

Utility of Inspiratory Volume in Incentive Spirometry

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ABSTRACT

Incentive spirometers (IS) were developed to reproduce sustained maximal inspiration. Most providers believe that achieving target inspiratory volume (ISV) is the most important factor for successful IS use. ISV has been used as a surrogate for deep breathing effort and has been correlated with various clinical outcomes, but the scientific validity of these correlations has yet to be demonstrated. Currently, the greatest utility of targeted ISV may be as a method of monitoring global patient progress and as a psychosocial instrument for patient engagement in care.

KEYWORDS: incentive spirometry, inspiratory volume, review of evidence, respiratory care, postoperative care, atelectasis, hospital-acquired pneumonia

HISTORY

The incentive spirometer was first developed in 1970 by Bartlett et al. after observations that yawning may generate pulmonary benefits for postoperative patients.¹ The device was constructed to coach patients to repeatedly generate a sustained maximal inspiration in an effort to prevent regional ventilation reduction and atelectasis. In 1972, Van de Water et al. reported clinical usage of IS.² In 1973, the Bartlett-Edward IS was developed to further incentivize patient usage by providing visual light feedback when patients achieved their inspiratory target volume.³ In 1975, Marion Laboratories, Inc. (Kansas City, MO) further enhanced the electronic IS's visual feedback by putting the display lights on a scale indicating increasingly larger achieved inspiratory volumes.⁴ Used for many years, the electronic IS devices were eventually replaced by less expensive, single-use, non-electronic units.⁵

DEVICE TYPES AND CLINICAL GUIDELINES

IS devices fall into two categories: flow-oriented (FIS) and volume-oriented (VIS). The FIS has a chamber with three interconnected columns wherein light plastic balls sit. The patient inhales through a tube connected to the chamber, attempting to raise the balls through the creation of negative intrathoracic pressure.⁶ The non-linear connections create turbulence of flow in order to increase the inspiratory effort

needed to raise the balls to various heights.⁷ In comparison, the VIS is composed of a tube connected to a chamber with displayed volume measurements. The patient inhales and the maximum volume of air displacement is indicated by the elevation of a float in the chamber.⁶

The FIS and VIS devices have different effects. Demanding greater respiratory effort, the FIS has been shown to increase chest muscle demands.⁸ Despite imposing less work of breathing,⁹ the VIS device has shown better improvement of diaphragmatic activity,^{8,10} along with earlier¹⁰ and greater^{11,12} pulmonary functional recovery. The American Association for Respiratory Care suggests use of VIS.¹³

PROVIDER PERSPECTIVES ON ISV

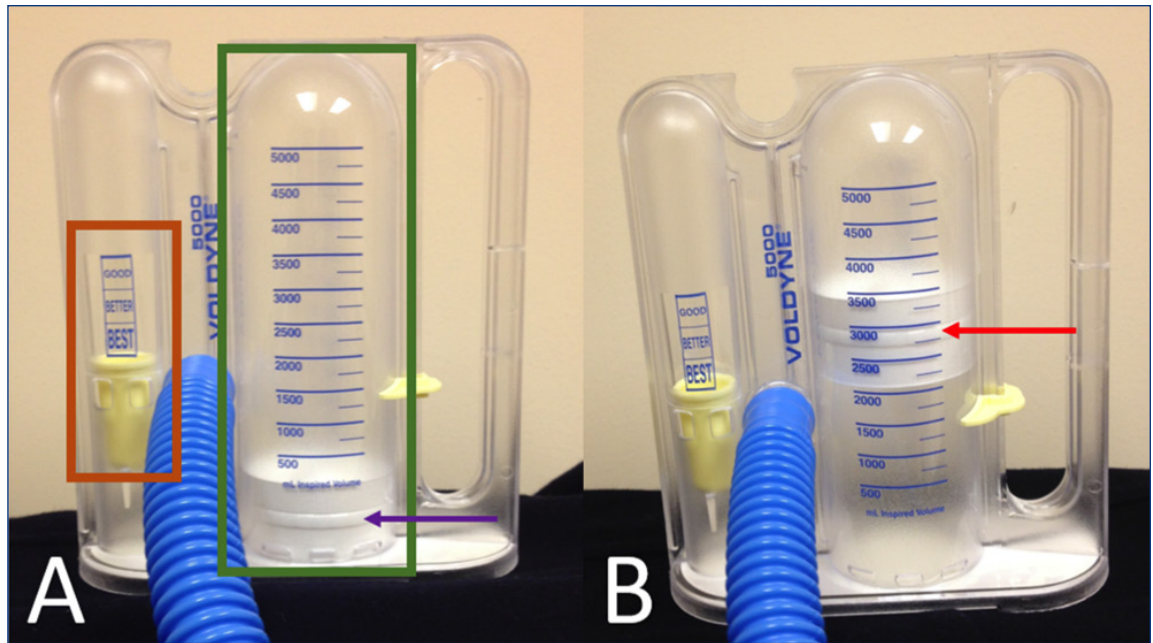
In a large national survey of nurses and respiratory therapists, the majority (51.1%) believed that achieving target inspiratory volume (**Figure 1**) is the most important factor for successful IS use, rather than achieving target inspiratory flow or breath hold. A higher percentage of nurse respondents held this belief than respiratory therapists. The study also demonstrated providers' perspectives on target initial ISV (1288.5 mL; 95%CI: 1253.8–1323.2) and daily ISV improvement (525.6 mL; 95%CI: 489.8–561.4).¹⁴

ISV AS AN OUTCOME

Multiple studies have utilized ISV as an objective measure of deep breathing effort. ISV was used by Edelen and Perlow to demonstrate that relaxation techniques could have comparable effects to opioid analgesia in deep breathing performance.¹⁵ Pieracci et al. argued that severe rib fracture patients had improved acute outcomes, such as higher daily ISV values, when surgical stabilization was utilized vs. medical management.¹⁶ Similar to Baker et al.'s study¹⁷ of surgery, trauma, and critical care patients, Dias et al. made the case that the respiratory therapy technique of breath stacking (preventing exhalation with a one-way valve) improved ISV vs. standard IS protocols in postoperative cardiac surgery patients.¹⁸ In a study of bariatric surgery patients, Cattano et al. demonstrated that preoperative use of IS did not improve postoperative ISV.¹⁹ Harton et al. determined that number of coronary bypass grafts and age were predictors of individual patients returned to preoperative ISV after cardiac surgery.²⁰

Figure 1.

A) Components of the incentive spirometer: flow meter (orange box), volume chamber (green box), volume float (purple arrow). **B)** Displaced volume float (red arrow).



ISV CORRELATION WITH CLINICAL OUTCOMES

ISV has been used as a surrogate for deep breathing effort and correlated with various clinical outcomes. In a study of rib fracture patients, Butts et al. demonstrated that lower ISV on admission predicted acute respiratory failure – defined as need for positive pressure ventilation.²¹ In a study of thoracic epidural analgesia, Harris et al. demonstrated that pain with maximal ISV had a greater predictive value than pain at rest with respect to indicating the effectiveness of thoracic epidurals.²² In a cohort of lobectomy patients, Bastin et al. demonstrated postoperative ISV to be a reliable indicator of vital capacity and inspiratory reserve volume.²³

Despite its *correlation* with certain clinical outcomes, IS has yet to demonstrate *causal* improvement in outcomes.²⁴ Well-designed clinical trials are needed to demonstrate evidence of benefit from IS use.

NEEDED STUDIES

In order to demonstrate evidence of IS benefit, the following areas^{13,14} need to be addressed:

- Patient education and reminder procedures
- Use settings and frequency
- Indications and contraindications
- Defining the clinically significant outcome measures
- Device and equipment design
- Adherence monitoring²⁵
- Outcomes in comparison to, and in combination with, other therapies
- When it should be used during the course of care

- Number of breaths per session and breath hold duration
- Target ISV/ ISV improvement goals and rate
- Impact of patient height and ideal body weight on target ISV
- Inspiratory flow targets
- Protocol advancement
- Parameter graduation and interaction effects
- Patient-specific use protocols
- Cost effectiveness in comparison to other therapies
- Specific patient groups affected
- Whether volume follows a linear dose-response curve with clinical outcomes or an absolute target volume threshold exists

CURRENT UTILITY

At present, the utility of ISV may be that of a global indicator of pulmonary function or patient status. For example, Brown and Walters described how tracking of ISV could be used to promptly detect decline in respiratory function and facilitate earlier intervention.²⁶ Loh et al. described how measurements of ISV in rapid succession could be used to score dyspnea severity.²⁷

The psychosocial implications of patient engagement and targeted ISV may represent the greatest benefit of IS in its current form. Patients who are engaged demonstrate self-efficacy, which has been shown to improve outcomes in pulmonary patients.²⁸ Cassidy et al. used IS as a focal point for patient engagement in a multidisciplinary approach to reducing hospital-acquired pneumonia.²⁹ Targeted ISV may help to internalize a patient's locus of control, which may

affect perceptions of their health status.³⁰ Engaging patients through IS may help to increase their sense of agency and responsibility for their own health and improvement.³¹

SUMMARY

IS was developed to reproduce a patient's sustained maximal ISV. Clinical guidelines suggest selection of volume-oriented devices, as most providers believe achieving target ISV to be the most important factor in successful IS use. ISV has been used as a surrogate for deep breathing effort and correlated with various clinical outcomes, but whether causal relationships exist remains to be determined. Currently, the greatest utility of targeted ISV may be as a method of monitoring global patient progress and promoting patient engagement in their care.

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