Postoperative pulmonary complications in contemporary cohort of patients with pulmonary hypertension

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ABSTRACT

Patients with pulmonary hypertension are at increased risk for postoperative pulmonary complications (PPCs). Herein, we review PPCs in pulmonary hypertension patients undergoing non-cardiac procedures under general anesthesia. The medical records of pulmonary hypertension patients who underwent surgery with general anesthesia between 2010 and 2017 were reviewed for PPCs. In addition we reviewed nursing-documented respiratory depressive episodes in the post-anesthesia care unit to assess the associations between these episodes and later PPCs. There were 20 PPCs among 128 patients who underwent 197 procedures (10.2 per 100 surgeries) [95% CI 6.7–15.2]. Of these, 5 occurred during anesthesia recovery and 15 following anesthesia recovery. Three-quarters of the PPCs occurred within 24 postoperative hours. All the PPCs were severe. The frequency of PPCs was significantly higher in those who experienced respiratory depression during anesthesia recovery vs. in those who did not (5/17, 29% vs. 10/175, 6%; odds ratio 5.15, 95% CI 1.58–16.81, $p = 0.007$). Increased PPC rates were observed among patients who were current/previous smokers and who routinely use benzodiazepines, and among those undergoing emergent surgery. With treatment, all PPCs resolved. The rate of PPCs in the population of contemporary surgical pulmonary hypertension patients was 10.2%, and three-quarters occurred during first 24 postoperative hours. Patients who had respiratory depression during anesthesia recovery were 5-fold more likely to experience later PPCs.

KEY WORDS: Pulmonary hypertension; postoperative pulmonary complications; PPCs; post-anesthesia care unit; PACU; respiratory specific events

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INTRODUCTION

Pulmonary hypertension (PH) is comprised of a cluster of medical conditions [1,2] associated with cardiopulmonary dysfunction as well as abnormalities of other organ systems [3]. Patients with PH undergoing surgery have increased risk for postoperative mortality and serious morbidity such as acute right ventricular failure, dysrhythmias, atrial fibrillation, coronary ischemia, respiratory failure, and stroke [4-7]. In general, perioperative outcome reports on patients with PH have focused on cardiovascular complications and have not extensively detailed the incidence or risk factors within that patient population for postoperative pulmonary complications (PPCs). These complications are important because they can result in permanent morbidity and death. Therefore, in this case series we examined the frequency, types, and outcomes of PPCs in PH patients undergoing non-cardiothoracic surgery with general anesthesia.

At our institution patients undergoing anesthesia recovery are monitored for episodes of respiratory depression (termed respiratory specific events, which are nursing documented episodes of hypoventilation, apnea, oxyhemoglobin desaturation, or patient report of severe pain despite moderate to deep sedation) [8,9]. We have observed that among the general patient surgical population patients who have a respiratory specific event during anesthesia recovery are at a five-fold increased risk for severe opioid-induced respiratory depression on postsurgical wards [10,11]. Thus, a secondary aim of this study is to test the hypothesis that respiratory specific events (nursing documented episodes of respiratory depression) during anesthesia recovery are associated with subsequent development of PPCs in surgical patients with PH. To the best of our knowledge, this is the first literature report that focuses exclusively on PPC in the large cohort of patients with PH.

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MATERIALS AND METHODS

This study was approved by the Mayo Clinic, Rochester MN, Institutional Review Board. Consistent with Minnesota Statute 144.295, all patients in this study provided prior authorization for research use of their medical records.

Study population

Adult patients with PH (identified from the Mayo Clinic Pulmonary Hypertension database) who underwent non-cardiac, non-transplant procedures under general anesthesia between February 10, 2010 and December 31, 2017 were included.

Study design

This study is representative of a high-volume surgical practice within a major tertiary academic institution. Patients with PH admitted to the post-anesthesia care unit (PACU) following general anesthesia were identified and their electronic medical records abstracted as previously described [12]. PACU nurses continuously monitored patients for 4 "respiratory specific events": 1) hypoventilation (3 episodes of <8 respirations/minute); 2) apnea (episode lasting ≥10 seconds); 3) hypoxemia (3 episodes of oxyhemoglobin desaturations [<90%, with or without nasal cannula], as measured by pulse oximetry); and 4) pain-sedation mismatch (defined as Richmond Agitation Sedation Score [13] of −3 to −5 and a numeric pain score >5 [from 0, no pain, to 10, worst pain imaginable]) [8,9]. The PACU records were reviewed to identify episodes of respiratory specific events, and both PACU and postoperative medical records were reviewed for the presence of PPCs, which were defined as tracheal reintubation, failure to extubate trachea at the end of surgery, *de novo* application of a noninvasive ventilation (continuous positive airway pressure [CPAP]; or bi-level positive airway pressure [BiPAP]), administration of naloxone or flumazenil, respiratory failure, pneumonia, pulmonary edema, atelectasis, and pneumothorax.

Data abstraction

Cardiology records were reviewed for PH World Health Organization (WHO) etiological classification and functional limitation classification [2], objective studies, and therapies of PH for each patient prior to each procedure. Etiologic classifications were Group 1 (pulmonary arterial hypertension due to etiologies such as familial, HIV, toxic, related to congenital heart disease, drugs and medications, etc.), Group 2 (PH due to left heart diseases, left heart failure, severe mitral valve, aortic valve disease, etc.), Group 3 (PH due to lung diseases or hypoxia, or both), Group 4 (chronic thromboembolic PH), and Group 5 (PH due to unclear or multifactorial mechanisms, connective tissue disease, sarcoidosis, mediastinal tumors, thyroid disease, etc.) [2,14]. Patients in this cohort with Group 2 or Group 3 PH were felt by cardiologists with expertise in the management of PH to have mixed etiology PH with a component of pulmonary arteriopathy and hence were treated with pulmonary targeted therapy. The WHO functional classifications were used to describe the classes (severity) of disease [2,15]: class I, no physical activity limitation; class II, slight limitation but comfortable at rest; class III, marked limitation of physical activity but comfortable at rest; less than ordinary physical activity causes dyspnea, fatigue, chest pain, or near syncope; and class IV, patients are unable to carry out any physical activity without symptoms. Severity of PH was also assessed from clinical testing, and we reported preoperative results of the 6-minute walk test which was dichotomized (≥330 vs. <330 meters) [16,17]. N-terminal fragment of the prohormone brain natriuretic peptide (NT-proBNP) is a biochemical marker used in risk stratification of patients with congestive heart failure [18] and for the purpose of this study was dichotomized using a cut-point of <300 pg/mL, which has been shown to have a 99% negative predictive value for excluding acute congestive heart failure [19]. Data from echocardiogram, heart catheterization, and pulmonary function tests were also abstracted. In addition, records were abstracted for pertinent comorbid disorders (e.g., treatment for hypertension, asthma, etc.) as well as the regular use of sedating medications (opioids, benzodiazepines, and gabapentinoids), which have been previously assessed as contributing to PPCs [20,21]. Periprocedural records were reviewed for surgical duration, anesthetic agents, vasoactive pharmacologic treatments, fluids administered and blood transfusions, the occurrence of respiratory depression in the PACU, and the development of PPCs. Opioid analgesics were converted to intravenous morphine equivalents using standard formulas [22,23]. The clinical course of patients who had one or more PPCs was reviewed and summarized.

Statistical analysis

Patient and procedural characteristics are summarized using count and percentage for nominal or dichotomous variables and mean ± standard deviation [SD] or median and interquartile range (25^{th}–75^{th} percentile) for continuous variables. The primary outcome of interest was the development of one or more PPCs. The overall rate of this complication is presented along with 95% confidence intervals (CIs). Characteristics were compared between those who experienced one or more PPCs vs. not using a Chi-square test or Fisher's exact test for nominal variables and the two-sample *t*-test or rank-sum test for continuous variables. Two-tailed $p < 0.05$ was considered statistically significant. Statistical analyses were performed with JMP Pro software version 13.0.0. (SAS Software Inc., Cary, NC, US).

RESULTS

During the study time frame, there were 128 PH patients who underwent 197 surgical procedures. PPCs were noted in 20, yielding a rate of 10.2% per 100 surgeries (95% CI 6.7–15.2). Of these 20 PPCs, 5 occurred in the PACU and 15 after PACU discharge. A total of 15 PPCs (75%) developed within the first postoperative day (5 in the PACU and 10 after PACU transfer to surgical wards). Table 1 summarizes baseline patient characteristics, overall and separately for patients who did and did not develop one or more PPCs. All patients were receiving one or more therapies for PH at the time of their procedure(s): prostacyclin analogs (n = 43), phosphodiesterase inhibitors (n = 86), endothelin receptor antagonist (n = 67), stimulator of soluble guanylate cyclase (riociguat, n = 7), or oral prostacyclin receptor agonist (selexipag, n = 1), and 16 patients were on home oxygen therapy. The frequency of PPC did not differ across types of PH therapy (p = 0.336). Smoking history was more frequent in PPC patients (70% vs. 44.1%, p = 0.034), as was the regular use of benzodiazepines (40% vs. 18.6%, p = 0.039); all other characteristics did not differ significantly between patients who experienced PPC(s) vs.

TABLE 1. Demographic and disease characteristics of patients with pulmonary hypertension who developed vs. not postoperative pulmonary complications

Patient characteristics	Overall N=197	Postoperative pulmonary complications		p
		Yes n=20	No n=177	
Age, years	59.4±14.3	62.3±12.1	59.1±14.5	0.344
Male sex	50 (25.4)	5 (25.0)	45 (25.4)	1.000
Body mass index, kg/m^2	29.7±7.9	30.3±8.3	29.6±7.9	0.709
Comorbid conditions				
Obstructive sleep apnea	76 (38.6)	8 (40.0)	68 (38.4)	1.000
Current or former smoker	92 (46.7)	14 (70.0)	78 (44.1)	0.034
Myocardial infarction	10 (5.1)	1 (5.0)	9 (5.1)	1.000
Cerebrovascular disease	18 (9.1)	2 (10.0)	16 (9.0)	1.000
Diabetes mellitus	38 (19.3)	4 (20.0)	34 (19.2)	1.000
Chronic kidney disease IV-V	15 (7.6)	3 (15.0)	12 (6.8)	0.184
Liver disease	30 (15.2)	2 (10.0)	28 (15.8)	0.744
Connective tissue disease	35 (17.8)	3 (15.0)	32 (18.1)	1.000
Chronic pulmonary disease	42 (21.3)	6 (30.0)	46 (26.0)	0.789
Home use				
Oxygen	16 (8.1)	2 (10.0)	14 (7.9)	0.669
Opioid	78 (39.6)	8 (40.0)	70 (39.6)	1.000
Benzodiazepines	41 (20.8)	8 (40.0)	33 (18.6)	0.039
Gabapentinoids	36 (18.3)	3 (15.0)	33 (18.6)	1.000
PH WHO classification				0.113
Group 1	117 (59.4)	8 (40.0)	109 (61.6)	
Group 2	20 (10.2)	1 (5.0)	19 (10.7)	
Group 3	29 (14.7)	7 (35.0)	22 (12.4)	
Group 4	30 (15.2)	4 (20.0)	26 (14.7)	
Group 5	1 (<1.0)	0 (0)	1 (0.6)	
WHO functional type Class III/ IV*	83 (42.1)	12 (60.0)	71 (40.1)	0.099
6-Minute walk <330 meters	28 (14.2)	2 (20.0)	26 (25.2)	1.000
NT-proBNP ≥300 pg/mL	76 (38.6)	8 (61.5)	68 (53.1)	0.772
Right ventricular systolic pressure				0.486
35–50 mmHg	50 (25.4)	3 (16.7)	47 (27.2)	
>50 mmHg	124 (62.9)	14 (77.8)	110 (63.6)	
RVSP/SBP ≥66%	36 (18.3)	5 (27.8)	31 (18.1)	0.345
Mean pulmonary arterial pressure				0.286
41–55 mmHg	61 (31.0)	5 (33.3)	56 (41.2)	
>55 mmHg	26 (13.2)	1 (6.7)	25 (18.4)	
Pulmonary function tests				
FEV1 <80%	125 (63.5)	10 (66.7)	115 (79.9)	0.317
FVC <70%	65 (33.0)	6 (40.0)	59 (41.0)	1.000
DLCO				0.983
≤40–79%	105 (53.3)	10 (71.4)	95 (69.9)	
<40%	24 (12.2)	2 (14.3)	22 (16.2)	

Data are n (%), or mean±SD. *Class III, marked limitation of physical activity but comfortable at rest; Class IV, patients are unable to carry out any physical activity without symptoms. PH: Pulmonary hypertension, WHO: World Health Organization, NT-proBNP: N-terminal fragment of the prohormone brain natriuretic peptide, RVSP/SBP: Right ventricular systolic pressure/systolic blood pressure ratio, FEV1: Forced expiratory volume, FVC: Forced vital capacity, DLCO: Diffusing capacity for carbon monoxide

those who did not. Of note, among PPC patients, 60% were classified as WHO Functional status ≥III compared to 40.1% patients without PPC, but this difference did not reach statistical significance, $p = 0.099$. Table 2 summarizes surgical and anesthetic course. Other procedural characteristics were similar between the two groups.

The presentation and clinical course for patients who had a PPC in the PACU are summarized in Table 3. Four of these PACU PPCs were primarily related to hypoventilation, hypoxemia, and volume overload. These were resolved with tracheal reintubation (n = 1), CPAP (n = 2), and furosemide treatment and supplemental oxygen (n = 1). The fifth patient had developed intraoperative cardiac arrest and was taken intubated to the PACU, where she remained unarousable and subsequently was admitted to the intensive care unit.

A subset analysis was performed, which excluded the 5 patients who experienced PPC in the PACU. Of the remaining 192 patients, 17 experienced respiratory specific events in the PACU and 175 did not. The frequency of PPC was significantly higher in those who experienced respiratory specific events vs. in those who did not (5/17, 29% vs. 10/175, 6%, respectively; odds ratio, 5.15, 95% CI 1.58–16.81, $p = 0.007$; (Figure 1).

The clinical courses of patients who had one or more PPCs after discharge from the PACU are summarized in Table 4. These PPCs were acute hypoxemia, hypercarbia, respiratory distress, and shortness of breath attributed to pneumonia (n = 3), pneumothorax (n = 1), pulmonary edema (n = 1), acute respiratory failure due to mechanical causes (n = 1), and respiratory failure due to unknown causes (n = 9). Two of these 15 patients required tracheal reintubation. One was a 56-year-old woman who developed apnea and hypotension on the second postoperative day and required mechanical ventilation for 4 days. The second was a 74-year-old woman who developed abdominal wound dehiscence and sepsis on the fourth postoperative day, resulting in respiratory failure; she was re-intubated and re-operated.

TABLE 2. Surgical and anesthetic characteristics of patients with pulmonary hypertension undergoing general anesthesia

Surgical and anesthesia characteristics	Overall N=197	Postoperative pulmonary complications		*p*
		Yes n=20	No n=177	
Surgical duration, min	79 [44, 130]	81 [36, 148]	79 [44, 123]	0.739
Type of surgery				0.348
Orthopedic	41 (20.8)	4 (20.0)	37 (20.9)	
Urological/Gynecological	28 (14.2)	2 (10.0)	26 (14.7)	
Vascular	4 (2.0)	0 (0)	4 (2.3)	
Wound care	21 (10.7)	1 (5.0)	20 (11.3)	
Plastic/Breast	11 (5.6)	1 (5.0)	10 (5.7)	
Intraperitoneal	40 (20.3)	9 (45.0)	31 (17.5)	
Thoracic	7 (3.6)	1 (5.0)	6 (3.4)	
Head/neck	29 (14.7)	1 (5.0)	28 (15.8)	
Neurological	2 (1.0)	0 (0)	2 (1.1)	
Miscellaneous*	14 (7.1)	1 (5.0)	13 (7.3)	
Emergency procedure	13 (6.6)	4 (20.0)	9 (5.1)	0.031
Anesthetic medications				
Volatile anesthetic	186 (94.4)	19 (95.0)	167 (94.4)	1.000
Intraoperative IVME mg	19 [10, 25]	25.0 [15, 29]	17.5 [10, 25]	0.069
Midazolam	66 (33.5)	7 (35.0)	59 (33.3)	1.000
Gabapentin	18 (9.1)	3 (15.0)	15 (8.5)	0.403
Ketamine	37 (18.8)	4 (20.0)	33 (18.6)	1.000
Muscle relaxants	94 (47.7)	11 (55.0)	83 (46.9)	0.638
Vasopressor infusions†	163 (98.0)	18 (90.0)	145 (81.9)	0.537
Pulmonary vasodilators‡	14 (7.1)	1 (5.0)	13 (7.3)	1.000
Invasive monitors				
Arterial line	96 (48.7)	14 (70.0)	82 (46.3)	0.059
Central line	9 (4.6)	3 (15.0)	6 (3.4)	0.051
Pulmonary catheter	5 (2.5)	1 (5.0)	4 (2.3)	0.418
Echocardiography	1 (0.5)	0	1 (0.5)	1.000
Volume replacements				
Crystalloids, liters	1.3±1.1	1.5±0.9	1.3±1.1	0.368
Packed red blood cells	14 (7.1)	2 (10.0)	12 (6.8)	0.639
Other blood products§	7 (3.6)	0 (0)	7 (4.0)	1.000

Data are n (%), median [IQR], or mean±SD. IVME: Intravenous morphine equivalents. *Cerebral angiogram and embolization; colonoscopy; cardioversion; and various endoscopic procedures. †Vasopressor=Vasopressin, dopamine, norepinephrine, epinephrine, phenylephrine (infusion). ‡Pulmonary vasodilators=Prostacyclin analogs (epoprostenol, treprostinil, and iloprost) and milrinone. §Other blood products=Fresh frozen plasma, platelets, and cryoprecipitate

TABLE 3. Postoperative pulmonary complications in post-anesthesia care unit in patients with pulmonary hypertension undergoing surgery with general anesthesia

Patient	Age Sex	FC EC	Surgery type	Presentation	Interventions outcome
1	69 F	Class III Group 4	Laparoscopic cholecystectomy	Apnea, hypoxemia, and deep sedation in PACU; Ventricular tachycardia	*De novo* BiPAP failed required reintubated in PACU; transfer to ICU remained 2 days intubated, CR; D/C home
2	60 F	Class III Group 1	Mastectomy	Intraoperative ventricular fibrillation requiring chest compressions and cardioversion; unarousable in PACU	Mechanical ventilation with transfer to ICU; extubated after 5 hours; CR; D/C home
3	53 F	Class II Group 3	Left knee arthroplasty	Repeated episodes of hypoxemia to SpO_2=70%	Face mask with high O_2 flow; furosemide; admitted to ICU; CR; D/C home
4	58 F	Class III Group 1	Nasal pack removal	Hypoxemia	*De novo* CPAP; CR; D/C home
5	79 M	Class II Group 3	Cystoscopy	Hypoventilation and apnea	*De novo* CPAP; CR; D/C home

FC: Functional classification, EC: Etiological classification, PACU: Post-anesthesia care unit, F: Female, M: Male, BiPAP: Bi-level positive airway pressure, ICU: Intensive care unit, SpO_2: Arterial oxygen saturation, CPAP: Continuous positive airway pressure, SOB: Shortness of breath, POD: Postoperative day, CXR: Chest X-ray. CR: Complete resolution of respiratory complication, D/C home: Discharged home

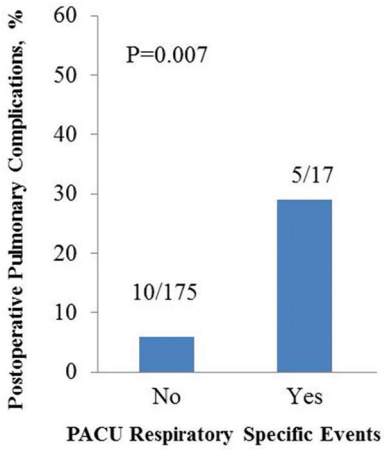

FIGURE 1. Percentage of patients experiencing postoperative pulmonary complications (PPCs) among those who did and did not experience post-anesthesia care unit (PACU) "respiratory specific events". Five patients who experienced PPC in the PACU are excluded from this analysis.

The patients with PPCs in our case series achieved complete resolution of respiratory complications, and all were successfully discharged from the hospital (Tables 3 and 4) and alive at 30 days. The hospital length of stay was greater among patients with PPCs (median 8 [3, 13] days) compared to those without PPCs (median 2 [1, 6] days), $p < 0.001$.

DISCUSSION

Our most significant finding is a PPC rate of 10.2 per 100 cases in patients with PH. This rate is substantially lower than the rate we found in an earlier study (time frame between 1991 and 2003) of a similar PH patient population. In that earlier study, we found a PPC rate of 28 per 100 cases in patients with PH [24]. The reduction in PPC rate between these two time frames could be due to enhanced perioperative care and improvements in medical management. One important practice difference between the PPC rate in the present and our earlier study is the universal use of new therapies for PH in the contemporary cohort. Many of these treatments were either unavailable or were not widely used during the time frame of the earlier study [24]. It has been shown that pulmonary vasodilators, specifically the use of prostacyclin receptor agonists, improve the WHO functional class with a reduction in complication and mortality rates in patients with pulmonary arterial hypertension [25,26]. Another more contemporary study by Kaw et al. [27] covered the time frame between 2002 and 2006 and reported 7.3 PPCs per 100 cases, which is similar to that found in the present study.

Respiratory complications after surgery may be especially frequent in high-acuity PH patients. For example, Lai et al. [28] reported 21% of delayed tracheal extubation in PH patients undergoing non-cardiac surgery. Collisson et al. [29] described 6 patients who underwent orthotopic liver transplantation for severe hepatopulmonary syndrome, 3 developed a PPC, including lobe collapse, pleural effusion, and pneumonia, and 5 out of 6 required oxygen support at the time of hospital discharge. The other high-risk surgery is cardiothoracic procedures, and PH patients undergoing these surgeries are at heightening risk for prolonged postoperative ventilatory support [30].

In this study, patients who experienced an episode of respiratory depression, as assessed from the respiratory specific events in the PACU, had higher rates of PPCs after transfer to general surgical wards. This is consistent with earlier observations that respiratory depression in the PACU is a marker for increased risk for postoperative respiratory complications [9,31]. This finding suggests that PH patients who experience any presentation of respiratory depression (respiratory specific events) in the PACU may benefit from higher levels of postoperative care and monitoring. The presentation and clinical course of PPCs in our patients were serious and, in some, life-threatening, but

TABLE 4. Postoperative pulmonary complications after discharge from post-anesthesia care unit in patients with pulmonary hypertension undergoing surgery with general anesthesia

Patient	Age Sex	FC EC	Surgery	Presentation	Interventions and outcomes
1	69 M	Class III Group 4	Abdominal exploration	Fever with SOB with hypoxemia (PaO_2 29 mmHg) on POD 18; CXR: pneumonia	Reestablished home CPAP/oxygenation Improved; IV antibiotics, CR; D/C-home
2	59 F	Class III Group 3	Abdominal exploration	Hypoxemia (PaO2 27 mmHg), fever on POD 2; CXR: pneumonia	ICU admission; reestablished home BiPAP oxygenation improved; IV antibiotics, CR; D/C-home
3	66 M	Class III Group 3	Lumbar discectomy	CXR lung opacity on POD 1: pneumonia	ICU admission; IV antibiotics, CR; D/C-home
4	48 F	Class II Group 1	Videothoracoscopy	SOB on POD 1; CXR: pneumothorax	Conservative management; Requiring supplemental O_2 for ambulation/ sleep. Discharged with portable O_2 concentrator; CR; D/C-home
5	42 M	Class III Group 4	Laparoscopic colectomy	SOB with desaturation on POD 3; pulmonary edema	ICU admission; CPAP followed by face mask with high O_2 flow (CFM); furosemide, CR; D/C-home
6	74 F	Class II Group 1	Laparotomy	Wound dehiscence on POD 4 causing respiratory failure with hypercapnia (PaCO2 76 mmHg)	Emergently reintubated and transferred to surgery, 2 days of mechanical ventilation; CR; D/C-home
7	38 F	Class I Group 1	Cesarean section	Hypoxemia (SpO_2 70–80%) in Eisenmenger's syndrome on POD 1 secondary to atelectasis	ICU admission; NC O_2: treprostinil inhaler incentive spirometry; furosemide, CR; D/C home
8	61 F	Class II Group 1	Below knee amputation	Somnolent and apnea on POD 1	Flumazenil; face mask with high O_2 flow; CR; D/C to nursing home. Died in another hospital cause unknown
9	86 F	Class II Group 1	Hip fracture pinning	SOB, hypoxemia on POD 0 with refractory hypotension	ICU admission; NC O_2; high dose furosemide for fluid overdose; inotropes, D/C-home
10	69 F	Class III Group 3	Laparoscopic cholecystectomy	Hypoxemia on POD 1	Nasal High Flow Therapy (Optiflow) furosemide; incentive spirometry, CR; D/C-home
11	69 F	Class III Group 3	ERCP	Hypoxemia (SpO_2 80–90%) on POD 0	Face mask with high O_2 flow; incentive spirometry; D/C home
12	56 F	Class IV Group 1	Choledochocholedochostomy	Apnea and hypotension on POD 2	Trachea re-intubated; inotropes Extubated after 4 days, CR; D/C-home
13	74 M	Class I Group 4	Hip arthroplasty	Hypoxemia and hypotension on POD 1	Face mask with high O_2 flow, CR; D/C-home
14	53 F	Class II Group 3	Cholecystectomy	Hypoxemia (SpO_2 70%) and hypotension on POD 0	Nasal High Flow O_2 Therapy (Optiflow™); furosemide; fluid, inotropes, CR (SpO_2 returned to baseline 80 s), CR; D/C-home
15	63 F	Class IV Group 1	Radiofrequency HCC	Hypoxemia on POD 0	*De novo* BiPAP, CR; D/C-home

De novo, not used at home, PACU: Post-anesthesia care unit, F: Female, M: Male, BiPAP: Bi-level positive airway pressure, ICU: Intensive care unit, SpO_2: Arterial oxyhemoglobin saturation, CPAP: Continuous positive airway pressure, SOB: Shortness of breath, POD: Postoperative day, CXR: Chest radiogram, ERCP: Endoscopic retrograde cholangiopancreatography, IV: Intravenous, HCC: Hepatocellular carcinoma, CR: Complete resolution of respiratory complication, NC: Nasal cannula, D/C home: Discharged home

with intense treatment all our patients achieved resolution and all were discharged home.

Fifteen of 20 PPCs occurred within the first 24 postoperative hours, which is consistent with the temporal patterns of respiratory failure in the general surgical population [32]. We did not observe a significant association between PH severity and PPCs, an unexpected observation because two large series of surgical patients found a link between PH severity and adverse outcomes [24,27]. By limiting our outcome of interest to PPC only, our study may lack the power to detect such associations (Table 1, WHO Functional Type class ≥III was present in 60% vs. 40.1% patients with PPC vs. not, respectively; $p = 0.099$). We observed an increased PPC rate among current or former smokers, consistent with our previous study [24]. Also, PPC rates were higher among patients on chronic benzodiazepine therapy. We previously found that chronic use of sedating medications in the general surgical population was associated with postoperative opioid-induced respiratory depression [10]. Pulmonary complications were also higher among patients undergoing emergent surgery.

Limitations of the study

This study has the inherent limitations of a retrospective study design, specifically details regarding practice

management goals (e.g., goal blood pressure, oxygen level, and fluid goals) are not able to be deduced. Even though the rate of PPCs was high, the cohort size was limited and these patients had considerable variation in functional class and underwent a wide variety of surgical procedures. Therefore, we were unable to perform more sophisticated analyses of the association between risk for PPCs and different patient and procedural variables. In addition, this study was conducted in a major tertiary center with considerable experience with high acuity patients; thus, our observations may not be generalizable to other medical practices.

CONCLUSION

In conclusion, the rate of PPC in the population of contemporary (2010–2017) surgical patients with PH was 10.2%. This rate was significantly lower compared to our earlier report of similar patient mix (1991–2003) of 28%. This reduction of PPC is likely related to improvements in the perioperative management of patients with PH, together with the availability of new medications designed for the treatment of PH. Three-quarters of PPCs occurred during the first 24 postoperative hours. This finding, along with the fact that patients who were diagnosed with a respiratory specific event in the recovery room were more likely to experience PPCs following discharge from the PACU, suggest that respiratory status of PH patients should be closely monitored in the immediate postoperative period.

DECLARATION OF INTERESTS

TNW currently serves as a consultant to Medtronic in the role as chairman of the Clinical Endpoint Committee for the Prodigy Trial; has received research support from Respiratory Motion (study equipment) and unrestricted investigator-initiated grants from Merck (active) and Baxter (completed). The other authors declare no conflict of interests.

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