

OPEN ACCESS

Citation: Obafemi T, Mullis D, Bajaj S, Krishna P, Boyd J (2023) Results following implementation of a cardiac surgery ERAS protocol. PLoS ONE 18(7): e0277868. https://doi.org/10.1371/journal. pone.0277868

Editor: Shukri AlSaif, Saud Al-Babtain Cardiac Centre, SAUDI ARABIA

Received: July 31, 2022

Accepted: November 4, 2022

Published: July 14, 2023

Copyright: © 2023 Obafemi et al. This is an open access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Data Availability Statement: All relevant data are within the paper.

Funding: The author(s) received no specific funding for this work.

Competing interests: The authors have declared that no competing interests exist.

RESEARCH ARTICLE

Results following implementation of a cardiac surgery ERAS protocol

Tomi Obafemi 👩 *, Danielle Mullis 👩, Simar Bajaj, Purnima Krishna, Jack Boyd

Department of Cardiothoracic Surgery, Stanford University, Stanford, CA, United States of America

* ooobafem@stanford.edu

Abstract

Introduction

Adequate peri-operative care is essential to ensuring a satisfactory outcome in cardiac surgery. In this study, we look at the impact of evidence-based protocols implemented at Stanford Hospital.

Methods

This study is a single-center, retrospective analysis. Enhanced recovery after surgery (ERAS) protocols were implemented for CABG/Valve and open Aortic operations on 11/1/2017 and 6/1/2018, respectively. Propensity-score matched analysis was used to compare 30-day mortality and morbidity of patients from the pre- and post-implementation cohorts. Secondary endpoints included the following: total hospital length of stay (LOS), ICU LOS, time until extubation, and time until urinary catheter removal.

Results

After the implementation of the ERAS protocols for CABG/Valve operations, the median post-op LOS decreased from 7.0 days to 6.1 days (p<0.001), and median ICU LOS decreased from 69.9 hours to 54.0 (p = 0.098). There was no significant decrease in 30-day mortality (4% to 3.3%, p = 0.47). However, the incidence of post-op ventilator associated pneumonia (VAP) decreased from 5.0% to 2.1% (p = 0.003) and post-op urinary tract infections (UTIs) from 8.3% to 3.6% (p<0.001). Patients who underwent open aortic procedures experienced an improvement in 30-day mortality (7% to 3.5%, p = 0.012), decrease in median ICU LOS (91.7 hours to 69.6 hours, p<0.001), and a decrease in duration of mechanical ventilation (79.3 hours to 46.3 hours, p = 0.003). There was a decrease in post-op LOS, post-op VAP, and post-op UTI, although statistical significance was not attained.

Conclusion

At Stanford Hospital, ERAS pathways have led to decreased morbidity and LOS while simultaneously improving mortality amongst our critically ill patient population.

Introduction

Comprehensive perioperative care is essential to ensuring excellent surgical outcomes. Such care promotes recovery and has the potential to improve postoperative morbidity after cardiac surgery [1]. Successful initiatives rely on cohesive multidisciplinary interactions between surgical, anesthetic, and intensive care unit (ICU) teams [2]. Evidence-based enhanced recovery after surgery (ERAS) protocols provide guidelines for the creation of perioperative pathways intended to optimize patient care. These protocols also help to standardize care. Medical knowledge continues to evolve at an exponential rate [3]; to maintain a standard of quality care, cardiovascular and thoracic surgeons must be continually educated about evidence-based practices through the use of clinical guidelines and consensus documents.

A small pilot study by Fleming and colleagues in 2016 demonstrated promising outcomes for ERAS implementation in cardiac surgery. The study showed that ERAS protocols were feasible and had the potential to result in improved postoperative morbidity [4]. Despite these findings, adoption of enhanced recovery protocols has faced resistance in the field of cardiac surgery due to the complexity of the operations, acuity of the patient population, and lack of published evidence to support implementation. In 2019, cardiac surgery ERAS recommendations were published by the ERAS Cardiac Society with guidelines developed by a multidisciplinary group consisting of cardiac surgeons, anesthesiologists, and intensivists with previous experience with ERAS. This group agreed upon 22 potential interventions and divided them into the preoperative, intraoperative, and postoperative phases of recovery [5].

In previous literature, postoperative ERAS strategies have focused on early extubation, promotion of patient mobility, pain control, nutrition, gastrointestinal function, and fluid management [6].

At our institution, we have established comprehensive evidenced-based ERAS post-operative care pathways for CABG/Valve and Aortic surgeries. In this study, we looked at the impact of these evidence-based pathways. We compare quality metrics measured in the post pathway implementation cohort with a similar patient population that preceded the implementation of the ERAS pathways.

Method

This study was a single-center retrospective analysis of consecutive patients undergoing Open Aortic, CABG, and Valve surgery at Stanford Hospital. The data was collected via the electronic medical record (EMR). The EMR utilized at Stanford Hospital during this time period was Epic Systems Corporations (Verona, WI). The study was approved by the Stanford IRB (#60785) and adhered to the institution's protocols. The Stanford IRB waived the requirement for informed consent for this study and HIPAA guidelines was adhered to during the collection of data and reporting of our results.

The start dates for the CABG & Valve pathway and the Aortic Procedure pathway were 11/ 01/2017 and 06/01/2018, respectively. Order sets were created within Epic to implement the post-operative care pathways and standardize care. Orders are placed by the surgical team immediately after the completion of the procedure prior to leaving the operating room. The orders are subsequently released by the ICU team on the arrival of the patient to the unit.

In our analysis of the impact of the CABG & Valve pathway, we included patients who underwent isolated CABG cases, isolated Valve repair and replacement operations, and CABG/Valve combination procedures via robot-assisted, full sternotomy, partial sternotomy, and thoracotomy approaches. Patients who underwent transcatheter valve repair or replacement were excluded from the study as they were not managed postoperatively using the CABG & Valve order set. We use propensity scores to match patients into the pre-implementation and post-implementation groups with a cohort that underwent similar operations prior to the implementation of the pathway from 08/05/2009–11/02/2017. Patients were stratified into these two groups, and a logistic regression model was used to calculate propensity scores based on history of COPD, dialysis, diabetes, and NYHA score. We applied a greedy nearest neighbor matching algorithm without replacement with a caliper of 0.01 to calculate propensity scores. Balance of the match was assessed using standardized differences.

The analysis of the Aortic Procedure pathway included patients who underwent open aortic surgery after its implementation in June 2018. Open aortic surgery at our institution addresses a wide spectrum of aortic disease including aneurysms, dissections, and rupture; operations span the entirety of the thoracic aorta, from valve sparing root replacements to thoracoabdominal aneurysm repairs. Patients who had surgeries that utilized an endovascular approach (i.e., TEVAR) were excluded from our study. Patients on ECMO or those who had an intra-aortic balloon pump (IABP) were also excluded from our study. These patients were also propensity matched with patients who had similar procedures prior to the pathway implementation from 09/15/2012–06/01/2018. A logistic regression model was similarly used to calculate propensity scores among the pre-implementation group versus the post-implementation group based on history of COPD, diabetes, and NYHA score. Mean pain scores were obtained from post-operative day three. They were obtained from the patient directly, if extubated. The scale used ranged from 0 to 10. 0 was considered no pain at all and 10 was considered to be the worst pain imagined.

The comprehensive evidence-based post-operative care pathways at our institution adopt a multimodal approach and are broken down into organ systems: neurological, cardiac, pulmonary, endocrine, renal, gastrointestinal, labs, anticoagulation, prophylaxis, wound, activity, patient education, and discharge planning. Figs 1 & 2 depict a complete breakdown of the CABG/Valve and Aortic procedure post op care pathways. Main components of the protocol were early extubation, ambulation, tight hemodynamic control, multimodal pain control and pre-emptive discharge planning. The primary endpoint of the study was impact of the post-op pathway on 30-day mortality and morbidity (UTIs, VAP, Wound infections). The secondary endpoints evaluated were total hospital length of stay (LOS), ICU LOS, time until extubation, time until first ambulation, time until urinary catheter removal, time until initiation of enteral feeding, and duration of mechanical ventilation.

Results

In the CABG/Valve group, 1131 patients were included in the pre-implementation cohort and 756 in the post-implementation cohort (Table 1). In the Aortic group, 601 patients were included in the pre-implementation cohort and 833 in the post-implementation cohort (Table 2). Prior to matching, there was no difference in age, race, or gender in the CABG/Valve group. The Euroscore between the pre- and post-implementation groups was similar. We observed a significant improvement in median post op LOS from 7.0 days to 6.1 day between the two groups (p<0.001). The ICU LOS also decreased from 70.2 hours to 56.4 hours (p = 0.002). There were similar improvements in duration of mechanical ventilation, time to urinary catheter removal, day to first ambulation, days until first bowel movement, incidence of postop ventilator associated pneumonia (VAP), and post op urinary tract infections (Table 1). In the Aortic cohort, the age, race, and gender were also comparable prior to propensity matching. The Euroscore between the pre- and post-implementation groups was also similar in this cohort. There was an improvement in 30-day mortality from 7.2% to 3.1%. Again, we observed an improvement in median postop LOS from 8.4 days to 7.8 days (p = 0.041). The ICU LOS also improved from 91.8 hours to 68.6 hours (p<0.001). Duration

| | 1011 | | | licii | |
|--|--|--|---|---|---|
| 1 | | ieu | | | |
| | A1 - Immediate Post-Op | | A2 - Prep for Transfer to Step-Down | B1 - Maintenance Recovery | B2 - Discharge Planning |
| | Delirium, F RAS | Fall Risk Assessments | | 1 | * |
| | Wean sedation t | to extubate in 6 hrs or less | | Sitter Assessments | • • |
| Neuro | Palin: Maintain (palind), 20 pini pung, PVB block 1. IV (Dituudi) 2. PO (Dirycodione, Tylenol, Galapentin) 1. PCA (post-entrubation, Galavati); Fjain not constraided w/ 1+2 | | (Consider adding Toradol to #1) | Pain: D(C SQ pain pump 1. Wean IV meds 2. Transition to PO meds 3. Wean PCA | Pain: 1. Transition to PO meds (add OxyContin in prep for discharge) |
| | Maintain Hem HR 60-100; MAP 60-80; CVP 5- | nodynamic Stability Goal: -12; MPAP 10-20; C.I. >2.2; SVR 750-1260 | Maintain Hernodynamic Stability Goal: HR 60-100; MAP 60-80; CVP 5-12 | Maintain Hemodynamic Stability Goal: HR 60-100; BP 95/50 to 150/90 | · |
| Cardiac | Wean inotropes & vasotropic drips as indicated per surgical team and CVICU providers CABE: Kees Nitro sitro vormipt, DIC YOO J Wean: Nitro dip POO 3 auto EKKI/POO 3 | | D/C Art line (early as possible) D/C PA cath | Consider post-op CT D/C Central line (early as possible) | Consider post-op Echo |
| | | | Assess appropriateness for pacing wire removal |) , | |
| | Temp Pacer Check Q4 hrs: Check % paced; underlying rhythm, setting-rate/ MA/ mode/ sensitivity | | | , , | Pacing wires removed |
| | Consider for all patients: A CABG: Statin (PO | ASA; Atrial Fib protocol (if indicated) DD 1 if no contraindications) | Consider for all patients: ASA, Beta Blocker (unless contraindicated), statin | 2 | > |
| | | | IICU Transfer Oxfordin II to di degressit: • Addin 188 di or shore: • Bit antici, pit annormationali • Paring arise present, fit functioning • Elissi of drighter with the UU | | |
| | While Insulated: Follow IRIP protocol; estubate pl in 6 hrs or less | Post-estubation: C 2-8L/min or 40K M to maintain Sp02 2 92%; If COPD pt: Titrate O2 to keep 2 88% (Wean O2 as able) Monitor Oxygenation Pulmonary totic (f indicated) — | | | |
| | Oral care BID (Chlorhexidine while intubated) | Cough, deep breathe, IS 10x C1 hr while availe Oral Care IID & PRN Flutter Valve (Acapella)/PEP therapy Q4 hrs while availe (RT to instruct x 2; pt to do self-care afterward) | | | |
| | STAT Portable | e CXR upon arrival to unit | Portable CKR | | 2v CKR with all lines out day before D/C |
| Pulmonary | Maintai | in chest tube drain | D/C chest tube if < 250ml/day AND per surgical team (need to be ODB x 1 before removal) Chest Tube Removal: Fentanyl x1 (not indicated for pt >75 yo) | | |
| | | | BCU Transfer Criteria - High Flow NC Requirement: • FIO2 60N or less • Stabile, estubated pts • Revuel cleaning encourse in advanced in bit and half OC servicements | | |
| | | | Pts w/ acute resp. decompensation may be appropriate for short term use | | |
| | | | | Assess home O2 requirements, order as needed | |
| | Glucose | e labs per protocol | | } | > |
| Endocrine | Insulin drip per protocol (Wean off insulin d | drip POD 1 as clinically indicated to SQ insulin injection) | | Transition to PO dishatic made or insulin injection/homa made as appropriate | |
| i i | | | If new Diabetes or A1C.2 6.5. Diabetic Magazement Copsult | | |
| 1 | Daily weight by | SAM (standing if possible) | | | · · · · · · · · · · · · · · · · · · · |
| Renal | | | | Malatais LIOP 0 Smil/ra/hr o shift | |
| Renal | Cool Basis di serie la basilita uniale (Tarada | n oor zim/kg/n | D/C Foley per protocol | Maintain UOP 0.5ml/kg/hr q shift | * |
| Renal | Goal: Begin diuresis to baseline weight (Transit | tion to PO/home diuretics as appropriate starting POD 1} - st-estubation: | D/C Foley per protocol | Maintain UOP 0.5ml/kg/hr q shift | |
| Renal | Goal: Begin diuresis to baseline weight (Transit Goal: Begin diuresis to baseline weight (Transit Po Bedai IF PASS Swallow evaluation: to | In ODP 21mp/kg/mr tion to PO/home diuretics as appropriate starting POD 1) st-extuation: de Swallow screen c logolyps of water 3 hrs post-estubation | D/C Foley per protocol | Maintain UDP 0.5ml/lig/hr q.brit | 3 3 3 |
| Renal | Goal: Begin diuresis to baseline weight (Transit Por Bedsid If PASS Swallow evaluation: Ice Regular Diet unie | In OUP 2110/02117 Ition to PO/home diuretics as appropriate starting POD 1) | D/C foliey per protocol | Maintain UDP 0.5ml/kg/hr q.b/th | |
| Renal | Goal: Begin diuresis to baseline weight (Transit Per Begin diuresis to baseline weight (Transit If PASS Swallow realization: to Regular Diet unie Start/complete diet education Dottorierthroad sund | In COP 21MINg/PP | B/C Febry per protocol | Mantain UDP 3.5m/kg/br q.MR Add multivitamin for all parients Add multivitamin for all parients Add multivitamin C (JHC/ C40 for 70m parients Add Source (Lance | Titerating (Ref. Regular Bit) |
| Gi | Goal: Begin diuresis to baseline weight ("main Period III") III PASS Seallow evaluations in Begin? Texture Sant/complete devaluation Sant/complete devaluation Detains fundational on/A Netritional angle Add | In core any energy of the support of | 0/C febry per protocol | Mantain UDP 3.5ml/gb/r q.NM Add multivitations for all parameters Add multivitations for all parameters Add Barry for V Varamic C (HIXCI-C4) For Ovenic Roberg Desses, result does Varamic C 128mg/ days 10 days. | Trinning Bri Replie SNI |
| Gi | Goal Begin diuresis to baseline weight (Trivis) Goal Begin diuresis to baseline weight (Trivis) Bedin If PASS Searline weight for serie Servicesites der det daciation Doctonitester der daciation Doctonitester der daciation Doctonitester der daciation Doctonitester der daciation (Figure 1 site in et dacia 15%). Liberatie der d. s. REO | In core zamogani to core canonical exercises as appropriate starting PDD 11 | B/C felar per protocol | Add multistaming for all partons Add multistaming for all partons Add multistaming for all partons Add multistaming of partons for Chronic Biolog Disease, multiple data Allance (1 Jing/ days 10 days | Türrstig det Regda BMs |
| Gi | Goal: Begin diuresis to basetine weight (Turnat Goal: Begin diuresis to basetine weight (Turnat II PAS Seallow evaluations) in Registro der union Serufcongelse der de duction Determ for ductarian (A Restructure 1) I ALC 2 to 5.7. Consider Dalesc Cert II and Instale Inst Sim SND, Liberard et dir (J RGC) II and Instale Inst Sim SND, Liberard et dir (J RGC) Rest Stands, Starker, S | No by Enropping | 0/C febry pet protocol | Martain UDP 3.5ml/gb/r q.NM Adf multivitations for all patients Add multivitations for all patients Add Source and Vitation C (21XC1-C4) For Onneic Rolling Datases, results down Vitation C 122mg/ Soy 3.0 days Source Datases, Source Datases, Source Datases Source Datases, S | Titorating Bel Titorating Bel Regular BMs |
| Gi | Goalt Begin diuresis to basetine weight (Turnati Goalt Begin diuresis to basetine weight (Turnati Besta If PAS Sealline evaluation): A Seart/conjects of eta Accidio Seart/conjects of eta Accidio Martinosi audusto/A Nantinosi audusto/A If Act a to 3: Cessión Deletic De Li If and Insta Inst Not. Users der (L. 1900) If and Inst Not. Users der (L. 19 | No or 2009 2000 2000 2000 2000 2000 2000 200 | 5/C febry per protocol. | Mantain UDP 3.5ml/g/br q.sh/H Add multivitamins for all particula. | Titerating dirt Replar 100 |
| Gi | Genel. Begin discretis to baseline weight ("Linear Genel. Begin discretis to baseline weight ("Linear Begin discretis discretis discretis discretis discretis Regulare discretis discretis discretis Beuticenjete discretis discretis Beuticenjete discretis discretis Beuticenjete discretis | In Los 7 January 2011 In Los 7 January 2011 to a school water in the part and part of the part of a school water in the part and balance is deviced a series in the part and balance is deviced a series of the part of the part of the part of the school water is the part of the part of the part is deviced a series of the part of the part of the part deviced a school water is the part of the part of the part of the part of the part of the part of the p | Diff fieling per protocol | Ader multi-taming for all particular Adel multi-taming for all particular Adel multi-taming for all particular for Orwark Ridney Oseans, result data Vitamic C 125 mg/ day at 0 days For Orwark Ridney Oseans, result data Vitamic C 125 mg/ day at 0 days Data Strand Strand Strand Strand Strand QDD: CRC (unless clinically indicated data) | Televoting diel Repubr 805 |
| Gi | Goal Begin diurnis to baseline weight (Transf Goal Begin diurnis to baseline weight (Transf Bead II PASS Sealine exhibition to Startizonita of the Startist Startizonita of the Startist Database of the Startist Startizonita of the Startist II ALS to SJ. Consider Datest Delet II ALS to SJ. Consider Delets Delets II ALS TO SJ. Consider Delets Delets Delets Delets II ALS TO SJ. Consider Delets Delets Delets Delets II ALS TO SJ. Consider Delets Delets Delets Delets Delets II ALS TO SJ. Consider Delets Delets Delets Delets II ALS TO SJ. Consider Delets Delets Delets Delets Delets II ALS TO SJ. Consider Delets Delets Delets Delets II ALS TO SJ. Consider Delets Delets Delets Delets Delets Delets II ALS TO SJ. Consider Delets D | No Dr Janger No Dr Janger et al. 2007 Annuel discretics as appropriate starting PDD 11 | BIC Febry per protocol | Martain UDP 35m/kg/br g1MT Add multivitamin for all particuls Add multivitamin for | Titerating Bet Regular RMs |
| Gi Labs Anticoagulation | Goal: Begin diuresis to basetime weight ("Turnat" Goal: Begin diuresis to basetime weight ("Turnat" Beda II" PAS Seallow evaluations in Registro Seal Control Seart/complete det education Detection Evaluation (A Notestanti and A Martinati and A If Alice 2 to 5-7. Consider Debelsc Control II" If Alice 2 to 5-7. Consider Debelsc Control II" If and instale loss than 50% Liberard edit (a RGU Edit States) (States) (States) (States) Bashy - 1807, Control Debel States) Control Control (III) Debel States) (States) (States) Control Control (III) Debel States) (States) (States) Control (III) Debel States) (States) (States) (States) Debel States) (States) (States) (States) Debel States) (States) (States | No or zamogaria N | SIC Febry per protocol | Martain UDP 3.5ml/gb/r q.WM Adf multivitations for all patients Add multivitations for all patients Add multivitations for all patients Add multivitations for all patients For Onverk Rolling Desaus, results don't Name C 12/2mg/ Boy and Mg Ool: Clic Losins, clinically reducted damp Ool: Clic Losins, clinically reducted damp | Titarating Bel Pagular BMs Regular BMs |
| Gi Gi Labs | Genit Begin diuresis to baseline weight (Transi Genit Begin diuresis to baseline weight (Transi Bedia If PASS Sealline exclusions) in Berline exclusions in Berline State (Sealer Berline Andream State Berline State) (Sealer If Ass) to 53. Consider If association and the Berline State (Sealer If association and State) (Sealer State) (Se | N LOF 2 FUNGATION CONTRACTOR OF A CONTRACTOR O | B(C Foley are protocol | Add multivitation for all particults Add multivitations Add multitations Add multivitations Add multivitations Add mul | Talending dint Reptor 1005 |
| Gi Labs | Genel Begin diurensis to baseline weight ("Lineasi Genel Begin diurensis to baseline weight ("Lineasi Begin diurensis to baseline weight ("Lineasi Begin diurensis to baseline weight ("Lineasi Begin diurensis to baseline diurensis Bestimmer diurensis to baseline diurensis and to baseline diurensis to baseline diurensis to baseline diurensis and to baseline diurensis to baseline diurensis to baseline diurensis and to baseline diurensis to baseline diurensis to baseline diurensis and to baseline diurensis to baseline diurensis to baseline diurensis to baseline diurensis to baseline diurensis and to baseline diurensis to basel | N LOF 2 INTO A THYON AND A THY A THYON AND A THYON AND A THYON AND A THYON AND A THY | B(C Febry per protocol | Martain UDP 35-Migble gLMR | Tearsing dirit Regular BAS |
| Renal Gi Labs Anticogulation Prophylanis | Goal: Begin diuresis to baseline weight ("Transi Goal: Begin diuresis to baseline weight ("Transi Bead II PASS Sealine weight ("Dear Service) and the sealing of the sealing Bead of the sealing of the sealing Bead of the sealing of the sealing II Ast a to 5.7. Consider Dearts (Dear II Ast a to 5.7. Consider Dearts (Dearts II Ast a to 5.7. Consider Dearts (Dearts) (Dearts Dearts), Forther II Ast a to 5.7. Consider Dearts (Dearts) (Dearts Dearts), Forther II Ast a to 5.7. Consider Dearts (Dearts), Forther II Ast a to 5.7. Consider Dearts (Dearts), Forther II Ast a to 5.7. Consider Dearts (Dearts), Forther II Ast a to 5.7. Consider Dearts (Dearts), Forther II Ast a to 5.7. Consider Dearts (Dearts), Forther II Ast a to 5.7. Consider Dearts (Dearts), Forther II Ast a to 5.7. Consider Dearts (Dearts), Forther II Ast a to 5.7. Consider Dearts (Dearts), Forther II Ast a to 5.7. Forther Dearts), Forther II Ast a to 5.7. Forther Dearts), Forther II Ast a to 5.7. Forther Dearts), Fo | NL DY JUNG/PM ALL DY LANG ALL DY LANG ALL AND ALL DY LANG ALL DY | B(C Felary per protection | Martain UDP 35%/gb/r g.NM M | Tierrating diet Regular BAN |
| Renal Gi Labs Anticagulation Prophytianis | Goal Begin diurnis to baseline weight (Turnat Goal Begin diurnis to baseline weight (Turnat Bead II PASS Sealine exclusions) Decision Foreign (Turnat Service) (Turnat Service) (Turnat Market Sealing) If Als: 8 to 5.7. Consider Deleter Deci- II and Instale Inst this Only. Uberst decision (Tara Sealing) If Als: 8 to 5.7. Consider Deleter Deci- II and Instale Inst this Only. Uberst decision (Tara Sealing) If Als: 8 to 5.7. Consider Deleter Decision (Tara Sealing) If Als: 8 to 5.7. Consider Deleter Decision (Tara Sealing) If Als: 8 to 5.7. Consider Deleter Decision (Tara Sealing) If Decision (Tara Sealing) Decision (Tara Sealing) If Decision (Tara Sealing) Only (Tara Sealing) Only (Tara Sealing) Also Noted Degineer: Documents, Sense Sealing, Also Also Noted Decision (Tara Sealing) Interstity (Tara Sealing) Also Noted Degineer: Documents, Sense Sealing, Also Also Noted Degineer: Documents, Sense Sealing, Sealing) | N Los 7 JUNG 2010 (2017) The Survey of Survey | B(C Febry per protect) | Martain UDP 35%/gb/r g.NH Add multivitaning for all patients Add multivitaning for all patients Add multivitaning (j) HCT - OR) For Ohmin Ethiory Datase, result wave relative (j) HCT - OR For Ohmin Ethiory Datase, result wave relative (j) HCT - OR OOC - OR (justice of beaution) indicated data) OOC - OR (justice of beaution) indicated data) | Transang ike Replay BM Replay BM |
| Gi Gi Labs Anticoggiation Prophytanis | Goal: Begin diurnis to basetine weight ("Livers) Goal: Begin diurnis to basetine weight ("Livers) Bedia IF PAS Sealine weighten to Service of the service Service of the se | ni cu z z zmogór – ni cu z z zmogór – st extrahilitoria de alexanica as appropriate starting PDD 11 – st extrahilitoria de alexanica as appropriate starting PDD 11 – st extrahilitoria de alexanica as appropriate starting PDD 11 – st extrahilitoria de alexanica as approximation as a strategia de alexanica de l'alexanica que cuita van forma partes a starting PDD 11 – 10 – 10 – 10 – 10 – 10 – 10 – 10 | Bit Febry per protectal | Add multivitanits for all patients Add multivitanits for all patients Add multivitanits for all patients Add multivitanits of all patients Add multivitanits | Tarrang det Regúr BM |
| Gi Gi Labs Anticoagulation Prophylanis | Genit Begin diurenis tas baseline angle di Transit Genit Begin diurenis tas baseline angle di Transit Begin diurenis tas baseline angle di Transit Begin di 7455 Sentise estuationi di Begin diurenis di 17455 Sentise estuationi Restricterista di senti Begin di Kabara di Sentis di Sentis Fond incade loss den 50%. Unersenti dei 16 estu Periodi incade loss den solutione anterne 52 dei veneti Resente Reginere: Discusanto, Sense, Biscanchi A. Hube Senset dei Sensette anterne 52 dei senti dei senti dei senti dei senti dei senti dei senti Senti dei senti dei senti Senti dei senti dei senti Senti dei senti dei | N LOF 2 FUNCTION N LOF 2 FUNCTION OF A SUBJECT A | B(C Febry per protocol | Martain UDP 35-Migble g.NM | Tiderating diet Repuir MM |
| Renal GI Labs Anticagulation Prophylasis Wound | Genel Begen diversis to baseline weight ("Liversi Genel Begen diversis to baseline weight ("Liversi Begel II PASS Seallow exclusions in Begel Deter sin Begel Deter Sin I Alac a to 3.7 Consider Datert Cont- I of an analysis to the sin Sin Begel Deter Sin | N Los 7 Jungger All Los 7 Jungger de schadur ister scher hann de sense i han ageregnietet skarting 2001) scher hann de sense i han ageregnietet skarting 2001) scher hann de sense i han ageregnietet skarting 2001 i scher hann de sense i hann de sense scher hann de scher hann de sense scher hann de scher hann de scher scher hann de scher hann de sch | B(C Febry per protocol | Martain UDP 354/kg/br q.VM | Terring det Region MA |
| Gi G | Const. Begin diversis to basetime weight ("Transit Goal: Begin diversis to basetime weight ("Transit Begin diversis to basetime weight ("Transit Begin diversis to basetime weight ("Diversit Begin diversity of the second se | Ni Lor Z Jingger All Lor Z Jingger Lo and Lorentia Lo and Lo and Lorentia Lo and Lo and Lorentia Lo and Lorentia Lo and Lorentia Lo and Lo and Lorentia Lo and Lo and Lorentia Lo and Lo and Lo and Lorentia Lo and Lo an | B(C Felary per protocol | Add multicitation for all partnets Add multicitation Add multicitatio | Tierrating diet Regular BMs |
| Gi Gi Labs Anticagulation Prophytanis Wound | Goal Begin diversis to baseline weight (Transi Goal Begin diversis to baseline weight) Brand If PASS Sealine exclusions in Service-relate of exclusion Decision for the sealing Service-relate of exclusion Decision for the sealing Service-relate of exclusion Decision for the sealing of PASS sealing to the sealing of PASS of PASS sealing to the sealing of PASS sealing to the Sealing of PASS sealing to the sealing of PASS of PASS sealing to the sealing of PASS sealing to the Sealing of PASS sealing to the sealing of PASS sealing to the Sealing of PASS sealing to the sealing of PASS sealing to the Sealing of PASS sealing to the sealing to the sealing of PASS of PASS sealing to the sealing to the sealing of PASS sealing to the sealing of PASS sealing to the sealing to the sealing of PASS sealing to the sealing of PASS sealing to the se | NL DY ZINGY/ NL DY ZINGY/ TO STAND AND AND AND AND AND AND AND AND AND | B(C Febry per protect) B(C Febry per protect) B(C Febry per protect) Besume hone articologilation meth Despine Der Of Arter service per protection despine per per per per per per per per per pe | Add multivitation for all partners Add multivitation Add mu | Thereading Best Thereading Best Regular BMs |
| Gi Gi Labs Anticagulation Prophylanik Wound | Genit Begin durins to beachine weight (Transit Genit Begin durins to beachine weight (Transit Beach of PASS Seallow extramol Beaching (Transit Beaching) (Transit Beaching) (Transit Beaching) (Transit Beaching) (Transit Beaching) (Transit of PASS 18:45) (Transit Beaching) (Transit Format Index 1996; University of PASS 1997) (Transit Format Index 1996; University of PASS 1997) (Transit Beaching) (Transit Beachi | N LOF 2 NUMPER A BURGES AS Appropriate Karting PDO 11 A De TANDARE A BURGES AS Approximate Karting PDO 11 A HELLES AND AND A BURGES AS A APPROXIMATION AND APPROXIMATION APPROXIMATION AND APPROXIMATION APPROXIMATION AND APPROXIMATION AND APP | B(C Febry per protocol B(C Febry per per protocol B(C Febry per | Ader multi-tapeling for g gAM Ader multi-tapeling for g gAM Ader multi-tapeling for g gatering Date g data and tape ODC: CCC Lockes climically indicated data) ODC: CCC Lockes climically indicated data) ODC: CCC Lockes climically indicated data) Advances to > 300 ft w/ PT/MU/MA 2200 Advances to > 300 ft w/ PT/MU/MA 2300 | Tierrating diet Repole MA |
| Renal Gi Labs Anticasgulation Prophylania Wound | Genel Begen diversits to baseline weight (Transit Genel Begen diversits to baseline weight (Transit Begel 2014) If PASS Seatiles exclusions in Begel 2014 (Transit Begel 2014) Begel 2014 Begel 2014 Begel 2014 If PASS Seatiles exclusions in Begel 2014 If PASS 2015, Consider 2014 Begel 2014 If PASS 2015, Consider 2014 If PASS 2014, Consider 2014, Consider 2014 If PASS 2014, Consider 2014, Consider 2014 If PASS 2014, Consider 2014, Conside | N LOF 2 INDOP THE GARGE AN ADDRESS AN ADDRESS AND ADDR | B(C Febry per protocol | Add multicitanis (bit 3.5%/gb/r g.)M Add multicitanis for all patients Add multicitanis for all patients Control (Control (Contr | Terrating dirt Repute 505 |
| Renal GI GI Labs Anticoagulation Prophysianis Wound Activity | Const. Begin durines to basetime weight ("Linear Const. Begin durines to basetime weight ("Linear Const." Goal: Begin durines to basetime weight ("Linear Const." For the second s | NL DY ZHUNGON NL DY CANNED AND AND AND AND AND AND AND AND AND AN | B(C Febry per protocol | Add multicitation for all patients Add multicita | Tierring det Repor SM: |
| Gi Labs Anticongulation Prophysianis Wound Activity | Goal: Begin diversis to basetime weight (Transit Goal: Begin diversis to basetime weight (Transit Bead If PASS Sealine evaluation to Service) and the sealine evaluation to Service) and the sealine evaluation to Development of the sealine of the sealine evaluation to Mark 2 to 5.7. Consider Detert Coler, and Instale into the Sealine Colerce Coler, and Instale into the Sealine Colerce Coler, and Instale into the Sealine Colerce Coler, and and the sealine evaluation to the Sealine Colerce Colerce Colerce (Sealine) and the Sealine Colerce Colerce (Sealine) and the Sealine Colerce Colerce (Sealine Sealine) and the Sealine Colerce Colerce (Sealine Sealine) and the Sealine Colerce Colerce (Sealine) and the Sealine Colerce Colerce (Sealine Sealine) and the Sealine Colerce (Sealine Sealine) and the Sealine (Colerce Colerce) and the Sealine (Sealine Colerce) and the Sealine (Sealine Sealine) and the Sealine (Sealine Colerce) and the Sealine (Sealine) and the Sealine) (Sealine) and the Sealine) (Sealine) and the Sealine) (Sealine) (Sealine) and the Sealine) (Sealine) and th | Ni Di S Di Di Dinge di Auricia si appropriate starting PDD 11 | Bit Felary per protecti Bit Stelary per protecti Besume hone articologication medis Decrotion computer (DOC) on the head decromputer (DOC) | Add multivitation for all particles Add multivitation Add multivi | Titerating diet Regular BML Regular BML |
| Gi Gi Labs Anticagulation Prophylania Wound Activity | Genel Begin durins to beachine weight (Thrant Genel Begin durins to beachine weight (Thrant Beach of 7455 Seatilities exclusions) and Beaching of the seatilities and beaching Beaching of the seatilities and beaching Beaching of the seatilities and Beaching of the seatilities and Beachi | N LOF 2 NUMPER A SUBJECT AND A | B(C Febry are protocol | Adet multi-tarries for all patients Adel multi-tarries for all patients For Overvic Ridnerg Oseans, result, data Vitantic C 123 out days Odd C C Lobest Clinear Unset of tarries Odd C Lobest Clinear Overvice Market data) | Tierrating diet Repuir Mit. |
| Renal GI GI Labs Labs Antinagulation Prophylania Wound Activity Patient Education | Genel Regen durensis tas baseline angle (Transi Genel Regen durensis tas baseline angle (Transi Regel Constant) (FASS Seatilities exclusions) Regel Constant angle Regel Regel Regel Constant angle Regel Regel Constant angle Regel Regel Constant angle Regel Regel Constant and Regel Regel Regel Regel Constant and Regel R | NL DY ZHUNGYON NL DY ZHUNGYON SHARE SHARE SHARES AN ADDRESS AN ADDRESS AND ADDRESS ADDRESS AND ADDRESS AND AND A | Bit Felary per protocol | Add multicitanis for all patients Add multicitanis Course Rolling Datase, marked with Vitemic C 123 and days Tor Orwark Rolling Datase, marked with Vitemic C 123 and days OOD: CCC (paties clinearly indicated days) OOD: CCC (| Tearsing det Report Mis Antibulition Goal - 201 ft or / 77/M/W/Yamily 3-MD (Staff/Handy Stats - back with Y7 f Indicated) EMC: Delivery of exponent |
| Renal GI GI Labs Labs Anticoaquistion Prophysionis Activity Patient Education | Genel Begen diversis to baseline weight (Transi Genel Begen diversis to baseline weight (Transi Bead II 7455 Seallow exclusions) Bead of the seal of the seal Bead of the seal of the seal Bead of the seal of the seal Bead of the seal of the seal of the seal of the seal of the seal of the sea of the seal of | N LOF 2 INDUCES IN CALL STATES AND ADDRESS | B(C Febry per protocol Becure house protocol Second house protocol Second house protocol protocol Second house protocol protocol Second house protocol protocol Second house protocol Second hous | Add multivitation for all patients Add multivitation Convert Riving Devase, markly disor Name (1) INCT CON Tor Chronic Riving Devase, markly disor Name (1) INCT CON Add multivitation for all patients Add multivitation for all patients Add multivitation Occ. CAC (patient softward Mag) Occ. CAC (patient | Transforg det Regder SMs |
| Gi Gi Labs Anticogolation Prophylanis Wound Atthity Patient Education | Const. Begin durins to basetime weight (Transf Geal: Begin durins to basetime weight (Transf Best If ASS Sealine exclusions) Best and the sealing of the sealing Best and the sealing of the sealing Best and the sealing of the sealing If ASS as to 5.7 Consider Deters Conf. If ASS as to 5.7 Consider and the SO If Bended Conf. Resource So If Bended Conf. Resource Market If Bended E Remove ASS handles as the SO If Bended E Remove ASS handles & GO O Deters Conf. If Bended E Remove ASS handles are marked If Bended E Remove ASS handles are marked If Bended E Remove ASS handles & GO O Deters Conf. If Bended E Remove ASS handles & GO O Deters Conf. If Bended E Remove ASS handles & GO O Deters Conf. If Bended E Remove ASS handles & GO O Deters Conf. If Determine ASS handles & GO O Deters Conf. If Determine ASS handles & GO O Deters Conf. If Determine ASS handles & GO O Determine ASS handles are marked If Bended E Remove ASS handles & GO O Determine ASS handles are marked If Bended E Remove ASS handles & GO O Determine ASS handles are marked If Bended E Remove ASS handles & GO O Determine ASS handles are marked If Bended E Remove ASS handles & GO O Determine ASS handles are marked If Bended E Remove ASS handles & GO O Determine ASS handles are marked If Bended E Remove ASS handles & GO O Determine | NL DY ZHUNGYON CHARACTER AND CONTROL C | Bit Felay per protecti Bit Stay per protecti Besume hore articopplation mels Deprint into it or articopplation Protection per person with removel Protection per person with removel Protection per person of the item into articopplation Protection per person of the item into articopplation Protection per person of the item into article person of the item into articopplation Protection per person of the item into article item intoarticle item into article item into article item intoarticle item | Add multitation for all patients Add multitations Add multitations The Chronic Rithing Decase, result where Volume C 13/mg/ May 100 fays The Chronic Rithing Decase, result where Volume C 13/mg/ May 100 fays Occ. CBC (prime and May Occ. CBC (| Tierrang det Repúr MA |
| Renal Gi Labs Anticoagulation Prophytianis Wound Activity Patient Education | Genel Begin durensis to baseline angle IT Unant Genel Begin durensis to baseline angle IT Unant Begin durensis to baseline angle IT | N LOF ZINGUT | B(C Febry are protocol B(C Febry are pr | Add multivitation for all patients Add multivitation Add Multiv | |
| Gi Gi Labs Antinagulation Prophylania Wound Activity Patient Education | Genit Begin diuresis to baseline angle IT Union Genit Begin diuresis to baseline angle IT Union Begin diuresis to baseline angle IT Union Begin diuresis to baseline angle IT Union Begins diversity of the State of the State Begins diversity of the State Begins di | N LOF ZINDAPP de Larreis su agregoriate daring 2001] te estaduito: bé autor son bé autor | Bit Freing and protocol Bit Protocol Bit Internet Norma anticologication meth Bit Internet Norma anticologication Protocol aport op toxicity position Protocol aport op toxicity bookinty/policit Set Internet Set Internet Set Internet Set Internet Normality | Add multicipanis for all patients Concerning and an analysis of the second seco | |

Fig 1. A breakdown of the CABG/Valve procedure post op care pathways. The comprehensive evidence-based post-operative care pathways at our institution adopt a multimodal approach and are broken down into organ systems: neurological, cardiac, pulmonary, endocrine, renal, gastrointestinal, labs, anticoagulation, prophylaxis, wound, activity, patient education, and discharge planning.

https://doi.org/10.1371/journal.pone.0277868.g001

of mechanical ventilation, time to urinary catheter removal, days to first ambulation, and incidence of postop UTIs all saw improvements as well (Table 2).

A total of n = 747 patients from the CABG/Valve pre-implementation group and CABG/Valve post-implementation groups were propensity matched, as seen in Table 3. There were

| | ICU | | | licu | | | |
|--------------------|--|---|--|--|--|--|--|
| | | A1 - Immediate Post-Op | A2 - Prep for Transfer to Step-Down | B1 - Maintenance Recovery | B2 - Discharge Planning | | |
| Neuro | De | lirium, Fall Risk Assessments | | | • | | |
| | Wean sedation to ex | tubate in 6 hrs or less for uncomplicated cases | | Sitter Assessments | | | |
| | For II, III & IV- Weah secation | n for neuro exam and excubate as per clinical condition | | | | | |
| | Ma | Post-op Pain Protocol: intain Epidural, SQ pain pump, | | Pain: D/C SQ pain pump | | | |
| | IV (Hydromorphone) If PCEA, initiate Acute Pain | , PO (Oxycodone, Acetaminophen, Gabapentin) Service Consult and follow protocol and neuro checks | (Consider adding Toradol to #1) | 1. Wean IV meds | Pain: 1. Transition to PO meds (add Oxycodone ER in prep for discharge) | | |
| | II & III : Spinal Cord Ischemia Prevention Protocol (Lumbar drain for 48hrs, Clamp for 24hrs, and remove at 94 hrs) IV: (Lumbar drain for 24hrs, Clamp for 24hrs, and remove at 72 hrs) | | | 3. Wean PCA | | | |
| | Maint | ain Hemodynamic Stability Goal: | Maintain Hemodynamic Stability Goal: | Maintain Hemodynamic Stability Goal: | | | |
| | HR 60-100; MAP 80-10 | 0; CVP 5-12; MPAP 10-20; C.I. >2.2; SVR 750-1260 | HR 60-100; MAP 80-100; CVP 5-12 | HR 60-120; SBP 90 to 120 | | | |
| | Wean inotropes & vasotropic drips as indicated per surgical team and CVICU providers | | D/C Art line (early as possible) D/C PA cath | Consider post-op CT D/C Central Line (early as possible) | Consider post-op Echo (only if valve procedure done) | | |
| | | | Arrange summaristances for maxim units summarial | | | | |
| | Temp Pacer Check O4 hrs: C | heck % paced: underlying rhythm, setting & threshold | House appropriate income and remove | | Pacing wires removed | | |
| Cardiac | Consider for all patients: ASA; Atrial Fib protocol (if indicated) | | Consider for all patients: ASA. Beta Blocker (unless contraindicated). statin | | | | |
| | Statir | (POD 1 if no contraindications) | IICU Transfer Criteria: | | | | |
| | | | If 3rd degree heart block present: Min HP 40 or above | | | | |
| | | | BP stable, pt asymptomatic Baring wires present & functioning | | | | |
| | | | If loss of rhythm or HR <40, pt will return to ICU Uumbar drain removed | | | | |
| | <u>.</u> | | Epidural removed by POD#5 | | | | |
| | While Intubated: | Post-extubation: NC 2-6L/min or 40% FM to maintain SpO2 ≥ 92%; If COPD pt: Titrate | | | | | |
| | Follow IREP protocol; extubate pt in 6 hrs or less | O2 to keep ≥ 88% (Wean O2 as able) Monitor Oxygenation | | | | | |
| | II, III, & IV: Extubate per patient's clinical condition | Pulmonary toilet (if indicated) Courb. deep breathe. IS 10x Q1 hr while awake | | | | | |
| | Oral care BID (Chlorhexidine while intubated) | Oral Care BID & PRN Flutter Value (dranella)/PEP therany Od hrs while awake | | | | | |
| | | (RT to instruct x 2; pt to do self-care afterward) | | | | | |
| | STATI | Portable CXR upon arrival to unit | Portable CXR | | 2v CXR with all lines out day before D/C | | |
| Pulmonary | | Maintain chest tube drain | D/C chest tube if < 250ml/day AND per surgical team (need to be OOB x 1 before removal) | | | | |
| | | | Chest Tube Removal: Fentanyl x1 (not indicated for pt >75 yo) | | | | |
| | | | IICU Transfer Criteria - High Flow NC Requirement: • FIO2 60% or less | , | | | |
| | | | Stable, extubated pts Pts w/ chronic resp. conditions that have elevated but stable Q2 requirements | | | | |
| | | | Pts w/ acute resp. decompensation may be appropriate | | | | |
| | | | - 7 | | | | |
| | | | | Assess nome 02 requirements, order as needed | | | |
| | | Glucose labs per protocol | | | • | | |
| Endocrine | Insulin drip per protocol (Wean off | insulin drip POD 1 as clinically indicated to SQ insulin injection) | | | 1 | | |
| | | | | Transition to PO diabetic meds or insulin injection/home meds as appropriate | | | |
| | Dallari | and the CARE (stars for a financial a) | If new Diabetes or A1C ≥ 6.5, Diabetic Management Consult | | | | |
| Renal | Cally W | Maintain UOP ≥1ml/kg/hr | 3 | Maintain UOP 0.5ml/kg/hr q shift | | | |
| | Goal: Begin diuresis to baseline weight | (Transition to PO/home diuretics as appropriate starting POD 1) | D/C Foley per protocol | | 3 | | |
| | Post-ex IF PASS Swallow evaluation: Ice chip | tubation: Bedside Swallow screen s/sips of water 3 hrs post-extubation for uncomplicated I & IV | | | | | |
| | For II & III - Assess patie Regular D | nt and consult with surgeon before any PO Intake iet unless therapeutic diet indicated | | | | | |
| | Start/complete diet ed | ucation if indicated, especially with family present | | Add multivitamins for all patients | Tolerating diet | | |
| G | Nutrition | al supplement, vitamins as needed | | Add Slow-Fe w/ Vitamin C (if HCT <30) | Regular BMs | | |
| | If Alic > to 5.7: Consider Diabe | Exceptions to Regular Diet: tic Diet. If heart failure nations: Consider Low Sodium Diet- | | | | | |
| | If oral intake less than 50%: Liberate diet | (Le.REGULAR Diet) and add nutritional supplements (Ensure, Glucerna) | | | | | |
| | STAT X1 from OR: K+ q4 hours x24 hou | BMP, CBC, Mg, ICa, Phos, Lactate, ABG, VBG irs, then PRN per potassium repletion protocol | | Daily: BMP and Mg | | | |
| Labs | Daily - BMP, | For II & III - LFTs CBC, Mg, Phos, ABG (if appropriate), ICa | | QOD: CBC (unless clinically indicated daily) | | | |
| | Electrolyte Re | placement Goal (Replacement Protocol) | | | | | |
| | | See Appendix | | | | | |
| Anticognitation | Immed | iate from OR: Consider coag panel | Resume home anticoagulation meds For II, III & IV, resume home anticoagulants only after epidural and lumbar drains | r <u></u> | | | |
| Antorongunation | If bleeding (Chest tub) | aily lab: INR (if on Cournadin) | are removed [Exception: Direct Oral Anticopaulation (DOAC) meds to be initiated | | | | |
| | For II, III & IV: if there is an epidura | al, tollow Anticoagulation Guideline for Neuraxial Procedures | after pacing wire removal] | | | | |
| | Consider sta | arting SQ, Heparin POD 1 (per protocol) | | | | | |
| Prophylaxis | Bowel Regimen: Docusate, Senna, Bisaco | Bowel Regime: Docust, Stone, Blacchyl, Polythylanej april, margetam hydradol (last chice lassitve, consider moving for rend pattertan) | | | | | |
| | Stress ulcer p | prophylaxis (per SHC Clinical Guidelines) | | | | | |
| | | Change of Change and Annual Provi | | | | | |
| | • If Standard: Remove 48 hrs after surgery; o | ontinue monitoring for drainage. If drainage, change Q24 hrs & PRN w/ | | | | | |
| Wound | • If Vac Dsg: sta | ory, sterile, gauze. ay on up to 7 days or until day of discharge | | | | | |
| | If Dsg with Silver (A | g): stay on up to 7 days or until day of discharge | | | | | |
| | Bedrest while in | tubated and on lumbar drain; turn Q2 hrs | | Ambulation Coal: > 50 ft w/ DT/DM/MA 2VP | | | |
| | Hitempt dange II, III, & IV | Dangle when lumbar drain is clamped | | Advance to > 100 ft w/ PT/RN/NA/Family 3-4XD | Ambulation Goal: > 200 ft w/ PT/RN/NA/Family 3-4XD | | |
| | Bedrest fo HOB 30 degr | ees or less for cases with lumbar drain; | | Out of bed 2 to 3x daily/all meals | (Staff/Family: Stairs - check with PT if indicated) | | |
| Activity | Out of bed 1 | to 3x daily with NURSING or REHAB staff | | Patient activity checklist on whiteboard | DME: Delivery of equipment | | |
| | DME: Bariatric bed/equipmen | Ambulate as tolerated ti if morbidly obese (8MI 40+); Therapy bed every ICU pt | | DME: PT/OT eval ASAP after transfer (order in EPIC as soon as identified) | | | |
| | Sternal Precaution/t | ransfer/mobility teaching with PT/OT/NURSING | | | · · · · · · · · · · · · · · · · · · · | | |
| | Intros Steroal (Those | duction of staff to family (POD 0) acotomy precautions/Activity teaching | | | | | |
| | Cough, c | Seep breathe, incentive spirometer Pain management | | | | | |
| Patient Education | | | Provide post-op teaching booklet/packet | | Cardiac Rehab teaching completed | | |
| | | | Set family expectation of EDD Intro to Cardiac Rehab except for TEVAR | Bedside RN to write EDD on white board after rounds | TEVAR teaching by RN Coordinator Coumadin teaching by Pharmacy (if indicated) | | |
| | Ca MSW I | se Management Eval (POD 1) Eval (POD 1 if indicated) and PRN | | | • | | |
| | more i | | | | NOTIFY PHARMACY AT 7AM TO ALLOW TIME TO RETURN PT'S HOME MEDS WHICH | | |
| Discharge Planning | | | SNF discussion/info provided for pt >75 yo or upon PT/OT evaluation | Start SNF referral ASAP (if indicated); Determine transport to SNF (Family vs. BLS) | WERE NOT USED DURING ADMISSION If SNF: SNF arranged/Transportation arranged w/ family (home or SNF) | | |
| | | | | | F/U appointments made/Outpatient referrals made (if indicated) (i.e. Urology, ENT) | | |
| | | | | | | | |

Fig 2. A breakdown of Aortic procedures post op care pathways. The comprehensive evidence-based post-operative care pathways at our institution adopt a multimodal approach and are broken down into organ systems: neurological, cardiac, pulmonary, endocrine, renal, gastrointestinal, labs, anticoagulation, prophylaxis, wound, activity, patient education, and discharge planning.

https://doi.org/10.1371/journal.pone.0277868.g002

Table 1. Pre-match CABG/Valve group.

| Patient Characteristic | Pre-Implementation | Post-Implementation | P-Value |
|--|---------------------|---------------------|---------|
| | 1131 | 756 | |
| Age at Procedure | 67.5 (59.6, 75.0) | 68.6 (60.9, 74.5) | 0.27 |
| Female Gender, n(%) | 259 (22.9%) | 159 (21.0%) | 0.34 |
| Race, n(%) | | | 0.88 |
| White | 646 (57.1%) | 411 (54.4%) | |
| Black | 29 (2.6%) | 18 (2.4%) | |
| Native American | 5 (0.4%) | 4 (0.5%) | |
| Pacific Islander | 20 (1.8%) | 14 (1.9%) | |
| Asian | 220 (19.5%) | 154 (20.4%) | |
| Other/Unknown | 211 (18.7%) | 155 (20.5%) | |
| Pre-Op COPD, n (%) | 110 (9.7%) | 50 (6.6%) | 0.017 |
| Pre-Op Dialysis, n(%) | 50 (4.4%) | 52 (6.9%) | 0.021 |
| Pre-Op Diabetes, n(%) | 474 (41.9%) | 405 (53.6%) | <0.001 |
| History of Atrial Fibrillation, n(%) | 120 (10.6%) | 101 (13.4%) | 0.069 |
| Pre-Op HTN, n(%) | 904 (79.9%) | 598 (79.1%) | 0.66 |
| History of Ventricular Tachycardia, n(%) | 19 (1.7%) | 21 (2.8%) | 0.10 |
| NYHA, n(%) | | | <0.001 |
| 0 | 507 (44.8%) | 277 (36.6%) | |
| 1 | 547 (48.4%) | 464 (61.4%) | |
| 2 | 49 (4.3%) | 6 (0.8%) | |
| 3 | 22 (1.9%) | 7 (0.9%) | |
| 4 | 6 (0.5%) | 2 (0.3%) | |
| Post-Op LOS day (IQR) | 7.0 (5.2, 11.2) | 6.1 (4.9, 8.8) | <0.001 |
| ICU LOS hours (IQR) | 70.2 (42.8, 118.0) | 56.4 (40.6, 99.2) | 0.002 |
| Post-Op Vent hours (IQR) | 286.1 (31.9, 844.5) | 23.9 (9.6, 127.4) | <0.001 |
| Days to Urinary Catheter Removal (IQR) | 2.6 (1.8, 4.0) | 1.9 (1.2, 3.0) | <0.001 |
| Days to First Ambulation (IQR) | 2.4 (1.6, 3.5) | 1.6 (1.5, 2.6) | <0.001 |
| Days to First Bowel Movement (IQR) | 3.0 (2.0, 4.0) | 2.0 (0.0, 3.0) | <0.001 |
| Post-Op Ventilator Associated Pneumonia | 58 (5.1%) | 17 (2.2%) | 0.002 |
| 30-day mortality | 43 (3.8%) | 26 (3.4%) | 0.68 |
| Post-Op Urinary Tract Infection | 99 (8.8%) | 27 (3.6%) | <0.001 |
| Post-Op Wound Infection | 7 (0.6%) | 1 (0.1%) | 0.11 |
| Euroscore (IQR) | 2.0 (1.0, 3.9) | 1.7 (1.0, 3.5) | 0.084 |

Pre-match CABG/Valve Group. Values are presented as n (%) or median (interquartile range).

https://doi.org/10.1371/journal.pone.0277868.t001

no significant differences between the demographic characteristics, comorbidities, or NYHA class of either group after matching. Between the two matched groups, there was a significant difference in the post-op length of stay, with the median LOS for the pre-implementation group being 7.0 days and the post-implementation group averaging 6.0 days (p<0.001). The median ICU LOS decreased from 69.9 hours to 54.0 hours in the post-implementation group (p<0.001). Patients in the post-implementation group also experienced a decreased incidence of postop UTIs (8.3% to 3.6%, p<0.001), faster return to ambulation after surgery (2.3 days vs 1.6 days, p = 0.001), and a shorter time to first bowel movement (3.0 days vs 2.0 days, p<0.001). The median duration of mechanical ventilation decreased from 272.4 hours to 23.5 hours (p<0.001). There was no significant decrease in 30-day mortality (4% to 3.3%, p = 0.47),

Table 2. Pre-match open aortic group.

| Patient Characteristic | Pre-Implementation | Post-Implementation | P-Value |
|--|--------------------|---------------------|---------|
| | 601 | 833 | |
| Age at Procedure | 61.6 (50.3, 71.8) | 62.1 (50.8, 70.7) | 0.68 |
| Female Gender, n(%) | 180 (30%) | 218 (26.2%) | 0.11 |
| Race, n(%) | | | 0.71 |
| White | 379 (63.1%) | 524 (62.9%) | |
| Black | 41 (6.8%) | 48 (5.8%) | |
| Native American | 3 (0.5%) | 1 (0.1%) | |
| Pacific Islander | 7 (1.2%) | 10 (1.2%) | |
| Asian | 70 (11.6%) | 108 (13.0%) | |
| Other/Unknown | 101 (16.8%) | 142 (17.0%) | |
| Pre-Op COPD, n (%) | 40 (6.7%) | 38 (4.6%) | 0.085 |
| Pre-Op Dialysis, n(%) | 7 (1.2%) | 16 (1.9%) | 0.26 |
| Pre-Op Diabetes, n(%) | 59 (9.8%) | 118 (14.2%) | 0.014 |
| History of Atrial Fibrillation, n(%) | 74 (12.3%) | 86 (10.3%) | 0.24 |
| Pre-Op HTN, n(%) | 354 (58.9%) | 489 (58.7%) | 0.94 |
| History of Ventricular Tachycardia, n(%) | 8 (1.3%) | 9 (1.1%) | 0.67 |
| NYHA, n(%) | | | 0.003 |
| 0 | 416 (69.2%) | 495 (59.4%) | |
| 1 | 177 (29.5%) | 324 (38.9%) | |
| 2 | 3 (0.5%) | 5 (0.6%) | |
| 3 | 4 (0.7%) | 9 (1.1%) | |
| 4 | 1 (0.2%) | 0 (0.0%) | |
| Post-Op LOS day (IQR) | 8.4 (5.9, 13.8) | 7.8 (5.8, 12.5) | 0.041 |
| ICU LOS hours (IQR) | 91.8 (50.7, 139.0) | 68.6 (45.0, 118.9) | <0.001 |
| Post-Op Vent hours (IQR) | 78.9 (16.6, 750.1) | 40.3 (13.2, 249.4) | <0.001 |
| Days to Urinary Catheter Removal (IQR) | 2.9 (1.8, 4.8) | 2.3 (1.6, 3.7) | <0.001 |
| Days to First Ambulation (IQR) | 2.5 (1.6, 3.6) | 1.7 (1.5, 3.2) | <0.001 |
| Days to First Bowel Movement (IQR) | 3.0 (1.0, 4.0) | 3.0 (1.0, 3.0) | <0.001 |
| Post-Op Ventilator Associated Pneumonia | 51 (8.5%) | 51 (6.1%) | 0.086 |
| 30-day mortality | 43 (7.2%) | 26 (3.1%) | <0.001 |
| Post-Op Urinary Tract Infection | 40 (6.7%) | 26 (3.1%) | 0.002 |
| Post-Op Wound Infection | 8 (1.3%) | 9 (1.1%) | 0.67 |
| Euroscore (IQR) | 3.1 (1.7, 5.5) | 2.9 (1.6, 5.9) | 0.76 |

Pre-match Open Aortic Group. Values are presented as n (%) or median (interquartile range).

https://doi.org/10.1371/journal.pone.0277868.t002

time to urinary catheter removal (2.4 days to 2.3 days, p = 0.82), and post-op wound infections (0.4% to 0.1%, p = 0.32) (Table 3).

586 patients were matched in the Aortic pre- and post- implementation cohorts (Table 4). Compared to the pre-implementation group, there was a decrease in 30-day mortality from 7% to 3.5% (p = 0.012) in the post-implementation group. In contrast to the CABG/Valve cohort, the decrease in post-op LOS did not reach the level of significance (8.5 days vs 7.9 days, p = 0.32) in the post-implementation group, but ICU LOS decreased from 91.7 hours to 69.6 hours (p<0.001). In the post-implementation group, there was also a decrease in the duration of mechanical ventilation decreased from 69.7 hours to 35.2 hours, (p<0.001) and a faster return to ambulation after surgery (2.5 days vs 1.8 days, p = 0.001). Patients in the post-implementation group also experienced a decreased incidence of postop UTIs (6.3% to 3.9%,

| Patient Characteristic | Pre-Implementation | Post-Implementation | P-Value |
|--|---------------------|---------------------|---------|
| | 747 | 747 | |
| Age at Procedure | 67.3 (59.4, 74.9) | 68.7 (60.9, 74.6) | 0.16 |
| Female Gender, n(%) | 165 (22.1%) | 157 (21.0%) | 0.61 |
| Race, n(%) | | | 0.98 |
| White | 409 (54.8%) | 410 (54.9%) | |
| Black | 21 (2.8%) | 17 (2.3%) | |
| Native American | 4 (0.5%) | 4 (0.5%) | |
| Pacific Islander | 15 (2.0%) | 13 (1.7%) | |
| Asian | 145 (19.4%) | 152 (20.3%) | |
| Other/Unknown | 153 (20.5%) | 151 (20.2%) | |
| Pre-Op COPD, n (%) | 47 (6.3%) | 50 (6.7%) | 0.75 |
| Pre-Op Dialysis, n(%) | 43 (5.8%) | 43 (5.8%) | 1.00 |
| Pre-Op Diabetes, n(%) | 394 (52.7%) | 396 (53.0%) | 0.92 |
| History of Atrial Fibrillation, n(%) | 83 (11.1%) | 98 (13.1%) | 0.23 |
| Pre-Op HTN, n(%) | 606 (81.1%) | 589 (78.8%) | 0.27 |
| History of Ventricular Tachycardia, n(%) | 11 (1.5%) | 20 (2.7%) | 0.10 |
| NYHA, n(%) | | | 1.00 |
| 0 | 276 (36.9%) | 275 (36.8%) | |
| 1 | 456 (61.0%) | 457 (61.2%) | |
| 2 | 6 (0.8%) | 6 (0.8%) | |
| 3 | 7 (0.9%) | 7 (0.9%) | |
| 4 | 2 (0.3%) | 2 (0.3%) | |
| Post-Op LOS day (IQR) | 7.0 (5.2, 11.0) | 6.0 (4.9, 8.8) | <0.001 |
| ICU LOS hours (IQR) | 69.9 (40.8, 116.7) | 54.0 (40.4, 97.0) | 0.010 |
| Post-Op Vent hours (IQR) | 272.4 (22.2, 839.9) | 23.5 (9.6, 122.6) | <0.001 |
| Days to Urinary Catheter Removal (IQR) | 2.4 (1.6, 3.9) | 2.3 (1.6, 3.9) | 0.82 |
| Days to First Ambulation (IQR) | 2.3 (1.6, 3.5) | 1.6 (1.5, 2.6) | <0.001 |
| Days to First Bowel Movement (IQR) | 3.0 (2.0, 4.0) | 2.0 (0.0, 3.0) | <0.001 |
| Post-Op Ventilator Associated Pneumonia | 37 (5.0%) | 16 (2.1%) | 0.003 |
| 30-day mortality | 30 (4%) | 25 (3.3%) | 0.47 |
| Post-Op Urinary Tract Infection | 62 (8.3%) | 27 (3.6%) | <0.001 |
| Post-Op Wound Infection | 3 (0.4%) | 1 (0.1%) | 0.32 |
| Euroscore (IQR) | 2.0 (1.0, 3.8) | 1.6 (0.9, 3.4) | 0.075 |

Table 3. Propensity-score matched CABG/Valve group.

Propensity-Score Matched CABG/Valve Group. Values are presented as n (%) or median (interquartile range).

https://doi.org/10.1371/journal.pone.0277868.t003

p = 0.064) and post-op VAP (8.5% to 6.1%, p = 0.12) although neither reached the level of significance. There was no decrease in time to urinary catheter removal (2.3 days to 2.4 days, p = 0.08) and post-op wound infections (1.4% to 1.2%, p = 0.79) (Table 4). Mean post-op day 3 pain scores in the matched post-implementation CABG/Valve cohort was 1.0 vs 1.2 (P = 0.008) when compared to the pre-ERAS cohort. In the Aortic group mean post-op day 3 pain scores were 0.8 vs 1.2 (p < 0.001), respectively.

Discussion

The ERAS concept was first introduced by academic surgeons aiming to improve perioperative care for patients receiving colorectal care [7]; it is now practiced in almost all surgical fields. ERAS pathways help optimize patient care and are often used to describe a multimodal

| Patient Characteristic | Pre-Implementation | Post-Implementation | P-Value |
|--|--------------------|---------------------|---------|
| | 586 | 586 | |
| Age at Procedure | 61.5 (50.1, 71.7) | 61.8 (50.6, 70.8) | 0.71 |
| Female Gender, n(%) | 173 (29.5%) | 173 (29.5%) | 1.00 |
| Race, n(%) | | | 0.85 |
| White | 370 (63.1%) | 356 (60.8%) | |
| Black | 38 (6.5%) | 42 (7.2%) | |
| Native American | 3 (0.5%) | 1 (0.2%) | |
| Pacific Islander | 7 (1.2%) | 9 (1.5%) | |
| Asian | 69 (11.8%) | 73 (12.5%) | |
| Other/Unknown | 99 (16.9%) | 105 (17.9%) | |
| Pre-Op COPD, n (%) | 27 (4.6%) | 27 (4.6%) | 1.00 |
| Pre-Op Dialysis, n(%) | 7 (1.2%) | 11 (1.9%) | 0.34 |
| Pre-Op Diabetes, n(%) | 58 (9.9%) | 73 (12.5%) | 0.16 |
| History of Atrial Fibrillation, n(%) | 71 (12.1%) | 59 (10.1%) | 0.26 |
| Pre-Op HTN, n(%) | 344 (58.7%) | 327 (55.8%) | 0.32 |
| History of Ventricular Tachycardia, n(%) | 8 (1.4%) | 7 (1.2%) | 0.79 |
| NYHA, n(%) | | | 0.076 |
| 0 | 403 (68.8%) | 423 (72.2%) | |
| 1 | 176 (30.0%) | 154 (26.3%) | |
| 2 | 3 (0.5%) | 0 (0.0%) | |
| 3 | 4 (0.7%) | 9 (1.5%) | |
| 4 | 0 (0.0%) | 0 (0.0%) | |
| Post-Op LOS day (IQR) | 8.5 (5.9, 13.8) | 7.9 (5.9, 13.0) | 0.32 |
| ICU LOS hours (IQR) | 91.7 (50.6, 139.4) | 69.6 (45.7, 127.9) | <0.001 |
| Post-Op Vent hours (IQR) | 79.3 (16.5, 740.3) | 46.3 (13.2, 308.6) | 0.003 |
| Days to Urinary Catheter Removal (IQR) | 2.3 (1.5, 3.8) | 2.4 (1.6, 4.3) | 0.080 |
| Days to First Ambulation (IQR) | 2.5 (1.6, 3.6) | 1.8 (1.5, 3.4) | <0.001 |
| Days to First Bowel Movement (IQR) | 3.0 (1.0, 4.0) | 3.0 (1.0, 3.0) | 0.003 |
| Post-Op Ventilator Associated Pneumonia | 50 (8.5%) | 36 (6.1%) | 0.12 |
| 30-day mortality | 41 (7%) | 21 (3.6%) | 0.012 |
| Post-Op Urinary Tract Infection | 37 (6.3%) | 23 (3.9%) | 0.064 |
| Post-Op Wound Infection | 8 (1.4%) | 7 (1.2%) | 0.79 |
| Euroscore (IQR) | 3.0 (1.6, 5.3) | 3.2 (1.7, 5.7) | 0.63 |

Table 4. Propensity-score matched open aortic group.

Propensity-Score Matched Open Aortic Group. Values are presented as n (%) or median (interquartile range).

https://doi.org/10.1371/journal.pone.0277868.t004

perioperative care program [8]. They standardize hospital workflows and ensure a standard of consistency and quality [9–11]. Studies have shown that ERAS protocols have been associated with a reduction in complication rates and LOS by up to 50% in general surgery patient populations [12].

Successful cardiac surgery requires cohesive integration of a sizeable team's workflows in all phases of care. Post-operatively, it is imperative that the surgical team works in concert with the clinical staff in the ICU and in step-down units to enhance patient care. Standardized, evidence-based protocols that address, glycemic control, opioid-sparing pain management, post-operative nausea and vomiting (PONV), timely lines and catheter removal, extubation strategies, and early enteral feeding reduce surgical morbidity and have been shown to result in a reduced total hospital LOS, ICU LOS [1, 4].

At our institution, we have created separate evidenced-based care pathways for post-op CABG/Valve patients and patients who have undergone open aortic surgery. We excluded all patients who underwent endovascular procedures (i.e., TAVR, TEVAR), or required ECMO or an Intra-Aortic Balloon Pump. The post-op care pathways are broken down into 13 components: Neurological, Cardiac, Pulmonary, Endocrine, Renal, Gastrointestinal, Labs, Anticoagulation, Prophylaxis, Wound, Activity, Patient Education, and Discharge planning. The care pathways focus on earlier extubation when appropriate, pain control, delirium management, expedient attempts at ambulation, early swallow screen after extubation, enteral nutrition, aggressive bowel regimen, and DVT prophylaxis. Prior to the ERAS order set, although there was a focus to reduce opioid utilization there was no standardization in the multi-modal pain control regimen, stool softener regimen, ambulation or extubation protocol.

Our study showed significant improvement in both postoperative LOS and total ICU LOS in patients undergoing CABG/Valve and open Aortic procedures post protocol implementation. Significant improvements were also made in duration of mechanical ventilation, time to foley catheter removal, time to first ambulation, and time to first bowel movement for both groups as well. These findings are in line with previous studies [13, 14].

Past literature has shown an association of early extubation with decreased pulmonary complications and decreased LOS [2, 5]. Our results echoed these findings. The early extubation protocol at our institution facilitates tracheal extubation within 6 hours of surgery if the patient meets the criteria. Patients in the post-implementation cohort had a decreased duration of mechanical ventilation and overall fewer occurrences of ventilator associated pneumonia. Early extubation within 6 hours of surgery has been shown to be safe and is a class IIa, level B recommendation [2].

Prolonged indwelling urinary catheters are associated with increased risk of UTIs and surgical morbidity [15, 16]. Our care pathway utilizes a foley catheter removal protocol that facilitates a timely removal of the urinary catheter. Although our study did not show a decrease in time to catheter removal there was a decrease in the incidence of UTIs in both the Aortic and CABG/Valve groups.

Early ambulation decreases the incidence of atelectasis and improves patient recovery [17]. Once extubated our protocol calls for patients to be dangled on the edge of their bed, the same day, and assessed by the bedside nurse and a physical therapist for mobility. Patients are provided strength and mobility exercises and gradually increase walking distance in subsequent days. Our post-implementation CABG/Valve and Aortic cohorts demonstrated a shorter time to first ambulation.

An aggressive bowel regimen and timely resumption of enteral nutrition has been shown to be associated with a faster return of bowel function and healing [18, 19]. Once extubated patients at our center are given a bedside swallow assessment by a nurse or speech and linguistic therapist and started on a bowel regimen. The patient is progressed to an oral diet if there are no concerns for aspiration during the assessment. Patients in both post-implementation groups had shorter times to return of bowel function.

It is important to recognize the synergistic impact one aspect of the care pathway may have on another. An early extubation protocol allows for a probable reduction in the total dose of opioids and is associated with a decreased incidence of ventilator associated pneumonia. Early extubation has a direct impact on the timing of patient ambulation and allows for consideration of timely urinary catheter removal. Furthermore, return of bowel function has been linked to ambulation and decreased usage of opioids. Fortunately, the COVID pandemic did not result in any staffing constraints within our department. We have not had to change any of our intra-op or ICU post op protocols as a result of the pandemic. Pre-operatively we have added COVID testing to be in compliance with California state mandates.

Conclusion

The implementation of the ERAS protocol at Stanford Hospital is associated with improvements in patient outcome and ensures patients will receive multi-modal care. Significant improvements in morbidity quality metrics can be expected to improve bed utilization and cost-revenue ratios.

Further investigation is warranted regarding the cost analysis of these post-op care pathways.

Author Contributions

Conceptualization: Tomi Obafemi, Jack Boyd.

Data curation: Tomi Obafemi, Purnima Krishna.

Formal analysis: Tomi Obafemi, Simar Bajaj.

Investigation: Tomi Obafemi, Purnima Krishna, Jack Boyd.

Writing - original draft: Tomi Obafemi, Danielle Mullis, Simar Bajaj.

Writing - review & editing: Tomi Obafemi, Jack Boyd.

References

- Ljungqvist O, Scott M, Fearon KC. Enhanced recovery after surgery: a review. JAMA Surg. 2017; 152 (3):292–298. https://doi.org/10.1001/jamasurg.2016.4952 PMID: 28097305
- Engelman DT, Ben Ali W, Williams JB, et al. Guidelines for Perioperative Care in Cardiac Surgery: Enhanced Recovery After Surgery Society Recommendations. JAMA Surg. 2019; 154(8):755–766. https://doi.org/10.1001/jamasurg.2019.1153 PMID: 31054241
- Densen P. Challenges and opportunities facing medical education. *Trans Am Clin Climatol Assoc.* 2011; 122:48–58. PMID: 21686208
- Fleming IO, Garratt C, Guha R, et al. Aggregation of Marginal Gains in Cardiac Surgery: Feasibility of a Perioperative Care Bundle for Enhanced Recovery in Cardiac Surgical Patients. *J Cardiothorac Vasc Anesth.* 2016; 30(3):665–670. https://doi.org/10.1053/j.jvca.2016.01.017 PMID: 27321791
- He S, Chen B, Li W, et al. Ventilator-associated pneumonia after cardiac surgery: a meta-analysis and systematic review. J Thorac Cardiovasc Surg. 2014; 148(6):3148–55.e555. https://doi.org/10.1016/j. jtcvs.2014.07.107 PMID: 25240522
- Baxter R, Squiers J, Conner W, et al. Enhanced Recovery After Surgery: A Narrative Review of its Application in Cardiac Surgery. Ann Thorac Surg. 2020; 109(6):1937–1944. https://doi.org/10.1016/j. athoracsur.2019.11.008 PMID: 31877291
- Gustafsson UO, Scott MJ, Hubner M, et al. Guidelines for Perioperative Care in Elective Colorectal Surgery: Enhanced Recovery After Surgery (ERAS®) Society Recommendations: 2018. World J Surg. 2019; 43(3):659–695. https://doi.org/10.1007/s00268-018-4844-y PMID: 30426190
- 11. Ljungqvist O. ERAS—enhanced recovery after surgery: moving evidence-based perioperative care to practice. JPEN J Parenter Enteral Nutr. 2014; 38(5):559–566. https://doi.org/10.1177/ 0148607114523451 PMID: 24567343
- Thiele RH, Rea KM, Turrentine FE, et al. Standardization of care: impact of an enhanced recovery protocol on length of stay, complications, and direct costs after colorectal surgery. *J Am Coll Surg.* 2015; 220(4):430–443. https://doi.org/10.1016/j.jamcollsurg.2014.12.042 PMID: 25797725
- Low DE, Allum W, De Manzoni G, et al. Guidelines for Perioperative Care in Esophagectomy: Enhanced Recovery After Surgery (ERAS®) Society Recommendations. *World J Surg.* 2019; 43 (2):299–330. https://doi.org/10.1007/s00268-018-4786-4 PMID: 30276441
- Bakaeen FG, Svensson LG, Mitchell JD, Keshavjee S, Patterson GA, Weisel RD. The American Association for Thoracic Surgery/Society of Thoracic Surgeons position statement on developing clinical practice documents. *J Thorac Cardiovasc Surg.* 2017; 153(4):999–1005. https://doi.org/10.1016/j.jtcvs. 2017.01.003 PMID: 28359374
- Brown JK, Singh K, Dumitru R, Chan E, Kim MP. The Benefits of Enhanced Recovery After Surgery Programs and Their Application in Cardiothoracic Surgery. *Methodist Debakey Cardiovasc J*. 2018; 14 (2):77–88. https://doi.org/10.14797/mdcj-14-2-77 PMID: 29977464

- Williams JB, McConnell G, Allender JE, et al. One-year results from the first US-based enhanced recovery after cardiac surgery (ERAS Cardiac) program. *J Thorac Cardiovasc Surg.* 2019; 157(5):1881–1888. https://doi.org/10.1016/j.jtcvs.2018.10.164 PMID: 30665758
- Li M, Zhang J, Gan TJ, et al. Enhanced recovery after surgery pathway for patients undergoing cardiac surgery: a randomized clinical trial. *Eur J Cardiothorac Surg.* 2018; 54(3):491–497. https://doi.org/10. 1093/ejcts/ezy100 PMID: 29514224
- Andrioli ER, Furtado GH, Medeiros EA. Catheter-associated urinary tract infection after cardiovascular surgery: Impact of a multifaceted intervention. Am J Infect Control. 2016; 44(3):289–293. <u>https://doi.org/10.1016/j.ajic.2015.09.030</u> PMID: 26585248
- Tyson AF, Campbell EF, Spangler LR, et al. Implementation of a Nurse-Driven Protocol for Catheter Removal to Decrease Catheter-Associated Urinary Tract Infection Rate in a Surgical Trauma ICU. J Intensive Care Med. 2020; 35(8):738–744. https://doi.org/10.1177/0885066618781304 PMID: 29886788
- Daskivich TJ, Houman J, Lopez M, et al. Association of Wearable Activity Monitors With Assessment of Daily Ambulation and Length of Stay Among Patients Undergoing Major Surgery. JAMA Netw Open. 2019; 2(2):e187673. Published 2019 Feb 1. https://doi.org/10.1001/jamanetworkopen.2018.7673 PMID: 30707226
- Warren J, Bhalla V, Cresci G. Postoperative diet advancement: surgical dogma vs evidence-based medicine. Nutr Clin Pract. 2011; 26(2):115–125. https://doi.org/10.1177/0884533611400231 PMID: 21447763
- Singer P, Blaser AR, Berger MM, et al. ESPEN guideline on clinical nutrition in the intensive care unit. Clin Nutr. 2019; 38(1):48–79. https://doi.org/10.1016/j.clnu.2018.08.037 PMID: 30348463