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Risk factors for and economic implications of prolonged ventilation after cardiac surgery

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Objective: The study's objective was to identify predictors of prolonged ventilation and assess clinical and cost implications in patients undergoing cardiac surgery.

Methods: Patients undergoing cardiac surgery were classified as (1) ventilated less than 96 hours or (2) ventilated 96 hours or more. Multivariate modeling was used to identify predictors of prolonged ventilation and to ascertain the impact of prolonged ventilation on in-hospital mortality and bed occupancy costs and 5-year survival.

Results: A total of 7553 patients were studied; 197 (2.6%) had prolonged ventilation. Median ventilation times were 8 and 192 hours, and in-hospital mortality was 1.0% and 22.2% in the control and prolonged ventilation groups, respectively ($P <$ .001). In-hospital mortality remained higher in the prolonged ventilation group after adjustment and when comparing propensity-matched patients (odds ratio 8.06; 95% confidence interval [CI] 4.27-15.2; $P <$ .001 for propensity-matched groups). Independent predictors of prolonged ventilation were as follows: older age, New York Heart Association class, ejection fraction less than 50%, creatinine greater than 200 μmol/L, multiple valve replacements, aortic procedures, operative priority, reoperation for bleeding, inotropes, and preoperative intra-aortic balloon pump. Five-year survival was lower in the prolonged ventilation group (56.1% [95% CI 46.6%-64.6%] vs 88.8% [95% CI 87.9%-89.6%]) also after adjustment for imbalances and when comparing propensity-matched patients (hazard ratio 2.39; 95% CI 1.75-3.27; $P <$ .001 for propensity-matched groups). Mean bed occupancy costs were \$14,286 (95% CI \$12,731-\$15,690) and \$2761 (95% CI \$2705-\$2814) in the prolonged ventilation and control groups, respectively ($P <$ .001).

Conclusion: Prolonged ventilation is associated with high in-hospital mortality and costs, and poor 5-year survival. Identified predictors of prolonged ventilation might help to optimize the clinical management of these patients.

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Over the past years there has been a renewed interest on cost containment by health care system producers.[1] Evidence has emerged suggesting that early extubation after cardiac surgery reduces the length of intensive care unit (ICU) and hospital stay, minimizing costs without compromising patients' clinical outcomes.[1-5] Conversely, prolonged ventilation (PV) may have an important impact on costs.[1] The burden on hospital resources of patients requiring a prolonged ICU stay is enormous, and it has also important indirect implications such as cancelations of the routine operative list.

This study determines the independent predictors of PV and its economic implications in patients undergoing cardiac surgery. We ascertain the in-hospital and midterm mortality of patients requiring PV after cardiac surgery.

Methods

Patient Selection

Data were extracted on a cohort of 7553 consecutive adult patients who underwent cardiac surgery between April 1996 and March 2003 at our institution. PV was defined as any patient

Abbreviations and Acronyms

CI = confidence interval
CPB = cardiopulmonary bypass
HDU = high-dependency unit
ICU = intensive care unit
NSTS = National Strategic Tracing Service
NYHA = New York Heart Association
PV = prolonged ventilation

who required mechanical ventilation for 96 hours or more either continuously or in total after reintubation. Patients who were ventilated throughout and died within 96 hours of surgery were excluded because they did not fit naturally into either group. A standard set of perioperative data are collected prospectively for all patients undergoing cardiac surgery at our institution. The data set comprises 5 sections, completed consecutively by the anesthetist, surgeon, ICU, high-dependency unit (HDU), and ward nurses. Data are entered into the Patient Analysis and Tracking Systems database (Dentrite Clinical Systems, London, United Kingdom).

Anesthetic and Surgical Technique

Anesthetic and surgical techniques were as reported previously.[6-8] Briefly, heparin was given intravenously at a dose of 300 IU/kg, with additional intravenous doses of 3000 IU to maintain the activated clotting time more than 480 seconds throughout cardiopulmonary bypass (CPB). A standard CPB circuit was used. Nonpulsatile flow was used, with a flow rate throughout bypass of 2.4 L · min · m. Mean arterial pressure was maintained at 50 to 60 mm Hg during CPB.

For conventional coronary artery bypass grafting operations, systemic temperature was maintained between 34°C and 36°C. Myocardial protection was achieved using intermittent antegrade warm blood cardioplegia. For all other operations, myocardial protection was predominantly by a combination of intermittent antegrade and retrograde cold blood cardioplegia, with moderate systemic hypothermia to 28°C to 32°C. With aortic surgery, in which deep hypothermic circulatory arrest was required, the target cooling temperature was 18°C, and cerebral protection was as previously reported.[8] The technique used for off-pump coronary artery bypass procedures has been reported.[9] Briefly, the target vessel was exposed and temporarily snared above the anastomotic site using a 4-0 Prolene suture (Ethicon, Inc, Somerville, NJ) with a soft plastic snugger. The coronary artery was then opened, an intracoronary shunt was systematically used, and the anastomosis was performed using a pressure stabilizer.

ICU Management

At the end of the operation, patients were transferred to the ICU. The lungs were ventilated with 60% oxygen using volume-controlled ventilation. Adjustments in F_{IO_2} and respiratory rate were made according to routine blood gas analysis, to maintain Pa_{O_2} between 80 and 100 mm Hg, and Pa_{CO_2} between 35 and 40 mm Hg. Forced air warming was used until a stable nasopharyngeal temperature of 37°C had been reached. The decision to extubate a patient is at the independent discretion of the consultant anesthetist and follows a predefined protocol, aiming at early extubation. Once the patient is warmed to 36°C, weaning is commenced by terminating any sedative drug infusions. A systolic blood pressure greater than 100 mm Hg and pulse rate less than 100 beats/min are aimed for. The blood loss must be less than 100 mL/h and decreasing from the chest drains. Arterial blood gas analysis must reveal a pH of 7.35 to 7.5, P_{CO_2} 35 to 49 mm Hg, and P_{O_2} greater than 90 mm Hg on an inspired oxygen concentration of 50% or less, base excess –3 to +3. Before extubation the patient must be neurologically alert and orientated with equal movement throughout all limbs, initiating adequate respiration and obeying commands. At the discretion of the consultant intensivist and according to the described protocol, elective patients are amenable to nurse extubation.

Decisions about transfers from the ICU to the HDU and from the HDU to the ward, and vice versa, are made by intensivists on the basis of predefined protocols. Extubated patients who require continuous monitoring of either blood pressure or urine output, or prolonged chest physiotherapy are moved to the HDU. The nurse/patient ratio at this level is 1:2, whereas it is 1:1 in the ICU and 1:4 at the ward level.

Bed Occupancy Cost

Costs were calculated according to nursing shifts (three 8-hour shift periods per day) at each dependency level. The cost was therefore calculated from respective shift rates and length of stay at each dependency level and included both the cost of maintaining the bed and nursing cost. The shift rate costs were $242.82 for an ICU bed, $123.35 for an HDU bed, and $60.71 for a ward bed. Suitability for discharge from the ICU and HDU followed unit protocol and was based on the judgment of an independent intensivist.

Follow-up

Postdischarge mortality data were obtained from the UK National Strategic Tracing Service (NSTS) in October 2004, and 99.5% of the study cohort was successfully matched to the NSTS database. Because most deaths are reported to NSTS within 2 months of the event, the survival time was calculated from the date of surgery to July 31, 2004, for surviving patients. For the patients who could not be traced through NSTS, the survival time was censored at hospital discharge.

Statistical Analysis

Data are reported as number and percentage (categoric data); mean and standard deviation (normally distributed continuous variables); or median and interquartile range (continuous variables with a skewed distribution). Baseline characteristics were compared using the chi-square or Fisher exact test (categorical variables) or the Wilcoxon rank-sum test (continuous or discretely measured variables). Patients with 3 or more baseline demographic or clinical data items missing were excluded from all analyses.

Predictors of PV were identified using backward stepwise logistic regression. Variables significant at the 10% level or less (likelihood ratio test) were retained. Model calibration and discriminatory ability were assessed using the Hosmer-Lemeshow test and the c-statistic, respectively. Candidate variables included factors believed to be important clinically plus those preoperative

TABLE 1. Preoperative characteristics

Variable	Control group (n = 7356)	% (97.4)	PV group (n = 197)	% (2.6)	*P* value
Age (y)	65 (58-71)		68 (62-73)		.0002
Body mass index (kg/m^2)	26.4 (23.8-29.2)		24.8 (21.1-27.7)		<.0001
Female gender	1779	(24.2)	59	(29.9)	.063
Dyspnea class					
NYHA I	1424	(19.3)	33	(16.8)	<.001
NYHA II	3034	(41.3)	35	(17.8)	
NYHA III	2394	(32.6)	66	(33.5)	
NYHA IV	501	(6.8)	63	(31.9)	
Canadian Cardiovascular Society score					
CCS 0/1	1622	(22.1)	84	(42.6)	<.001
CCS 2	1996	(27.1)	27	(13.7)	
CCS 3	2094	(28.5)	38	(19.3)	
CCS 4	1641	(22.3)	48	(24.4)	
Parsonnet score	7 (3-13)		19 (12-29)		<.0001
Congestive heart failure	1309	(17.8)	85	(43.3)	<.001
Previous MI					
1	2085	(28.4)	57	(28.9)	.78
2+	476	(6.5)	15	(7.6)	
Timing of previous MI					
≤1 mo	304	(4.2)	24	(12.2)	<.001
>1 mo	2239	(30.5)	48	(24.8)	
Hypertension	3952	(53.8)	94	(47.7)	.093
Diabetic	1068	(14.5)	25	(12.7)	.47
Hypercholesterolemic	4596	(62.6)	74	(37.8)	<.001
Respiratory condition					
COPD	371	(5.1)	15	(7.6)	.054
Asthma	362	(4.9)	15	(7.6)	
Smoking history	5040	(68.5)	120	(60.9)	.023
Renal dysfunction*	146	(2.0)	26	(13.2)	<.001
Extent of coronary disease					
Normal	1192	(16.4)	60	(31.4)	<.001
1 vessel	649	(8.9)	13	(6.8)	
2 vessels	1508	(20.8)	30	(15.7)	
3 vessels	3869	(53.4)	76	(39.8)	
Not investigated	34	(0.5)	12	(6.3)	
Moderate or poor ejection fraction† (<50%)	2095	(28.6)	91	(47.4)	<.001
Previous surgery	337	(4.6)	21	(10.6)	<.001
Preoperative inotropes	36	(0.5)	33	(16.8)	<.001
Ventilated	21	(0.3)	14	(7.1)	<.001
Preoperative intra-aortic balloon pump	33	(0.5)	24	(12.2)	<.001
Operative priority					
Elective	3340	(45.4)	53	(26.9)	<.001
Urgent	3821	(52.0)	82	(41.6)	
Emergency	176	(2.4)	54	(27.4)	
Salvage	15	(0.2)	8	(4.1)	
Type of operation					
CABG	5430	(73.8)	66	(33.5)	<.001
CABG - OPCAB	1759	(32.4)	16	(24.2)	
Valve	1079	(14.7)	38	(19.3)	
Valve + CABG	523	(7.1)	30	(15.3)	
Aortic surgery	208	(2.8)	43	(21.8)	
Other combined procedures	116	(1.6)	20	(10.1)	

PV, Prolonged ventilation; *NYHA,* New York Heart Association; *CCS,* Canadian Cardiovascular Score; *MI,* myocardial infarction; *COPD,* chronic obstructive pulmonary disease; *OPCAB,* off-pump coronary artery bypass; *CABG,* coronary artery bypass graft. *Serum creatinine >200 μmol/L or either acute or chronic renal failure requiring dialysis. †Moderate ejection fraction, 30% to 49%; poor ejection fraction, <30%.

TABLE 2. In-hospital outcomes

Variable	Control group (n = 7356)	%	PV group (n = 197)	%
In-hospital death	73	(1.0)	44	(22.3)
Perioperative MI	137	(1.9)	9	(4.6)
Atrial fibrillation	1138	(15.5)	120	(60.9)
Chest infection	393	(5.3)	93	(47.2)
Reintubated	159	(2.2)	78	(39.6)
Tracheostomy	63	(0.9)	115	(58.4)
Permanent stroke	44	(0.6)	16	(8.3)
Transient ischemic attack	45	(0.6)	17	(8.7)
Sternal rewiring	56	(0.8)	10	(5.1)
Septicemia	86	(1.2)	83	(42.8)
Renal dysfunction†	76	(1.0)	73	(37.0)
Gastrointestinal complications	82	(1.1)	44	(22.2)
Multisystem failure	34	(0.5)	61	(31.1)
Reoperation for bleeding/tamponade	290	(4.0)	41	(20.8)
	2921	(46.1)	161	(96.9)
	2 (1-3)		7 (4-11)	
Patients requiring fresh-frozen plasma*	901	(14.3)	101	(62.7)
	4 (2-4)		4 (3-8)	
Patients requiring platelets*	1122	(17.8)	106	(64.2)
	1 (1-2)		2 (1-3)	
ICU stay (d)	1 (1-2)		14 (7-23)	
HDU stay (d)	1 (1-2)		4 (2-7)	
Ward stay	4 (3-6)		6 (3-10)	

PV, Prolonged ventilation; *MI,* myocardial infarction; *ICU,* intensive care unit; *HDU,* high-dependency unit. *Transfusion data were not collected before April 1997. †Serum creatinine >200 μmol/L or either acute or chronic renal failure dialysis.

risk factors and operative procedure variables that showed significant imbalance between the groups.

In-hospital morbidity is reported without adjustment for differences between the control and PV groups because it is not possible to separate cause and effect; most complications occur while the patient is ventilated and before the classification to control or PV group can be made. In contrast, in-hospital mortality and 5-year survival in the control and PV groups are reported with and without adjustment for potential confounding variables. The variables included in the adjustment were specified in advance of the analysis, and no attempt was made to assess their statistical significance, either individually or together (see footnote to Table 3 for details). Confirmatory analyses, comparing outcomes for the PV group and a propensity-matched group of control patients (up to 5 matched controls selected per patient in PV group), were also carried out. Patient and operative variables included in the adjusted analyses were used to calculate the propensity score, and a greedy algorithm was used to select the matched pairs. Standard regression methods were used: logistic regression for in-hospital mortality and Cox proportional hazards regression for 5-year survival. Model assumptions were checked, and where they were untenable alternative models were explored. All analyses calculated robust confidence intervals (CIs), taking account of clustering of patients. Results are reported with 95% CIs. No correction was made for the number of outcomes compared. Our interpretation of the findings is based on the consistency of the findings and their magnitude as well as their statistical significance.

Ninety-five percent CIs for the mean economic costs were calculated from 100 bootstrap samples and are based on percentiles of the bootstrap estimates obtained. This method was chosen

TABLE 3. Effect sizes (95% confidence interval): In-hospital mortality and 5-year survival

Variable	Unadjusted	Adjusted*	Propensity matched†
In-hospital death	28.7 (20.3-40.6)	7.48 (4.56-12.3)	8.06 (4.27-15.2)
Survival to 5 y (excluding in-hospital deaths)	5.13 (3.70-7.11)	2.48 (2.02-3.02)	2.39 (1.75-3.27)

*Robust CIs clustered by consultant team. Adjustment included age, gender, body mass index, NYHA and Canadian Cardiovascular Score classes, congestive cardiac failure, previous myocardial infarction, diabetes, smoking history, respiratory problem, renal dysfunction, hypertension, extent of coronary disease, hypercholesterolemia, previous surgery, ejection fraction <50%, ventilation, inotropes and an intra-aortic balloon pump used preoperatively, operative priority, valve procedures, aortic procedure, CABG, double thoracic graft, use of CPB and prolonged CPB time >90 minutes, and postoperative bleed. †Robust CIs clustered by matched PV-control group; 14 patients in PV group were excluded because a propensity-matched control was not found. The other 183 patients in the PV group were matched to between 2 and 5 control patients (mean 4.5).

TABLE 4. Independent risk factors for prolonged ventilation

Variable	Multivariate odds ratio	95% CI	*P* value
Age (y)			
<55	1.00		<.001
55-59	1.25	1.15-1.37	
60-64	1.58	1.32-1.89	
65-70	1.99	1.53-2.59	
71-89	2.50	1.76-3.56	
NYHA			
Class I	1.00		<.001
Class II	0.81	0.60-1.06	
Class II	1.72	1.16-2.55	
Class IV	3.41	2.28-5.10	
Moderate or poor ejection fraction (<50%)*	1.55	1.03-2.33	.034
Renal dysfunction†	3.01	2.05-4.43	<.001
CPB time >90 min	1.55	1.14-2.11	.004
Double valve procedure	3.22	2.18-4.75	.001
Aortic procedure	8.59	5.25-14.05	<.001
Preoperative inotropes	4.50	2.38-8.48	<.001
Preoperative intra-aortic balloon pump	3.65	1.94-6.89	.001
Operative priority			
Elective	1.00		<.001
Urgent	1.06	0.69-1.64	
Emergency	2.89	1.85-4.53	
Salvage	4.98	2.37-10.46	
Reoperation for bleeding	4.69	2.47-8.92	<.001

NYHA, New York Heart Association; *CPB,* cardiopulmonary bypass; *CI,* confidence interval. *Moderate ejection fraction, 30% to 49%; poor ejection fraction, <30%. †Serum creatinine >200 μmol/L or either acute or chronic renal failure dialysis.

in preference to the normal approximation because economic costs followed a highly skewed distribution.

Analyses were performed using Stata version 8.2 (Stata Corporation, College Station, Tex).

Results

Seventy patients (including 28 emergency or salvage cases) who were ventilated throughout and died within 96 hours of surgery were excluded. Of these, 42 died within the first 24 hours postsurgery. A total of 197 patients, 2.6% of the study population (59 women, median age 68 years, interquartile range 62-73), were ventilated for 96 hours or longer, 119 (59.4%) continuously and 78 (40.6%) in total after reintubation. The control group consisted of the remaining 7356 patients (97.4%). Median ventilation times were 8 and 192 hours in the control and PV groups, respectively. Preoperative characteristics and types of surgery for both groups are shown in Table 1. On average, patients in the PV group were older and more likely to have had a recent myocardial infarction, previous cardiac surgery, ejection fraction less than 50%, congestive heart failure, renal dysfunction, and advanced New York Heart Association (NYHA) class and Canadian Cardiovascular Society score. Conversely, control patients were more likely to have hypercholesterolemia, a smoking history, and more extensive coronary artery disease.

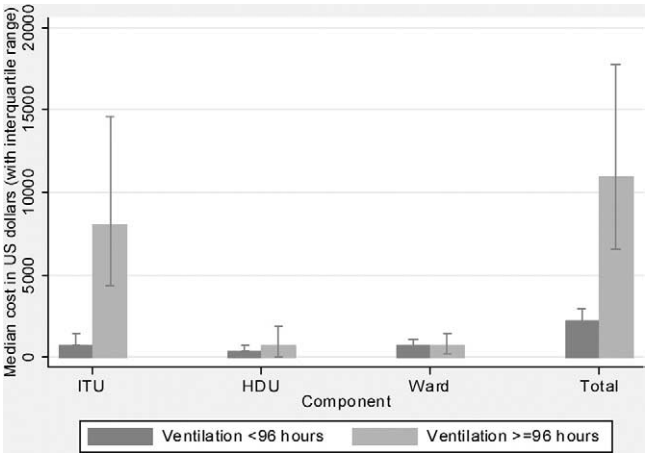

Figure 1. Five-year Kaplan-Meier survival curve for patients discharged after surgery. *ITU,* Intensive therapy unit; *HDU,* high-dependency unit.

The in-hospital outcomes are shown in Table 2. The primary cause of PV was low cardiac output in 92 patients (46.7%) and pneumonia/chest infection in 29 patients (14.7%). For the remaining 76 patients (38.6%) the cause was considered mixed; several complications occurred during the first 48 hours postsurgery, but the actual sequence of events was not recorded. As expected, in-hospital morbidity was significantly higher in the PV group ($P < .001$ for all outcomes). In-hospital mortality was also significantly higher (1.0% vs 22.3%). The magnitude of the increased risk of in-hospital death was reduced after adjustment for imbalances between the groups and when comparing propensity-matched patients, but remained significantly higher for patients ventilated for 96 hours or more ($P < .001$, Table 3). More than 60% of all patients had transfusion of blood products, with 96.9% of patients receiving a blood transfusion in the PV group compared with 46.1% of the control group.

Twenty-eight potential predictors for PV were considered, and of these age, NYHA class, ejection fraction less than 50%, renal dysfunction, CPB time more than 90 minutes, multiple valve replacements, aortic procedures, use of preoperative inotropes and intra-aortic balloon pump, operative priority, and reoperation for bleeding were found to be independent predictors of PV (Table 4).

Median follow-up for survival was 3.4 (1.7-5.5) years versus 3.7 (1.7-5.5) years for PV and control groups, respectively. The Kaplan-Meier survival curve is shown in Figure 1. The 5-year survival (excluding in-hospital deaths)

was significantly lower for the PV group (56.1% [95% CI 46.6%-64.6%] vs 88.8% [95% CI 87.9%-89.6%]). The magnitude of the increased risk of death after hospital discharge was reduced after adjustment for imbalances between the groups and when comparing propensity-matched patients but remained significantly higher for patients ventilated for 96 hours or more ($P < .001$, Table 3).

Distribution of bed occupancy cost between groups is shown in Figure 2. Mean total bed occupancy costs were \$14,286 (95% CI \$12,731-\$15,690) and \$2761 (95% CI \$2705-\$2814) in the PV and control groups, respectively ($P < .001$). Patients in the PV group, on average, were associated with higher ICU and HDU costs ($P < .0001$), but ward costs were similar across the 2 groups ($P = .35$). Although the 197 patients in the PV group represented only 2.6% of the entire population, they accounted for 12.2% of the total bed occupancy costs.

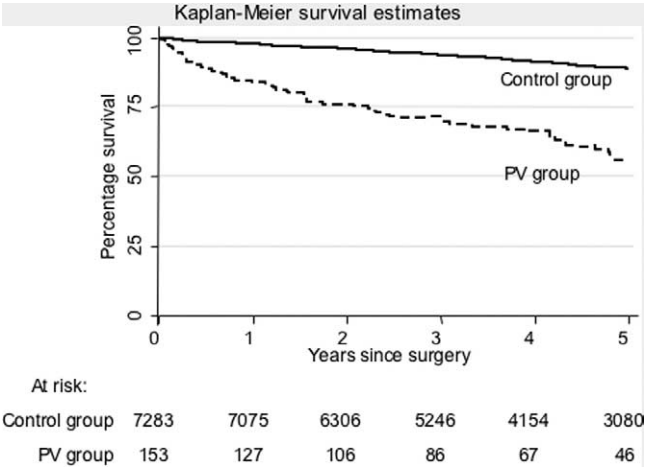

Figure 2. Distribution of bed occupancy cost between groups. *PV,* Prolonged ventilation.

Discussion

This study has 3 major findings. First, patients experiencing PV after cardiac surgery have a significantly higher in-hospital mortality and morbidity and poorer 5-year survival. Second, this study identifies a list of independent predictors of PV (see below). Finally, the study reveals that this small percentage (2.6%) of patients has an enormous impact on the cardiac surgery unit budget, accounting for 12% of the total bed occupancy costs.

The mortality and morbidity reported in the literature seem to depend on the definition of PV, which varies from 24 hours to 14 days.[10-13] Our cutoff at 96 hours was chosen prospectively to include those patients who had more than transient clinical deterioration. We decided not to consider other strata (ie, 24 or 48 hours of PV) because this would detract from the main focus of the study, which is about patients requiring PV for a long period of time, not attributable to simple slow recovery or transient minor clinical complications. The in-hospital mortality of 22.3% in our study is in keeping with other reports.[10,11] Studies that defined PV as ventilation more than 7 days reported an in-hospital mortality of 45%;[12,13] PV more than 48 hours in 19.6%;[11] and PV more than 24 hours in 18.5%.[10] In accordance with other reports,[12,13] 5-year survival was significantly poorer for the PV group (56.1% vs 88.8%), and this difference remained significant even after adjustment for possible confounding variables and when comparing propensity-matched groups.

Our study identified a list of independent predictors of PV including increasing age, NYHA class, ejection fraction less than 50%, renal dysfunction (creatinine >200 μmol/L or dialysis), CPB time more than 90 minutes, multiple valve replacements, aortic procedures, operative priority, reoperation for bleeding, and need for inotropes or an intra-aortic balloon pump preoperatively. The value of identifying independent risk factors is that it may allow preoperative optimization of patients at risk and resource allocation. This is particularly relevant when considering that, in the future, the proportion of high-risk patients requiring PV might increase, because there has been a 30% increase in predicted operative risk in the past decade.[14]

Patients with ejection fraction less than 50% were 1.6 times more likely to require PV. In this subgroup the increased metabolic demands of breathing might be inadequately supported by the impaired pump function leading to PV as suggested by others.[15,16]

Contrary to other studies,[10,13,17,18] the presence of chronic obstructive pulmonary disease or asthma preoperatively, and smoking were not found to be associated with PV. This finding is somehow surprising, because one would expect PV to be more common in these patients. One explanation might be that PV is associated with severe, rather than mild or moderate baseline respiratory dysfunction. However, this is difficult to ascertain with our study because of the lack of baseline lung function tests, which prevents stratifying the analysis by degree of lung dysfunction and warrants a dedicated prospective study.

Several intraoperative and postoperative factors were identified as independent predictors of PV. Aortic surgical procedures carried 8.5 times the risk of PV compared with other procedures. Higher morbidity and mortality after aortic procedures are commonly associated with neurologic complications, the incidence of which is reported to vary from 5% to 70%.[19] Also, these procedures often require prolonged CPB, a further independent predictor of PV in our study.

A staggering 12.2% of our total bed occupancy costs have been dedicated to caring for 2.6% of patients. The cost of caring for patients who require PV might be grossly

underestimated because consumables are not included. From a practical perspective, and on the basis of bed occupancy costs alone, the 197 patients in the PV group cost the equivalent of more than 1000 routine patients. We are not implying, however, that patients predicted to require PV should be denied their operation. In fact, more than 50% of patients in the PV group survived to 4 years after the operation in our series.

There are a number of implications arising from the findings of our study. Predicting the likely occurrence of PV could help optimize the preoperative patient information and consenting process, patient management, and case-mix scheduling. First, because the right of cure of each patient is coupled with his or her right to be fully informed, the information provided by our study might help surgeons better inform their patients about the risk/benefit balance associated with the intended surgical procedure. Second, some of the predictors of PV identified, including creatinine greater than 200 μmol/L, operative priority, and reoperation for bleeding, may be managed differently to minimize their impact on clinical outcome. It has been suggested that preoperative volume depletion and recent administration of nephrotoxic drugs in patients with serum creatinine greater than 200 μmol/L enhance acute renal failure, a recognized independent predictor of in-hospital death.[20] As a result, at our institution we have started to use preoperative (12 hours) volume replacement therapy in patients with mild to moderate renal insufficiency and have adopted a more critical approach to preoperative radiographic contrast agents exposure scheduling. With regard to operative priority, up to 50% of our patients were urgent referrals (48% in the PV group), which, at our institution, is defined as any patient, at our or another hospital in the region, referred for surgery to be carried out during the same admission. These patients are managed on cardiac wards until the day before surgery under the care of an independent consultant cardiologist, and the waiting time varies from 1 to 14 days, on average. This might have led to a difference in preoperative waiting time between groups, and possibly to a difference in pneumonia/chest infection–induced PV, because a prolonged preoperative in-hospital stay has been linked to hospital-acquired infections.[21] Finally, many potential actions could be taken to minimize the incidence of reopening for bleeding and tamponade including optimal hemostasis before closure and a diagnosis-directed management of postoperative coagulopathy.

This study is not without its limitations. First, there were important preoperative imbalances between groups. Regression modeling and propensity score matching can never entirely account for these imbalances, and the adjusted estimates may still be subject to some residual confounding. Nevertheless, such confounding is unlikely to change the direction of the differences seen. Furthermore, in our institution strict local guidelines are used to make decisions about perioperative patient care, and these guidelines were applied throughout the study period.

Conclusion

Our study suggests that PV is associated with high in-hospital morbidity, mortality, and bed occupancy costs, and significantly reduced 5-year survival. Given the limited resources and the ever-increasing demand of medical care, the independent predictors of PV identified by our study may help to optimize the preoperative and postoperative clinical management of these patients.

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