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COMPARISON BETWEEN THE SHORT-TERM EFFECTS OF INVERSE RATIO BREATHING AND INCENTIVE SPIROMETRY ON THORACIC EXPANSION AND MAXIMAL INSPIRATORY PRESSURE IN UPPER ABDOMINAL SURGERY PATIENTS

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ABSTRACT

Abstract - BACKGROUND: Upper abdominal surgeries (UAS) were frequently associated with significant postoperative pulmonary complications, which led to decreased thoracic expansion and maximal inspiratory pressure. Inverse Ratio Breathing (IRB) and Incentive Spirometry (IS) had gained attention for their potential benefits in improving lung mechanics, this study aimed to evaluate and compare the short-term effects of IRB and IS on thoracic expansion and maximal inspiratory pressure (MIP) in patients undergoing upper abdominal surgeries. METHOD: Study was conducted on total 33 patients. The Subjects were randomly allocated to perform inverse ratio breathing and incentive spirometry for 5 days. Inverse ratio breathing was administered for 10 minutes 3 times daily, Incentive spirometry was conducted for 3 sets of 10 repetitions 3 times daily. Thoracic expansion and maximal inspiratory pressure were assessed on day 1 and day 5. RESULTS: In Intra-group Comparison, both the groups revealed a statistically significant increase in thoracic expansion and in MIP while the inter-group comparison revealed no statistically significant differences. CONCLUSION: Inverse Ratio Breathing and Incentive Spirometry were both effective when incorporated into early postoperative physiotherapy protocols in upper abdominal surgery patients to promote thoracic expansion and improve maximum inspiratory pressure.

INTRODUCTION

Abdominal surgery encompasses a range of operative interventions performed within the abdominal cavity for both diagnostic and therapeutic purposes(1).Upper abdominal surgery (UAS) is characterized by an incision located above or extending superior to the umbilicus(1,4).

Abdominal surgeries can be broadly categorized into open and laparoscopic approaches. Laparoscopic surgery is a minimally invasive procedure performed through small incisions, in contrast open abdominal surgery requires a large incision to provide direct visualization and access to the operative field(22,9).

Upper abdominal surgeries (UAS) are frequently associated with significant postoperative pulmonary complications (PPCs)(1).The reported incidence of PPCs following upper abdominal surgery ranges from 17% to 88%, highlighting their prevalence and clinical significance(12).PPCs are a leading contributor to increased postoperative morbidity and mortality, prolonged hospitalization durations, elevated healthcare costs, and a reduction in overall quality of life(5).

The postoperative recovery process following abdominal surgery is typically complex and necessitates a multidisciplinary approach to ensure optimal outcomes. In the early postoperative period, patients frequently experience fatigue and restricted respiratory mechanics, primarily due to pathophysiological alterations that impair respiratory muscle function. These changes stem from disruptions in muscle integrity, the length–tension relationship, and the thoracoabdominal coordination, which collectively predispose patients to the development of postoperative pulmonary complications (PPCs)(7,17). Anesthesia and surgery-related factors contribute to respiratory events, such as reduced pulmonary function and cough effort,

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respiratory muscle strength, and impaired breathing and diaphragmatic dysfunction. These undesirable respiratory events increases the risk of developing Post Operative Pulmonary complications following surgeries(19).

Thoracic expansion and maximal inspiratory pressure (MIP) are key measures of chest wall mobility and inspiratory muscle strength, both of which decline postoperatively. Physiotherapy has been shown to improve pulmonary function, enhance early mobilization, and reduce postoperative complications, thereby contributing to improved clinical outcomes and shortened hospital stays.(15). Manzano Roberta , et al [2008] studied effects of Breathing exercises, upper Limb and Lower Limb mobility exercises and chest wall expansion exercises immediately after surgery showing improvement on oxygen hemoglobin saturation without increasing pain along with reduction on PPC's(6).Reducing post-operative problems and the duration of the patient's hospital stay is another important function of post-operative therapy(10).

Incentive spirometry is a mechanical device designed to promote lung expansion by providing visual feedback during inspiratory breathing exercises and there are several studies showing its effects(11). It encourages the patient to take long, slow deep breaths, which decreases pleural pressure, thereby promoting increased lung expansion and improved gas exchange.When performed regularly, this procedure may prevent or reverse atelectasis(5).

A study by Thomas J., et al. (2016) investigated the efficacy of incentive spirometry, deep breathing exercises, and intermittent positive pressure breathing in patients undergoing upper abdominal surgery. The study concluded that all three interventions were equally effective in reducing the incidence of postoperative pulmonary complications (PPCs) compared to no intervention(16).

Inverse Ratio Breathing (IRB) is a breathing pattern in which the inspiratory phase is deliberately prolonged, altering the I:E ratio to 2:1, as opposed to the normal 1:2 or 1:3(8). IRB promotes a longer inspiratory time relative to expiratory time, leading to improved alveolar recruitment and a higher mean airway pressure, which aids in improving ventilation-perfusion mismatch and increasing lung compliance. This ultimately contributes to reducing basal atelectasis and enhancing thoracic mobility and inspiratory muscle strength(8).

Respiratory physiotherapy plays a vital role in preventing PPCs by promoting optimal lung function in the immediate postoperative period. Various techniques and conventional physiotherapy methods are used immediately after surgery. Among various techniques, Inverse Ratio Breathing (IRB) and Incentive Spirometry (IS) have gained attention for their potential benefits in improving lung mechanics. However, their short-term comparative effects on Thoracic Expansion and Maximal Inspiratory Pressure in UAS patients remain underexplored.

This study aims to fill this critical knowledge gap by evaluating and comparing the short-term effects of IRB and IS on thoracic expansion and maximal inspiratory pressure in patients undergoing upper abdominal surgeries. Understanding these effects will help physiotherapists and clinicians select the most effective early intervention, thereby optimizing recovery and respiratory outcomes.

METHODOLOGY

This randomized controlled trial was conducted over a period of nine months in the Surgical Intensive Care Unit and Inpatient Ward Department of a tertiary care hospital. The study population consisted of patients who had undergone open upper abdominal surgery, and a total of 33 participants were recruited using a simple random sampling method. Patients of both genders, aged 18- 60 years, who had undergone open upper abdominal surgery and were in the postoperative period from day 1 onward were included in the study. Patients who had undergone laparoscopic upper abdominal surgery; those with postoperative complications, diagnosed cardiovascular, pulmonary, or neuro-musculoskeletal conditions, cognitive impairment; or those unwilling to provide informed consent were excluded. Prior to the commencement of the study, approval was obtained from the Institutional Ethical Committee. All participants were informed about the study in a language they best understood, and written informed consent was obtained. Demographic details includingage, gender, surgical details, and comorbidities were recorded. Baseline assessments of thoracic expansion and maximal inspiratory pressure were performed on postoperative day one before the initiation of the intervention. Thoracic expansion was measured using a measuring tape at the level of the 2nd, 4th, and 6th intercostal spaces with the participant positioned in supported sitting(25). After several normal breaths, participants were instructed to exhale fully followed by maximal inhalation, and three readings were recorded at each level, with the best value considered for analysis(5). Maximal inspiratory pressure was assessed using a pressure manometer device with the participant in supported sitting(24,21). After a few normal breaths, the participant placed the mouthpiece securely in the mouth and inhaled maximally, and the highest value from three trials was recorded(23). Participants were then randomly allocated into three groups using computer-generated randomization through Random.org software, with an equal number of participants assigned to each group.

Group A received inverse ratio breathing combined with conventional physiotherapy, which included deep breathing exercises, splinted coughing and huffing, active movements of the upper and lower limbs, and early mobilization. For inverse ratio breathing, participants were positioned in erect sitting or crook-lying position and instructed to inhale for four seconds and exhale for two seconds under therapist guidance for 10 minutes, three times daily(23). Group B received incentive spirometry along with conventional physiotherapy consisting of deep breathing exercises, splinted coughing and huffing, active range-of-motion exercises of the upper and lower limbs, and early mobilization. Participants were positioned in upright sitting or half-crook lying position and instructed to exhale fully, place the mouthpiece securely between the lips, and inhale slowly and deeply to their maximum inspiratory capacity, followed by a breath hold of 2–3 seconds. For the one-ball spirometer, the initial flow rate was set at 200 cc/sec and progressively increased based on patient tolerance, while the three-ball spirometer was used with maximal inspiratory effort; in both devices, three sets of ten repetitions were performed with a rest period of 30–60 seconds between sets to prevent adverse effects, and the intervention was administered three times daily

(14). Group C served as the control group and received conventional physiotherapy alone, which included deep breathing exercises, splinted coughing and huffing, active movements of the bilateral upper and lower limbs, and early mobilization comprising bedside sitting and bedside ambulation for 15–20 minutes covering one to two laps as tolerated. The intervention protocol for all three groups was implemented for five consecutive days, with sessions conducted three times daily, and the sets and repetitions of conventional physiotherapy exercises were standardized for all participants

RESULTS

Table 1: Shows the baseline characteristics of subjects included in the three groups.

Parameter	Sample Variable (n=11) Group A	Sample Variable (n=11) Group B	Sample Variable (n=11) Group C
Male n	4	4	3
Female n	7	7	8
Age	45.27±14.59	46.54±17.82	41.81±17.56

DISCUSSION

The study examined the difference between short-term effects of Incentive spirometry and Inverse ratio breathing on thoracic expansion and maximal inspiratory pressure in patients undergoing upper abdominal surgeries. A statistically significant increase in thoracic expansion was observed at the 4th and 6th intercostal levels from POD1 to POD5. Although thoracic expansion at the 2nd level did not reach statistical significance. This finding aligns with the pathophysiology of upper abdominal surgeries, where diaphragmatic dysfunction is more pronounced in the lower thoracic region due to the proximity to the surgical site and the impact of pain on lower chest wall excursion. Additionally, a significant increase in MIP was observed, indicating enhanced inspiratory muscle strength.

IRB demonstrated significant improvement in thoracic expansion at 4th (p=0.046) and 6th (p=0.011) ICS along with improvement in MIP (p=0.005). IRB promotes a longer inspiratory time relative to expiratory time, leading to improved alveolar recruitment and a higher mean airway pressure, which aids in improving ventilation-perfusion mismatch and increasing lung compliance. This ultimately contributes to reducing basal atelectasis and enhancing thoracic mobility and

Table 2. Presents the preand post-intervention values of thoracic expansion and maximal inspiratory pressure for Group A, Group B and Group C

Outcome Measure	Time (Pre and Post)	Group A		p value	Group B		p value	Group C		p value
		Mean	SD		Mean	SD		Mean	SD	
Thoracic Expansion(2nd ICS)	POD1	1.72	0.46	0.317	1.40	0.58	0.59	1.90	0.30	1.00
	POD5	1.81	0.40		1.72	0.46		1.90	0.30	
Thoracic Expansion(4th ICS)	POD1	1.27	0.46	0.046	0.95	0.15	0.020	1.27	0.46	0.157
	POD5	1.63	0.50		1.45	0.52		1.45	0.52	
Thoracic Expansion(6th ICS)	POD1	0.95	0.15	0.011	0.81	0.25	0.015	1.04	0.35	0.317
	POD5	1.54	0.52		1.27	0.46		1.13	0.45	
MIP	POD1	25.45	8.20	0.005	27.27	9.04	0.034	24.54	6.87	0.046
	POD5	30	8.36		30	8.94		26.36	6.74	

Table 3. Presents the between- group p-values and effect sizes for thoracic expansion and maximal inspiratory pressure.

Outcome Measures	Comparison	p value	Effect size (cohen's d)	Interpretation
Thoracic Expansion (2nd ICS)	A vs B	0.553	0.20	Small
	B vs C	0.478	0.47	Small
	A vs C	0.748	0.25	Small
Thoracic Expansion (4th ICS)	A vs B	0.701	0.36	Small
	B vs C	1.000	0	Negligible
	A vs C	0.478	0.36	Small
Thoracic Expansion (6th ICS)	A vs B	0.431	0.56	Medium
	B vs C	0.562	0.31	Small
	A vs C	0.116	0.87	Large
MIP	A vs B	0.660	0	Negligible
	B vs C	0.303	0.46	Small-medium
	A vs C	0.332	0.48	Small-medium

inspiratory muscle strength(13,18,20).

During inverse ratio ventilation, the inspiration time exceeds the expiration time, which increases mean airway pressure. An increase in mean airway pressure enhances alveolar stability and recruitment, reduces dead space ventilation, and thus improves oxygenation. Furthermore, as the expiration time is shorter than the inspiration time, alveoli may not have sufficient time to empty completely during exhalation, leading to gas trapping in the lungs. This trapped gas creates pressure in the alveoli, known as auto-PEEP, which recruits alveoli requiring more time for recruitment. Consequently, the alveolar surface area increases, providing more surface area for gaseous exchange, thereby improving ventilation(6,10,15).

Pedamkar , Soman . et al (2016) also concluded in their study that inspiratory vital capacity and thoracic expansion increase significantly after Inverse Ratio Breathing, attributing this to the mechanism whereby an intrinsic PEEP is generated in the alveoli due to the short expiratory phase, thus increasing the end-expiratory volume.

Incentive Spirometry (IS), exhibited significant improvements in thoracic expansion at the 4th ($p = 0.020$) and 6th ($p = 0.015$) intercostal levels, as well as a notable increase in Maximum Inspiratory Pressure (MIP) ($p = 0.034$).Incentive Spirometry facilitates slow, deep inhalation through visual feedback, thereby promoting patient engagement and enhancing inspiratory effort, which decreases pleural pressure, thereby promoting increased lung expansion and improved gas exchange, encourages the use of the diaphragm rather than accessory muscles, IS assists in restoring normal breathing mechanics and preventing the restrictive ventilatory patterns observed postoperatively(27). The patients mobilize a large tidal volume at a low respiratory rate when performing breathing exercises with an IS, which tends to develop muscle strength because of the increased inhalation/exhalation ratio(3).

According to Anandhi D. and Divya P. (2018), Incentive Spirometry is crucial for thoracotomy patients as it increases inspiratory capacity and enhances inspiratory muscle strength. Incentive Spirometry increases intrapleural and intra-alveolar pressure following a deep inhalation and by increasing the transpulmonary pressure gradient, which is sustained for a few seconds with a breath hold. Atelectasis can frequently be prevented or treated by increasing the transpulmonary pressure gradient and further expanding the alveoli(2). Shazly B. Ali et.al (2018) stated that the combined approach of Incentive spirometry and diaphragmatic breathing significantly improved pulmonary function, prevented respiratory complications and reduced the length of hospital stay.

Although both interventions independently led to significant improvements in thoracic expansion and MIP, inter-group comparisons revealed no statistically significant differences between Group A (IRB) and Group B (IS) at any level of thoracic expansion or in MIP on postoperative day 5 ($p > 0.05$). This suggests that both interventions are equally effective when administered over a short duration of five days. This finding can be attributed to the fact that both techniques aim to enhance lung volumes and inspiratory strength, through different mechanisms. While IRB passively increases inspiratory time and encourages diaphragmatic recruitment through altered respiratory patterns, IS provides an active, volitional breathing effort that also recruits the diaphragm and expands the lungs.

Outcomes in the Control Group (Group C), which did not receive any structured respiratory intervention, exhibited no significant improvement in thoracic expansion at any level ($p = 0.05$). However, a borderline significant improvement in MIP was observed ($p = 0.046$), likely attributable to natural recovery processes and general postoperative mobilization. This lack of significant improvement highlights the importance of targeted respiratory therapy in the early postoperative period.

The data did not reveal any statistically significant differences; however, there was a notable clinical difference. At the thoracic expansion at the 2nd and 4th levels, IRB demonstrates small but clear benefits ($d = 0.25$ and 0.36), while at the 6th level, the benefit is substantial ($d = 0.87$), indicating strong efficacy in enhancing complex skills. The moderate increase in MIP ($d = 0.48$) further supports IRB's practical value in patient-relevant outcomes. In comparison, IS provides small improvements at 2nd level ($d = 0.47$) and 6th level($d = 0.31$), but shows no benefit at the 4th level ($d = 0.00$), and a modest gain in overall performance in MIP ($d = 0.46$). When directly compared, IRB slightly outperforms IS at 2nd and 4th levels ($d = 0.20$ and 0.36) and demonstrates a clear medium advantage at 6th level ($d = 0.56$), while both interventions remain equivalent on MIP ($d = 0.00$).Clinically, these findings suggest that IRB is the preferred method for developing advanced clinical competencies, as it achieves stronger and more reliable improvements.The pattern also indicates that IS may require further refinement to effectively address mid-stage learning needs. Emphasizing effect sizes—rather than p-valuesalone-allows for the assessment of the true clinical relevance of these interventions, consistent with best practices in modern clinical research.

The study had some limitations such as; subjective pain levels, which influence thoracic mobility, were not quantified; any outcome measure for assessing PPC's was not taken and follow-up was limited to POD-5 rather than longer-term outcomes.

Future studies can implement a specific outcome measure for PPCs to provide a more comprehensive evaluation of intervention efficacy along with providing longer-term interventions to better assess the sustained effects of physiotherapy techniques and can also emphasize pain evaluation, as postoperative pain is a critical factor influencing chest expansion, inspiratory effort, and overall recovery.

CONCLUSION

Inverse Ratio Breathing (IRB) and Incentive Spirometry (IS) can both be effectively incorporated into early postoperative physiotherapy protocols for patients undergoing upper abdominal surgeries, such as exploratory laprotomy and open cholecystectomy, to promote thoracic expansion and improve maximum inspiratory pressure.

Inverse Ratio Breathing may be considered as an alternative intervention in patients who experience difficulty performing Incentive Spirometry, particularly in cases where postoperative pain or limited compliance affect the use of mechanical devices.

Both IRB and IS are non-invasive, cost-effective techniques that can be taught easily at the bedside and require minimal equipment, making them suitable for use in both high- resource and resource-limited healthcare settings.

Given the comparable clinical outcomes observed in thoracic expansion and MIP, physiotherapists can individualize respiratory interventions based on patient tolerance, preference, and clinical status, thereby enhancing adherence and optimizing recovery in the early postoperative phase

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