complications. Thorax 2013;68(6):580-585.
17. Odor PM, Bampoe S, Gilhooly D, Creagh-Brown B, Moonesinghe R. S. Perioperative interventions for prevention of postoperative pulmonary complications: systematic review and meta-analysis. BMJ 2020; 368:3-7.
18. Stannard D. Incentive spirometry for preventing pulmonary complications after coronary artery bypass graft. J Perianesth Nurs 2013;28 (4):236-238.
19. do Nascimento P Junior, Módolo NSP, Andrade S, Guimarães MMF, Braz LG, El Dib R. Incentive spirometry for prevention of postoperative pulmonary complications in upper abdominal surgery. Cochrane Database Syst Rev 2014;2:CD006058.
20. Pantel H, Hwang J, Brams D, Schnelldorfer T, Nepomnayshy D. Effect of incentive spirometry on postoperative hypoxemia and pulmonary complications after bariatric surgery: a randomized clinical trial. JAMA Surg 2017;152(5):422-428.
21. Weiner P, Man A, Weiner M, Rabner M, Waizman J, Magadle R, et al. The effect of incentive spirometry and inspiratory muscle training on pulmonary function after lung resection. J Thorac Cardiovasc Surg 1997;113(3):552-557.
22. Parsons HM. What happened at Hawthorne?: new evidence suggests the Hawthorne effect resulted from operant reinforcement contingencies. Science 1974;4183(4128):922-932
23. Miskovic A, Lumb AB. Postoperative pulmonary complications. Br. Anaesth J 2017;118(3):317-334.
24. Martin TJ, Patel SA, Tran M, Eltorai AS, Daniels AH, Eltorai A. Patient factors associated with successful incentive spirometry. R I Med J (2013) 2018;101:14-18.
25. Eltorai AEM, Baird GL, Eltorai AS, Pangborn J, Antoci V, Cullen HA, et al. Incentive spirometry adherence: a national survey of provider perspectives. Respir Care 2018;63(5):532-537.
26. Eltorai AEM, Baird GL, Pangborn J, Eltorai AS, Antoci V, Paquette K, et al. Financial impact of incentive spirometry. Inquiry 2018;55: 46958018794993.
27. Cassidy MR, Rosenkranz P, McCabe K, Rosen JE, McAneny D. I COUGH: Reducing postoperative pulmonary complications with a multidisciplinary patient care program. JAMA Surg 2013;148(8):740-745.