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Research Article

A Prospective Study on Post-Operative Pulmonary Complications and the Efficacy of Pre-Operative Pulmonary Rehabilitation in Elderly Patients Undergoing Lower Limb Arthroplasty at a Tertiary Care Center in India

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ABSTRACT
Background: Post-operative pulmonary complications (PPCs), particularly pneumonia, are significant causes of morbidity, prolonged hospital stay, and increased healthcare costs following major orthopedic surgery. Elderly patients undergoing hip and knee arthroplasty are at a heightened risk. While pre-operative pulmonary rehabilitation (Prehab) is established in cardiothoracic surgery, its role in orthopedic populations, especially in the Indian context, is less explored.
Aim: To determine the incidence and risk factors for post-operative pneumonia in patients undergoing hip/knee arthroplasty and to evaluate the effect of a short-term, intensive pre-operative pulmonary rehabilitation program on reducing PPCs.
Materials and Methods: A prospective cohort study was conducted on 80 patients aged ≥60 years scheduled for elective total hip or knee arthroplasty. Patients were non-randomly allocated into two groups: the Intervention Group (n=40) received a structured 2-week pre-operative pulmonary rehabilitation program, while the Control Group (n=40) received standard pre-operative care. The primary outcome was the incidence of post-operative pneumonia, diagnosed using the Centers for Disease Control and Prevention (CDC) criteria. Secondary outcomes included other PPCs (atelectasis, pleural effusion, respiratory failure), SpO2 levels, post-operative hospital stay, and need for supplemental oxygen.
Results: The overall incidence of post-operative pneumonia was 13.75% (11/80). Multivariate analysis identified age >70 years (OR=4.1, p=0.03), pre-existing COPD (OR=5.8, p=0.008), and general anesthesia (OR=3.9, p=0.04) as significant independent risk factors. The Intervention Group demonstrated a significantly lower incidence of pneumonia compared to the Control Group (5% vs. 22.5%, p=0.02). Furthermore, the Intervention Group had a lower incidence of overall PPCs (10% vs. 35%, p=0.007), shorter mean hospital stay (5.2 ± 1.1 days vs. 7.1 ± 1.8 days, p<0.001), and reduced need for prolonged oxygen therapy.
Conclusion: Post-operative pneumonia is a prevalent complication in elderly Indian patients undergoing lower limb arthroplasty, driven by advanced age, COPD, and anesthetic technique. A short-term, intensive pre-operative pulmonary rehabilitation program is a highly effective and feasible strategy to significantly reduce the incidence of PPCs, improve respiratory outcomes, and decrease hospital length of stay.

Keywords: Post-Operative Pneumonia, Pulmonary Complications, Hip Replacement, Knee Replacement, Pre-Operative Rehabilitation, Elderly, Risk Factors, India.

INTRODUCTION
Total hip arthroplasty (THA) and total knee arthroplasty (TKA) are highly successful procedures for alleviating pain and restoring function in patients with end-stage arthritis. In India, with a growing elderly population and increasing access to healthcare, the volume of these procedures is rising steadily [1]. While generally safe, these major surgeries are not without risks. Post-operative pulmonary complications (PPCs) represent a significant cause of non-surgical morbidity, leading to extended hospital stays, higher treatment costs, and increased patient mortality [2].
Pneumonia is the most severe and common form of PPC, with reported incidence rates after

major non-cardio-thoracic surgery ranging from 2% to 10% in global literature, with higher rates in the elderly and those with comorbidities [3]. The pathophysiology involves a combination of general anesthesia-induced diaphragmatic dysfunction, post-operative pain, opioid use, and immobility, leading to reduced lung volumes, atelectasis, and impaired mucociliary clearance, which predispose to infection [4].

In the Indian healthcare context, patients often present with a different profile of comorbidities and nutritional status compared to Western populations. Furthermore, pre-operative optimization protocols are not uniformly standardized. Pre-operative pulmonary rehabilitation (Prehab), a multidisciplinary program including patient education, breathing exercises, and physical conditioning, has proven efficacy in reducing PPCs in abdominal and thoracic surgeries [5]. However, its application and validation in the elective orthopedic setting, particularly in India, are sparse.

This study aims to address this gap by:

1. Determining the incidence and identifying independent risk factors for post-operative pneumonia in elderly patients undergoing THA and TKA in an Indian tertiary care hospital.
2. Evaluating the effect of a short-term, intensive pre-operative pulmonary rehabilitation program on the incidence of PPCs in this patient population.

MATERIALS AND METHODS

Study Design and Setting: A prospective cohort study was conducted between January 2023 and December 2023 at the Department of Orthopedics.

Participants: A total of 80 patients scheduled for elective, primary THA or TKA were enrolled after providing written informed consent.

- **Inclusion Criteria:** Age ≥60 years; American Society of Anesthesiologists (ASA) physical status I-III.
- **Exclusion Criteria:** Emergency surgery; active respiratory or systemic infection; pre-operative oxygen dependency; cognitive impairment preventing participation in rehabilitation; revision arthroplasty.
- **Group Allocation:** Consecutive eligible patients were allocated into two groups. The first 40 patients formed the **Intervention Group** and received pre-operative pulmonary rehabilitation. The subsequent 40 patients formed the **Control Group** and received standard pre-operative care. This non-randomized, sequential allocation was chosen for logistical feasibility.

Intervention:

- **Control Group:** Received standard pre-operative care, which included a routine medical check-up, anesthetic assessment, and general advice on deep breathing.
- **Intervention Group:** Received standard care plus a structured 2-week pre-operative pulmonary rehabilitation program, supervised by a physiotherapist, comprising:

1. **Education:** On the importance of post-operative lung expansion, early mobilization, and pain management.
2. **Breathing Exercises:** Incentive spirometry (goal: 10-15 breaths/hour while awake), diaphragmatic breathing, and pursed-lip breathing.
3. **Airway Clearance Techniques:** Forced expiratory technique (huffing).
4. **Physical Conditioning:** Upper and lower limb endurance exercises and early ambulation practice.

Data Collection

Pre-operative data included demographics, body mass index (BMI), smoking history, comorbidities (COPD, diabetes, cardiac disease), type of surgery, and anesthetic plan. Intra-operative data included type of anesthesia (general vs. spinal) and duration of surgery. Post-operatively, all patients were monitored daily until discharge for:

- **Primary Outcome:** Development of pneumonia, defined as per CDC criteria: new or progressive radiographic infiltrate PLUS at least two of: fever (>38°C), leukocytosis/leukopenia, purulent sputum, and new-onset hypoxia [6].
- **Secondary Outcomes:** Other PPCs (clinically significant atelectasis, pleural effusion, respiratory failure), daily SpO2 on room air, duration of post-operative hospital stay, and need for supplemental oxygen beyond 24 hours.

Statistical Analysis

Data were analyzed using SPSS version 26.0. Continuous variables were expressed as mean ± standard deviation and compared using Student's t-test. Categorical variables were

expressed as numbers (percentages) and compared using the Chi-square test or Fisher's exact test as appropriate. A p-value of <0.05 was considered statistically significant. Multivariate logistic regression analysis was performed to identify independent risk factors for pneumonia, including variables with p<0.1 in univariate analysis.

Table 1: Baseline Characteristics of the Study Population (N=80)

Characteristic	Intervention Group (n=40)	Control Group (n=40)	p-value
Age (years), Mean ± SD	68.1 ± 5.2	69.4 ± 6.1	0.29
Gender, Male:Female	16:24	18:22	0.66
BMI (kg/m²), Mean ± SD	26.8 ± 3.1	27.3 ± 3.5	0.49
Smokers (Current/Ex), n(%)	9 (22.5%)	11 (27.5%)	0.61
Comorbidities, n(%)			
· COPD	5 (12.5%)	6 (15.0%)	0.74
· Diabetes Mellitus	14 (35.0%)	16 (40.0%)	0.64
· Ischemic Heart Disease	7 (17.5%)	8 (20.0%)	0.78
Type of Surgery, n(%)			0.66
· Total Hip Arthroplasty	18 (45.0%)	16 (40.0%)	
· Total Knee Arthroplasty	22 (55.0%)	24 (60.0%)	
Type of Anesthesia, n(%)			0.66
· General Anesthesia	22 (55.0%)	24 (60.0%)	
· Spinal Anesthesia	18 (45.0%)	16 (40.0%)	

The pre-operative demographics and clinical profiles of the 80 patients are detailed in Table 1. The study population was divided into two cohorts: the Intervention Group (n=40), which received pre-operative pulmonary rehabilitation, and the Control Group (n=40), which received standard care. Statistical analysis confirmed that the two groups were well-matched at baseline, with no significant differences observed in any demographic or clinical parameter. The mean age was similar between the Intervention and Control groups (68.1 ± 5.2 years vs. 69.4 ± 6.1 years, p=0.29). The gender distribution, body mass index (BMI), proportion of smokers, and prevalence of key comorbidities—including Chronic Obstructive Pulmonary Disease (COPD), diabetes mellitus, and ischemic heart disease—were also comparable. Furthermore, the distribution of the type of surgery (Total Hip vs. Total Knee Arthroplasty) and the choice of anesthetic technique (General vs. Spinal) were not significantly different between the groups, ensuring that subsequent outcome differences are unlikely to be attributable to baseline imbalances.

Table 2: Multivariate Logistic Regression Analysis of Risk Factors for Post-Operative Pneumonia

Risk Factor	Adjusted Odds Ratio (OR)	95% Confidence Interval	p-value
Age >70 years	4.1	1.12 - 15.01	0.03
Pre-existing COPD	5.8	1.58 - 21.29	0.008
General Anesthesia	3.9	1.04 - 14.61	0.04

Over the course of the post-operative period, a total of 11 patients developed pneumonia, yielding an overall incidence of 13.75% (11/80). To identify independent predictors of this complication, a multivariate logistic regression analysis was performed, the results of which are presented in Table 2. The analysis identified three significant risk factors. Patients over the age of 70 years had four-fold increased odds of developing pneumonia compared to their younger counterparts (Adjusted Odds Ratio [OR]=4.1, 95% CI: 1.12-15.01, p=0.03). The presence of pre-existing COPD was the strongest predictor, associated with a nearly six-fold increase in odds (OR=5.8, 95% CI: 1.58-21.29, p=0.008). Finally, the use of general anesthesia, as opposed to spinal anesthesia, was also a significant independent risk factor, conferring a nearly four-fold increase in the odds of post-operative pneumonia (OR=3.9, 95% CI: 1.04-14.61, p=0.04).

Table 3: Comparison of Post-Operative Outcomes between Groups

Outcome	Intervention Group (n=40)	Control Group (n=40)	p-value
Primary Outcome			
· Pneumonia, n(%)	2 (5.0%)	9 (22.5%)	0.02*
Secondary Outcomes			
· Overall PPCs, n(%)	4 (10.0%)	14 (35.0%)	0.007*
- Atelectasis	3 (7.5%)	8 (20.0%)	
- Pleural Effusion	1 (2.5%)	4 (10.0%)	
- Respiratory Failure	0 (0.0%)	2 (5.0%)	
· Hospital Stay (days), Mean ± SD	5.2 ± 1.1	7.1 ± 1.8	<0.001**
· O2 therapy >24 hours, n(%)	3 (7.5%)	12 (30.0%)	0.01*

The impact of the pre-operative pulmonary rehabilitation program on post-operative outcomes is comprehensively detailed in Table 3. A stark contrast was observed in the primary outcome: the incidence of pneumonia was significantly lower in the Intervention Group at 5% (2/40) compared to 22.5% (9/40) in the Control Group (p=0.02). This benefit extended to overall Post-operative Pulmonary Complications (PPCs), which included atelectasis, pleural effusion, and respiratory failure. The Intervention Group experienced a significantly lower rate of overall PPCs (10% vs. 35%, p=0.007). Furthermore, the benefits of prehabilitation translated into tangible clinical and resource-use outcomes. The mean post-operative hospital stay was significantly shorter for the Intervention Group (5.2 ± 1.1 days) than for the Control Group (7.1 ± 1.8 days, p<0.001). Additionally, significantly fewer patients in the Intervention Group required supplemental oxygen for more than 24 hours post-surgery (7.5% vs. 30.0%, p=0.01), indicating a faster recovery of baseline pulmonary function.

DISCUSSION

This prospective study yields two principal findings critical to optimizing care in elective orthopedic surgery within the Indian context. First, it identifies a clinically significant incidence of post-operative pneumonia of 13.75% in an elderly cohort undergoing lower limb arthroplasty, with advanced age, pre-existing COPD, and the use of general anesthesia as its dominant, independent risk factors. Second, and more importantly, it demonstrates that a short-term, intensive pre-operative pulmonary rehabilitation program is a profoundly effective intervention, significantly reducing the incidence of pneumonia, overall PPCs, hospital length of stay, and the need for prolonged oxygen therapy.

The incidence of pneumonia observed in our study (13.75%) falls on the higher end of the spectrum reported in global literature for major non-cardiac surgery, which typically ranges from 2% to 10% [3, 7]. This elevated rate is likely a reflection of our specific study population, which was exclusively elderly (≥60 years) and conducted in a setting where patients may present for surgery with a higher burden of unoptimized comorbidities. Our findings on risk factors are consistent with established pathophysiology. The identification of age >70 years as a significant risk factor (OR=4.1) aligns with the natural decline in respiratory muscle strength and immune competence with aging [7]. Similarly, the powerful association with COPD (OR=5.8) underscores the critical role of diminished pulmonary reserve in predisposing patients to post-operative decompensation [7]. The strong independent association with general anesthesia (OR=3.9) compared to spinal anesthesia is a pivotal finding. This supports the well-documented phenomenon of anesthesia-induced diaphragmatic dysfunction and alveolar collapse, which is markedly attenuated with regional techniques [8]. Our results strongly advocate for the preferential use of neuraxial anesthesia in this vulnerable demographic whenever feasible.

The most compelling contribution of our study lies in the demonstrated efficacy of pre-operative pulmonary rehabilitation. The 77% relative reduction in pneumonia incidence in the Intervention Group (5% vs. 22.5%) is both clinically and statistically significant. This finding finds strong support in the literature. A seminal meta-analysis by Katsura et al. (2015) demonstrated that pre-operative pulmonary

rehabilitation significantly reduced PPCs and length of stay in patients undergoing lung cancer surgery, establishing the principle of "prehab" in a high-risk pulmonary population [5]. More pertinently, our results extend this concept to orthopedic surgery. While direct comparisons in orthopedics are fewer, a study by Moran et al. (2016) on pre-operative exercise therapy ("prehab") for various surgical patients found a consistent trend towards reduced post-operative complications and enhanced recovery, corroborating the multi-systemic benefits of pre-operative conditioning that our pulmonary-focused program achieved [9].

The mechanisms through which our short-term "Prehab" program conferred benefit are likely multifactorial. Beyond the obvious physiological improvements in respiratory muscle strength and endurance, the program served as a crucial educational and psychological intervention. By training patients in incentive spirometry and breathing techniques *before* surgery, we ensured they were proficient and confident in performing these critical maneuvers post-operatively, despite pain and sedation. This "rehearsal" likely led to better compliance and more effective lung expansion, directly combating atelectasis, the precursor to pneumonia. The consequent reduction in hospital stay by nearly two days is a substantial outcome, highlighting not only an improvement in patient recovery but also a significant reduction in healthcare costs and resource utilization, a consideration of paramount importance in any healthcare system, particularly in a resource-constrained environment.

Limitations and Future Directions

Several limitations of this study must be acknowledged. The non-randomized, sequential allocation of patients, while logistically practical, introduces the potential for selection bias. However, the robust comparability of our baseline groups mitigates this concern somewhat. The single-center design and modest sample size may affect the generalizability of our findings. Furthermore, the physiotherapists and assessing physicians were not blinded to the group allocation, which could introduce observer bias. A larger, multi-center, randomized controlled trial with a blinded outcome assessment would provide the highest level of evidence to confirm our results and facilitate the widespread adoption of this protocol.

CONCLUSION

In conclusion, this study confirms that post-operative pneumonia is a prevalent and serious complication in elderly Indian patients undergoing hip and knee arthroplasty, driven by non-modifiable and modifiable risk factors. The implementation of a simple, low-cost, short-term pre-operative pulmonary rehabilitation program is a highly effective strategy to markedly reduce the incidence of this complication and other PPCs. It leads to faster functional recovery, shorter hospital stays, and more efficient use of hospital resources. We strongly recommend that such pre-operative optimization be integrated as a standard component of the surgical pathway for all at-risk elderly patients undergoing major orthopedic surgery.

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