Application of a Multidisciplinary Enhanced Recovery After Surgery Pathway to Improve Patient Outcomes After Transcatheter Aortic Valve Implantation

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Enhanced recovery after surgery (ERAS) protocols have proven effective in a variety of surgical specialties. Published reports on these pathways within cardiac surgery and interventional cardiology are limited. Invasive aortic valve replacement procedures are increasingly being performed by hybrid groups of interventional cardiologists and surgeons through transcatheter aortic valve implantation (TAVI). The TAVI patient population is at a higher surgical risk compared with those undergoing surgical aortic valve replacement since they are older, frailer, and have significant co-morbidities which result in an increased risk of perioperative complications. ERAS protocols have the potential to help these patients undergoing TAVI procedures. In conclusion, we propose a TAVI ERAS protocol with a call-to-action for other centers to implement an ERAS protocol to improve hospital and cardiac outcomes. **(Am J Cardiol 2016;118:418−423)**

Enhanced recovery after surgery (ERAS) clinical pathways have been shown to decrease complications in various surgical fields but have not been tested in the population undergoing percutaneous valve therapies. ERAS pathways serve as a framework for comprehensive multidisciplinary perioperative care that include evidence-based, best practice recommendations for preoperative, intraoperative, and postoperative management. Led by a dedicated multidisciplinary team of cardiologists, surgeons, anesthesiologists, advanced practice providers, and nurses, our institution designed and implemented an ERAS clinical pathway for patients undergoing transcatheter aortic valve implantation (TAVI). Herein, we describe our ERAS clinical pathway, describe our beliefs and goals for the program, share a framework that can be adopted at other institutions, and encourage others to join in implementing similar ERAS pathways for TAVI that provide these complex patients the highest likelihood of a successful recovery.

The goals of a traditional ERAS clinical pathway are (1) to accelerate patient recovery and (2) maintain normal homeostasis through application of evidence-based, best practice guidelines. The core components of ERAS clinical pathways include preoperative patient optimization and education, multimodal opioid-sparing analgesia, standardized intraoperative anesthetic management, and postoperative systems of care to limit immobility and nosocomial infection risk.[1,2] ERAS clinical pathways have been developed for a variety of different surgical specialties.[3−5] These pathways have demonstrated a variety of improved clinical outcomes including decreased hospital length of stay,[3,4,6] improved pain management,[3] and decreased surgical site[7] and urinary tract infections.[6]

Although there has been significant research on ERAS clinical pathways for traditional surgical procedures, research is lacking on how the principles of ERAS could be applied to cardiac surgery and hybrid cardiovascular procedures, including TAVI. This is particularly important as the population of patients presenting for TAVI are often older, frailer, with multiple co-morbidities, and are at an elevated risk for perioperative complications.[8]

The aortic stenosis patient population: Severe calcific aortic stenosis is a common valvular disease with a prevalence of 3.4% in the population over 75 years old.[9] This age group is expected to grow from 6.1% in 2010 to 8.9% of the total US population by 2030.[10] Many of these patients are at higher risk, or even prohibitive risk, for traditional open heart surgery due to the increased risk of perioperative complications related to advanced age, frailty, and significant co-morbidities.[11,12] Postoperative complications, including renal and pulmonary complications are common in this patient population.[13] Furthermore, elderly patients with high surgical risk can encounter postoperative delirium up to 53% of the time depending on the type of the surgery and up to 70% to 87% if an intensive care unit (ICU) admission is necessary.[14] TAVI has been developed to address the difficulties of treating severe aortic stenosis, particularly in patients considered high risk for surgery.[15] Historically, TAVI has had similar postsurgical risks to surgical aortic valve replacement (AVR).[16] However, with the newest generation of transcatheter valves, TAVI is shown to reduce postsurgical complications, including reducing the risk of acute kidney injury (AKI) to 6.2% compared to

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15.1% with surgical AVR.[17] Furthermore, recent clinical trial data have shown that TAVI is associated with lower all-cause mortality compared with surgical AVR in patients who are deemed high risk for surgery (3% vs 5% at 30 days, 14% vs 19% at 1 year, and 22% vs 29% at 2 years, respectively).[17,18] As a result, TAVI has become the preferred method of AVR in those deemed at high risk for an open surgical procedure.

Supported by these data, many more patients at high and extreme risk for surgery are now coming to the operating room for transcatheter approaches to AVR. Therefore, the need to care for these patients in a systematic manner that incorporates many of the proved principles of ERAS is growing at a rapid pace. ERAS clinical pathways could help minimize the risk of significant postoperative complications for the TAVI patient population such as postoperative delirium, postoperative cognitive dysfunction, pneumonia, deep venous thrombosis, urinary tract infection, and postoperative functional decline.

Current Challenges Defined

Patients with symptomatic aortic stenosis who may be candidates for TAVI tend to be older, frail, malnourished, and physically deconditioned from activity intolerance secondary to debilitating symptoms. Due to their age, nutritional status, and co-morbidities, these patients are frequently too high risk for surgical AVR. Co-morbidities, including preoperative renal dysfunction and pulmonary dysfunction, are more prevalent in this older population[19,20] and have been shown to increase mortality after surgery.[21,22] This combination of factors often results in delayed functional recovery and difficulty returning to normal daily activities after valve implantation.

Increased frailty status is associated with an increase in 1-year mortality after TAVI.[23] Poor preoperative nutritional status occurs in approximately 10% to 25% of cardiac surgery patients[24] and has been shown to increase hospital stay as well as negatively impact patient outcomes.[25,26] Elderly patients tend to remain protein deficient throughout the perioperative period which is shown to be an independent risk factor for increased mortality in the elderly population.[27]

Postoperative delirium has been shown to significantly impact patient recovery and delay hospital discharge across all surgical specialties, including TAVI.[28] The risk factors for postoperative delirium include advanced age, preexisting dementia, general anesthesia, and perioperative use of benzodiazepines and opioids.[29] As such, intraoperative anesthetic technique and drug selection becomes paramount for prevention of postoperative delirium.

Other intraoperative issues for TAVI center on dynamic changes in hemodynamics related to valve positioning and deployment. Periods of hypotension (even brief) may pose increased risk for stroke and myocardial ischemia.[30,31] Embolization of calcium during valve deployment may also lead to stroke and myocardial ischemia.

Pain management is crucial to promote early ambulation and to prevent postoperative complications such as pneumonia and deep venous thrombosis. Uncontrolled pain after any surgical procedure is associated with longer hospital length of stay, delayed ambulation, and poorer outcomes.[32] TAVI has several valve delivery approaches including transfemoral, transapical, subclavian, suprasternal, and transaortic, which represent a varying intensity of postsurgical pain. The technical aspects of transfemoral TAVI have advanced and percutaneous techniques and smaller delivery systems have decreased the need for surgical cutdowns to expose the femoral vessels. This has helped improve perioperative pain control for this particular subset of patients undergoing TAVI. However, the transapical approach to TAVI necessitates an anterior thoracotomy, which is much more painful. The pain associated with an anterior thoracotomy incision for a transapical TAVI poses significant risk of postoperative pulmonary complications including atelectasis, pneumonia, and respiratory failure.[33] As such, studies have shown a 30-day all-cause mortality for the transapical approach to be >9%.[34,35] Although opioids have been the mainstay of postsurgical analgesia, side effects such as delirium, nausea, vomiting, and constipation are often seen, especially in the elderly population.

Patients undergoing TAVI are also at increased risk for postoperative AKI. AKI after percutaneous coronary interventions has been shown to increase postprocedural mortality.[36] An increase in creatinine of 0.3 mg/dl from baseline after TAVI has been shown to have a worse prognosis, including increased ICU time, in-hospital mortality, and 30-day mortality.[19]

Prolonged immobilization for postsurgical elderly patients may lead to skin breakdown, vasomotor instability, decline in respiratory function, urinary incontinence, and other functional complications.[37] Early mobilization after surgery can decrease the risk of pneumonia, postsurgical delirium, and ileus.[14,38] In addition, patients more quickly recover the ability to perform activities of daily living with timely postsurgical mobilization[39] which has been shown to help decrease hospital length of stay.[40]

Table 1 outlines the framework of our ERAS protocol. It involves interventions in the preoperative, intraoperative, and postoperative phases of care. A focus on nutrition, mobilization, physical therapy, and enhancing respiratory function all comprise the components of the preoperative protocol. Intraoperative management is largely led by the team of cardiac anesthesiologists who employ the use of short-acting anesthetics to decrease the likelihood of delirium and allow for early functional recovery. The postoperative care focuses on early ambulation, removal of hemodynamic monitors as soon as possible, a focus on nutrition and bowel/urinary function, and opioid-sparing analgesia.

Solution Details

Before patients begin the process of preparing for their TAVI procedure, a significant amount of preoperative education takes place. This serves to engage patients as active participants in their care and to explain how each of the ERAS pathway components contributes to an early return to functional recovery. Patients are encouraged to participate in physical activity, such as walking, if possible. For patients who are physically deconditioned, and/or have a history of recent falls, and meet the Centers for Medicare and Medicaid Services homebound criteria, in-home physical therapy is considered for strength and balance training.

Table 1
A broad overview of an enhanced recovery after surgery (ERAS) protocol for transcatheter aortic valve implantation (TAVI) surgery. As shown, the protocol has been structured into preoperative, intraoperative, and postoperative sections. Within each section, there are evidence-based recommendations to promote early functional recovery and for prevention of postoperative complications

Enhanced Recovery after Surgery (ERAS) Protocol - Overview	
Pre-Operative	• Pre-operative Education and Wellness Programs ○ Clinical Walking Programs ○ Pre-operative physical fitness evaluation and education ○ Home physical therapy for select patients ○ Incentive Spirometry program ○ Baseline nutrition assessment and recommendations • Frailty and Cognitive Assessments • Carbohydrate drink 2 hours prior to induction
Intra-Operative	• Defined blood pressure goals • Antibiotic prophylaxis per SCIP guidelines • Opioid-sparing multi-modal analgesia
Post-Operative	• Admission to intensive care unit • Removal of hemodynamic lines POD 0 unless patient is hemodynamically unstable • Groin sheath pulled when ACT <140 • Opioid-sparing multi-modal analgesia • Pulmonary Wellness ○ Incentive spirometry every hour while awake ○ Wean O_2 to room air for SpO_2 >90% within 4-6 hours of ICU arrival • Screenings for ICU delirium and/or follow-up cognitive testing • Quick advancement to regular diet if pass bedside evaluation by nurse ○ If fail beside evaluation, consult speech therapy POD 1 • Bowel regimen started immediately • Foley catheter removed POD 0 unless otherwise needed ○ Daily dose of tamsulosin for males at risk for urinary retention • Out of bed and early ambulation ○ Up and out of chair 6 hours post-transfemoral or 3 hours post-non transfermoral ○ Ambulation goal three time daily around unit

ACT = activated clotting time; POD = postoperative day; SCIP = Surgical Care Improvement Project.

Cognitive dysfunction and a high frailty score before surgery is shown to be related to increased long-term mortality, length of hospital stay, and increased complications after surgery.[41,42] A preoperative screening test for dementia is administered to all patients, The Mini-Cog assessment was selected as it has a comparable detection rate for dementia as a full neurophysiological examination (76% vs 75% sensitivity and 89% vs 90% specificity, respectively) and requires minimal time to administer.[43] A Mini-cog score ≤3 or abnormal clock drawing prompts consideration for a referral for a formal geriatric neurocognitive assessment. The Mini-Cog's result also informs clinicians which patients are at highest risk for postoperative delirium if cognitive impairment is found preoperatively.[28] Frailty severity, quality of life, and symptom burden is determined at pre-procedure clinic using the following tests:

- The Kansas City Cardiomyopathy Questionnaire
- EuroQol 5-D
- Katz Index of Independence in Activities of Daily Living
- Lawton-Brody Instrumental activities of daily living
- 5-meter walk test
- Grip strength

Screenings for malnutrition, recent falls, and tobacco abuse takes place preoperatively, as these are significant risk factors for future postsurgical morbidity.[26,44] Screening methods for malnutrition include serum prealbumin and total albumin labs which are collected preoperatively for every patient. Malnourished patients and patients with an unintended weight loss of >10 pounds in the last 6 months receive a formal preoperative consultation with a dietician to optimize both protein and caloric intake. Patients are given a "TAVI Nutritional Therapy" document that outlines specific dietary modifications which emphasize eating healthy, increasing protein intake, and minimizing sodium consumption (Appendix A).

Patients with ongoing tobacco abuse are referred to a smoking cessation program. Co-morbid conditions including diabetes, congestive heart failure, coronary artery disease, and renal failure are carefully evaluated to ensure optimization before TAVI.

Two hours before anesthesia induction, patients consume an 8 oz. carbohydrate beverage along with optional small sips of water and ice chips. The carbohydrate drink serves to ease the fasting state, reduce dehydration, provide caloric support, and improve patient satisfaction. Preoperative carbohydrate beverage use has been shown to reduce postoperative nausea and decrease length of hospital stay.[45]

The main anesthetic goals for this patient population are (1) avoidance of medications that may contribute to delayed emergence from general anesthesia and delirium and (2) maintenance of hemodynamic stability. Anesthesia maintenance includes propofol 50 to 100μg/kg/min + remifentanil 0.05 to 0.08 μg/kg/min. Benzodiazepines are avoided, opioid use is minimized, and short-acting anesthetics are used as part of the intraoperative protocol. Local anesthesia (lioposomal bupivacaine infiltration or paravertebral nerve block for transapical, subclavian, or direct aortic approaches) is used to help minimize opioids.

As valve delivery devices and techniques continue to evolve, it is likely that a conscious sedation technique may ultimately be preferable to general anesthesia for most patients. Avoidance of general anesthesia may help decrease the incidence of postoperative delirium. Further advantages may include improved hemodynamic stability, reduced need for vasopressor and/or inotropic support, and elimination of endotracheal intubation, which may lead to decreased procedure time and hospital stay.[46]

After consideration of the risks and benefits of conscious sedation versus general anesthesia, we chose general anesthesia as our preferred technique primarily to use real-time transesophageal echocardiography assessment during valve positioning and deployment. Real time transesophageal

echocardiography significantly assists with accurate valve deployment.

The crux of enhanced recovery after TAVI is avoidance of opioids. Multimodal analgesia is used, which includes the use of long-acting local anesthetic infiltration and scheduled acetaminophen. Nonsteroidal anti-inflammatories are avoided due to risk of platelet dysfunction and renal injury.

Postoperative pulmonary wellness strategy focuses on incentive spirometry use. During a presurgical clinic visit, each patient is given an incentive spirometer, educated in proper technique, and given a log book to monitor their inspiratory volumes as they practice. After surgery, patients are provided with a bedside log to record maximum incentive spirometry volume efforts and frequency of use. Nursing staff and family encourage the patient to use the incentive spirometer every hour while awake.

Postoperative delirium screening consists of a scheduled Confusion Assessment Method for ICU patients.[47] Confusion Assessment Method for ICU is documented upon arrival to the cardiac intensive care unit and once per shift by nursing staff. Postoperative cognitive dysfunction is assessed at the first follow-up clinic visit 2 to 4 weeks after hospital discharge using the Mini-Cog assessment. If postoperative cognitive dysfunction is present or worsened, a referral for a formal geriatric neurocognitive assessment is considered.

For transfemoral procedures, we have begun bypassing the use of Foley catheters since these procedures are typically faster and result in minimal blood loss compared with more invasive transapical, subclavian, suprasternal, and transaortic TAVI procedures. If a Foley catheter is necessary, it will be removed on postoperative day 0. Furthermore, a once-daily dose of tamsulosin is considered for all male patients on arrival to the cardiac intensive care unit. This aids to minimize the risk of urinary retention after Foley removal due to benign prostatic hypertrophy.[48]

Invasive monitors are removed postoperative day 0 unless the patient is hemodynamically unstable after surgery. The patient's arterial and venous groin sheaths are removed when the patient's activated clotting time is <140 seconds.

Patient mobility is a key factor in the recovery process for patients undergoing TAVI. Unless contraindicated, the patients are out of bed and into a chair within 6 hours after transfemoral approach or within 3 hours for a nontransfemoral approach (transaortic, transapical, suprasternal, and subclavian). Patients who have their procedures completed earlier in the day ambulate on postoperative day 0, whereas those who have their procedures completed later in the day are asked to get out of bed early in the morning of postoperative day 1. The patients are given a goal of ambulating 3 times per day around the unit with assistance from physical therapy and nursing staff. The daily ambulation distances are recorded by the nurse in our electronic medical record system and reviewed by the attending team.

Postoperative care continues after the patient is discharged from the hospital. Depending on the physical status of the patient on hospital discharge, the patient may be offered home physical therapy or a bed at a skilled nursing facility. Each patient's home needs are evaluated before discharge, and at-home nursing assistance is provided if necessary. All patients are strongly encouraged to enroll in a postoperative cardiac rehabilitation program starting approximately 4 weeks after procedure, as this has been shown to reduce mortality after cardiac surgical procedures.[49]

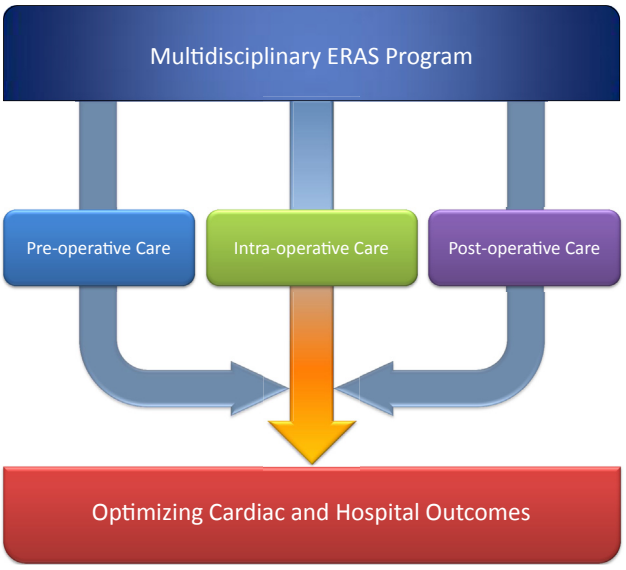

Figure 1. The ERAS model. The use of a multidisciplinary team is shown affecting preoperative, intraoperative, and postoperative patient care. Through this teamwork and pathway, a higher level of patient care is delivered to optimize cardiac and hospital outcomes.

The patient is contacted through phone by a provider within a few days of hospital discharge to address any questions, clarify discharge instructions, and screen for potential clinical issues that could lead to hospital readmission. The patient is seen in valve clinic within 2 weeks of discharge.

Summary and Call to Action

Advances in technology, procedural techniques, and operator experience have made TAVI a rapidly adopted technology that is now the standard of care for the treatment of aortic valve stenosis in patients at high or extreme risk for traditional open heart surgery. Since its introduction into the US, much effort has been put forth to help operators learn how to perform this procedure in a safe manner. This has paid dividends as the national outcomes mirror the positive outcomes seen in the preapproval clinical trials.[50]

Now is the time to refocus our attention away from procedural technicalities and focus our efforts on patients' functional recovery. ERAS pathways are patient centered and provide a framework to ensure evidence-based, best practices are used throughout the perioperative period. We have demonstrated that this framework can be applied to the high-risk patient population presenting for TAVI and believe it will expedite patient recovery, reduce length of hospital stay, and decrease postoperative complications.

Our institution has begun using the ERAS pathway for all patients undergoing TAVI. We have collaborated with health care professionals from a variety of different specialties to create this pathway Figure 1. To fully demonstrate the impact of the ERAS pathway on the patient outcomes, data are being collected and analyzed. Our primary outcomes measures include hospital length of stay, major adverse cardiac events, and 30-day readmission rate.

After the initiation of our TAVI program, our institution identified a specific need to help address common and potentially life-threatening complications in our high-risk patient population. Such complications have a significant impact on hospital length of stay and functional recovery outcomes, both of which are reported as metrics of success for individual programs and may soon be tied to reimbursement. As new techniques are developed and TAVI becomes even more accessible, ERAS pathways can help ensure all details of the perioperative experience are addressed using evidence-based care. Application of an ERAS pathway will help decrease perioperative risk and enable a faster recovery. We believe other centers should join us in adopting an ERAS framework and principles in their TAVI program.

Disclosures

The authors have no conflicts of interest to disclose.

Supplementary Data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.amjcard.2016.05.015.

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