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Perioperative & Critical Care: Short Report

Pulmonary Complications After Cardiac Surgical Procedures: A Tertiary Centre Audit of Elective and Urgent Cases

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BACKGROUND Inadequate time for preoperative optimization can lead to adverse outcomes after urgent cardiac surgical procedures. In this audit, we compared the incidence of postoperative pulmonary complications (PPCs) and other adverse outcomes after elective and urgent cardiac surgical procedures.

METHODS Adult patients who underwent nonemergency open heart surgical procedures were included. PPCs were defined as a composite of atelectasis, pneumonia, acute respiratory distress syndrome, respiratory failure, and pulmonary aspiration. Logistic regression analysis identified factors associated with PPCs. Other pulmonary and systemic complications were examined.

RESULTS In a sample of 6138 patients, PPCs were observed in 1996 (32.5%) participants. The urgent group had higher rates of pneumonia, respiratory failure, pleural effusion, and pulmonary embolism compared with elective patients ($P < .001$). Mild and moderate-severe respiratory diseases were associated with PPCs (adjusted odds ratio [OR], 1.34; 95% CI, 1.14-1.58; $P < .001$ and OR, 1.66; 95% CI, 1.32-2.09; $P < .001$, respectively). Other associated factors included age ($P = .006$), coronary artery bypass surgery, obesity, reduced left ventricular ejection fraction, preoperative creatinine level, and perfusion time ($P < .001$).

CONCLUSIONS Pulmonary complications increased after urgent compared with elective cardiac surgical procedures, with a higher incidence of pneumonia, respiratory failure, pleural effusion, and pulmonary embolism.

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Surgical urgency affects postoperative outcomes and is used as a risk predictor variable in cardiac surgical procedures.[1] Urgent procedures are typically performed during the same hospital stay to prevent further deterioration in the patient's clinical condition after an unplanned admission. Evidence from studies indicates that patients undergoing urgent noncardiac surgical procedures have higher rates

IN SHORT

- Pulmonary complications and other adverse outcomes are significantly more after urgent compared with elective cardiac surgical procedures.
- Factors such as respiratory diseases, age, coronary artery bypass surgery, obesity, perfusion time, preoperative creatinine levels, reduced left ventricular function, and urgency of surgical procedures all contribute to the risk of PPCs.

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of morbidity and mortality compared with elective surgical patients.[2]

Postoperative pulmonary complications (PPCs) are strongly associated with increased mortality and higher health care costs after surgical procedures.[3] Approximately 50% of patients undergoing elective cardiac surgical procedures may experience PPCs.[4] However, there is limited evidence on PPCs after urgent cardiac surgical procedures. Existing studies on urgent cardiac surgical procedures have been conducted on small patient samples, were not relevant to local settings, or did not specify PPC rates.[5,6] We therefore aimed to compare the incidence of PPCs and other complication rates after urgent cardiac surgical procedures with those of elective cardiac surgical procedures. Additionally, we sought to identify the factors associated with the development of PPCs after urgent cardiac surgical procedures.

PATIENTS AND METHODS

STUDY DESIGN. This retrospective review included adult patients (aged ≥18 years) who underwent any type of elective or urgent cardiac surgical procedures requiring cardiopulmonary bypass between January 1, 2016 and December 31, 2021, at The Prince Charles Hospital, Australia's largest cardiothoracic referral hospital. "Urgent surgical procedures" referred to an operation performed within 72 hours of an unplanned hospital admission or angiography or during the same hospitalization in a clinically compromised patient to minimize the chances of further deterioration.[7] Indications included the following: threatening coronary anatomy identified on angiography, during either elective or acute admissions; preoperative intraaortic balloon pump insertion for threatening anatomy, hemodynamic compromise, or ongoing ischemia related to coronary admissions; medically stabilized acute coronary admissions; and severe acute native or prosthetic valve dysfunction.[7] We excluded emergency procedures (unscheduled operations performed on the day of admission in response to angina or hemodynamic instability refractory to medical management) and salvage procedures (requiring preoperative cardiopulmonary resuscitation en route to the operating room).[7] The hospital Human Research Ethics Committee approved this project as a quality assurance activity and waived individual patient consent (Project ID: EX/2021/QPCH/81282).

DATA COLLECTION AND DEFINITIONS. Data, including patient demographics and medical, surgical, and outcome details, were obtained from the hospital Australian & New Zealand Society of Cardiac & Thoracic Surgeons registry and the coders (Supplemental Table 1). Our primary outcome was the incidence of PPCs, defined according to the Standardized Endpoints in Perioperative Medicine (StEP) as a composite of atelectasis, pneumonia, acute respiratory distress syndrome, respiratory failure and pulmonary aspiration.[8] Each component of the StEP outcome, as well as individual complications (eg, pulmonary embolism, pneumothorax, pleural effusion, cardiogenic pulmonary edema, bronchospasm), was assessed following the same guidelines.[8] Secondary outcomes included nonpulmonary complications, length of hospital and intensive care unit stay, return to the operating room, and 30-day and 90-day mortality.

STATISTICAL ANALYSIS. Statistical analyses were conducted using Stata software version 17 (StataCorp). All data are presented as mean (SD) or counts (percentages). Where appropriate, *t* tests, χ^2 tests, and Fisher exact tests were used. Logistic regression analysis identified factors associated with PPCs. Where factors exhibited collinearity, only 1 was included in the multivariable model. Missing data ranged from 2% to 7%, and all available data were used without imputation. The level of significance for the independent variables was set at $P < .05$.

RESULTS

A total of 6138 patients were included in the study, with 62% (n = 3814) undergoing elective operations and 38% (n = 2324) undergoing urgent cardiac surgical procedures. The mean (SD) age was 64 (13.7) years, 71.8% (n = 4406) of these patients were male, and the mean (SD) body mass index (BMI) was 29.3 (6.4) kg/m^2. The baseline characteristics of the patients categorized by the urgency of their surgical procedures are provided in Table 1.

Approximately 32.5% (1996 of 6138) patients had PPCs before hospital discharge (Supplemental Table 2). These patients were heavier, had multiple comorbidities, and predominantly underwent CABG ($P < .001$) (Supplemental Table 2). They also experienced more systemic complications, greater postoperative recovery challenges, higher mortality rates and extended hospital stays after surgical procedures ($P < .001$) (Supplemental Table 2).

PPCs occurred in 36% (n= 836) of urgent surgical patients and 30% (n= 1160) of elective surgical patients ($P < .001$) (Supplemental Table 3). Of the 1996 patients with PPCs, 40% (n = 794)

TABLE 1 Baseline and Surgical Characteristics of Audit Participants (N = 6138)

Characteristics	Elective (n = 3814)	Urgent (n = 2324)	*P* Value
Age, y	63.38 [14.70]	64.93 [11.84]	<.001
BMI, kg/m^2	29.12 [6.66]	29.49 [5.97]	.032
Male	2610 (68.4)	1796 (77.3)	<.001
Current smoker[a]	444 (20.0)	543 (36.1)	<.001
Diabetes	880 (23.1)	791 (34.1)	<.001
Hypercholesterolemia	2,331 (61.2)	1,660 (71.6)	<.001
Hypertension	2,501 (65.6)	1,651 (71.1)	<.001
Cerebrovascular disease	476 (12.5)	359 (15.5)	.005
Peripheral vascular disease	410 (10.8)	377 (16.3)	<.001
Respiratory disease			<.001
Mild	467 (12.2)	324 (13.9)	
Moderate-severe[b]	184 (4.8)	178 (7.7)	
Immunosuppressive treatment	129 (3.4)	73 (3.1)	.66
CHF at admission	205 (44.4)	346 (82.8)	<.001
EuroSCORE-II	2.35 [2.60]	4.11 [5.55]	<.001
Preoperative arrhythmia	827 (21.7)	452 (19.5)	.038
LVEF percentage	57.25 [10.12]	51.94 [13.55]	<.001
NYHA functional class			.009
I	1339 (35.1)	830 (35.8)	
II	1569 (41.2)	900 (38.8)	
III	863 (22.6)	541 (23.3)	
IV	41 (1.1)	47 (2.0)	
Preoperative creatinine, μmol/L	92.39 (49.95)	100.78 [74.05]	<.001
Preoperative hemoglobin, mg/dL	137.26 [16.41]	133.19 (20.60)	<.001
Type of surgical procedures			
CABG	1697 (44.5)	1821 (78.4)	<.001
Valve surgical procedures	2262 (59.3)	659 (28.4)	<.001
Other cardiac surgical procedures[c]	542 (14.2)	165 (7.1)	<.001
Combined	502 (13.2)	295 (12.7)	.60
Aortic surgical procedures	513 (13.4)	134 (5.8)	<.001
Minimally invasive surgical procedures with bypass	169 (4.43)	8 (0.34)	<.001
Cumulative cross-clamp time, min	67.42 [37.39]	61.82 [34.54]	<.001
Cumulative perfusion time, min	99.02 [55.33]	89.71 [51.02]	<.001
Intraarterial balloon pump	110 (2.9)	213 (9.2)	<.001
Ventricular assist device	110 (2.9)	213 (9.2)	<.001

[a]Unknown status in 8 patients; [b]Both moderate respiratory disease (patients taking long-term oral steroids) and severe disease (Po_2 <60 mm Hg or Pco_2 >50 mm Hg or mechanical ventilation) were combined because of <10 severe cases in each group; [c]Other cardiac surgical procedures: left ventricular outlet myomectomy, atrial septal defect, left ventricular aneurysm repair, atrial and ventricular septal defect repair, left ventricular rupture repair, pericardiectomy, pulmonary thromboembolectomy, left ventricular reconstruction, cardiac tumor, left atrial appendage closure, permanent left epicardial lead, and atrial arrythmia surgical procedures. Values are mean [SD] or n (%). BMI, body mass index; CABG, coronary artery bypass surgery; CHF, congestive heart failure; EuroSCORE-II, European System for Cardiac Operative Risk Evaluation; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association.

experienced more than 1 pulmonary complication. The most common pulmonary complications overall were atelectasis (23.7%; n = 1457), respiratory failure (18.5%; n = 1134), and pleural effusion (10.5%; n = 642). Specifically, patients in the urgent cardiac surgical group had higher rates of pneumonia, respiratory failure, pleural effusion ($P < .001$ for all), and pulmonary embolism ($P = .003$) compared with the elective surgical cohort (Supplemental Table 3).

Univariable regression analysis found that multiple factors were associated with PPCs (Supplemental Table 4). Multivariable analysis showed that the presence of mild and moderate-severe respiratory diseases was associated with PPCs (odds ratio [OR], 1.34; 95% CI, 1.14-1.58; $P < .001$ and OR, 1.66; 95% CI, 1.32-2.09; $P < .001$, respectively). Moderate respiratory diseases (patients taking long-term oral steroids) and severe diseases ($Po_2 < 60$ mm Hg or $Pco_2 > 50$ mm Hg or mechanical ventilation) were combined because of <10 severe cases in each group. Furthermore, patients undergoing CABG were at a higher risk of PPCs ($P < .001$), whereas other risk factors were older age ($P = .006$), increased BMI, reduced left ventricular ejection fraction, increased

TABLE 2 Multivariable Logistic Regression of the Predictors Associated With Postoperative Pulmonary Complications

Predictors	Odds Ratios (95% CIs)	*P* Value
Age (per 10 y)	1.06 (1.02–1.11)	.006
Body mass index	1.06 (1.05–1.07)	<.001
Preoperative creatinine (per 10 U)	1.01 (1.00–1.02)	.001
Respiratory disease (vs none)		
Mild	1.34 (1.14–1.58)	<.001
Moderate–severe	1.66 (1.32–2.09)	<.001
LVEF percentage	0.99 (0.98–0.99)	<.001
CABG	1.33 (1.17–1.51)	<.001
CPB perfusion time (per 30 min)	1.17 (1.14–1.21)	<.001

CABG, coronary artery bypass surgery; CPB, cardiopulmonary bypass; LVEF, left ventricular ejection fraction.

preoperative creatinine levels, and perfusion time ($P < .001$) (Table 2). A post hoc regression analysis using an alternative PPC definition (European Perioperative Clinical Outcome)[9] revealed that urgent cardiac surgical procedures increased the odds of PPC compared with elective surgical procedures (adjusted OR, 1.16; 95% CI, 1.03-1.31; $P < .001$).

Regarding secondary outcomes, more adverse events occurred after urgent cardiac surgical procedures compared with elective cardiac surgical procedures (Supplemental Table 5). In-hospital mortality occurred in 1.6% (n = 99) of the patients, and this rate was higher after urgent cardiac surgical procedures compared with elective cardiac surgical procedures (2.6% vs 1.0%; $P < .001$) (Supplemental Table 5).

COMMENT

This single-center audit of 6138 patients showed a significantly higher incidence of multiple adverse outcomes and in-hospital mortality after urgent cardiac surgical procedures when compared with elective cardiac surgical procedures. Approximately one-third of patients undergoing elective or urgent cardiac surgical procedures experienced PPCs, and a significantly higher incidence of pneumonia, respiratory failure, pleural effusion, and pulmonary embolism was observed in the urgent surgical group. Older age, higher BMI, increased preoperative creatinine levels, presence of baseline respiratory disease, CABG, increased perfusion time, and reduced left ventricular ejection fraction percentage were associated with the development of PPCs. We observed that the in-hospital mortality rate for patients with PPCs was approximately 4 times higher than for patients without PPCs. There was also a notable increase in other systemic complications among patients with PPCs.

Our audit provides insights into the rates of complications that arise from urgent cardiac surgical procedures, by using data from a substantial sample at the largest Australian cardiothoracic center. Despite the retrospective design of the audit, the data were collected prospectively according to standardized definitions.[7]

This study has some limitations. Our results come from a single center with limited generalizability; however, they align with results of multicenter studies.[3,4] We investigated PPCs as a composite outcome to study the associations with predictor variables. Each element of the composite outcome was also individually examined to gain a better understanding of the results. We acknowledge the potential bias from competing risks of death given the high operative risk and patient comorbidities.

This audit demonstrated that PPCs are more prevalent in urgent cardiac surgical patients compared with elective cases and that surgical acuity may be a potential predictive factor. Our patients in the urgent cardiac surgical group were older and had more comorbidities than the elective patients, thus increasing their baseline risk. Within such time constraints of urgent cardiac surgical procedures, optimizing high-risk complex patients can be a challenging task. Further research is essential on the benefits of preoperative breathing exercises, prophylactic noninvasive respiratory support such as high-flow nasal oxygen therapy, and intraoperative lung-protective strategies for reducing PPCs after urgent cardiac surgical procedures.

The Supplemental Tables can be viewed in the online version of this article [https://doi.org/10.1016/j.atssr.2025.05.021] on http://www.annalsthoracicsurgeryshortrep.org.

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DISCLOSURES

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REFERENCES

1. Nashef SA, Roques F, Sharples LD, et al. EuroSCORE II. *Eur J Cardiothorac Surg*. 2012;41:734–744 [discussion: 744–735].

2. Mullen MG, Michaels AD, Mehaffey JH, et al. Risk associated with complications and mortality after urgent surgery vs elective and emergency surgery: implications for defining "quality" and reporting outcomes for urgent surgery. *JAMA Surg*. 2017;152:768–774.

3. Hadaya J, Verma A, Marzban M, Sanaiha Y, Shemin RJ, Benharash P. Impact of pulmonary complications on outcomes and resource use after elective cardiac surgery. *Ann Surg*. 2023;278:e661–e666.

4. Fischer MO, Brotons F, Briant AR, et al. Postoperative pulmonary complications after cardiac surgery: the VENICE international cohort study. *J Cardiothorac Vasc Anesth*. 2022;36:2344–2351.

5. Mohammad WA, Ashraf Z, Sayed HF. Urgent versus elective coronary artery bypass grafting in acute coronary artery syndrome. *J Egypt Soc Cardiothorac Surg*. 2018;26:17–23.

6. Crawford TC, Magruder JT, Grimm JC, et al. Complications after cardiac operations: all are not created equal. *Ann Thorac Surg*. 2017;103:32–40.

7. Australian and New Zealand Cardiothoracic Surgery (ANZSCTS) National Cardiac Surgery Program. *Data Definitions Manual*. Version 4.1.1. ANZSCTS; 2018.

8. Abbott TEF, Fowler AJ, Pelosi P, et al. A systematic review and consensus definitions for standardised end-points in perioperative medicine: pulmonary complications. *Br J Anaesth*. 2018;120:1066–1079.

9. Jammer I, Wickboldt N, Sander M, et al. Standards for definitions and use of outcome measures for clinical effectiveness research in perioperative medicine: European Perioperative Clinical Outcome (EPCO) definitions: a statement from the ESA-ESICM Joint Taskforce on Perioperative Outcome Measures. *Eur J Anaesthesiol*. 2015;32:88–105.