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Research paper

Respiratory complications after surgery in Vietnam: National estimates of the economic burden

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ABSTRACT

Background: Estimating the cost of postoperative respiratory complications is crucial in developing appropriate strategies to mitigate the global and national economic burden. However, systematic analysis of the economic burden in low- and middle-income countries is lacking.

Methods: We used the nationwide database of the Vietnam Social Insurance agency and extracted data from January 2017 to September 2018. The data contain 1 241 893 surgical patients undergoing one of seven types of surgery. Propensity score matching method was used to match cases with and without complications. We used generalized gamma regressions to estimate the direct medical costs; logistic regressions to evaluate the impact of postoperative respiratory complications on re-hospitalization and outpatient visits.

Findings: Postoperative respiratory complications increased the odds of re-hospitalization and outpatient visits by 3·49 times (95% CI: 3·35–3·64) and 1·39 times (95% CI: 1·34–1·45) among surgical patients, respectively. The mean incremental cost associated with postoperative respiratory complications occurring within 30 days of the index admission was 1053·3 USD (95% CI: 940·7–1165·8) per procedure, which was equivalent to 41% of the GDP per capita of Vietnam in 2018. We estimated the national annual incremental cost due to respiratory complications occurring within 30 days after surgery was 13·87 million USD. Pneumonia contributed the greatest part of the annual cost burden of postoperative respiratory complications.

Interpretation: The economic burden of postoperative respiratory complications is substantial at both individual and national levels. Postoperative respiratory complications also increase the odds of re-hospitalization and outpatient visits and increase the length of hospital stay among surgical patients.

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Research in context

Evidence before this study

The individual- and national-level estimates of incremental costs due to respiratory complications after surgery are not well known. We searched on PubMed and Google Scholar to identify peer-reviewed articles published in English between Jan 1, 1990 and November 01, 2020; using keywords ("respiratory" OR "pulmonary") AND ("complication" OR "consequence") AND ("postoperative" OR surg*) AND ("cost" OR "economic"). We complemented the searching database with a manual search on reference lists. We identified a total of 14 studies that examined the incremental cost of respiratory complications after surgery. All studies were conducted in high-income countries (with most of the studies were from the US), there was no study conducted in a low- middle-income country to investigate the cost of PRCs in specific. No study has comprehensively investigated the incremental cost of PRCs by specific respiratory complication and by types of surgery.

Added value of this study

In this study, we used the nationwide database of the Vietnam Social Insurance agency to estimate the individual- and national-level of incremental costs due to postoperative respiratory complications (PRCs). We also estimated the costs by seven types of surgery and ten groups of complications. PRCs increased the 30-day costs of 1053·3 USD per procedure at the individual level, and contributed to the annual incremental cost of 13·87 million USD at the national level. Respiratory failure was the costliest complication, with an estimated incremental cost of 2694·0 USD per procedure, while pneumonia contributed the greatest part of the annual cost burden. We found that PRCs also increased the length of stay and the odds of re-hospitalization and outpatient visits of surgical patients.

Implications of all the available evidence

The economic burden of PRCs is substantial at both individual and national levels. Creating appropriate prevention strategies for PRCs is extremely important, not only to improve the quality of healthcare but also to save considerable sums each year.

Introduction

A postoperative respiratory complication (PRC) is defined as new onset or exacerbated respiratory failure following cardiothoracic or non-cardiothoracic surgery [1]. PRCs are common and occur in 2% to 37·8% of surgical cases, depending on the type of surgical procedure and patient comorbidity [2-4]. Previous studies have shown that PRCs are more common than cardiovascular complications [5,6], and result in higher mortality [7–9], longer length of hospital stay (LOS) [2,10,11], greater likelihood of intensive care unit (ICU) admission and re-hospitalization [4,7,12], and higher hospital care costs [4,7,13]. Along with the mortality burden from PRCs, the economic burden is also a significant problem, and re-hospitalization is one of the most persistent and costly occurrences. A study by Lawson et al. indicated that the rate of re-hospitalization among US elderly patients is about 12·8% [12], and it is estimated that the cost of PRC-related re-hospitalization is approximately 835 million USD per year [4]. The additional cost related to PRCs may differ depending on the type of complication, as well as the health system and hospital type [4]. A study in the US showed that the excess cost of PRCs ranged from 5983 USD to 120 579 USD per procedure, with higher costs associated with mechanical ventilation or tracheostomy [4]. The extra cost per procedure associated with PRCs may be up to 12 times higher than for a procedure without PRCs [14].

Despite the huge estimated health and economic burden of PRCs, there is still a lack of systematic and current data regarding these adverse events, especially in low- and middle-income countries (LMICs) where the health information system has not been optimized [15]. Vietnam is a developing country located in Southeast Asia with a population of 96·5 million people [16] and the GDP per capita was 2566 USD in 2018. The total healthcare expenditure in Vietnam amounted to approximately 17·2 billion USD, with the health expenditure per capita was 152 USD (5·9% GDP) in the same period [17]. Vietnam has improved the quality of healthcare services and management systems in recent years. However, to the best of our knowledge, no study has investigated the burden of PRCs in Vietnam. The lack of such information may result in limited evidence to develop the cost-effectiveness programs on preventing PRCs, which is especially important in the context of the limited resources in Vietnam. On the global scale, study on cost of PRCs can contribute to the scientific evidence for Global Surgery progress towards 2030 goals, especially on the target of protecting against impoverishing health expenditure, given data in LMICs are extremely scarce [15].

In this study, we used the nationally representative data from the Vietnam Social Insurance agency database to estimate the economic burden due to PRCs and evaluate the impact of PRCs on re-hospitalization, outpatient visits, and length of hospital stay (LOS) within 30 days after surgery.

Methods

Data source

The data used in this study was from the electronic payment portal database managed by the Vietnam Social Insurance (VSI) agency. This database is a standardized system nationwide using an Oracle© database, which has been operated officially since January 1, 2017 [18]. All hospitals in Vietnam are mandatory to register and input data into the VSI database server to receive reimbursement. According to the Vietnam health insurance scheme, patients are reimbursed 80 to 100% of the cost of primary services and 40 to 100% of the cost of specialized services [18]. The VSI database captures data on care at all levels, from primary to tertiary care, including information on medical care, preventive care, medical examinations, rehabilitation, maternity care, and prescribed medications listed in the formulary. Data of patients seeking self-treatment in retail pharmacies and private clinics are not captured. In this database, the diagnosis data are managed using the International Classification of Diseases, 10th revision (ICD-10) codes, while medical procedures, including surgery, are coded using a domestic coding system that is adapted from the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) classification system [18]. In this study, we extracted all records that were available from January 1, 2017 to September 30, 2018.

Study participants

The study sample included patients aged $\geq$ 18 who experienced any procedures of seven groups of surgeries: (1) spinal-neurological, (2) cardiothoracic, (3) vascular, (4) gastrointestinal, (5) urological, (6) orthopaedic, and (7) plastic. The list of surgical procedures identified by the domestic code and the equivalence

code of ICD-9-CM is provided in the supplemental materials (Appendix 1). Patients were excluded from the study if they had undergone another surgery within 30 days before being recruited into the study. A total of 1 241 893 surgical patients were included in the final study sample.

Measurements

Postoperative respiratory complications

In this study, we evaluated 86 respiratory complications, which were grouped into 10 categories: (1) pleural complications, (2) fungal lung infection, (3) pulmonary edema, (4) respiratory failure, (5) mechanical ventilation, (6) pneumonia, (7) aspiration pneumonia, (8) viral pneumonia, (9) atelectasis, and (10) lung abscess. The ICD-10 list of the 86 respiratory complications is provided in the supplemental materials (Appendix 2). Patients were classified as having respiratory complications if they had adverse events in any of the above categories in-hospital or within 30 days after surgery.

Re-hospitalization and outpatient visits

We examined the impact of PRCs on two outcomes: (1) re-hospitalization with a PRC, (2) outpatient visit with a PRC. Re-hospitalization refers to any overnight stay at a hospital. An outpatient visit occurs when a patient visits any hospital, surgical center, emergency department, or other healthcare centers. The re-hospitalization and outpatient visit of patients were assessed within 30 days after surgery.

Cost

We assessed the direct medical costs from healthcare sector perspective using the bottom-up approach, which represented the total amount of reimbursement by health insurance, and payment that is not covered by health insurance from patients. We evaluated the total index treatment cost and costs within 30 days after surgery. The total index treatment cost is the cost for the entire episode of the index treatment from admission to discharge, including cost for registration, doctor visits, examinations, drugs, and hospital stay. The costs within 30 days after surgery include total index treatment cost and all service, drug costs that occur within 30 days after surgery. All costs were exchanged to USD with the values were in 2018 (1 USD = 23 255 Vietnamese dong).

Length of stay

LOS was defined as the number of days of treatment during the index hospital admission, from the date of surgery to discharge. LOS at 30 days included both the stay for the index hospital admission and stays for any corresponding re-hospitalization.

Statistical analysis

To detect the differences in patients' characteristics between the two groups (with and without PRCs), we used Chi-squared tests for categorical variables and t-tests for continuous variables.

Effects of PRCs on re-hospitalization and outpatient visits

Logistic regressions were carried out to evaluate the effect of PRCs on re-hospitalization and outpatient visit within 30 after surgery. The models were adjusted for patient socio-demographic and hospital characteristics, emergency hospitalization status, and preoperative comorbidities.

Matching

Given differences in patient characteristics between the two groups, the estimate of costs associated with PRCs could potentially be biased. To overcome this problem, we applied the propensity score matching (PSM) method with a matched ratio of 1:1 using nearest neighbour algorithms. PSM is a statistical technique in which an individual in a group is matched with one or more individuals in another group based on their propensity score. This technique can help to increase the balance in participants' characteristics between groups and reduce selection bias [19,20]. The propensity scores were calculated based on the logistic regression with covariates of patient socio-demographic, emergency hospitalization status, hospital classification and preoperative comorbidities. These factors were included in the model based on the list of chronic comorbidities introduced by Elixhauser et al [21].

Incremental cost estimation

We excluded patients with multiple complications to avoid the compounding effect and to achieve a more precise estimate of the burden attributable to PRCs. After matching, we used generalized linear models to estimate the incremental cost of PRCs. A log link function was used for all models. Due to the nature of the costs, which were positively skewed, a Gamma distribution was chosen [22,23]. To further adjust for the imbalances between the two groups and to estimate the incremental cost of PRCs on specific type of surgery or type of complication, we applied the doubly robust regression approach [24,25]. In brief, this approach uses two steps to combine a form of outcome regression with the propensity score obtained from a model for the exposure, which provides an unbiased estimate for the causal effect of an exposure on an outcome [24,25]. The 95% confidence intervals (95% CI) were estimated based on the bootstrapping method with 1000 replications. To estimate the annual economic burden of PRCs at national-level, we multiplied the incremental cost of PRCs by the total number of patients calculated by the number of patients having PRC each year in the VSI database, adjusting for the coverage of 87%. The same procedure was applied for estimating the incremental LOS, except that a Poisson distribution was used, reflecting the nature of the count data. The robust sandwich estimator was applied to account for the overdispersion in the Poisson regressions.

A significance level of 0·05 was used for all statistical tests. Data were managed and analysed using Stata v16 (StataCorp, College Station, TX, USA).

Ethical approval

All procedures performed in this study were in accordance with the ethical standards of the Ethical Review Board of Hanoi Medical University (IRB approval No. 67/HDDDDHYHN; Dated: March 24, 2017). All patient information was anonymous.

Role of the funding source

The authors did not receive any funds for conducting this study

Results

Study sample

Fig. 1 provides information on the sample size of this study. The original sample contained 1 241 893 surgical patients undergoing one of seven types of surgery. We found that during the study period 20 051 of 1 241 893 (1·6%) surgical patients had PRCs. After excluding patients with multiple complications or missing data, the complete-case sample of 1 025 221 patients was used in the analysis.

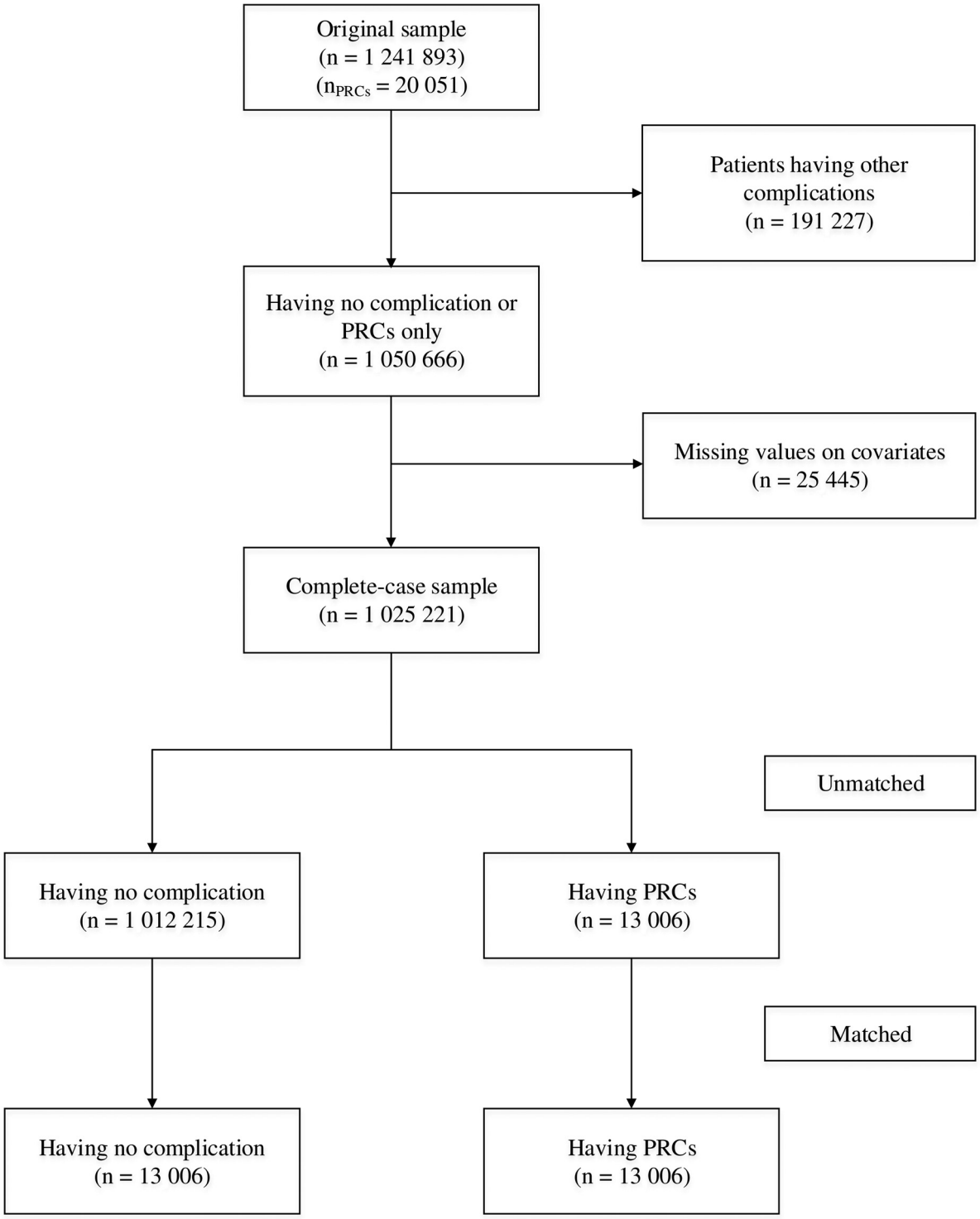

Fig. 1. Flow diagram of study sample size
PRC: Postoperative respiratory complications

Patient characteristics

Table 1 summarizes the preoperative characteristics of surgical patients with PRCs before and after matching. In the unmatched data, significant differences between the two groups (with and without PRCs) were found in all variables. In the PSM procedure, we matched the 13 006 patients who had PRCs with 13 006 patients who had no respiratory complications. There were no significant differences in patient characteristics between the two groups, except for paralysis and chronic renal failure, however the sizes of these differences were small.

Incidence of PRCs

The incidence of the 10 PRCs by seven types of surgery is presented in **Fig. 2**. PRCs were most common with cardiothoracic surgery, in 26·1% of the cases. PRCs occurred at a rate of less than 1% with orthopaedic and plastic surgeries. The most frequent

Table 1
Baseline characteristics of surgical patients by respiratory complications before and after matching.

Factors	No PRCs		PRCsn (%)	P value	
	Raw samplen (%)	Matched samplen (%)		Raw sample	Matched sample
N	1 012 215	13 006	13 006		
Age, mean (SD)	46·8 (17·3)	56·7 (18·7)	56·5 (18·7)	<0·0001	0·49
Gender					
Male	604 517 (59·7)	9417 (72·4)	9344 (71·8)	<0·0001	0·31
Female	407 698 (40·3)	3589 (27·6)	3662 (28·2)		
Region					
Northern Midlands and Mountainous	133 528 (13·2)	1455 (11·2)	1448 (11·1)	<0·0001	0·99
Red River Delta	226 778 (22·4)	2635 (20·3)	2623 (20·2)		
North Central and South Central Coast	256 884 (25·4)	3043 (23·4)	3010 (23·1)		
Central Highland	59 834 (5·9)	602 (4·6)	610 (4·7)		
Southeast	179 915 (17·8)	2474 (19·0)	2487 (19·1)		
Mekong River Delta	155 276 (15·3)	2797 (21·5)	2828 (21·7)		
Emergency hospitalization	192 795 (19·0)	3976 (30·6)	4077 (31·3)	<0·0001	0·18
Hospital classification					
Special/Level 1	507 576 (50·1)	3974 (30·6)	4089 (31·4)	<0·0001	0·12
Level 2 or lower	504 639 (49·9)	9032 (69·4)	8917 (68·6)		
Preoperative concomitant diseases					
Heart failure	6724 (0·7)	289 (2·2)	331 (2·5)	<0·0001	0·088
Valvular heart disease	3871 (0·4)	58 (0·4)	69 (0·5)	0·007	0·33
Peripheral vascular disease	2057 (0·2)	41 (0·3)	52 (0·4)	<0·0001	0·25
Hypertension	89 644 (8·9)	2280 (17·5)	2263 (17·4)	<0·0001	0·78
Paralysis	962 (0·1)	11 (0·1)	24 (0·2)	0·0001	0·028
Chronic lung disease	14 774 (1·5)	1126 (8·7)	1133 (8·7)	<0·0001	0·88
Diabetes	35 566 (3·5)	853 (6·6)	873 (6·7)	<0·0001	0·62
Complicated diabetes	571 (0·1)	8 (0·1)	12 (0·1)	0·088	0·37
Hypothyroidism	1214 (0·1)	14 (0·1)	17 (0·1)	0·72	0·59
Chronic renal failure	5767 (0·6)	254 (2·0)	302 (2·3)	<0·0001	0·040
Liver diseases	23 660 (2·3)	428 (3·3)	448 (3·4)	<0·0001	0·49
Metastatic cancer	4667 (0·5)	110 (0·8)	130 (1·0)	<0·0001	0·19
Cancer	43 457 (4·3)	1174 (9·0)	1152 (8·9)	<0·0001	0·63
Joint disease	11 434 (1·1)	159 (1·2)	182 (1·4)	0·004	0·21
Weight loss	8224 (0·8)	199 (1·5)	229 (1·8)	<0·0001	0·14
Fluid and Electrolyte Disorders	1403 (0·1)	55 (0·4)	73 (0·6)	<0·0001	0·11
Anemia	3391 (0·3)	68 (0·5)	92 (0·7)	<0·0001	0·057
Depression/Addiction	575 (0·1)	5 (<1)	10 (0·1)	0·34	0·20

PRC: Postoperative respiratory complications

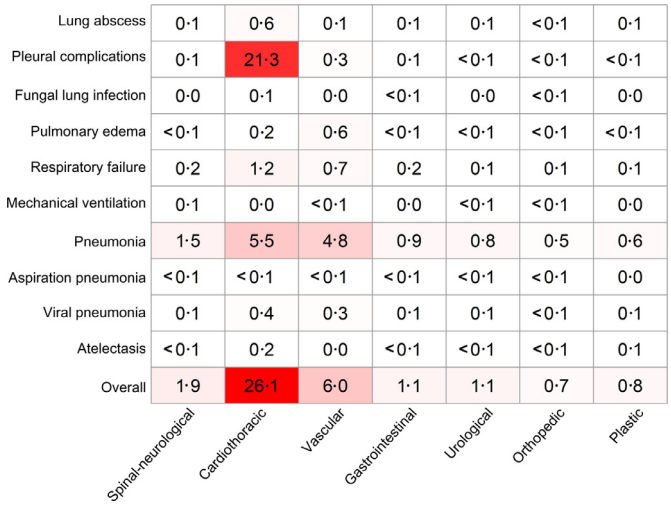

Fig. 2. Incidence of 10 postoperative respiratory complications by seven types of surgery

complications were pleural complications and pneumonia. In contrast, aspiration pneumonia and mechanical ventilation occurred at a rate of less than 0·1% for all types of surgery.

Impact of PRCs on re-hospitalization and outpatient visits

Table 2 and supplemental materials (Appendix 3) show the impact of PRCs on re-hospitalization and outpatient visit of surgical patients. The proportions of patients re-hospitalized within 30 days were 27·7% and 7·8% for patients with and without PRCs, respectively. The figures for outpatient visits of patients with and without PRCs were 49·4% and 38·0%, respectively. All the differences were significant with p-value $< 0·0001$.

After controlling for patient socio-demographic, hospital characteristics, emergency hospitalization status, and preoperative comorbidities, patients with PRCs had 3·49 times higher odds of re-hospitalization (95% CI: 3·35 – 3·64) as compared to patients without PRCs. PRCs were also associated with an increase of 39% (95% CI: 34% – 45%) in the odds of an outpatient visit within 30 days after surgery.

Economic burden of PRCs

Predictors of cost based on Gamma regressions are shown in the supplemental materials (Appendix 4). After multivariable adjustment, several patient and hospital variables were associated with a higher 30-day cost. Specifically, patients with older age, males, those who had pre-existing medical comorbidities, and those who treated in a higher level of hospital were associated with a higher cost.

The matched sample was used to estimate the cost and incremental cost of PRCs (**Table 3**). Significant increments were found in most types of cost, except for the cost of outpatient visits and the drug cost associated with outpatient visits. The mean costs within 30-day were 3272·8 USD and 2225·6 USD for patients with and without PRCs, respectively. The incremental cost associated with PRCs occurring within 30 days after surgery was 1053·3 USD (95%

Table 2
Impact of postoperative respiratory complications on re-hospitalization and outpatient visits.

Factors	Re-hospitalization		Outpatient visit	
	OR	95%CI	OR	95%CI
PRCs	3·49***	3·35 – 3·64	1·39***	1·34 – 1·45
Age	1·01***	1·01 – 1·01	1·00	1·00 – 1·00
Gender *(Ref: Male)*				
Female	0·88***	0·87 – 0·89	1·08***	1·07 – 1·09
Region *(Ref: Northern Midlands and Mountainous)*				
Red River Delta	0·77***	0·76 – 0·79	1·32***	1·29 – 1·34
North Central and South Central Coast	0·86***	0·84 – 0·88	1·89***	1·86 – 1·92
Central Highland	0·92***	0·89 – 0·95	2·77***	2·71 – 2·83
Southeast	0·57***	0·56 – 0·59	5·26***	5·18 – 5·35
Mekong River Delta	0·67***	0·65 – 0·69	5·17***	5·09 – 5·26
Emergency hospitalization	1·06***	1·04 – 1·08	1·00	0·99 – 1·01
Hospital classification *(Ref: Level 2 or lower)*	1·94***	1·91 – 1·97	0·98***	0·97 – 0·99
Preoperative concomitant disease				
Heart failure	0·96	0·89 – 1·04	0·97	0·92 – 1·02
Valvular heart disease	1·09	0·98 – 1·21	1·91***	1·78 – 2·05
Peripheral vascular disease	1·19**	1·04 – 1·35	1·13**	1·03 – 1·24
Hypertension	1·16***	1·13 – 1·18	1·82***	1·79 – 1·85
Paralysis	1·88***	1·59 – 2·21	0·80**	0·70 – 0·92
Chronic lung disease	1·16***	1·10 – 1·22	1·23***	1·19 – 1·27
Diabetes	1·19***	1·15 – 1·24	2·12***	2·07 – 2·17
Complicated diabetes	1·10	0·86 – 1·39	1·60***	1·33 – 1·92
Hypothyroidism	0·98	0·81 – 1·19	1·65***	1·47 – 1·86
Chronic renal failure	2·94***	2·76 – 3·13	1·24***	1·17 – 1·31
Liver disease	1·09***	1·05 – 1·14	1·17***	1·14 – 1·21
Metastatic cancer	2·15***	2·01 – 2·31	1·20***	1·13 – 1·27
Cancer	4·66***	4·56 – 4·77	1·18***	1·16 – 1·21
Joint disease	1·03	0·96 – 1·10	1·50***	1·44 – 1·56
Weight loss	1·15***	1·08 – 1·24	1·24***	1·18 – 1·29
Fluid and Electrolyte Disorders	1·15	0·99 – 1·35	0·68***	0·61 – 0·76
Anaemia	1·47***	1·34 – 1·61	1·06	0·99 – 1·14
Depression/Addiction	1·27	0·97 – 1·68	1·53***	1·28 – 1·83

CI: Confidence interval; PRC: Postoperative respiratory complications; OR: Odds ratio
All estimates were calculated using unmatched sample
*** $p < 0.0001$;
** $p < 0.01$;
* $p < 0.05$

Table 3
Costs, length of hospital stay, and incremental estimates due to postoperative respiratory complications.

	Mean cost (USD)		Cost ofPRCs,USD (% GDP[a])	95% Bootstrap CI	P value
	No PRCs	PRCs			
N	13 006	13 006			
Treatment cost					
Total cost of the indexed treatment	1044·4	1499·0	457·1 (17·8)	410·9 – 503·4	<0·0001
30-day costs					
Service cost for 30-day re-hospitalization	876·5	1251·6	376·8 (14·7)	335·7 – 417·9	<0·0001
Drug cost for 30-day re-hospitalization	216·5	427·8	213·8 (8·3)	185·3 – 242·2	<0·0001
Service cost for 30-day outpatient visits	59·5	64·7	9·6 (0·4)	-2·2 – 21·5	0·112
Drug cost for 30-day outpatient visits	28·7	29·7	5·9 (0·2)	-7·4 – 19·2	0·383
Total 30-day cost	2225·6	3272·8	1053·3 (41·0)	940·7 – 1165·8	<0·0001
	Difference in LOS				
Length of stay (days)					
Length of hospital stay	8·7	11·4	2·7	2·5 – 2·9	<0·0001
Total length of treatment within 30 days[b]	13·5	19·1	5·6	5·3 – 6·0	<0·0001

95% CI: 95% Confidence interval; LOS: Length of stay; PRCs: Postoperative respiratory complications
All estimates were calculated using matched sample
[a] Compared to GDP per capita in Vietnam in 2018 (2566 USD)
[b] Includes length of hospital stay in the treatment and 30-day re-hospitalization periods

CI: 940·7 – 1165·8), which was equivalent to 41·0% of the GDP per capita in Vietnam in 2018. The service costs of re-hospitalization contributed the most to the incremental cost of PRCs, while the drug cost associated with outpatient visits was the smallest contributor.

Table 4 shows the 30-day incremental costs of PRCs breakdown by types of surgery or types of PRC. The highest incremental cost of PRCs was associated with spinal-neurological surgery, at 3143·4 USD (95% CI: 2653·7 – 3633·2) per procedure. In contrast, the incremental cost of PRCs associated with cardiothoracic surgery was

Table 4
Total 30-day cost and estimated incremental payments, by type of surgery and complications.

	Mean cost (USD)		Cost ofPRCs,USD (% GDP[a])	95% Bootstrap CI	P value
	No PRCs	PRCs			
Total 30-day cost breakdown by types of surgery					
Spinal-neurological (n matched = 1278)	3279·9	6420·3	3143·4 (122·5)	2653·7 – 3633·2	<0·0001
Cardiothoracic (n matched = 12204)	2792·2	2913·3	114·4 (4·5)	-9·6 – 238·4	0·071
Vascular (n matched = 506)	6340·6	7735·0	1508·2 (58·8)	361·1 – 2655·3	0·010
Gastrointestinal (n matched = 4852)	1959·5	3530·2	1589·8 (62·0)	1372·9 – 1806·7	<0·0001
Urological (n matched = 1526)	1640·2	3027·6	1398·3 (54·5)	1100·8 – 1695·9	<0·0001
Orthopaedic (n matched = 4446)	2127·4	2951·4	843·7 (32·9)	443·4 – 1244·1	<0·0001
Plastic (n matched = 380)	953·1	2491·5	1529·7 (59·6)	841·5 – 2217·9	<0·0001
Total 30-day cost breakdown by PRCs					
Pleural complications (n matched = 10850)	2183·2	2368·6	187·9 (7·3)	-5·2 – 381·0	0·057
Fungal lung infection (n matched = 39)	2770·5	4565·0	1794·6 (69·9)	140·8 – 3448·3	0·033
Pulmonary edema (n matched = 222)	2836·0	4555·7	1746·0 (68·0)	961·5 – 2530·5	<0·0001
Respiratory failure (n matched = 1733)	2833·9	5489·1	2694·0 (105·0)	2296·0 – 3092·0	<0·0001
Mechanical ventilation (n matched = 44)	1862·4	3939·4	2077·0 (80·9)	-2·4 – 4156·3	0·050
Pneumonia (n matched = 10911)	2233·2	4071·9	1850·7 (72·1)	1702·8 – 1998·6	<0·0001
Aspiration pneumonia (n matched = 33)	1569·1	2312·0	767·3 (29·9)	-1694·9 – 3229·4	0·541
Viral pneumonia (n matched = 761)	2036·2	3783·6	1767·0 (68·9)	1322·6 – 2211·4	<0·0001
Atelectasis (n matched = 109)	2387·8	3378·2	1021·3 (39·8)	-131·5 – 2174·1	0·082
Lung abscess (n matched = 1308)	2067·3	2338·2	257·5 (10·0)	-11·1 – 526·1	0·060

CI: Confidence interval; PRCs: Postoperative respiratory complications;
All estimates were calculated using matched sample
[a] Compared to GDP per capita in Vietnam in 2018 (2566 USD)

only 114·4 USD (95% CI: -9·6 – 238·4). Regarding types of PRC, respiratory failure was the costliest complication, with an estimated incremental cost of 2694·0 USD (95% CI: 2296·0 – 3092·0), while the lowest incremental cost was 187·9 USD (95% CI: -5·2 – 381·0) among patients with pleural complications.

The estimated national economic burden of PRCs in Vietnam is shown in **Table 5**. The annual incremental cost due to PRCs was 6·02 (95% CI: 5·41 – 6·63) million USD for indexed treatment, and the 30-day cost was 13·87 (95% CI: 12·39 – 15·35) million USD. PRCs associated with gastrointestinal surgery contributed the most to the annual cost burden, at 4.91 million USD each year. In term of types of complication, pneumonia accounted for 13·55 million USD, which was the highest single annual cost burden from PRCs.

Along with the incremental cost due to PRCs, the LOS also increased for patients with PRCs. On average, the LOS for patients who developed PRCs was longer compared to those who did not have PRCs, by 2·7 days (95% CI: 2·5 – 2·9). The incremental LOS within 30 days after surgery was 5·6 days (95% CI: 5·3 – 6·0). All the increments in LOS were significant with p-value < 0·0001. (**Table 3**)

Discussion

Medical complications, particularly surgical complications, have long been recognized as a major factor that contributes to the economic burden in both developed and developing countries [10,26]. At a patient level, the excess payments due to surgical complications can contribute to catastrophic health expenditure of patients [26,27], which can push them into poverty, especially in LMICs [26]. Estimating the incremental cost of complications is crucial in developing appropriate strategies to mitigate the global and national economic burden. However, doing so can be a huge challenge due to the unavailability of the data [15,28]. To our best knowledge, this is the first study in Vietnam to estimate the national economic burden of PRCs. The findings of this study may serve as a reference to develop cost-effective prevention strategies for PRCs.

In the 21 months from January 2017 to September 2018, we identified 1 241 893 surgical patients who underwent surgery in one of seven main groups, namely spinal-neurological, cardiothoracic, vascular, gastro-intestinal, urological, orthopaedic and plastic surgery. We found that 20 051 of the 1 241 893 (1·6%) surgical patients had PRCs, which were most common with cardiothoracic surgery, at 26.1%. PRCs increased the odds of both rehospitalization and outpatient visits. The mean incremental cost associated with PRCs within 30 days after surgery was 1053·3 USD, which was equivalent to 41% GDP per capita in Vietnam in 2018. We estimated that the annual incremental 30-day cost of PRCs was 13·87 million USD in Vietnam.

In the literature, the frequency of PRCs varies widely between studies, mainly due to different types of surgery, levels of hospital, and definition of PRCs. A systematic review of non-cardiothoracic surgery reported that the incidence of PRCs varied from 2% to 19% [3]. However, most of these studies involved small sample sizes

Table 5
Estimated annual cost burden due to postoperative respiratory complications.

	Estimated annual number of patients[a]	Cost ofPRCs, (USD)	Estimated annual cost burden, million USD	95% CI
Treatment cost				
Total cost of the indexed treatment	13 170	457·1	6·02	5·41 – 6·63
Total 30-day cost				
Overall	13 170	1053·3	13·87	12·39 – 15·35
Total 30-day cost breakdown by types of surgery				
Spinal-neurological	923	3143·4	2·9	2·45 – 3·35
Cardiothoracic	5064	114·4	0·58	-0·05 – 1·21
Vascular	572	1508·2	0·86	0·21 – 1·52
Gastrointestinal	3089	1589·8	4·91	4·24 – 5·58
Urological	967	1398·3	1·35	1·06 – 1·64
Orthopedic	2352	843·7	1·98	1·04 – 2·93
Plastic	203	1529·7	0·31	0·17 – 0·45
Total 30-day cost breakdown by PRCs[b]				
Pleural complications	4615	187·9	0·87	-0·02 – 1·76
Fungal lung infection	20	1794·6	0·04	0·00 – 0·07
Pulmonary edema	185	1746·0	0·32	0·18 – 0·47
Respiratory failure	1149	2694·0	3·1	2·64 – 3·55
Mechanical ventilation	32	2077·0	0·07	0·00 – 0·13
Pneumonia	7323	1850·7	13·55	12·47 – 14·64
Aspiration pneumonia	24	767·3	0·02	-0·04 – 0·08
Viral pneumonia	490	1767·0	0·87	0·65 – 1·08
Atelectasis	59	1021·3	0·06	-0·01 – 0·13
Lung abscess	587	257·5	0·15	-0·01 – 0·31

CI: Confidence interval; PRCs: Postoperative respiratory complications
[a] Number of patients were estimated based on the total annual number of patients undergone seven types of surgery in the VSI database, accounted for 87% coverage.
[b] Each patient might have more than one complication, thus the total number of complication might be larger than the number of patient.

and had a potential risk of sampling bias [3]. A study by Canet et al. indicated that thoracic surgery had a much higher PRC incidence (37·8%) than upper abdominal (12·2%) and peripheral (2·2%) surgery [2]. The incidence of PRCs can also depend on diagnostic criteria. The overall incidence of PRCs in our study was lower than in the above-mentioned studies; however, the pattern was similar, in that PRCs were higher in cardiothoracic surgeries than in other surgeries.

Hospital readmission is a persistent and costly occurrence [4,29]. In the US, the public health cost of PRC-related readmissions was estimated at approximately 835 million USD per year [4,12]. Readmissions or outpatient visits by surgical patients may be planned or unplanned [12]. However, most of the potential causes of unplanned re-hospitalization or outpatient visits may be preventable [12]. Understanding risk factors is extremely important for improving the quality and safety of hospital care, as well as reducing its economic burden. In line with previous studies [4,12], our findings confirm that PRCs are risk factors for both hospital readmission and outpatient visits.

Regarding the economic burden of PRCs after surgery, we found that the overall incremental cost associated with PRCs within 30 days after surgery was 1053·3 USD per procedure. This increment contributed to an increase of 13·87 million USD in medical care costs each year. Previous studies report a wide range of cost of PRCs. The cost of PRCs depends on the type of procedure, type of complication, and length of follow-up, as well as the health system, but it is substantial in any context. A study by Whitmore et al [13] reported that the mean incremental cost of PRCs of patients who had undergone spinal surgery was 7233 USD. Idrees et al [30] reported that the cost of respiratory failure was 25 169 USD per procedure, and the estimated annual cost burden was 6·43 million USD. The increase in the cost of care for postoperative pneumonia ranges from 12 220 USD [31] to 28,161 USD [32], for aspiration pneumonia from 10 921 USD to 13 932 USD [33,34], and for respiratory failure from 5983 USD to 120,579 USD [31, 33], It is notable that the absolute incremental cost of PRCs in our study is far lower than in the above-mentioned studies; this is because most of these studies were conducted in the high income countries. When comparing the GDP per capita, the incremental cost due to PRCs within 30 days after surgery in our study is equivalent to 41% GDP per capita, which is consistent with studies in the US [30]. The findings indicate that in both high-income countries and low-income countries, irrespective of the context of the healthcare system, the cost burden of PRCs is substantial. Thus, creating appropriate prevention strategies for PRCs is extremely important, not only to improve allocation of healthcare resources but also to save considerable sums each year.

Besides the direct incremental cost of PRCs, our findings confirm that PRCs also increase the postoperative LOS for patients [2,10,35]. The increase of postoperative LOS also increases any indirect cost that contributes to the economic burden of PRCs [2,7,36].

In Vietnam, the quality of healthcare services has increased over the last decade, and this has resulted in decreased mortality among surgical patients. However, prevention of postoperative complications, particularly PRCs, is not considered a priority. Our findings are significant in alerting policymakers to the economic burden of PRCs. Implementing evidence-based practices and monitoring systems can help reduce the cost of complications and, in turn, improve the allocation of healthcare resources, which is especially important in the context of the limited resources in Vietnam [37, 38]. Improving the health information systems in hospitals should be considered to provide more comprehensive pre- and post-operative information on patients and to enable accurate decision-making. Global Surgery [15] should also be researched and implemented to achieve the SDG target for 2030 in protecting against impoverishing health expenditure.

This is the first study in Vietnam to investigate the economic burden of PRCs with surgical patients, using standardized, nationally representative data with a large sample size. We also examined a wide range of PRCs in seven types of surgery, which gave general insights into the economic burden of PRCs. By applying the propensity score matching method, we were able to control

for the imbalance in patient socio-demographic and hospital characteristics, emergency hospitalization status, and preoperative comorbidities between the two groups (with and without PRCs). This technique allowed us to obtain unbiased estimates of incremental cost of PRCs, thus increasing the robustness of our findings.

We acknowledge some limitations in this study. First, we were only able to analyse the direct medical cost, which underestimated the economic burden of PRCs. The true cost should include indirect costs, such as loss of productivity, lost wages, and out-of-pocket expenses. Second, although the dataset used in this study is large and nationally representative, there is a possibility of errors that are inherent in most retrospective reports, such as random errors in coding and lack of details to isolate specific costs. Finally, the VSI database did not capture data on patients who seek self-treatment in the pharmacies, and private clinics, or using drugs that are not listed in the formulary, which are popular in Vietnam, especially when health problems are not serious.

Contributors

BMH and KQL designed the study; BMH and TTH collected and cleaned data; BMH and KQL performed the official statistical analyses and interpreted the results; BMH, KQL, and LPA wrote the manuscript; DQH, DTD, PTV, TTH, NHH, TBG, DDH, HGD, DXT, and LQC provided the critical revision of the manuscript for important intellectual content. All authors have read and approved the final manuscript

Data sharing statement

The data analysed in this study are available from an institutional repository, but restrictions apply to the data's availability, thus are not publicly available. The data (with the exclusion of patient's and hospital's identifiers), data dictionary, statistical analysis plan, and code for the analysis are available for research purposes upon reasonable request through the corresponding author, with permission from the Vietnam Social Insurance Agency, and signed data access agreements.

Declaration of Competing Interest

The authors declare that they have no conflict of interest

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.lanwpc.2021.100125.

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