A 3-hour fast-track extubation protocol for early extubation after cardiac surgery

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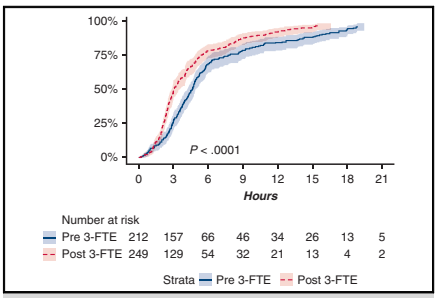
ABSTRACT

Objectives: Early extubation after cardiac surgery improves outcomes and reduces cost. We investigated the effect of a multidisciplinary 3-hour fast-track protocol on extubation, intensive care unit length of stay time, and reintubation rate after a wide range of cardiac surgical procedures.

Methods: We performed an observational study of 472 adult patients undergoing cardiac surgery at a large academic institution. A multidisciplinary 3-hour fast-track protocol was applied to a wide range of cardiac procedures. Data were collected 4 months before and 6 months after protocol implementation. Cox regression model assessed factors associated with extubation time and intensive care unit length of stay.

Results: A total of 217 patients preprotocol implementation and 255 patients postprotocol implementation were included. Baseline characteristics were similar except for the median procedure time and dexmedetomidine use. The median extubation time was reduced by 44% (4:43 hours vs 3:08 hours; $P < .001$) in the postprotocol group. Extubation within 3 hours was achieved in 49.4% of patients in the postprotocol group compared with 25.8% patients in the preprotocol group; $P < .001$. There was no statistically significant difference in the intensive care unit length of stay after controlling for other factors. Early extubation was associated with only 1 patient requiring reintubation in the postprotocol group.

Conclusions: The multidisciplinary 3-hour fast-track extubation protocol is a safe and effective tool to further reduce the duration of mechanical ventilation after a wide range of cardiac surgical procedures. The protocol implementation did not decrease the intensive care unit length of stay. (JTCVS Open 2022;12:299-305)



Extubation time was decreased with the application of the 3-FTE protocol.

CENTRAL MESSAGE

The 3-FTE protocol is a safe and effective tool to further reduce the duration of mechanical ventilation but not ICU LOS after a wide range of cardiac surgical procedures.

PERSPECTIVE

The 3-FTE protocol is a safe and effective tool to further reduce the duration of mechanical ventilation but not ICU LOS after a wide range of cardiac surgical procedures.

Evidence-based postoperative management of the cardiac surgical patient is essential to provide high-quality care. Early extubation after cardiac surgery has been shown to be an important postoperative aspect of this management, improving outcomes and reducing cost.[1] Earlier extubation is associated with decreased ventilator-associated pneumonia,[2,3] decreased use of sedatives,[4] earlier rehabilitation, and shorter intensive care unit (ICU) length of stay (LOS).[5-7] In a busy ICU, clinicians prioritize their time and attention to the most critical issues, distracting them from making timely simple decisions, such as early sedation weans. This can result in missed opportunities for early extubation.[8] Postoperative ventilation that exceeds 24 hours is a performance measure published by the National Quality Forum in the United States.[9] Extubation within 6 hours for coronary artery bypass grafting (CABG) procedures, aortic valve replacement (AVR) procedures, and combined CABG/AVR procedures may soon be integrated in the Society of Thoracic Surgeon quality metrics.[10]

Multidisciplinary extubation protocols have been developed recently by many centers to expedite extubation and have been demonstrated to be safe and effective.[1,6] They have been associated with a significant reduction in duration of mechanical ventilation and ICU LOS after elective cardiac surgery.[6,8,11-13] After improving our postoperative extubation time in recent years, we strived to further

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Abbreviations and Acronyms

AVR = aortic valve replacement
CABG = coronary artery bypass grafting
IABP = intra-aortic balloon pump
ICU = intensive care unit
LOS = length of stay
3-FTE = 3-hour fast-track extubation

improve this goal. We developed a 3-hour fast-track extubation protocol (3-FTE) for earlier extubation. This protocol was developed through collaboration among intensivists, cardiac surgeons, ICU nurses, and respiratory therapists. We sought to encompass a broader range of cardiac surgery patients. The protocol establishes a timeline with several time points for the nursing staff and respiratory therapists to follow as patients progress after surgery. We hypothesized that the 3-FTE would further reduce time to extubate after cardiac surgery and would translate to reduce ICU LOS.

MATERIALS AND METHODS

This study was an observational study of adult patients undergoing cardiac surgery, aged 18 years or older, at a single academic institution. The cardiothoracic ICU at Barnes Jewish Hospital is a 27-bed ICU in an academic tertiary center. The study included respiratory management practices before and after an implementation of a 3-FTE protocol from July 1, 2019, to April 30, 2020. The new protocol was implemented on November 1, 2019.

Prior early extubation practice consisted of a written sheet that identified the 6-hour extubation timeline outside the patient's room to inform clinicians. Reminders from the tele-ICU team to the bedside team were communicated at the 3- and 5-hour marks to actively work on weaning sedation and promote extubation. Weaning started after all postoperative laboratory results were returned and 2 hours passed with minimal chest tube outputs.

The 3-FTE protocol (Figure 1) aimed to empower nurses and respiratory therapists to initiate sedation and ventilator weaning soon after arrival and to standardize spontaneous breathing trial practices. During 3-FTE implementation, point of care arterial blood gas was only sent 15 minutes after admission to evaluate oxygenation and acid-base status. If a patient was eligible for fast-track extubation, according to the protocol, sedation was weaned aggressively within 30 minutes of arrival by the bedside nurse. The respiratory therapist started the spontaneous breathing trial practice promptly as the sedation weaned down and the patient started to be responsive. The patient was extubated after 20 to 30 minutes after successful spontaneous breathing trial practice. The 3-FTE protocol was formulated after a literature review of early extubation protocols after cardiac surgery and a multidisciplinary discussion among clinicians.

Inclusion criteria for early extubation during the study period were any patient who underwent open cardiac surgery, including coronary artery bypass graft surgery, valve repair or replacement, aortic aneurysm or dissection repair, maze procedures, pericardiectomy or a combination of these, and surgery was performed in an elective, urgent, or emergency setting. Patients were excluded from the study if they were ineligible for early extubation including after heart or lung transplant, required advance circulatory support other than intra-aortic balloon pump (IABP), requiring inhaled pulmonary vasodilating agents, patients with an open chest, patients with significant lactic acidosis (lactate >4 mmol/L postadmission or >6 mmol/L after 1/2020 with bicarbonate <18 mmol/L), or with an ongoing bleeding (>200 mL/h in the first postoperative hour) (Figure 1).

To measure the impact of the protocol on extubation metrics, data were collected prospectively both before and during the 3-FTE implementation as part of a quality improvement process. No other changes were made in the ICU's workflow during the study. Intraoperative anesthesiology practice as well as intraoperative and postoperative pain management were not modified, except for a communication from the ICU leadership encouraging the use of dexmedetomidine instead of propofol for postoperative sedation.

Extubation data were collected prospectively for all patients. Consent was not obtained because this was an ICU quality improvement project. Approval from the hospital Internal Review Board (number 202010076, 10/13/2020) was obtained to extract missing baseline characteristics from the electronic medical record.

Baseline characteristics were collected from patients' charts and included age, gender, race, and body mass index. Patient comorbidities included a history of hypertension, congestive heart failure, coronary artery disease, previous cardiac surgery, chronic lung disease, cerebrovascular disease, peripheral vascular disease, chronic renal disease, and diabetes mellitus. Intraoperative measurement included procedure type and status (elective vs urgent/emergency), use of IABP, and cardiopulmonary bypass time.

Postoperative measurement included sedation on admission (dexmedetomidine vs propofol), arrival time to ICU (6 am-6 pm vs 6 pm to 6 am), and time to extubation as hours and minutes. The outcomes of interest included the time from arrival to ICU to extubation time, the ICU LOS, and the number of patients requiring reintubation for acute respiratory failure.

Statistical Analysis

Data were presented using descriptive measures. Demographic and baseline characteristics were summarized as medians with interquartile range (as the difference between quarter 3 and quarter 1) for continuous variables, because variables were not normally distributed (Kolmogorov–Smirnov and Shapiro–Wilk tests were statistically significant) and as percentages for categorical variables. Statistical comparisons between the pre–3-FTE and 3-FTE groups with respect to baseline characteristics and outcomes were made using the independent-samples Mann–Whitney *U* test for continuous variables and chi-square or Fisher exact 2-tailed test for categorical variables.

Cox regression assessed factors associated with extubation time and ICU LOS. The impact of 3-FTE, presence of IABP, use of dexmedetomidine, and admission time to ICU were assessed after controlling for other variables. To minimize the effect of outliers on analysis, patients were censored if postoperative mechanical ventilation time was prolonged (>24 hours). Analyses were performed using SPSS 27.0 (IBM), and figures were generated using RStudio (RStudio Team 2020; RStudio: Integrated Development for R. RStudio, PBC, http://www.rstudio.com; packages survival and survminer). Analyses were 2-sided. There were no missing data in the cohort.

RESULTS

There were 217 patients included as part of the 4-month pre–3-FTE protocol, and 255 patients met the inclusion criteria for early extubation in the following 6-month period after the 3-FTE protocol was implemented. Baseline characteristics were similar in both groups except the total procedure time, which was longer in the pre–3-FTE group and the increase of dexmedetomidine use as postoperative sedation by the anesthesiologists in the post–3-FTE group (Table 1).

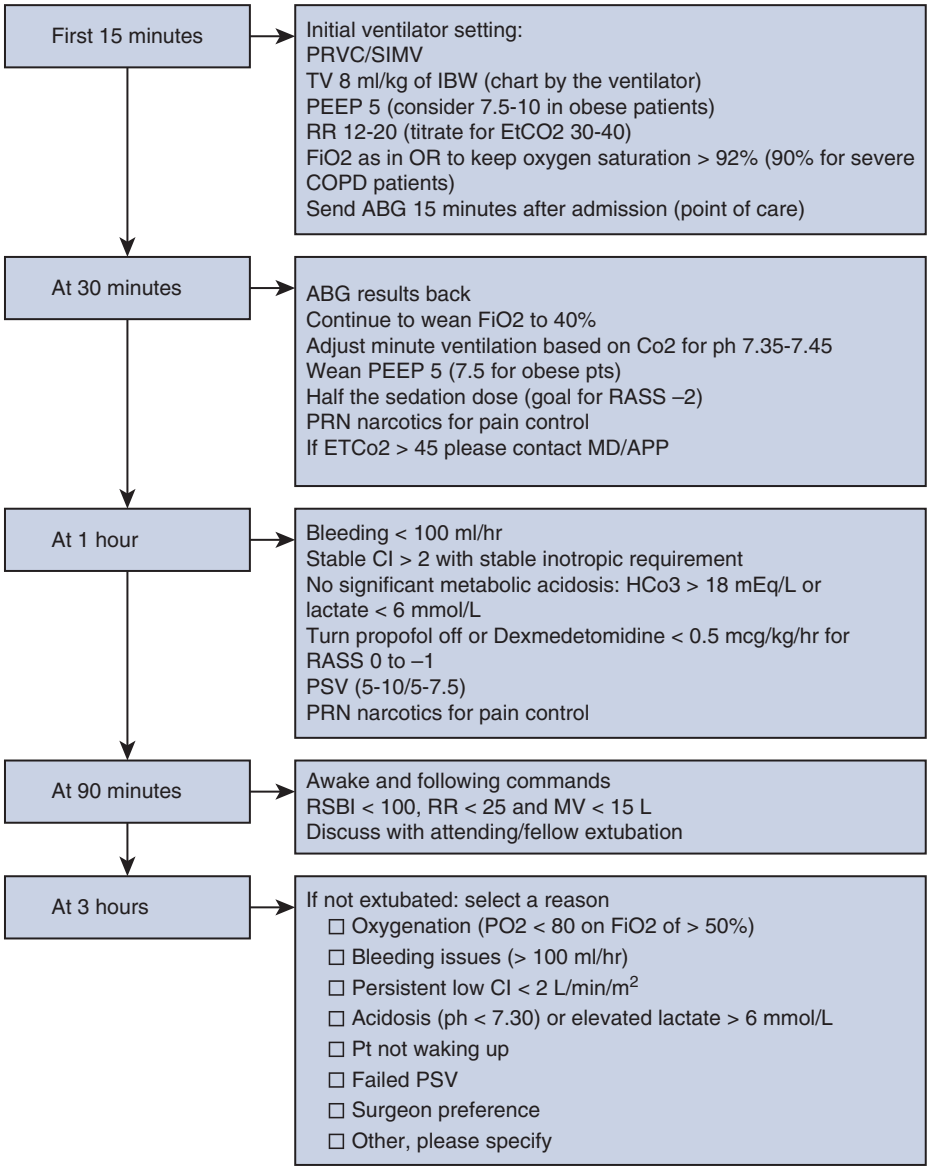

FIGURE 1. 3-FTE protocol. *PRVC*, Pressure regulated volume control; *SIMV*, synchronized intermittent mandatory ventilation; *TV*, tidal volume; *IBW*, ideal body weight; *PEEP*, positive end-expiratory pressure; *RR*, respiratory rate; $EtCO_2$, end tidal carbon dioxide; FiO_2, fraction of inspired O_2; *OR*, operating room; *COPD*, chronic obstructive pulmonary disease; *ABG*, arterial blood gas; *RASS*, Richmond Agitation Sedation Scale; *PRN*, as needed; *MD*, medical doctor; *APP*, advance practice provider; *CI*, cardiac index; HCO_3, bicarbonate; *PSV*, pressure support ventilation; *RSBI*, rapid shallow breathing index; *MV*, minute ventilation; *PO2*, partial pressure of oxygen.

Overall, 97.7% of the patients were extubated within 24 hours postoperatively: 461 of 472 patients. Median extubation time was reduced by 1:35 hours (44%), comparing the extubation time before with the extubation time after implementation of the protocol (4:43 vs 3:08 hours, $P < .001$). This reduction was more pronounced in the CABG/AVR group with reduction of 1:49 hours (74%; 4:45 vs 2:56 hours, $P < .001$). Extubation within 3 hours was almost doubled after protocol implementation (25.8% to 49.4%, $P < .001$) with less effect on the 6-hour extubation time (67.3% vs 76.5%, $P = .03$). Only 11 patients remained intubated after 24 hours (only 1 in the CABG/AVR group). No differences were noted between the pre- and post-groups ($P > .99$) because the effect of the protocol faded over time (Figure 2). The ICU LOS was slightly reduced but was not significantly different (Table 2). Despite the earlier extubation, there was no increase in reintubation rate (0 reintubation vs 1 reintubation, prospectively).

Factors affecting extubation time were assessed during the study period adjusting for other factors using Cox

TABLE 1. Patients' baseline characteristics

Baseline characteristics	Pre–3-FTE (n = 217)	Post–3-FTE (n = 255)	*P* value
Median age (IQR) y	65 (16)	62 (17)	.109
Non-White race (%)	26 (12.0)	35 (13.7)	.585
Male gender (%)	139 (64.1)	162 (63.5)	.924
Median BMI (IQR)	29.9 (9.0)	28.9 (8.4)	.300
COPD (%)	58 (26.9)	68 (26.7)	>.99
ESRD (%)	7 (3.2)	12 (4.7)	.486
Prior cardiac surgery (%)	13 (6.0)	12 (4.7)	.544
Emergency (%)	6 (2.8)	8 (3.1)	>.99
Admission (6 pm-6 am) (%)	28 (12.9)	37 (14.5)	.688
Procedure: CABG/AVR (%)	93 (42.9)	119 (46.7)	.458
Median procedure time (IQR)	447 (131)	412 (118)	.002
IABP (%)	20 (9.2)	20 (7.8)	.622
Dexmedetomidine on admission	44 (20.3)	75 (29.4)	.026

FTE, Fast-track extubation protocol; *IQR*, interquartile range; *BMI*, body mass index; *COPD*, chronic obstructive pulmonary; *ESRD*, end-stage renal disease; *CABG*, coronary artery bypass surgery; *AVR*, aortic valve replacement; *IABP*, intra-aortic balloon pump.

regression. The 3-FTE protocol was associated with shorter intubation time ($P < .001$; Figure 2). Also, the use of dexmedetomidine sedation on admission to the ICU was associated with shorter intubation time. We found that procedures other than CABG/AVR, ICU admission between 6 pm and 6 am and longer total procedure time were associated with delayed extubation (Figures 3 and 4).

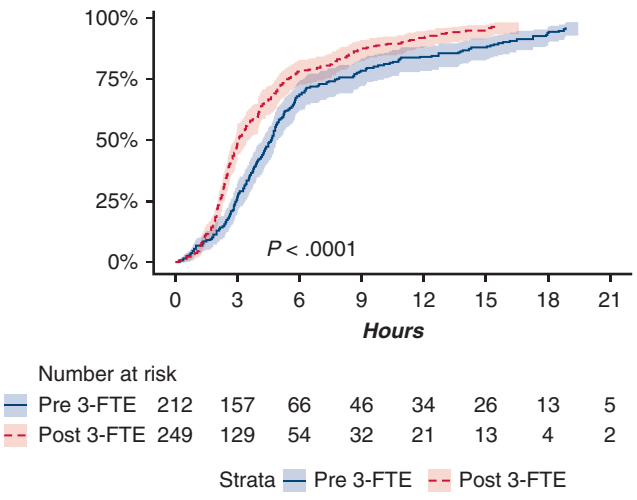

FIGURE 2. Extubation time before and during the 3-FTE protocol implementation: extubation time shortened after protocol implementation. The number of subjects at risk or evaluated for extubation are shown periodically along and below the X axis and as percentage of patients extubated on the Y axis. The 95% confidence limits are shown as *shading along the lines*. The individual graph lines are truncated before the number of subjects at risk decreases to less than 10. *3-FTE*, 3-hour fast-track extubation protocol.

TABLE 2. Comparison of pre– and post–3-fast-track extubation protocol on postoperative ventilation time, extubation time, and intensive care unit length of stay

Outcomes	Pre–3-FTE (n = 217)	Post–3-FTE (n = 255)	*P* value
Ventilation median time: all procedures (IQR)	4:43 (5:44)	3:08 (3:34)	<.001
In CABG/AVR	4:45 (2:55)	2:56 (2:29)	<.001
Extubation within 3 h: all procedures (%)	56 (25.8)	126 (49.4)	<.001
In CABG/AVR	18/93 (19.4)	66/119 (55.5)	<.001
Extubation within 6 h: all procedures (%)	146 (67.3)	195 (76.5)	.030
In CABG/AVR	69/93 (74.2)	103/119 (86.6)	.033
Extubation after 24 h: all procedures (%)	5/212 (2.3)	6/249 (2.4)	>.99
In CABG/AVR	0	1/119 (0.8)	>.99
Median ICU LOS: all procedures (IQR)	1.95 (2.88)	1.92 (1.96)	.287
In CABG/AVR	1.88 (1.97)	1.78 (1.97)	.335

FTE, Fast-track extubation protocol; *IQR*, interquartile range; *CABG*, coronary artery bypass surgery; *AVR*, aortic valve replacement; *ICU LOS*, intensive care unit length of stay.

Analysis was additionally carried out to explore factors resulting in prolonged ICU LOS in all patients. We found that the main factors affecting ICU LOS are related to procedures. Emergency/urgent type, prolonged procedure time, and procedures other than CABG/AVR were associated with longer ICU stay. Also, there was an association between longer ICU LOS and the admission time between 6 pm and 6 am. The 3-FTE protocol was associated with a nonsignificant decrease in ICU LOS after controlling for other factors (Table 3).

DISCUSSION

In the present study, we demonstrate the safety and feasibility of an aggressive nurse and respiratory therapist-led extubation protocol within 3 hours after a wide range of cardiac surgical procedures. After implementation of the 3-FTE, time to extubation was reduced by 24.7%, from 4:43 hours to 3:34 hours. All CABG/AVR cases, except 1 patient, were extubated within 24 hours after surgery. This is a higher rate than other studies reported,[12] reflecting awareness and the commitment of our team regarding the importance of early extubation.

Studies have shown that minimizing the time spent being sedated and intubated reduces the incidence of ventilator-associated pneumonia, hastens rehabilitation, and reduces elective cancellations and healthcare costs.[1-7,14] Other potential benefits include early removal of central venous catheters and urinary catheters postextubation, which could result in decreasing infection related to these invasive catheters. These benefits are potentially accentuated by the fact

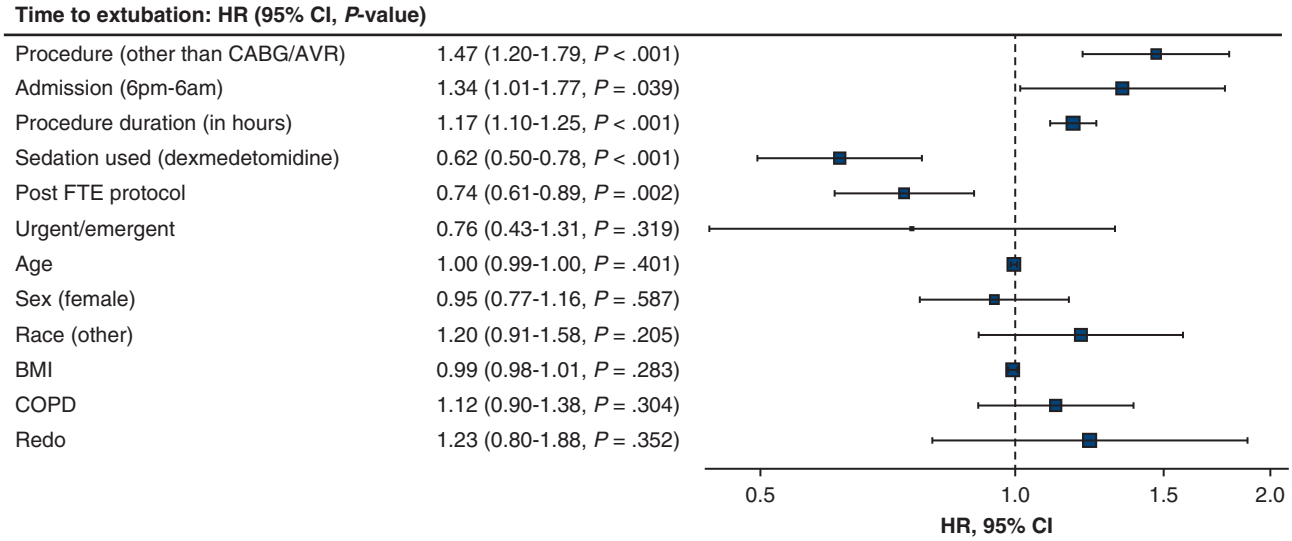

FIGURE 3. Factors impacting extubation time after cardiac surgery after controlling for other variables. *HR*, Hazard ratio; *CI*, confidence interval; *CABG*, coronary artery bypass grafting; *AVR*, aortic valve replacement; *FTE*, fast-track extubation protocol; *BMI*, body mass index; *COPD*, chronic obstructive pulmonary disease.

that the 3-hour time mark aimed for in this initiative is a more ambitious goal than the usual mark of 6 hours that is frequently targeted in similar studies. These benefits are important in the era when the Centers for Medicare and Medicaid Services is proposing expansion of bundled payments.

Some controversy exists as to whether the benefit of more aggressive postcardiac surgery extubation protocols

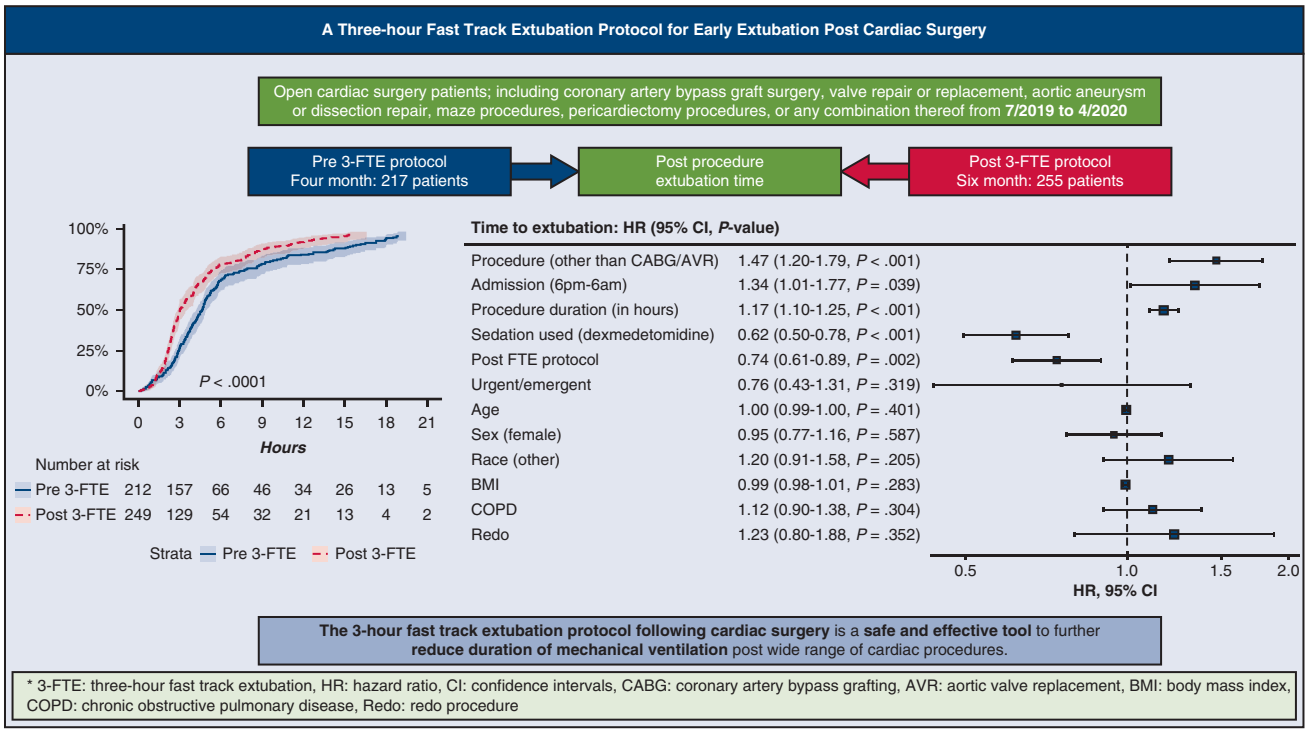

FIGURE 4. Summary of the main findings before and after 3-FTE protocol and factors affecting time to extubation after a wide range of cardiac surgical procedures.

TABLE 3. Factors affecting intensive care unit length of stay after cardiac surgery over the period of the study: The higher odds ratio, the longer the intensive care unit length of stay

Factors affecting ICU LOS	OR (95% CI)
Procedure (other than CABG/AVR)	1.26 (1.05-1.52)
Post-FTE protocol	0.88 (0.74-1.06)
ICU admission time (6 pm-6 am)	1.30 (0.99-1.72)
Procedure duration (h)	1.12 (1.06-1.1.18)
Emergency/urgent	1.68 (0.92-3.07)

Factors not significantly affecting ICU LOS included age, sex, race, body mass index, chronic obstructive pulmonary disease, redo procedures, sedation used, and the FTE protocol. *ICU LOS*, Intensive care unit length of stay; *OR*, odds ratio; *CI*, confidence interval; *CABG*, coronary artery bypass grafting; *AVR*, aortic valve replacement; *FTE*, fast-track extubation protocol; *ICU*, intensive care unit.

outweighs potential risks.[15] Concerns have been raised that patients who are extubated too early may have other end-organ effects and have higher rates of reintubation, which in itself has been shown to increase morbidity and mortality.[16,17] One of the aims of the present study was to examine the differences in reintubation rates between the 2 groups, and the authors found no difference between the 3-FTE protocol and prior standard care. Numerous other trials have also shown multidisciplinary extubation protocols have no detrimental effect on patient outcomes.[5-8] Not all trials are in concordance, however, as Richey and colleagues[18] demonstrated that earlier extubation at their facility via an extubation protocol surprisingly led to longer ICU stays, although with no difference in morbidity and mortality.

The present study did not reveal a difference in ICU LOS. Earlier extubation did not translate to shortened ICU LOS due to a few potential factors. One could be the possibility of the reduction in ventilation time from a median of 4.43 to 3.08 hours may not be clinically significant. On the other hand, the ICU LOS might have been reduced, but a main factor affecting ICU LOS is related to the workflow, because most transfers happened on the next day after regular floor discharges. Other potential benefits of a more aggressive extubation protocol could be an earlier return to resuming a diet and not masking pain by keeping patients sedated and intubated. Patient readiness for discharge from ICU rather than ICU LOS would more accurately reflect the effect of the protocol. Other potential factors affecting the potential benefit on ICU LOS include a relatively small cohort size, making it more difficult to find statistical significance and the need to stay in the ICU due to hemodynamic instability, inotrope requirement, renal failure requiring renal replacement, rhythm disturbances such as complete heart block, delirium, and ongoing bleeding.[19,20] As in prior reports, we demonstrated that extubation time and ICU LOS are related to the complexity of procedure and medical condition of patients, reflected by 3 factors analyzed in this study: procedures other than CABG/AVR, procedure duration, and ICU arrival.[11,12]

The OR anesthesiologists' choice of postoperative sedation agent was interesting because of the significant effect it had on mechanical ventilation times. On the basis of previous studies, anesthesiologists were encouraged, but not mandated, to use dexmedetomidine for postoperative sedation before transport to the ICU. Dexmedetomidine use resulted in earlier extubation compared with propofol. This is consistent with a recent meta-analysis that showed earlier extubation with dexmedetomidine.[21] The reasoning for this finding may be related to the reduced respiratory depression with dexmedetomidine compared with propofol or that dexmedetomidine at commonly used doses is less sedating while also providing analgesic relief. These benefits of dexmedetomidine are controversial as a recent large retrospective study found that dexmedetomidine was associated with higher postoperative delirium rate, pain scores, and reintubation rate.[22] This study also demonstrated the importance of the anxiolytic effect of dexmedetomidine in agitated patients, because 43 of 353 patients (12.2%) admitted in the propofol group were switched to dexmedetomidine for smoother extubation, which could also contribute to delayed extubation in the propofol group.

Quality improvement in the ICU is a dynamic process. We found that extubation was delayed in some patients who had metabolic acidosis with a lactate level greater than 4. This spurred a discussion to revise the protocol and change the acceptable higher lactate level as long as the overall metabolic acidosis was not severe, because complete lactate clearance may take several hours postoperatively. We also asked bedside nurses to document reasons for the inability to extubate within 3 hours to identify obstacles and to help revise the protocol in the future to achieve our goal.

Study Limitations

This study has a few limitations that may hinder its broad applicability. First, blinding of the healthcare providers was not possible because ICU staff were aware of when the 3-FTE protocol was implemented. This is not really a significant limitation because healthcare providers are part of the protocol. Second, this was a single-center study performed in a single surgical cardiothoracic ICU. Communication across multiple disciplines would vary in other centers, making open discussion among stakeholders of paramount importance to achieve success. Third, there was no standardization of intraoperative care, and anesthesiologists were only encouraged to use dexmedetomidine. Clinicians may have been more apt to choose dexmedetomidine if they thought that early extubation for the patient was more likely. This could cause bias to the effects of dexmedetomidine. Finally, the authors did not link earlier extubation to patients-centered clinical outcomes, due to small cohort

size, but rather concentrated on proving the concept that earlier extubation is safely achievable. Potential benefits of early extubation have been found in other studies.

CONCLUSIONS

This single-center quality improvement initiative demonstrates the safety and feasibility of an aggressive 3-hour multidisciplinary extubation protocol after a wide range of cardiac surgical procedures. Although reduction of mechanical ventilation time has multiple potential benefits, such as reduced sedatives, early resumption of diet, early rehabilitation, and earlier readiness for ICU discharge, more studies are warranted to investigate the effect of early extubation on postoperative outcomes. More investigations are needed to evaluate the effect of sedatives and analgesics on early extubation and develop better care models to optimize cardiac postsurgical care.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: cardiac surgery, early extubation, multidisciplinary protocol