

A protocol-driven approach to early extubation after heart surgery

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Objective: We assessed the effectiveness of standardized protocols in decreasing postoperative mechanical ventilation time to <6 hours.

Methods: In 2061 patients undergoing coronary bypass, the proportion extubated in <6 hours was calculated for 3 sequential time periods. During period 1 patients were weaned per baseline practices; during period 2, per a protocol developed by a multidisciplinary committee; and during period 3, as in period 2 but with paralytic reversal and extubation performed at lower body temperatures and an extubation reminder sheet prominently displayed. We used a χ^2 test to examine differences in ventilation times among the 3 time periods and logistic regression modeling to control for independent risk factors for prolonged ventilation. As measures of patient safety, we examined rates of reintubation and rates of patient shivering following paralytic reversal.

Results: Twelve percent of patients were extubated in <6 hours during period 1, 24% during period 2 ($P < .01$), and 38% during period 3 ($P < .01$ compared with both periods 1 and 2). After controlling for 12 risk factors, patients were more likely to be extubated in <6 hours during period 2 (odds ratio, 2.39; 95% confidence interval, 1.84-3.10) and period 3 (odds ratio, 5.05; 95% confidence interval, 3.65-6.99) than during period 1. There was no difference in reintubation rates across periods, and the rate of patient shivering did not increase with paralytic reversal at lower body temperature.

Conclusions: The standardized protocols outlined in this article dramatically improved early extubation performance. (J Thorac Cardiovasc Surg 2014;147:1344-50)

Prolonged mechanical ventilation after heart surgery has been defined in studies as mechanical ventilation lasting longer than some specified amount of time, usually in the range of 24 hours to 7 days, and is reported to occur in 5% to 10% of patients undergoing cardiac surgery.¹⁻⁵ Prolonged mechanical ventilation has been demonstrated to be associated with increased hospital and intensive care unit (ICU) lengths of stay; higher health care costs; and morbidity resulting from atelectasis, intrapulmonary shunting, and pneumonia.⁶⁻⁹ In contrast, early extubation of postoperative heart surgery patients has been associated with shorter ICU and overall hospital stays and decreased resource use.¹⁰⁻¹⁴ Moreover, extubation within 6 hours has been shown to be safe and effective even in elderly patients, with no increased risk of reintubation.¹⁵ Despite this knowledge, there are few established protocols for promoting early extubation in postoperative heart surgery patients. We therefore developed and assessed 2 different sets of standardized interventions designed to reduce time to extubation in postoperative cardiac surgical patients to <6 hours.

METHODS

After receiving institutional review board approval and informed consent, we prospectively collected data on 2061 successive patients undergoing coronary artery bypass grafting (CABG) between January 3, 2005, and June 30, 2012. The study period was subdivided into 3 smaller periods. During period 1 (January 3, 2005, through September 29, 2009) patients were weaned to extubation according to the practices and preferences of individual intensivists and surgeons. During period 2 (October 1, 2009, through August 31, 2011) patients were weaned according to a standardized protocol developed by a multidisciplinary performance improvement committee composed of cardiac surgeons, intensivists, anesthesiologists, advanced care practitioners, nurses, respiratory therapists, pharmacists, and administrators. The protocol called for all postoperative patients to receive the same ventilator settings: a respiratory rate of 16 breaths per minute with a tidal volume of 8 cc/kg ideal body weight. Paralysis in all patients was to be reversed at a bladder temperature of 36°C as determined by indwelling Foley catheter. Guided by predetermined parameters, the bedside nurse was then charged with judging extubation readiness by assessing hemodynamic stability, the degree of patient bleeding, the resolution of acidosis, and patient cognition. When nurses judged a patient ready, a respiratory therapist was then charged with setting the patient to minimal ventilator settings: pressure support and continuous positive airway pressure of 5 cmH₂O. After 30 minutes at these settings an arterial blood gas was drawn. Only after return of the arterial blood gas results was the provider charged with evaluating for extubation. (See [Appendix 1](#) for the protocol algorithm). During period 3 (September 1, 2011, through June 30, 2012) patients were weaned as during period 2 but with 3 changes. First, paralytic reversal was performed at a bladder temperature of 35.5°C rather than 36°C. When patients reached either 36°C (during period 2) or 35.5°C (during period 3) the provider was called by the bedside nurse to reverse neuromuscular blockade with neostigmine and glycopyrrolate. Second, extubation was performed at a body temperature of 36°C instead of 36.5°C. Third, a highly visible pink extubation reminder sheet was placed in every patient room upon arrival in the ICU ([Figure 1](#)). This timing

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Abbreviations and Acronyms

CABG = coronary artery bypass grafting
ICU = intensive care unit

sheet noted the time of ICU arrival and the 4-hour and 6-hour ventilation time points, serving as an ever-present reminder to extubate patients early.

During all 3 periods, the nurse-to-patient ratio was 1:1 in our ICU, whereas the respiratory therapist-to-patient ratio was between 1:5 and 1:8.

As a measure of patient safety, we used a χ^2 test of proportions to compare reintubation rates across all 3 periods. Because paralysis was reversed at a lower body temperature during period 3, we used a χ^2 test to compare the rate of patient shivering during period 3 to the rate of shivering during period 2. Shivering rates were determined by calculating the proportion of patients who received at least 1 postoperative dose of meperidine, which is used in our unit to treat postoperative shivering. A dose of meperidine therefore served as a surrogate for patient shivering.

Table 1 summarizes patient characteristics for each of the 3 periods, including median initial postoperative ventilation time (in hours) for each period. It includes data on patient age (in years), last recorded preoperative serum creatinine level (in milligrams per deciliter), history of peripheral vascular disease, and surgical urgency, all factors demonstrated to be independent risk factors for prolonged mechanical ventilation.⁹ Table 1 also displays data on the following additional risk factors: chronic obstructive pulmonary disease, congestive heart failure, recent myocardial infarction (ie, within 21 days of surgery), redo surgery (defined here as having undergone previous CABG), and placement of an intra-aortic balloon pump. Peripheral vascular disease was defined as claudication either with exertion or rest; amputation for arterial insufficiency; aorto-iliac occlusive disease reconstruction; peripheral vascular bypass surgery, angioplasty, or stent; documented abdominal aortic aneurysm, abdominal aortic aneurysm repair, or stent; or documented positive noninvasive testing. The definition of peripheral vascular disease excluded cerebrovascular disease.

Patient-level factors were compared across periods using χ^2 tests for dichotomous variables and analysis of variance for differences in mean values for continuous variables. For periods 1, 2, and 3 we calculated the percentage of patients who were extubated postoperatively in <6 hours, then used a χ^2 test of proportions to examine the significance of differences across the 3 periods. We used logistic regression modeling to calculate the odds of extubation in <6 hours during periods 2 and 3 compared with period 1, controlling for the potential independent risk factors for prolonged mechanical ventilation outlined above (see Table 1). We then used the same regression model to determine how each independent risk factor for prolonged mechanical ventilation was associated with the odds of extubation in <6 hours. Finally, differences in median initial postoperative ventilation time across the 3 study periods were examined using the Kruskal-Wallis equality of proportions rank test. All data for this study were interpreted exclusively by the authors and all analyses were conducted using Stata 12.1 (StataCorp LP, College Station, Tex).

Anesthesia Practices

Anesthesia for patients undergoing coronary bypass was performed according to the discretion of the attending anesthesiologist. The majority of patients were anesthetized in the following manner: 0.1 mg/kg midazolam, 1 to 4 μ g/kg fentanyl, and 0.1 mg/kg vecuronium (adjusted for renal failure). Routinely patients (both men and women) were intubated using an 8.0 endotracheal tube, following which a transesophageal echo probe (Philips Healthcare, Andover, Mass) was placed and central access obtained. Anesthesia was provided using isoflurane (0.5-1 minimum alveolar concentration) and additional doses of 1 to 3 μ g/kg fentanyl up to a total dose of 10 to 20 μ g/kg as needed. Muscle paralysis was maintained until

separation from cardiopulmonary bypass. All patients received an antifibrinolytic agent (eg, aminocaproic acid), insulin, as well as ionotropic and vasoactive medications as needed. Neither parasternal blocks nor epidural catheters were used for intra- or postoperative pain management.

During the study period 2 changes in anesthetic technique occurred. Due to increasing concern with postoperative cognitive dysfunction and delirium associated with benzodiazepines, at the beginning of period 2, administration of additional doses of midazolam (0.05 mg/kg) after separation from cardiopulmonary bypass ceased. Sedation for ICU transport was accomplished with low-dose propofol infusions (15 μ g/kg/minute up to 50 μ g/kg/minute). Second, during time period 3 of the study, paralytics ceased after separation from cardiopulmonary bypass.

RESULTS

During periods 1, 2, and 3, the rate of extubation in <6 hours was 12%, 24%, and 38%, respectively. A χ^2 test of proportions showed $P < .01$ for all groups compared with each other (Figure 2).

Table 2 shows the results of logistic regression modeling. After controlling for age, sex, preoperative serum creatinine level, history of peripheral vascular disease, urgent surgical status, emergent surgical status, chronic obstructive pulmonary disease, congestive heart failure, redo surgery, dialysis dependency, recent myocardial infarction, and placement of an intra-aortic balloon pump during period 2 patients were approximately twice as likely to be extubated in <6 hours compared with patients in period 1 (odds ratio [OR], 2.39; 95% confidence interval [CI], 1.84-3.10). Patients in period 3 were >5 times more likely to be extubated in <6 hours compared to patients in period 1 (OR, 5.05; 95% CI, 3.65-6.99). Consistent with these results, median initial postoperative ventilation time declined from 11.0 hours during period 1 to 8.8 hours during period 2 to 7.1 hours during period 3 ($P < .001$).

In our model, women in any period were approximately 40% less likely to be extubated within 6 hours than men (OR, 0.61; 95% CI, 0.45-0.82). Although not statistically significant, there was a trend toward lower likelihood of early extubation for patients with peripheral vascular disease (OR, 0.81; 95% CI, 0.56-1.16), urgent surgical status (OR, 0.85; 95% CI, 0.66-1.10), emergent surgical status (OR, 0.72; 95% CI, 0.31-1.66), chronic obstructive pulmonary disease (OR, 0.73; 95% CI, 0.50-1.06), congestive heart failure (OR, 0.96; 95% CI, 0.66-1.40), and recent myocardial infarction (OR, 0.99; 95% CI, 0.76-1.31). For every additional year in age, patients were less likely to be extubated early (OR, 0.98 per year; 95% CI, 0.97-0.99). For each additional milligram per deciliter increase in preoperative serum creatinine there was a trend toward lower likelihood of early extubation (OR, 0.84 per mg/dL; 95% CI, 0.69-1.03). Placement of an intra-aortic balloon pump significantly reduced odds of early extubation (OR, 0.38; 95% CI, 0.24-0.60).

The proportion of overall patients undergoing reintubation did not differ across the 3 time periods, ranging from

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