Incidence of Venous Thromboembolism after Sternal Reconstruction: A Single-center Retrospective Review

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Background: Deep sternal wound infection and mediastinitis following sternotomy are associated with significant morbidity and mortality, and often require sternal reconstruction by plastic surgeons. Despite this patient population having a substantial risk of venous thromboembolism, there are no reports of the incidence of venous thromboembolism in patients undergoing sternal reconstruction. The authors sought to evaluate the incidence of venous thromboembolism in sternal reconstruction patients and to identify common risk factors for venous thromboembolism in this patient population.
Methods: A single-center retrospective review was completed of all patients who underwent sternal reconstruction by plastic surgeons between January 2012 and July 2020. Demographic data, antiplatelet and anticoagulant use, 2005 Caprini score, operative time, bleeding events, and postoperative venous thromboembolism events were recorded.
Results: A total of 44 patients were identified for analysis. The average 2005 Caprini score for the cohort was 10.9. In total, 93.2% of patients received perioperative antiplatelet and anticoagulant therapy (either chemoprophylaxis or systemic). Two patients developed postoperative venous thromboembolism events, for a total venous thromboembolism rate of 4.6%. Four patients had bleeding events requiring reoperation. No deaths were reported from either of these complications.
Conclusions: Patients undergoing sternal reconstruction are at a high risk for venous thromboembolism and postoperative bleeding events. Despite the growing body of literature on venous thromboembolism in various surgical populations, the optimal management of thromboembolic risk in patients with high Caprini scores undergoing sternal reconstruction requires additional investigation. *(Plast Reconstr Surg Glob Open 2021;9:e3735; doi: 10.1097/GOX.0000000000003735; Published online 16 August 2021.)*

INTRODUCTION

Deep sternal wound infection and mediastinitis following sternotomy has a reported incidence between 1% and 4% of all cardiac procedures.[1–3] Acute mortality rates are as high as 40%, with 39% 10-year survival in patients with poststernotomy mediastinitis, compared with 70% in patients without.[4] Several risk factors for deep sternal wound complications include obesity,[5] older age and more severe heart disease,[6] diabetes,[7] and chronic obstructive pulmonary disease (COPD).[2] Unfortunately, the rate of these comorbidities is rising among patients undergoing sternotomy for cardiothoracic procedures,[8] leading to more complications requiring complex reconstruction and the involvement of plastic surgeons in the management of sternal wounds.

Patients undergoing cardiac procedures, as well as those requiring sternal reconstruction, are known to be at risk of venous thromboembolism (VTE); however, the incidence and optimal management of thromboembolic risk in cardiothoracic patients requiring sternal reconstruction is unknown. In cardiac surgery patients, the incidence of deep vein thrombosis (DVT) has been reported to be around 2%, compared with about 1% in vascular surgery patients and 0.66% in general surgery patients.[9] The incidence of pulmonary embolism after coronary artery bypass grafting has been reported to be around 4%.[10,11] Risk factors for VTE in cardiac surgery patients include operative time more than 4 hours,[9] older age,[12]

postoperative complications,[12,13] and prolonged hospitalization.[10,14] Guidelines exist for risk-stratifying patients and managing thromboembolic risk in the plastic surgery and cardiac surgery subpopulations[15,16]; however, patients undergoing sternal reconstruction likely represent a subpopulation with markedly different characteristics.

Although studies exist reviewing the incidence of VTE in abdominoplasty,[17] abdominal wall reconstruction,[18] and breast reconstruction,[19] currently there are no reports of VTE incidence in patients who have undergone sternal reconstruction. The goal of this study was to evaluate the incidence of VTE events after sternal reconstruction at a single institution and to compare this incidence with those in previously published literature on similar patient populations. Additionally, in this patient population, we identify specific factors and treatments that affect their VTE risk.

PATIENTS AND METHODS

Institutional review board exemption was obtained for retrospective review of patients undergoing sternal reconstruction by plastic surgeons at The Ohio State University between January 2012 and July 2020. Medical records were obtained for all patients who underwent the following procedures: CPT codes 15734 (flap muscle/myocutaneous/fasciocutaneous trunk), 11042 (debridement SQ tissue), 11043 (debridement fascia muscle), and 21627 (debridement sternum). Charts were individually reviewed and included for data collection and analysis if the patient underwent sternotomy (median or transverse) and had subsequent flap reconstruction by a plastic surgeon. Data collected included age, gender, race and ethnicity, body mass index (BMI), medical comorbidities, American Society of Anesthesiologists (ASA) class, anticoagulant use, antiplatelet use, operative time, preoperative 2005 Caprini score, index procedure, details of reconstructive procedure, presence of hemorrhage that required reoperation, and DVT or pulmonary embolism occurrence.

RESULTS

After reviewing all patients who underwent chest wall reconstruction between January 2012 and July 2020, 44 patients who developed deep sternal wound infection requiring reconstruction by a plastic surgeon were identified for analysis. The average age of all patients was 60.3 years (range, 23–82 years). Twenty-seven patients (61%) were men, and 39 were White (88.6%). Average BMI was 33.8 kg/m² (range 19.7–55.8), nine patients (20.5%) were ASA class 3, and 35 (79.6%) were class 4. Twenty-six patients (59.1%) underwent coronary artery bypass grafting as their index procedure before reconstruction, and the average operative time for the reconstruction was 273 minutes (range, 116–497 minutes). Additional demographic information is presented in Table 1.

Forty patients (91%) were on antiplatelet therapy following their index cardiac procedure before reconstruction. All 40 patients continued antiplatelet therapy after

Takeaways

Question: What is the rate of venous thromboembolism in patients undergoing sternal reconstruction by plastic surgeons and what are the common risk factors in patients undergoing sternal reconstruction?

Findings: A review of patients at a single major academic institution found a venous thromboembolism rate of 4.6% with a significant portion of patients being overweight, having a central line, and having a history of deep vein thrombosis. Most of these patients were receiving both antiplatelet therapy in addition to being on either deep vein thrombosis prophylaxis or therapeutic anticoagulation.

Meaning: Sternal reconstruction patients are often high risk for thromboembolic events despite chemo- and mechoprophyaxis. Close monitoring of clinical signs of thromboembolism and high index of suspicion is also paramount in this patient subpopulation.

reconstruction, and two of the four patients not receiving preoperative antiplatelet therapy before reconstruction were started on aspirin after reconstruction (Fig. 1).

Table 1. Patient Cohort Characteristics

Category	
Total no. patients	44
Age (y)	
Mean	60.34
Range	23–82
BMI	
<40 kg/m²	31
>40 kg/m²	13
Gender	
Men	27
Women	17
Race	
White	39
Black	3
Other/unknown	2
Diabetes	
Yes	27
No	17
COPD	
Yes	16
No	28
Current smoker	
Yes	7
Former smoker	20
Never smoker	17
ASA class	
1–2	0
3	9
4	35
Total operative time	
120–179 min	6
180–239 min	11
>240 min	27
Index procedure	
CABG	26
Valve replacement	8
Ventricular assist device	4
Lung transplant	4
Heart transplant	1
Pulmonary thromboendarterectomy	1
30-day PE	
Yes	1
No	43
30-Day DVT	
Yes	1
No	43

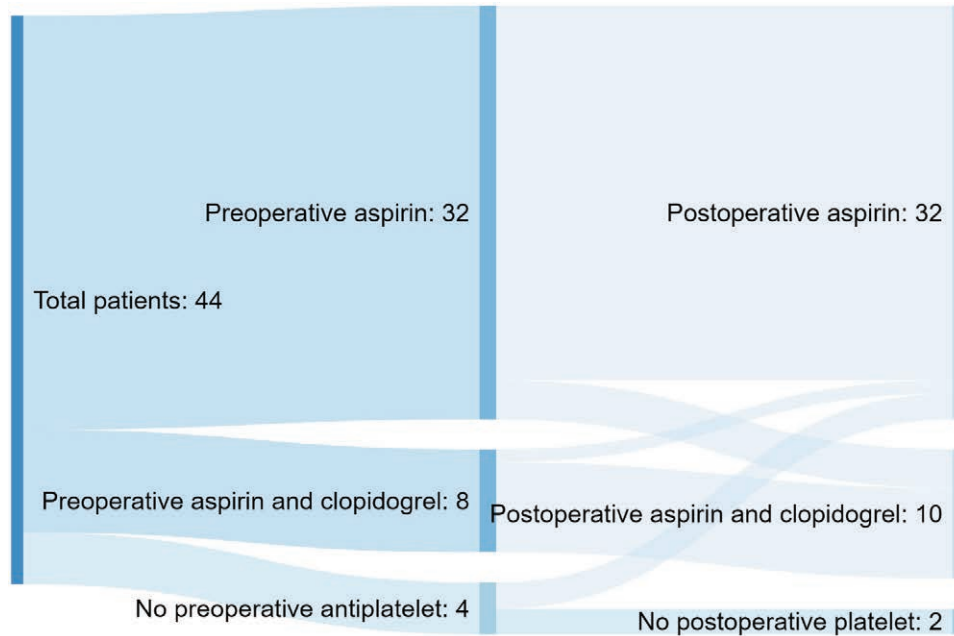CABG, coronary artery bypass grafting; PE, pulmonary embolism.

Fig. 1. Pre and postoperative antiplatelet use.

Our institution guidelines for anticoagulation recommend VTE prophylaxis in high-risk patients (ie, patients that are not ambulatory, have an expected length of stay more than 48 hours, or have additional VTE risk factors) with weight-based dosing of subcutaneous heparin or enoxaparin. In our cohort, 37 patients (84.1%) received chemoprophylaxis or systemic anticoagulation before reconstruction. Of these, 22 (59.5%) received weight-based subcutaneous heparin, 13 (35.1%) received a heparin drip titrated to a partial thromboplastin time goal of 52–75 seconds, and two patients (5.4%) received enoxaparin. All 37 patients receiving preoperative anticoagulant therapy continued anticoagulant therapy postoperatively, and five of the seven patients not receiving preoperative anticoagulant therapy were started on postoperative anticoagulant therapy (Fig. 2). Of the seven patients who did not receive preoperative chemoprophylaxis, one patient refused heparin and two patients received a heparin drip. Two patients were admitted on the day of surgery and received chemoprophylaxis postoperatively. The
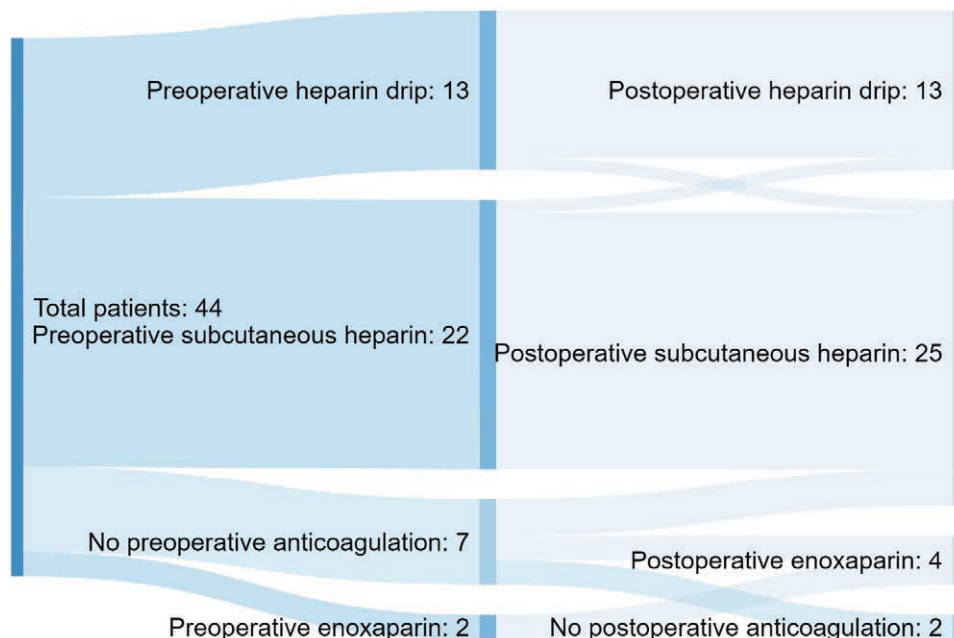

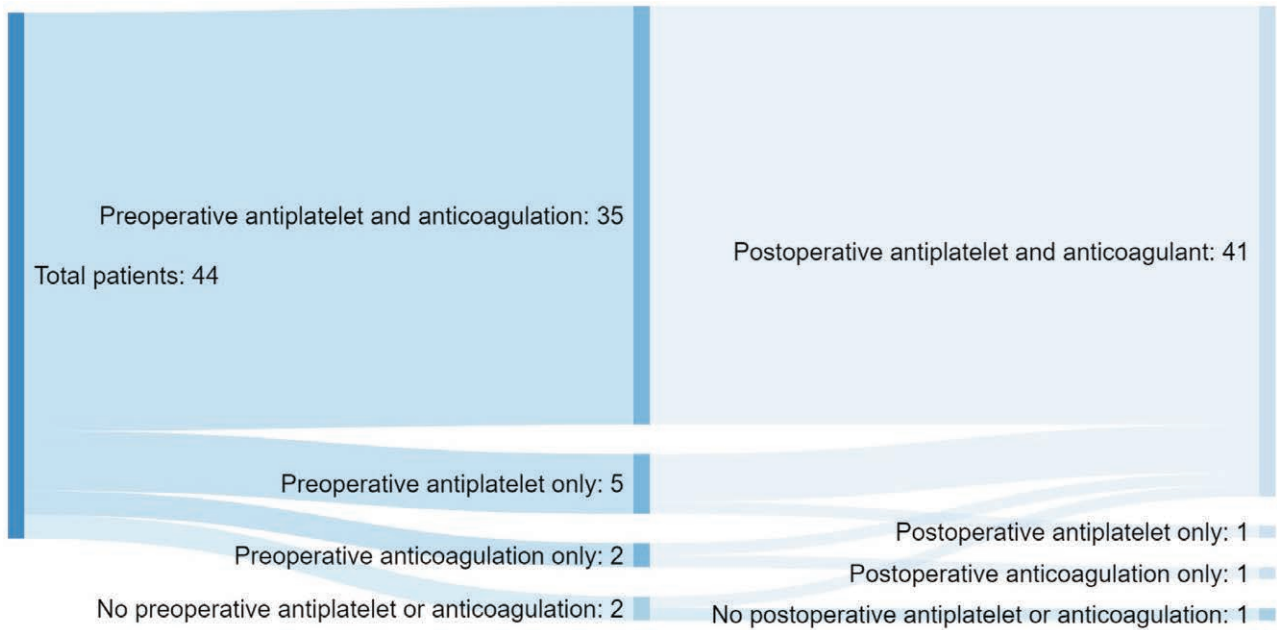**Fig. 2.** Preoperative and postoperative anticoagulant therapy use.

Fig. 3. Use of preoperative and postoperative antiplatelet and anticoagulation therapies.

remaining two patients were not given preoperative chemoprophylaxis due to hospital stay of less than 48 hours, based on our institution guidelines.

Thirty-five patients (79.6%) received both antiplatelet and anticoagulant therapy before reconstruction. Postoperatively, 41 patients (93.2%) received both antiplatelet and anticoagulant therapy (Fig. 3). Only one patient (2.3%) received neither antiplatelet nor anticoagulant therapy perioperatively (Fig. 4). Twenty-one patients (47.7%) were discharged with extended anticoagulant therapy: 15 (71.4%) were discharged on warfarin, three (14.3%) on subcutaneous heparin, and one each (4.8%) on apixaban, enoxaparin, and dabigatran.

Nineteen patients (43.2%) had a history of VTE, none of whom developed VTE postoperatively. Two patients (4.6%) had a history of hereditary hypercoagulable disorder, none of whom had postoperative VTE events. Figure 5 shows the frequency of several VTE

risk factors present in our patient cohort. The average length of stay following reconstructive procedure was 14.5 days.

Twenty-five patients (51.8%) underwent pectoralis major flap reconstruction alone, nine (20.5%) had pectoralis flap combined with rectus abdominis flap, six patients (13.6%) underwent rectus abdominis flap, two (4.6%) had pectoralis combined with omental flap, one (2.3%) had pectoralis combined with omental and rectus abdominis flaps, and one (2.3%) had a rotation-advancement fasciocutaneous propeller flap. The frequency of different reconstructive options with average operative length for each procedure is shown in Figure 6 with a histogram of procedure length shown in Figure 7.

Two patients developed a VTE for a total VTE event rate of 4.6%. Neither patient had a history of venous thromboembolism and both patients had Caprini scores
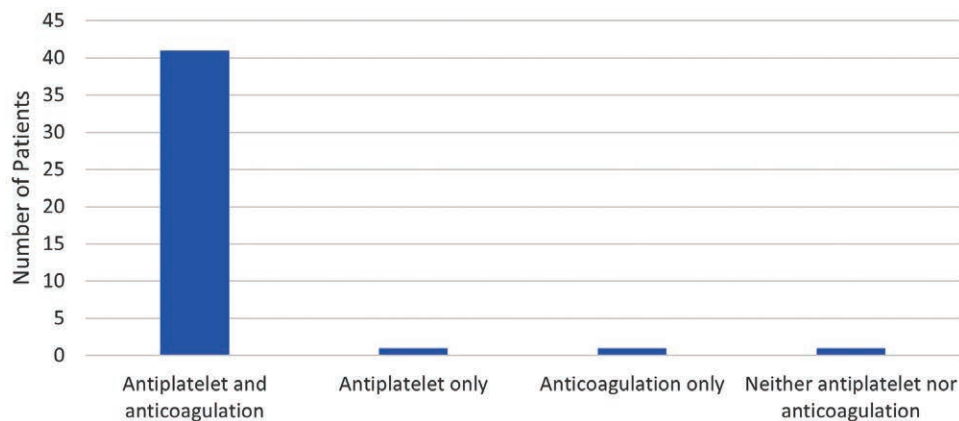

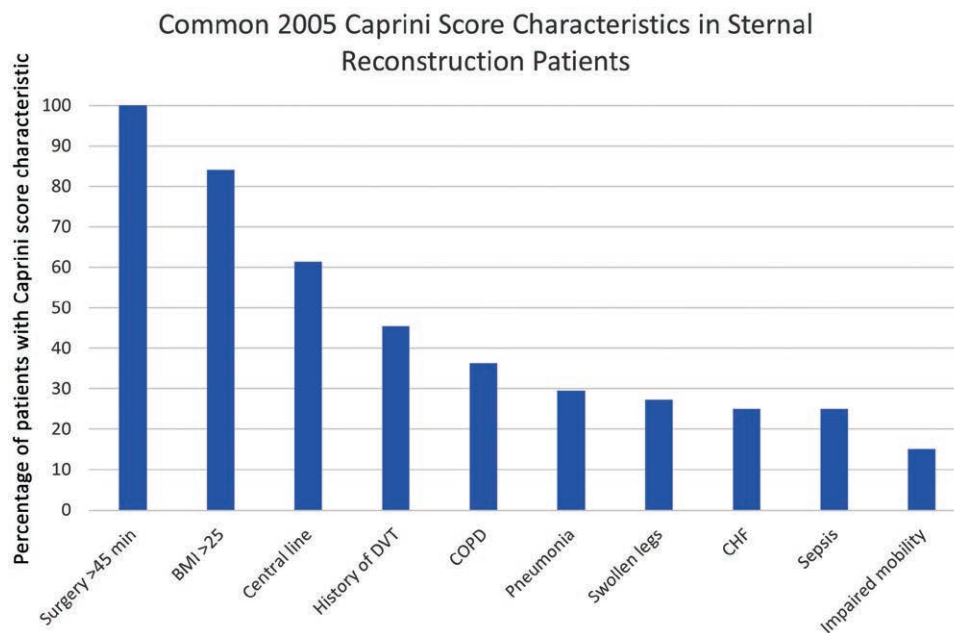**Fig. 4.** Perioperative antiplatelet and anticoagulant use.

Fig. 5. 2005 Caprini score characteristics of patient cohort. Impaired mobility includes being ordered to bed rest and sedated for more than 72 hours. CHF, congestive heart failure.

of 9. Characteristics for these two patients are included in Table 2, and their preoperative 2005 Caprini score breakdown is included in Table 3.

Patient 1 was diagnosed with a pulmonary embolism on postoperative day 5 after bilateral pectoralis advancement and left vertical myocutaneous rectus abdominis flaps (32 days after index procedure for aortic valve replacement), which was confirmed with CT scan with pulmonary embolism protocol. This patient was receiving perioperative aspirin as well as subcutaneous heparin injections of 5000 units every 8 hours since the index procedure, receiving his last dose 1 hour before reconstruction and restarting 10 hours postoperatively. He was switched from heparin to warfarin at the time of discharge.

Patient 2 developed a DVT on postoperative day 6 following bilateral pectoralis advancement flap reconstruction (21 days after coronary bypass), which was confirmed by venous duplex ultrasound. Of note, this DVT was related to a peripherally inserted central catheter placed on postoperative day 2 and thus was not included in the preoperative Caprini score. This patient was receiving perioperative aspirin and clopidogrel as well as 5000 units of subcutaneous heparin every 8 hours, receiving the last dose 90 minutes before reconstruction. He was restarted on heparin the morning of postoperative day 5 and transitioned to warfarin at the time of discharge.

The average preoperative 2005 Caprini score for this cohort was 10.9 (range 5–19). Before reconstruction, the average number of debridements was 4.6. Nine patients required debridement after reconstruction with the average number in this group being 2.8. In total, 12 patients (27.3%) underwent reoperation: five patients for infection, one for sternal dehiscence, one for second stage of delayed flap reconstruction, and one for wound exploration due to inadequate coverage of sternum. Four patients (9.1%) had bleeding complications after reconstructive procedure requiring reoperation. Thirteen patients (29.6%) had died at the time of database completion. There were no deaths resulting from venous thromboembolism or bleeding events.

DISCUSSION

Patients undergoing sternal reconstruction are at a high risk of venous thromboembolism. In our analysis, we found one patient with a DVT and one patient with pulmonary embolism for an overall incidence of 4.6%. Although there is now greater investigation into VTE events within patient subpopulations undergoing reconstructive procedures (eg, abdominal wall reconstruction[18] and microsurgical breast reconstruction).[19] This is the first study to report the incidence of venous thromboembolism in patients undergoing sternal reconstruction by plastic surgeons. Within the cardiothoracic subpopulation, the incidence of VTE has been characterized and can vary between various cardiothoracic procedures.

Aziz et al performed analysis of the American College of Surgeons National Surgical Quality Improvement Program database from 2005 to 2010 looking at patients undergoing cardiac surgery, vascular surgery, or general surgery procedures. They found 2.07% of patients undergoing any cardiac surgery developed DVT within 30 days of surgery. They identified operative time as more than 4 hours, need for blood transfusion, and postoperative cardiac arrest as risk factors for postoperative DVT.[9] In 1993 Josa et al reported a pulmonary embolism incidence of 32 of 819 patients (3.9%) undergoing coronary bypass surgery. History of DVT or PE was noted to be a risk factor for VTE following cardiac surgery; however, less than 7% of their patients had a history of VTE in contrast to over
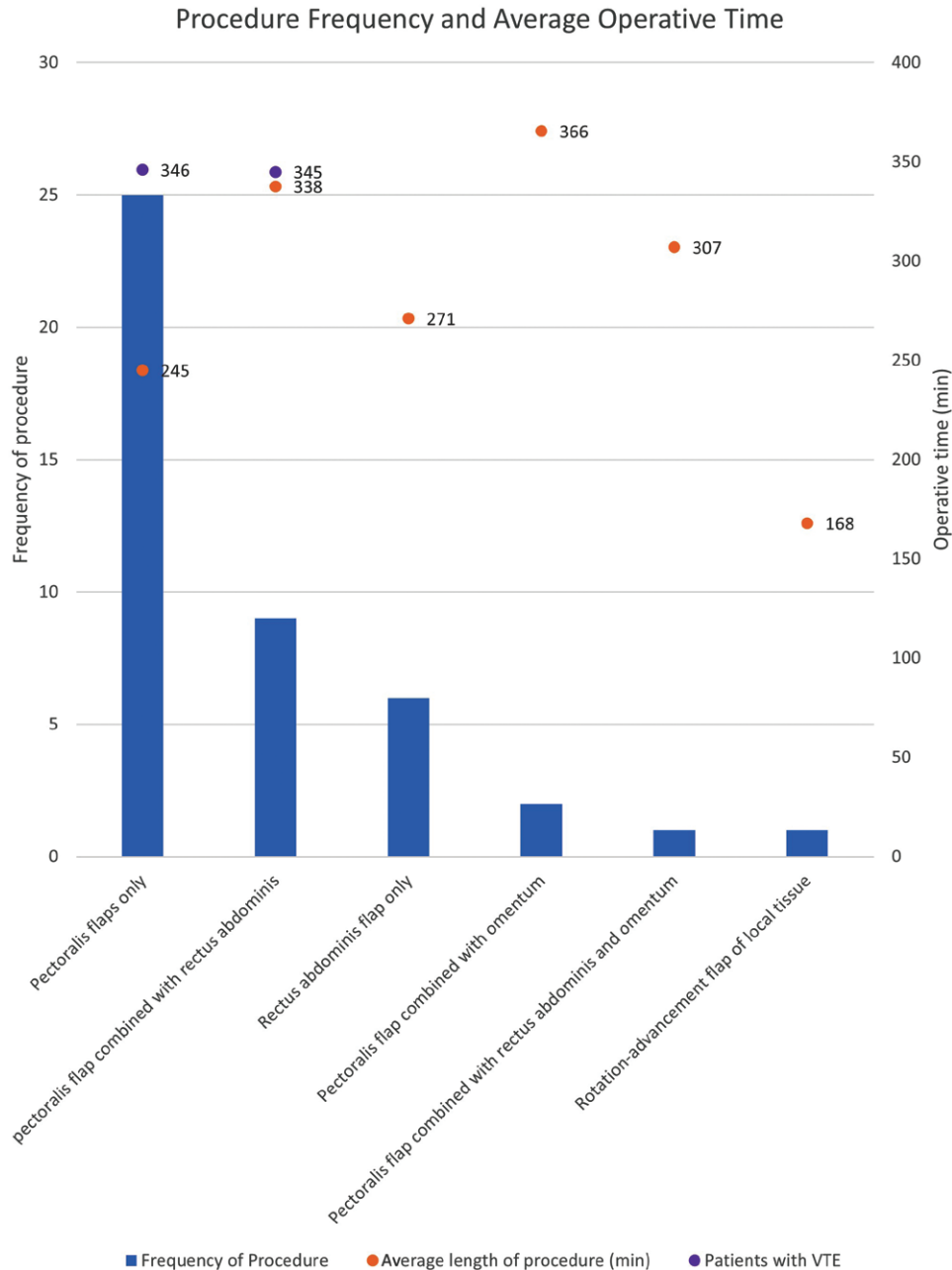
Procedure Frequency and Average Operative Time

Fig. 6. Type of flap reconstruction utilized for sternal reconstruction.

40% in our patient cohort. Additionally, none of the 120 patients undergoing isolated valve replacement developed pulmonary embolism.[10] Iribarne et al analyzed patients in the Nationwide Inpatient Sample database from January 1, 2005 to December 31, 2007. In total, 16,788 patients who underwent mitral valve surgery were included, and a venous thromboembolism rate of 0.8% was found.[20]

Among plastic surgery patients, the 2005 Caprini Risk Assessment Model has been validated in the use of stratifying patients' risk for VTE.[21] The incidence of VTE increases with increasing Caprini score in patients not receiving chemoprophylaxis, with a rate of 11.3% in patients with Caprini scores greater than 8.[21] For hospitalized patients with Caprini scores of 7–8 undergoing plastic surgery procedures, the American College of Chest Physicians estimates a VTE incidence of 6% if they do not receive pharmacologic or mechanical VTE prophylaxis. In these patients, the estimated incidence is reduced to 2.6% when using low-dose unfractionated heparin and 1.8% if using low-molecular-weight heparin.[16] Subsequent metaanalysis of patients undergoing procedures by surgeons in several different fields found that chemoprophylaxis resulted in a significantly reduced risk of VTE for patients with Caprini scores of 7–8 (OR 0.60, $P = 0.04$) and greater than 8 (OR 0.41, $P = 0.0002$). Although the overall risk of clinically relevant bleeding
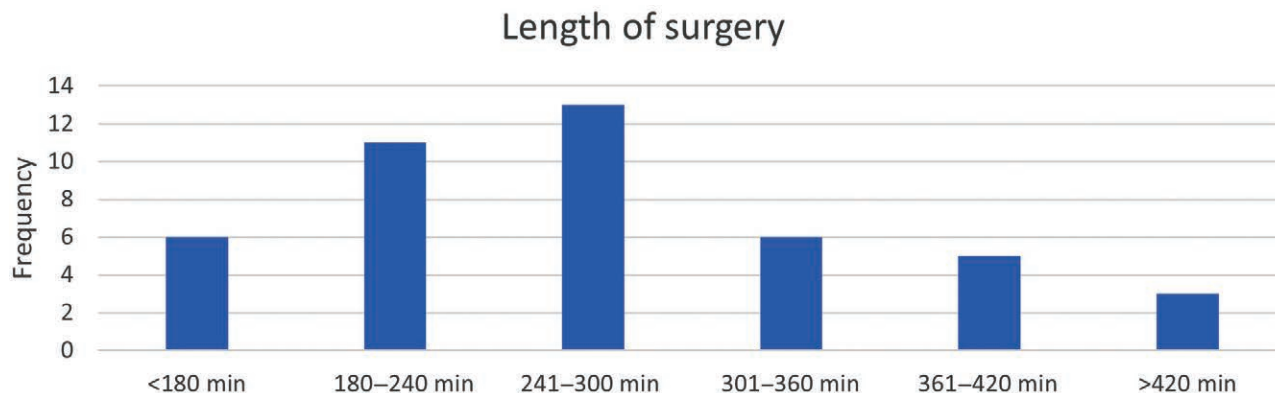
Length of surgery

Fig. 7. Histogram of procedure length.

Table 2. Summary of Data for Patients with a Venous Thromboembolism within 30 Days after Reconstructive Surgery

Patient	Age	Gender	Race	ASA Class	Operative Time (min)	BMI (kg/m²)	Diabetes	COPD	Antiplatelet/ Anticoagulants
1	55	Man	White	4	345	29.48	No	Yes	Aspirin/subcutaneous heparin
2	67	Man	White	4	346	36.95	Yes	Yes	Aspirin, clopidogrel/ subcutaneous heparin

was increased while on chemoprophylaxis (OR 1.69, $P = 0.006$), risk-stratified analysis did not show a significant association between clinically relevant bleeding at individual risk levels (ie, patients with Caprini scores 7–8 or greater than 8).[22]

The American College of Chest Physicians estimated that the rate of major bleeding complications at 7–10 days to be 3.5% for hospitalized surgical patients at high-risk of VTE receiving low-dose unfractionated heparin and 3.1% for those receiving low-molecular-weight heparin. In patients at high-risk of VTE receiving aspirin, the rate of major bleeding is estimated to be 5.3% compared with 4.0% in patients receiving no prophylaxis (relative risk 1.32, confidence interval 1.17–1.48).[16] In our cohort, four patients (9.1%) had bleeding complications after reconstruction that required reoperation, somewhat higher than the rate of bleeding complications following cardiac surgery, which is reported to be around 5% across several studies.[16] All four of these patients received aspirin and heparin preoperatively and postoperatively, and all four patients had indications for systemic anticoagulation: one

Table 3. Summary of Preoperative Risk Factors for Each Patient with Documented Venous Thromboembolism Event Using the 2005 Caprini Risk Score Calculator

Risk Factors	Patient 1	Patient 2
BMI	>25 kg/m²	>25 kg/m²
Age (y)	31–60	51–74
Surgery	Major surgery (>45 min)	Major surgery (>45 min)
Major surgery in the last 30 days	Yes	Yes
Sepsis in the last 30 days	Yes	No
Immobile >72 hours	Yes	No
COPD	Yes	Yes
History of malignancy	No	Yes
Total score	9	9

for history of VTE and atrial fibrillation, one for atrial fibrillation, one for the presence of left ventricular assist device, and one for a mechanical heart valve. Of these patients, three were discharged on warfarin, and one was discharged on subcutaneous heparin.

As outlined by the American Society of Plastic Surgeons's VTE Task Force, plastic surgery patients should undergo individual risk assessment using the 2005 Caprini Risk Assessment Model, and patients scoring 7 or greater should be considered for VTE risk reduction (eg, limiting operating time, weight reduction, etc).[15] For scores greater than 8, chemoprophylaxis on a case-by-case basis is recommended by Pannucci et al.[23] The American College of Chest Physicians recommends the use of intermittent pneumatic compression devices in addition to chemoprophylaxis with unfractionated heparin or low-molecular-weight heparin for plastic surgery patients with Caprini scores of 7–8 who are not at a high risk of bleeding complications.

While modifying individual risk factors before surgery is ideal,[15,24] this patient population often undergoes their index procedure emergently.[25] Sternal reconstruction patients are medically complex with a high risk for VTE, as demonstrated by our patient cohort having an average Caprini score of 10.9. In our review, most patients had an operative time greater than 4 hours with both patients diagnosed with VTE having longer surgeries than average (346 and 345 minutes versus average 269 minutes). Also, the majority of patients had central lines, and average hospital stay was greater than 14 days following reconstruction. The rate of additional risk factors encountered in our population is shown in Figure 5. Notably, the history of past VTE is worth three points in the Caprini score calculation; however, more than 40% of our cohort had a history of previous VTE event, yet none of these patients were

diagnosed with VTE following sternal reconstruction. In fact, the two patients who were diagnosed with VTE events had no previous history of VTE.

Additionally, 61.4% of patients had central lines placed before reconstructive procedure. Although the pathologic process behind catheter-associated DVT is different from perioperative lower extremity DVT, the prevalence of central line usage in this patient population is an important consideration in the risk management of this patient population. The rate of upper extremity DVT in all patients with central catheterization has been reported to occur between 14% and 23%, with pulmonary embolism occurring in 6% of upper extremity DVT patients.[26] Our patient cohort had a central-catheter–associated DVT rate of about 3%. While the Caprini score is evaluated preoperatively for determining appropriate DVT prophylaxis, the changing clinical conditions of this patient population must be considered. Our suggestion is to recalculate the Caprini score in between the stages of a staged procedure to properly identify risk factors that can potentially increase VTE risk.

The addition of antiplatelet therapy in our cohort may be adding additional protection against VTE. The American College of Chest Physicians estimated a rate of VTE in hospitalized patients undergoing surgery with 2005 Caprini scores of 7–8 to be 4.3% in patients receiving low-dose aspirin and 6.0% in patients receiving no prophylaxis (RR 0.71, 95% confidence interval 0.52–0.94) at 350 day follow-up. Although the American College of Chest Physicians does not recommend the use of aspirin as VTE chemoprophylaxis unless heparin is contraindicated or unavailable, other surgical populations routinely use aspirin as VTE chemoprophylaxis: the American Academy of Orthopedic Surgeons consensus guidelines recommend antiplatelet therapy as a primary pharmacologic method of preventing deep venous thromboses.[23] Other studies exist in the literature supporting the use of aspirin for chemoprophylaxis in orthopedic surgery with reported incidences of less than 1% when antiplatelet therapy is used alone.[24]

There are a number of limitations to this study. The data were obtained from a single institution in a retrospective fashion. This institution is a tertiary care center and receives transfers from surrounding hospitals, resulting in selection of patients with more complex disease, which may limit generalizability of the data. Another limitation is the small number of patients analyzed in this single-center cohort, making the true VTE rate in this patient subpopulation difficult to extrapolate. This is further compounded by the fact that VTE is a relatively rare complication. Ideally the incidence of VTE in sternal reconstruction patients should be in a prospective, multicenter fashion. However, this study represents the single largest series of patients reported to date on the incidence of VTE in sternal reconstruction patients, which can help guide awareness and treatment while further studies are developed. Another limitation is that our VTE outcomes were confined to patients with clinical evidence of symptomatic DVT or PE, which may have resulted in missing asymptomatic VTE events. While the VTE events in our patients

presented acutely and are likely related to their perioperative course, it is possible that the VTE events began asymptomatically and related to a previous procedure but presented symptomatically following reconstruction.

CONCLUSIONS

Patients undergoing sternal reconstruction are at a high risk for venous thromboembolism due to the nature of cardiothoracic procedures coupled with the comorbidities of this patient population. This is the first study to document the incidence of VTE among sternal reconstruction patients, adding to the growing interest of VTE in plastic surgery. Sternal reconstruction patients have high Caprini scores which are driven by high BMI, history of VTE, length of surgery, and the presence of central catheters, among other risk factors. Additional research should be considered to determine the impact of VTE in sternal reconstruction patients and develop additional VTE risk-stratifying tools for patients at a higher risk of VTE. Although the usage of aspirin in addition to conventional anticoagulation may prevent VTE events in this patient population, additional research should be conducted to prospectively evaluate the use of specific aspirin and anticoagulation regimens in this patient population. Despite following current guidelines for VTE risk management, the incidence of VTE in sternal reconstruction patients remains significant, and plastic surgeons should maintain a high index of suspicion for VTE and bleeding complications when caring for these complex patients.

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