Postoperative Pulmonary Complications after Laparotomy

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Key Words

Surgical complications · Laparotomy · Pneumonia · Atelectasis · Respiratory failure

Abstract

Background: The frequency of, and risks for, postoperative pulmonary complications (PPCs) after laparotomy are incompletely understood. The wide-ranging incidence of PPCs in the literature reflects methodological issues including variable definitions of PPCs and varied patient populations. **Objectives:** We sought to elucidate the incidence of PPCs after laparotomy and clarify risks for their development. **Methods:** We conducted a retrospective study of all laparotomies in adult patients on the general surgery service at our university-affiliated hospital in 2004. The definition of PPCs was rigorous and relevant in terms of key outcomes (morbidity, mortality, length of stay). We used a template for the review of medical records to identify PPCs and their consequences. **Results:** Twenty-five PPCs (7.0%) occurred in 359 laparotomies. Logistic regression modeling identified the following independent predictors of risk: upper abdominal incisions (OR 15.3; $p = 0.025$), reoperation (OR 7.1; $p = 0.013$), emergency surgery (OR 6.3; $p = 0.001$) and nasogastric tubes (OR 5.4; $p = 0.008$). PPCs were associated with

increased mortality (OR 6.17; $p = 0.01$), intensive care unit care (OR 13.0; $p = 0.001$), increased mean hospital length of stay (17.7 days longer; $p = 0.001$) and longer mean postoperative length of stay (15.2 days longer; $p = 0.001$). **Conclusions:** The incidence of PPCs after laparotomy in this study is lower than in many prior reports and reflects the relevant definition of PPCs used. Upper abdominal surgery carried the greatest risk. Reoperation was a risk not identified previously. Emergency procedures and the use of nasogastric tubes were confirmed as key risks. Morbidity, mortality and lengths of stay were significantly increased after PPCs.

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Introduction

Postoperative pulmonary complications (PPCs) occur with a frequency equal to or greater than cardiac complications and may be more likely than cardiac complications to predict long-term mortality after surgery [1]. The overall incidence of PPCs has been estimated at 5–10% [2]. The frequency of PPCs after laparotomy reported in the literature has varied widely [3]. It has ranged from 20 to 69% for atelectasis, and from 9 to 40% for postoperative pneumonia [4].

A number of factors may be responsible for this variability including patient selection, differences in the surgical procedures studied and variation in the definition of PPCs. Similarly, reported risk factors for PPCs have varied considerably. The objective of the present study was to elucidate the incidence of, and risk factors for, PPCs after laparotomy.

Materials and Methods

In this retrospective study, we reviewed the medical records of all adult patients 18 years of age and older undergoing abdominal surgery on the general surgery service in 2004. The study was approved by the internal review board of the hospital. The hospital has 450 beds and is affiliated with the SUNY-Downstate Medical Center. It is a primary site for the Downstate general surgery training program. Only open, nonambulatory abdominal procedures were included in the data analysis. Laparoscopic procedures, inguinal hernia repairs and purely retroperitoneal procedures were excluded. Trauma surgeries were excluded as were organ transplants which are not performed at our institution.

PPCs were defined by the occurrence of 1 or more of the following during the first postoperative week: respiratory infection (pneumonia and acute bronchitis), major atelectasis (1 or more pulmonary segments), exacerbation of preexisting lung disease, respiratory failure due to primary pulmonary disorders (extra-pulmonary sepsis with acute respiratory distress syndrome, cardiogenic pulmonary edema and other nonpulmonary conditions) were excluded, and pulmonary embolism. The identification of respiratory infection was adapted from Brooks-Brunn [5] and required 2 or more of the following for at least 2 consecutive days: (1) new cough/sputum production, (2) physical findings compatible with pneumonia, (3) temperature $\geq 38^{\circ}\text{C}$, and (4) the development of a new infiltrate on radiographs.

Demographic and clinical variables were recorded that have been identified in the literature as risk factors for PPCs. We included 2 variables that have not been routinely evaluated in prior studies: emergency surgery and reoperation during the same admission. Mortality, hospital length of stay (LOS), postoperative LOS and frequency of intensive care unit (ICU) care were scrutinized to assess the impact of PPCs.

Chart reviews were guided by a template with the variables of interest. We examined physician and nursing notes, orders, anesthesia records, operative reports, diagnostic studies and pathology reports. Data were entered into an Excel spreadsheet. All database entries were reviewed independently by 2 members of the study team (V.B., P.R.S.).

Emergency surgery was defined as a nonelective procedure performed within 48 h of hospital admission, or within 48 h of onset of a new surgical condition in a patient hospitalized for an unrelated disorder. Active smokers were patients who had not stopped prior to admission. A history of lung disease included chronic conditions such as chronic obstructive lung disease, asthma and interstitial lung disease. A history of heart disease did not include hypertension unless there was evidence of cardiac dysfunction. Upper abdominal incisions were defined as those above the umbilicus, whereas lower abdominal incisions were below the

umbilicus, and upper/lower incisions were continuous incisions from the upper to the lower abdomen. Incentive spirometry was identified from physicians' orders. Respiratory failure was defined as inability to discontinue mechanical ventilation within 48 h postoperatively, resumption of mechanical ventilatory support with intubation and mechanical ventilation, or bi-level positive airway pressure, new onset hypercapnia with $\text{PaCO}_2 \geq 50$ mm Hg, or severe hypoxemia with a $\text{PaO}_2/\text{FiO}_2 < 250$ mm Hg. Reoperations included only repeat laparotomies.

Statistical analyses were performed using SPSS version 16. Univariate comparisons between the presence and absence of PPCs among potential categorical predictor variables were analyzed using Fisher's exact test. Comparisons of differences for continuous variables between operations with and without PPCs were analyzed by the Student *t* test and the nonparametric Mann-Whitney rank sum test.

Multiple variable logistic regression models were used to predict the presence or absence of PPCs based on values of a set of predictor variables which were selected from the univariate analyses. This approach is similar to a multiple linear regression but is suited to models where the dependent variable is dichotomous. Logistic regression coefficients are used to estimate odds ratios (ORs) for each of the independent variables in the model and their 95% confidence intervals (CIs). To limit the possibility of false-negative results, all predictor variables associated with PPCs in the univariate analyses with a *p* value ≤ 0.2 were included in the initial model. A backward stepwise procedure was used to determine which variables would remain in the model. Removal testing was based on the probability of the likelihood ratio statistic derived from the maximum partial likelihood estimates. The Hosmer-Lemeshow goodness-of-fit statistic, model χ^2 and improvement χ^2 were used to assess the adequacy of the fit of the models.

Results

During the 12 months of the study, 2,519 operations were performed on the general surgery service. There were 359 laparotomies in 329 patients. All were performed under general anesthesia. No patient received epidural analgesia postoperatively. The type and number of specific operations are shown in table 1. The mean age of the patients was 58.3 years. There were 200 women and 129 men. PPCs were identified in 25 of 359 laparotomies (7.0%). They occurred in 24 patients (1 patient suffered 2 episodes after successive operations). The types of PPCs are shown in table 2. Pneumonia was the sole PPC in 6 instances and associated with respiratory failure in 8 more. Respiratory failure alone accounted for 3 PPCs and was associated with pneumonia in 8 instances and with chronic obstructive pulmonary disease, bronchitis and pulmonary embolism once each. Mechanical ventilation was required in 9 of 14 episodes of respiratory failure (62.3%).

Table 1. Operative procedures in 359 laparotomies

	n	PPCs
Abdominal aortic aneurysm repair	3	0
Abdominal perineal resection	4	0
Appendectomy	55	0
Bowel resection (large or small bowel)	115	11 (9.6)
Esophagectomy	1	0
Exploratory laparotomy	27	5 (18.5)
Gall bladder surgery	42	2 (4.8)
Gastric surgery	15	3 (20)
Gastric bypass	4	0
Hepatectomy	2	0
Lysis adhesions	17	0
Ostomy (creation or takedown, large or small bowel)	16	1 (6.3)
Pancreatectomy	2	0
Umbilical hernia repair	8	0
Ventral hernia repair (including incisional hernia)	38	1 (2.6)
Whipple procedure	3	1 (33.3)
Miscellaneous	7	1 (14.3)
Total	359	25

Figures in parentheses are percentages.

Univariate analysis of potential risk factors for PPCs are shown in table 3. Heart or lung disease were significant risks for PPCs, as were a higher American Society of Anesthesiology risk stratification, longer anesthesia time, emergency surgery, reoperation, the presence of nasogastric tubes postoperatively, and upper or upper/lower abdominal incisions (versus lower incisions). PPCs occurred in only 1 of 77 patients (1.3%) with lower incisions compared with 5 of 60 (8.3%) with upper incisions, and 19 of 222 patients (8.6 %) with upper/lower incisions. There was a trend toward older age in the PPC group ($p = 0.065$). Gender, smoking history (ever or active), surgery for malignant disease and ordering incentive spirometry did not impact the occurrence of PPCs.

Independent predictors of PPCs identified by logistic regression modeling are shown in table 4. Overall, the data fit the model well ($p = 0.60$). Upper abdominal incisions were over 15 times more likely than lower incisions to be associated with PPCs. Upper/lower abdominal incisions were associated with a more than 7-fold increase in risk compared with lower incisions, although the difference just missed statistical significance ($p = 0.07$). The risk was more than 6 times greater after emergency procedures ($p = 0.001$). The likelihood was 7 times greater

Table 2. PPCs in 359 laparotomies

PPC description	n
Atelectasis	1
Pneumonia	6
Pneumonia and respiratory failure	8
Respiratory failure	4
Pulmonary embolism	1
Pulmonary embolism and respiratory failure	1
COPD exacerbation	1
COPD exacerbation and respiratory failure	1
Asthma exacerbation	2
Total	25

COPD = Chronic obstructive pulmonary disease.

when patients underwent reoperation ($p = 0.013$). There were 16 patients requiring repeat laparotomy. Eleven of 16 were for complications related to the initial procedure. PPCs occurred in 4 of these 11 (36.4%). Five of 16 were for staged or unrelated procedures. There were no PPCs in this group. The use of nasogastric tubes postoperatively conveyed a more than 4-fold increase in risk. A history of lung disease was associated with increased risk but was just below the threshold for statistical significance (OR 2.45; $p = 0.063$).

The consequences of PPCs were considerable. In-hospital mortality was 16% (4 of 25) after PPCs versus 3% (10 of 334) without PPCs. Three of the 4 deaths were in patients with respiratory failure requiring mechanical ventilation. There was a 6-fold increase in mortality risk after PPCs (OR 6.17; 95% CI 1.79–21.34; $p = 0.01$). Management in the ICU was required in 68% (17 of 25) of laparotomies with PPCs compared with 14.1% (47 of 334) without these complications. The risk for ICU management was 13-fold greater after PPCs (OR 13.0; 95% CI 5.30–31.76; $p = 0.001$). Mean hospital LOS was 17.7 days longer and the mean postoperative LOS was 15.2 days longer after PPCs ($p = 0.001$ for both comparisons).

Discussion

The main objectives of our study were clarification of the frequency of PPCs after laparotomy and the risk factors for their occurrence. We found a 7.0% incidence of PPCs after laparotomy. Upper abdominal incisions, reoperation, emergency surgery and nasogastric tubes were independent predictors of risk for PPCs. Upper/lower in-

Table 3. Risk variables associated with PPCs in 359 laparotomies

Variable	PPCs (n = 25)	No PPCs (n = 334)	p value
Mean age $\pm$ SE, years	63.7 $\pm$ 2.25	58.4 $\pm$ 3.12	0.065
Male gender	17 (68)	197 (59)	0.41
Smoking, ever	12 (48)	112 (33.5)	0.19
Smoking, active	5 (20)	48 (14.4)	0.72
History of lung disease	10 (40)	61 (18.3)	0.016
History of cardiac disease	10 (40)	69 (20.7)	0.04
Mean ASA $\pm$ SE	3.04 $\pm$ 0.42	2.38 $\pm$ 0.42	0.001
Mean anesthesia time $\pm$ SE, min	252.2 $\pm$ 5.5	177.8 $\pm$ 26.0	0.002
Emergency surgery	13 (52)	89 (26.6)	0.01
Surgery for malignancy	10 (40)	88 (26.3)	0.163
Lower abdominal incision	1 (4)	76 (22.8)	0.001
Nasogastric tube	21 (84)	162 (48)	0.001
Incentive spirometry	20 (80)	305 (91.3)	0.15
>1 operation during admission	4 (16)	12 (3.6)	0.02

Figures in parentheses are percentages. SE = Standard error of the mean; ASA = American Society of Anesthesiology risk stratification.

Table 4. Independent predictors of PPCs in 359 laparotomies

Variable	OR	95% CI	p value
History of lung disease	2.45	0.95–6.30	0.063
Emergency surgery	6.35	2.43–16.61	0.001
Upper versus lower incision	15.30	1.42–165.18	0.025
Upper/lower versus lower incision	7.17	0.82–62.72	0.075
Nasogastric tube	5.44	1.57–18.84	0.008
Reoperation during admission	7.09	1.51–33.32	0.013

cisions and chronic lung disease were associated with increased risk but were not quite statistically significant.

In prior reports, the range of incidence of PPCs after laparotomy has been wide. Smetana et al. [1] reviewed the literature on frequency and risk factors for PPCs after noncardiothoracic surgery spanning the years 1980–2005. Nine papers focused on laparotomies [6–14], and PPCs ranged from 0.9 to 69.5%. A prospective cohort study published in 1997 not included in the review of Smetana et al. [1] included 400 patients and reported a PPC frequency of 22.5% [4]. A study of elective nonthoracic operations with 1,055 patients included 413 laparotomies [15]. Overall, PPCs occurred in 2.7%. The frequency after laparotomies was not stated. The National Hospital Discharge Survey of major abdominal opera-

tions in the United States for 1989–2004 showed a PPC rate of 6.5% in 12,897,800 procedures [16], similar to the incidence in our study.

Reasons for the broad range of PPC frequencies after laparotomy previously reported relate to several factors. These include various definitions of PPCs, the time frame included postoperatively, the specific surgical sites (upper abdominal only versus all abdominal), specific exclusions (e.g., hernia repairs), varied patient populations and study design.

Variability in the definition of PPCs in prior studies has been considerable. In the reports cited above, pneumonia alone defined PPCs in 4 [7, 8, 10, 12] and pneumonia and atelectasis in 2 studies [4, 11]. In the remainder, PPCs usually included pneumonia and atelectasis plus any of the following: respiratory failure, bronchitis, bronchospasm, pleural effusion, pulmonary embolism and pneumothorax. Our definition only included events affecting key outcomes including serious morbidity, mortality and LOS. We also included exacerbation of pre-existing lung disease which has not been routinely assessed in prior studies. Sixteen percent (4/25) of the PPCs in our study were exacerbations of underlying pulmonary disease.

Another variable aspect in reported studies is the time frame in which PPCs were assessed. Although in most studies PPCs were defined as occurring within the first postoperative week, some reports included PPCs occurring anytime prior to discharge [17, 18]. In at least 1 study,

PPCs were evaluated only through 48 h postoperatively [19]. In our study, only PPCs identified within the first postoperative week were included. Events after the first week are less likely, due specifically to the operation. Laparotomy reduces diaphragmatic function via reflex inhibition of phrenic nerve output, during the first postoperative week [20]. Atelectasis and pneumonia are promoted by rapid-shallow breathing due to the impairment of diaphragmatic function.

The incidence of PPCs after laparotomy was lower in the present study than in many prior reports [4, 6, 7, 9–12, 14]. The most important aspect of our study responsible for this observation relates to our definition of PPCs which excluded transient and minor events, as well as complications secondary to nonpulmonary causes such as cardiogenic pulmonary edema. An additional albeit minor factor impacting the frequency of PPCs we observed could be the relatively small number of open abdominal aortic aneurysm repairs in our study. This operation is associated with the greatest risk for PPCs of any specific procedure [1, 2].

Our data confirm that in contrast to cardiac complications, procedure-related factors confer a greater risk for PPCs than patient-related factors, and amongst procedure-related factors, the surgical site has the largest impact [1]. Upper abdominal incisions imparted the greatest risk followed by combined upper/lower incisions. Reoperation during the same admission, emergency procedures and postoperative nasogastric tubes were also independent risk factors. The only independent, patient-related risk factor was a history of lung disease and this just missed statistical significance.

Upper abdominal incisions have long been considered to impose a higher risk for PPCs than lower incisions [21]. More profound reflex inhibition of diaphragmatic function after upper abdominal procedures is believed to be the operative mechanism [20]. The lower risk after lower abdominal incisions has been documented in a number of prior reports including a study of 560 gynecologic surgeries [22].

Our data confirm an increased risk for PPCs related to nasogastric tubes. This has been previously reported including a recent large prospective trial [15]. Accumulating evidence suggests that routine use of nasogastric tubes after laparotomy is not indicated [23–25]. How nasogastric tubes increase the risk for PPCs is not completely clear. Interference with cough due to discomfort, incomplete closure of the glottis and fostering transfer of microorganisms from the oropharynx to the airways are suggested mechanisms [17]. Nasogastric tubes may also

promote diaphragmatic dysfunction through reflex mechanisms [26]. We did not demonstrate reduction in PPCs with incentive spirometry. Actual frequency and adequacy of use of this modality could not be determined from the records.

Emergency surgery and reoperation were independent risk factors for PPCs in our study. Emergency surgery has been believed to increase the risk for postoperative complications [2, 27], but most studies have included only elective procedures. A study of emergency laparotomy in 266 patients found a 28.2% incidence of PPCs [28]. Intuitively it would seem that there would be an increased risk for postoperative complications when unplanned reoperations are performed during the same admission, but to our knowledge, this has not been previously reported. We found a 7-fold greater risk for PPCs after reoperation.

The consequences of PPCs in the present study were considerable. In-hospital mortality, ICU care, hospital LOS and postoperative LOS all increased significantly after PPCs. Similarly, a prior study reported in-hospital mortality of 22% after elective laparotomy in 82 patients with PPCs and none in 82 controls [18]. In a prospective study of 283 patients undergoing upper abdominal surgery, 69 (24.4%) experienced PPCs, and of these, 14 died (20.3%) [29]. In that report, PPCs were the only variable showing a significant association with death. Our data also expand the understanding of the impact of PPCs. Increased utilization of ICU beds and longer postoperative hospitalizations are consequences that have not received adequate attention in the past.

Our study has certain limitations. It was based on chart reviews. Thus, it is subject to the limitations of all retrospective studies, most importantly, the potential for misclassification of, or failure to identify data of interest. To mitigate this limitation, we employed a rigorous definition of PPCs, used a template for data collection, and had 2 authors independently review all data. Other limitations are the small number of abdominal aortic aneurysm repairs, a single-center experience and applicability to institutions without surgery training programs.

In conclusion, the present study clarifies several key issues concerning PPCs after laparotomy. We employed a clear and relevant definition of PPCs, included events only during the first postoperative week and excluded low-risk procedures such as laparoscopies. Thus, the 7% PPC frequency we report should be a truer benchmark than previously reported. Our study identifies reoperation as a risk factor for PPCs for the first time. The risk associated with emergency laparotomy has not been

clearly defined in the past. We found it to be an independent risk factor for PPCs. Finally, our study strengthens the importance of upper abdominal incisions and nasogastric tubes as key risks for PPCs after laparotomy.

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