Published in final edited form as:

Plast Reconstr Surg. 2017 August ; 140(2): 390–400. doi:10.1097/PRS.00000000000003514.

A National Study of the Impact of Delayed Flap Timing for Treatment of Patients with Deep Sternal Wound Infection

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Abstract

Background—This study aims to evaluate the impact of delayed flap closure on mortality and resource utilization for treatment of deep sternal wound infection (DSWI).

Methods—We analyzed the Truven MarketScan Databases from 2009 – 2013 to identify adult patients who developed DSWI after open cardiac surgery and who received flap closure for treatment. A multivariable logistic regression model was created to evaluate the relationship between mortality and flap timing. Multivariable Poisson regressions were utilized to investigate the relationship between flap timing and number of procedures, number of hospitalizations, and length of stay (LOS) outcomes. A multivariable log-linear regression model was created for cost analysis. All analyses were adjusted for patient risk factors and treatment characteristics.

Results—We identified 612 patients with DSWI who underwent flap closure. The timing of flap closure was delayed >7 days after diagnosis in 39% of patients. Delayed time to flap closure >3 days after diagnosis of DSWI was associated with higher mortality odds (4–7 days OR 2.94; >7 days OR 2.75, $P<0.03$), greater additional procedures (4–7 days IRR 1.72; >7 days IRR 1.93, $P<0.001$), up to 43% longer hospital LOS, and 37% greater costs compared to patients having flap closure 0 – 3 days after diagnosis.

Conclusions—Delay in flap closure was associated with greater mortality and resource utilization. Prompt involvement of reconstructive surgeons may improve quality and efficiency of DSWI care.

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Disclosure: None of the authors have any financial interest or conflicts of interest to declare in relation to the content of this article.

Keywords

deep sternal wound infection; flap timing; mortality; surgical treatment; hospitalization; length of stay; cost

Deep Sternal Wound Infection (DSWI) is a devastating complication that is estimated to occur in 1 – 3% of patients after open cardiac surgery in recent times (1–8). Although the incidence of DSWI is relatively low, the associated mortality is reported as high as 30% (1, 6, 8) and the complication more than doubles the cost of care (4, 9, 10). For this reason, recent policy changes have aimed to prevent DSWI after cardiac surgery. Beginning October 2008, the Centers for Medicare and Medicaid Services (CMS) began denying payment for avoidable complications, including mediastinitis after coronary artery bypass graft (CABG) surgery (11, 12). The goal of the CMS policy change is to encourage higher quality inpatient care and ultimately motivate hospitals to take responsibility for potentially preventable complications. Despite these policies, there is concern that the incidence of postoperative infection after cardiac surgery has remained stagnant in recent years (6, 13–16).

With hospitals assuming greater responsibility for the burdens of DSWI, it is imperative to understand the treatment and process variation that exists in managing this complication, with the goal of improving patient outcomes and resource utilization. Over the past 50 years, the treatment of sternal wound infection has evolved. Although there is not a standardized treatment algorithm for DSWI after cardiac surgery, debridement with flap reconstruction has become a widely used method of reconstruction (17). The use of flaps has reduced the mortality rate from post-sternotomy mediastinitis to an estimated 8–15% (18–21). Previous to widespread use of muscle flap closure, mortality rates were as high as 40% (22, 23). Furthermore, single-stage debridement and flap reconstruction have been shown to have a comparable morbidity and mortality profile as other reconstructive methods in single-centered studies (21, 24).

Although several studies have advocated for early debridement (25, 26) and single-stage flap coverage (21, 24, 27) for reconstruction of sternal wounds, little attention is paid to understand the impact of the time lapse between diagnosis of DSWI and flap coverage. Given the low incidence of DSWI, a population-level analysis is helpful to investigate the influence of process and treatment variation on patient outcomes at a broad level. The purpose of this study was to evaluate the impact of delayed flap closure on patient outcomes for treatment of DSWI using national claims data. We hypothesized that patients undergoing delayed flap closure after DSWI would have higher mortality and resource use.

METHODS

Dataset and Study Selection

This study received exempt status from the Institutional Review Board. We conducted a retrospective cohort study using the 2009 to 2013 Truven MarketScan Commercial Claims and Encounters and Medicare Supplement/Coordination of Benefits (MarketScan) databases to evaluate a sample of patients undergoing flap closure after DSWI. The MarketScan databases are comprised of a national convenience sample of beneficiaries from large

employers, health plans, government, and public organizations. The dataset includes inpatient, outpatient, and pharmacy encounters for over 55 million enrollees per year, for the duration of time that individuals are enrolled in the included health plan (28). Each patient has a unique identifier that facilitates longitudinal evaluation of health care utilization.

Patients age 18 years and older were selected with primary and secondary diagnoses of DSWI after undergoing open cardiac surgery. Current Procedural Terminology, Fourth Edition (CPT-4) procedure codes and International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) were used to identify patients having common open cardiac surgery procedures, including coronary artery bypass graft surgery (CABG), open valvular repair/replacement, and open thoracic aneurysm repair. DSWI complication after open cardiac surgery was defined as having primary or secondary diagnosis of mediastinitis, osteomyelitis, or chest wall wound. Lastly, CPT-4 procedure codes were used to identify the final cohort of patients undergoing flap reconstruction after DSWI, including muscle, fascia, or omental flaps (See Supplemental Digital Content 1, Appendix 1 which shows the Procedure Codes and Diagnosis Codes for Patient Selection and Identification of Treatment and Risk factors, INSERT LINK) (Supplemental Digital Content 2, Appendix 2 shows the Full Multivariable Poisson Regression of Number of Procedures, Number of Admissions, and Total Hospital Day Outcomes Based on Flap Timing (N=514), INSERT LINK) (Supplemental Digital Content 3, Appendix 3 shows the Multivariable Log-Linear Regression of Cost Outcomes Based on Flap Timing (N=514), INSERT LINK). The full inclusion and exclusion algorithm is outlined in Figure 1.

Predictor and Outcome Variables

The key predictor variable of interest for this study included the timing of flap reconstruction in days from diagnosis of DSWI to the first flap closure. The first inpatient or outpatient healthcare encounter with a diagnosis of DSWI was recorded as the day of diagnosis. Based on the distribution, timing of flap closure was categorized into four categories including: same day of DSWI diagnosis, 1 – 3 days after diagnosis, 4 – 7 days after diagnosis, and >7 days after diagnosis.

The outcomes of interest for the study cohort included in-hospital mortality and 90-day post-DSWI diagnosis health care utilization for patients who were alive and followed in the dataset for at least 90 days after diagnosis. The 90-day utilization outcomes included the number of total DSWI-related operations, number of infection-related admissions, number of days spent in the hospital, and total costs for DSWI-related inpatient hospital stays. CPT-4 codes were used to identify the number of DSWI-related operations, which were counted as total number of trips to the operating room on separate calendar days. Related admissions were identified by examining the primary diagnosis of inpatient services to capture hospitalizations related to DSWI in addition to the initial hospital stay in which DSWI was diagnosed (see Supplemental Digital Content 1, Appendix 1 for ICD-9-CM diagnosis codes). Total hospital days were calculated as the sum length of stay for all DSWI-related hospitalizations. Total cost was calculated as the sum of payments for all DSWI-related inpatient care. All costs were adjusted for year-specific inflation (29).

Control Variables

In our analyses we controlled for patient demographic, treatment characteristics, and risk factors to account for additional variables that may impact the outcomes of interest. Patient age at the time of DSWI was recorded. We considered treatment characteristics that could impact complexity and healthcare use related to the index cardiac procedure and DSWI treatment, including number of patient comorbidities, length of stay after the initial cardiac surgery, timing of DSWI diagnosis, timing of initial debridement, use of negative pressure therapy, and type of flap reconstruction. Additional post-cardiac surgery complications were recorded, including postoperative sepsis, having an operation for bleeding, and need for a blood transfusion within 7 days of the index procedure. Patient comorbidities were characterized by the Elixhauser Index (30), which were grouped by number of Elixhauser conditions (0 – 2, 3 – 6, and 7 or greater comorbidities). The timing of diagnosis was defined as days between the most recent cardiac surgery and DSWI diagnosis. The El Oakley classification system for timing of mediastinitis was used to define categories for diagnosis timing, with the exception of the >6 week El Oakley category which was divided into two groups (6 weeks – 3 months, and greater than 3 months) (3). The type of flap reconstruction used was categorized as 1) muscle and/or fascia, 2) omentum flap only, and 3) combined omentum muscle and/or fascia flap.

Data Analysis

Multivariable regression models were chosen based on the distribution of each outcome of interest, while controlling for patient risk factors and treatment characteristics. A logistic regression model was created to evaluate the relationship between flap timing and mortality. The number of independent covariates in the mortality model were limited to 7 variables based on a recommended maximum 10:1 outcome to predictor ratio for logistic regression models for sufficient power to predict the outcome of interest (31). Thus, the variables with the greatest impact on mortality outcomes in bivariate comparisons were included in the final model to not surpass the 10:1 ratio recommendation. Poisson regressions were created to model the impact of flap timing on number of total operations, admissions related to DSWI, and total hospital length of stay for DSWI-related treatment. Poisson regression models are often used to model count variables, which had the best fit for the models in this study compared to negative binomial regression models. A log-transformed linear regression model, often used for positively skewed outcomes such as cost, was created to model the relationship between flap timing and cost outcomes. For all of the outcome models except for mortality, patients were excluded if they were not alive or enrolled for observation for at least 90 days after diagnosis of DSWI. Post-estimation marginal effects were calculated for each model to compare adjusted mean outcome predictions among patients in each flap timing group using STATA (version 12, StataCorp LP; College Station, TX). The post-estimation marginal calculation is helpful because it allows comparison of the groups of interest in a measure that is easier to understand compared to odds ratio (OR) and incidence rate ratio (IRR) output from logistic and Poisson regressions respectively, while still controlling for patient variables in the model. The significance level for statistical analyses were set at $p < 0.05$.

RESULTS

Among the 1,335 patients with DSWI who received operative treatment, 46% (n=612) underwent flap reconstruction (Figure 1). The final cohort of patients having flap reconstruction were observed in the dataset for a median of 16 months (interquartile range 7 – 30 months) prior to the index cardiac surgery and median of 14 months (interquartile range 5 – 28 months) after DSWI diagnosis. The median time from index cardiac surgery to DSWI diagnosis was 16 days (interquartile range 3 – 38 days). Muscle or fascia flaps were used in 91% of patients (n=554), whereas omentum only flaps were used in 4% (n=25), and combined omentum and muscle/fascia flaps were used in 5% of patients (n=33). The timing of flap closure was delayed more than 7 days after DSWI diagnosis in 39% of patients, and 86% underwent flap closure for treatment of DSWI during the initial hospitalization in which their cardiac surgery occurred. The remaining sample characteristics, risk factors, and treatment characteristics are outlined in Table 1.

The incidence of in-hospital mortality was 12% (n=76) in the flap reconstruction cohort. The median time between DSWI diagnosis and death in patients who died was 40 days (interquartile range 12 – 113 days). Unadjusted estimates of the study outcomes based on flap timing groups are outlined in Table 2. In the multivariable analysis, patients in the delayed flap timing groups had greater odds of mortality (4 – 7 days after diagnosis, OR = 2.94, CI = 1.09 – 7.93; >7 days after diagnosis OR = 2.75, CI = 1.15 – 6.59) compared to patients having earlier flap closure (Table 3). The timing of initial debridement and the type of flap used did not have a significant impact on mortality in patients having flap reconstruction. While controlling for independent variables in the model, patients having flap closure 4 – 7 days and >7 days after DSWI diagnosis had approximately double the predicted probability of death (0.17 and 0.16, respectively) compared to patients having closure the same day as DSWI diagnosis and 1 – 3 days after diagnosis (0.08 and 0.07, respectively) (Figure 2). Among the other control variables included in the model, an increased length of stay during the index cardiac surgery admission was most strongly related to higher mortality odds (Table 3).

In the adjusted models evaluating the number of procedures, number of admissions, and total hospital length of stay, delayed flap timing 4 or more days after DSWI diagnosis was associated with an increased number of procedures (4 – 7 days after diagnosis IRR = 1.72, CI 1.38 – 2.16; >7 days after diagnosis IRR = 1.93, CI 1.58 – 2.35) and longer hospital length of stay (4 – 7 days IRR 1.43, CI 1.35 – 1.52; >7 days after diagnosis IRR = 1.37, CI = 1.30 – 1.45). IRRs are interpreted as the relative increase in the outcome compared to the reference group. Therefore, for patients having flap closure more than 7 days after diagnosis, patients experience a 93% increase in number of procedures and 37% increase in length of stay compared to the reference group of patients having flap closure the same day as DSWI diagnosis (Table 4). Delayed flap timing was not associated with a significant increase in number of admissions. The mean predicted number of procedures ranged from 1.46 procedures in patients with the earliest flap closure to 2.82 procedures in patients with flap closure beyond 1 week after DSWI diagnosis (Figure 3). Similarly, the range of predicted hospital length of stay ranged from 27 days in patients with earliest flap closure compared to 38 days in patients in the group with greatest delay (Figure 4). Lastly, patients in the latest

flap closure group had nearly \$100,000 greater total mean costs for DSWI-related care compared to patients in the earliest flap closure group (Table 2). In the controlled analysis, delayed flap closure 4 or more days after DSWI diagnosis was associated with 37% greater costs compared to patients having early flap closure. The full multivariable regression models for number of procedures, number of admission, hospital length of stay, and cost outcomes are outlined in Appendices 2 and 3.

The relationship between negative pressure therapy (NPT) and flap delay is unclear and was likely unreliably captured in the administrative dataset. NPT use was recorded in 17% of patients having flap closure. However, in these patients, NPT was associated with a significant increase in number of procedures (IRR=1.38, CI 1.20 – 1.59), admissions (IRR = 1.22, CI 1.01 – 1.47), and prolonged length of hospital stay (IRR 1.20, CI 1.15 – 1.24).

DISCUSSION

Over time, flap reconstruction has become widely used in the treatment of DSWI. This population-based cohort study of patients undergoing flap reconstruction after DSWI suggests that patients treated with earlier flap coverage had lower mortality and resource use in procedures, hospital days, and costs compared to patients with prolonged time between DSWI diagnosis and flap coverage. Although the type of flap used did not impact overall mortality, most patients received muscle or fascia flap reconstruction, with less than 10% of patients having reconstruction using an omental flap. NPT use was captured in only 17% of all patients. This low rate of NPT use is likely underestimated because procedures that are not associated with high reimbursement, compared to a more invasive operation, are often unreliably captured in administrative databases. However, rates of NPT use were highest in the groups with the greatest flap delay and NPT was associated with higher resource use in the adjusted analyses. Given the recent policy change by CMS to designate DSWI as a preventable hospital-acquired condition, providers and hospitals must be proactive in identifying processes of care that contribute to inefficient use of resources. It is unclear whether the decreased mortality associated with early flap closure is due to the physiologic benefits of prompt flap closure, or whether facilities that are more aggressive with plastic surgeon consultation and early flap closure are better at managing DSWI as a whole, which then leads to decreased mortality. The current study is unable to answer this question, but we hypothesize that the latter phenomenon is the likely explanation.

Timely surgical intervention has been associated with decreased resource use among several surgical conditions, including sternal wound infection, lower extremity trauma, and hip fractures (25, 32, 33). In a previous study of 1,335 patients who underwent various surgical treatments for DSWI, we demonstrated the important association between early excisional debridement, decreased hospital days, and lower number of admissions (25). Delayed initial debridement timing was not associated with increased mortality in the previous cohort of patients having any surgical treatment for DSWI, nor in the current study of flap closure patients. However, delay of flap treatment was directly related to both increased mortality odds and increased resource use outcomes in the present study. This finding may argue against the likelihood that patients with flap delay are sicker and therefore have increased mortality. If patient stability were the sole cause of delayed flap reconstruction and increased

mortality, we would expect to see a similar relationship between delayed initial excisional debridement and higher mortality. However, this was not the case.

Previous single-center studies have advocated for immediate single-stage flap reconstruction in patients with DSWI (21, 24). In line with our findings, Cabbabe et al found that early debridement and bilateral pectoralis muscle flap reconstruction demonstrated a significant decrease in morbidity, mortality, and length of stay compared to patients with delayed reconstruction (24). However, many patients in the early treatment group in Cabbabe's study underwent reconstruction within 5 – 10 days of diagnosis of DSWI, often with referral to the plastic surgeon within 4 days of diagnosis. The findings of the current study suggest that mortality and resource use vary even within the first week of DSWI diagnosis and that patients may benefit from plastic surgery consultation and reconstruction as early as possible.

The current study has limitations inherent to any administrative data study. First, clinical information such as wound severity, size, and the number of excisional debridements needed before flap closure cannot be captured in the dataset. However, we would not expect these traits to be different between the flap timing groups. In addition, clinical factors that may increase complications related to the original cardiac surgery and risk for developing infection, such as timing of antibiotic administration, thermoregulation, or glycemic control are not available. However, we captured general complexity of the cardiac surgery and DSWI with creation of variables such as postoperative sepsis, reoperation for bleeding/need for transfusion, and hospital length of stay after the index cardiac surgery. These variables are validated in the models by demonstrating an expected increase in mortality and resource use. Furthermore, we cannot identify reasons for flap delay using this database, which could be systems-related or attributable to the medical stability of the patient. However, we used the initial operative debridement timing as a control variable to account for patients who started with delay of their initial surgical treatment to account for patients who may have been unstable for an early initial debridement. We hypothesize that some component of delay is related to provider or facility-level attributes, but these considerations were unable to be studied due to limitations of the dataset in not containing provider or facility variables. Lastly, the dataset does not capture uninsured patients and information about patient socioeconomic status, which may impact timing of treatment after DSWI and patient outcomes.

Despite these limitations, this study highlights the relationship between flap reconstruction delay and increased mortality and resource use. Given this relationship, there is a need to prospectively study flap timing in relation to important markers of clinical severity of sepsis and the wound conditions. Furthermore, comparative evaluation of patient outcomes between institutions with varying timing of closure would highlight the impact of systems-based factors. Providers must be cognizant of the potential impact of treatment variation on the quality of DSWI care. With greater financial burdens placed on hospitals due to lack of reimbursement for treatment of DSWI and bundled payment initiatives on the horizon, providers and health systems must seek to identify modifiable systems factors that lead to inefficient surgical care. Prompt involvement of reconstructive surgeons at the time of DSWI

diagnosis is one step that health systems may consider to reduce systems-based delays, with the potential of improving patient outcomes and resource utilization.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Results from this study were presented at a podium presentation at the 2016 Annual Meeting of the American Association of Plastic Surgeons (New York, NY).

Support for this study was provided in part by the grants from the Plastic Surgery Foundation (to Drs. Erika D. Sears and Jennifer F. Waljee), the Michigan Institute for Clinical and Health Research (to Drs. Adeyiza O. Momoh and Erika D. Sears), and the National Institute of Arthritis and Musculoskeletal and Skin Diseases of the National Institutes of Health under Award Number 2 K24-AR053120-06, a Midcareer Investigator Award in Patient-Oriented Research (to Dr. Kevin C. Chung). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. Dr. Waljee receives research funding from the Agency for Healthcare Research and Quality (K08 1K08HS023313-01), the American College of Surgeons, and the American Foundation for Surgery of the Hand.

References

1. Kaye AE, Kaye AJ, Pahk B, et al. Sternal wound reconstruction: management in different cardiac populations. *Ann Plast Surg*. 2010; 64:658–666. [PubMed: 20395796]
2. Atkins BZ, Onaitis MW, Hutcheson KA, et al. Does method of sternal repair influence long-term outcome of postoperative mediastinitis? *Am J Surg*. 2011; 202:565–567. [PubMed: 21924401]
3. Floros P, Sawhney R, Vrtik M, et al. Risk factors and management approach for deep sternal wound infection after cardiac surgery at a tertiary medical centre. *Heart Lung Circ*. 2011; 20:712–717. [PubMed: 21906999]
4. Graf K, Ott E, Vonberg RP, et al. Economic aspects of deep sternal wound infections. *Eur J Cardiothorac Surg*. 2010; 37:893–896. [PubMed: 19896860]
5. Kobayashi T, Mikamo A, Kurazumi H, et al. Secondary omental and pectoralis major double flap reconstruction following aggressive sternectomy for deep sternal wound infections after cardiac surgery. *J Cardiothorac Surg*. 2011; 6:56. [PubMed: 21501461]
6. Mauermann WJ, Sampathkumar P, Thompson RL. Sternal wound infections. *Best Pract Res Clin Anaesthesiol*. 2008; 22:423–436. [PubMed: 18831296]
7. Petzina R, Hoffmann J, Navasardyan A, et al. Negative pressure wound therapy for post-sternotomy mediastinitis reduces mortality rate and sternal re-infection rate compared to conventional treatment. *Eur J Cardiothorac Surg*. 2010; 38:110–113. [PubMed: 20171898]
8. Kubota H, Miyata H, Motomura N, et al. Deep sternal wound infection after cardiac surgery. *J Cardiothorac Surg*. 2013; 8:132. [PubMed: 23688324]
9. Speir AM, Kasirajan V, Barnett SD, et al. Additive costs of postoperative complications for isolated coronary artery bypass grafting patients in Virginia. *Ann Thorac Surg*. 2009; 88:40–45. discussion 45–46. [PubMed: 19559186]
10. Mokhtari A, Sjogren J, Nilsson J, et al. The cost of vacuum-assisted closure therapy in treatment of deep sternal wound infection. *Scand Cardiovasc J*. 2008; 42:85–89. [PubMed: 18273735]
11. Stone PW, Glied SA, McNair PD, et al. CMS changes in reimbursement for HAIs: setting a research agenda. *Medical care*. 2010; 48:433–439. [PubMed: 20351584]
12. McNair PD, Luft HS, Bindman AB. Medicare's policy not to pay for treating hospital-acquired conditions: the impact. *Health Aff (Millwood)*. 2009; 28:1485–1493. [PubMed: 19738267]
13. Edmiston CE, Spencer M, Lewis BD, et al. Reducing the risk of surgical site infections: did we really think SCIP was going to lead us to the promised land? *Surg Infect (Larchmt)*. 2011; 12:169–177. [PubMed: 21767147]

14. Stulberg JJ, Delaney CP, Neuhauser DV, et al. Adherence to surgical care improvement project measures and the association with postoperative infections. *JAMA*. 2010; 303:2479–2485. [PubMed: 20571014]
15. van Wingerden JJ, Lapid O, Boonstra PW, et al. Muscle flaps or omental flap in the management of deep sternal wound infection. *Interact Cardiovasc Thorac Surg*. 2011; 13:179–187. [PubMed: 21543366]
16. Athanassiadi K, Theakos N, Benakis G, et al. Omental transposition: the final solution for major sternal wound infection. *Asian Cardiovasc Thorac Ann*. 2007; 15:200–203. [PubMed: 17540987]
17. Jurkiewicz MJ, Bostwick J 3rd, Hester TR, et al. Infected median sternotomy wound. Successful treatment by muscle flaps. *Ann Surg*. 1980; 191:738–744. [PubMed: 7387236]
18. Jones G, Jurkiewicz MJ, Bostwick J, et al. Management of the infected median sternotomy wound with muscle flaps. The Emory 20-year experience. *Ann Surg*. 1997; 225:766–776. discussion 776–768. [PubMed: 9230817]
19. Castello JR, Centella T, Garro L, et al. Muscle flap reconstruction for the treatment of major sternal wound infections after cardiac surgery: a 10-year analysis. *Scand J Plast Reconstr Surg Hand Surg*. 1999; 33:17–24. [PubMed: 10207961]
20. Ivert T, Lindblom D, Sahni J, et al. Management of Deep Sternal Wound Infection After Cardiac Surgery—Hanuman Syndrome. *Scandinavian Journal of Thoracic and Cardiovascular Surgery*. 1991; 25:111–117. [PubMed: 1947904]
21. Ascherman JA, Patel SM, Malhotra SM, et al. Management of sternal wounds with bilateral pectoralis major myocutaneous advancement flaps in 114 consecutively treated patients: refinements in technique and outcomes analysis. *Plast Reconstr Surg*. 2004; 114:676–683. [PubMed: 15318045]
22. Engelman RM, Williams CD, Gouge TH, et al. Mediastinitis following open-heart surgery. Review of two years' experience. *Arch Surg*. 1973; 107:772–778. [PubMed: 4582921]
23. Sarr MG, Gott VL, Townsend TR. Mediastinal infection after cardiac surgery. *Ann Thorac Surg*. 1984; 38:415–423. [PubMed: 6385892]
24. Cabbabe EB, Cabbabe SW. Immediate versus delayed one-stage sternal debridement and pectoralis muscle flap reconstruction of deep sternal wound infections. *Plast Reconstr Surg*. 2009; 123:1490–1494. [PubMed: 19407620]
25. Wu L, Chung KC, Waljee JF, et al. A National Study of the Impact of Initial Debridement Timing on Outcomes for Patients with Deep Sternal Wound Infection. *Plast Reconstr Surg*. 2016; 137:414e–423e.
26. Aliu O, Diaz-Garcia RJ, Zhong L, et al. Mortality trends and the effects of debridement timing in the management of mediastinitis in the United States, 1998 to 2010. *Plast Reconstr Surg*. 2014; 134:457e–463e.
27. Ascherman JA, Hugo NE, Sultan MR, et al. Single-stage treatment of sternal wound complications in heart transplant recipients in whom pectoralis major myocutaneous advancement flaps were used. *J Thorac Cardiovasc Surg*. 1995; 110:1030–1036. [PubMed: 7475131]
28. Danielson E. White Paper: Health Research Data for the Real World: The Marketscan Databases. Truven Health Analytics. 2014
29. Peduzzi P, Concato J, Kemper E, et al. A simulation study of the number of events per variable in logistic regression analysis. *Journal of clinical epidemiology*. 1996; 49:1373–1379. [PubMed: 8970487]
30. Elixhauser A, Steiner C, Harris DR, et al. Comorbidity measures for use with administrative data. *Medical care*. 1998; 36:8–27. [PubMed: 9431328]
31. Peng CYJ, So TSH, Stage FK, et al. The use and interpretation of logistic regression in higher education journals: 1988–1999. *Research in Higher Education*. 2002; 43:259–293.
32. Sears ED, Burke JF, Davis MM, et al. The influence of procedure delay on resource use: a national study of patients with open tibial fracture. *Plast Reconstr Surg*. 2013; 131:553–563. [PubMed: 23142940]
33. Orosz GM, Magaziner J, Hannan EL, et al. Association of timing of surgery for hip fracture and patient outcomes. *JAMA*. 2004; 291:1738–1743. [PubMed: 15082701]

Figure 1.

Patient selection of cohort undergoing flap reconstruction after deep sternal wound infection. DSWI, deep sternal wound infection. Cardiac surgery includes coronary artery bypass graft surgery, open valve replacement/repair, and open thoracic aneurysm repair.

Figure 2. Adjusted mean probability of mortality based on flap timing after deep sternal wound infection diagnosis. Black lines represent 95% confidence intervals.

Figure 3. Adjusted mean number of procedures based on flap timing after deep sternal wound infection diagnosis. Black lines represent 95% confidence intervals.

Figure 4. Adjusted total hospital days based on flap timing after deep sternal wound infection diagnosis. Black lines represent 95% confidence intervals.

Table 1

Study Sample Characteristics Based on Timing of Flap Closure

Time between DSWI Diagnosis and Flap Closure						
	All Patients N=612	0 days N=143; 23%	1 – 3 days N=98; 16%	4 – 7 days N=132; 22%	>7 days N=239; 39%	P*
Demographic Characteristics						
Age, mean (SD)	61 (10)	61 (11)	61 (11)	62 (9)	61 (10)	0.877
Gender (%)						
Male	401 (66)	93 (65)	67 (68)	83 (63)	158 (66)	0.847
Female	211 (34)	50 (35)	31 (32)	49 (37)	81 (34)	
Risk Factors						
Number of comorbidities (%)						
0 – 2 comorbidities	81 (13)	24 (17)	16 (16)	10 (7)	31 (13)	0.223
3 – 6 comorbidities	322 (53)	73 (51)	49 (50)	80 (61)	120 (50)	
+7 comorbidities	209 (34)	46 (32)	33 (34)	42 (32)	88 (37)	
Sepsis after initial cardiac surgery (%)						
	78 (13)	12 (8)	11 (11)	12 (9)	43 (18)	0.017
Bleeding/transfusion after initial cardiac surgery (%)						
	156 (25)	28 (20)	29 (30)	26 (20)	73 (31)	0.029
LOS after initial cardiac surgery (%)						
1 – 7 days	175 (29)	40 (28)	31 (32)	38 (29)	66 (28)	0.008
8 – 14 days	154 (25)	34 (24)	20 (20)	49 (37)	51 (21)	
15 – 30 days	139 (23)	42 (29)	26 (27)	20 (15)	51 (21)	
31 – 60 days	80 (13)	18 (13)	11 (11)	16 (12)	35 (15)	
61+ days	64 (10)	9 (6)	10 (10)	9 (7)	36 (15)	
Timing of diagnosis of DSWI						
< 2 weeks from cardiac surgery	264 (43)	56 (39)	51 (52)	50 (38)	107 (45)	0.004
2 – 6 weeks from cardiac surgery	217 (35)	46 (32)	32 (33)	54 (41)	85 (36)	
>6 weeks – 3 months from cardiac surgery	81 (13)	17 (12)	12 (12)	18 (14)	34 (14)	
>3 months from cardiac surgery	50 (8)	24 (17)	3 (3)	10 (8)	13 (5)	

	Time between DSWI Diagnosis and Flap Closure					P*
	All Patients N=612	0 days N=143; 23%	1 – 3 days N=98; 16%	4 – 7 days N=132; 22%	>7 days N=239; 39%	
Treatment Characteristics						
Debridement timing (%)						
Same day of diagnosis	280 (46)	143 (100)	22 (22)	44 (33)	71 (30)	**
1 – 3 days after diagnosis	153 (25)	0 (0)	76 (78)	26 (20)	51 (21)	
4 – 7 days after diagnosis	79 (13)	0 (0)	0 (0)	62 (47)	17 (7)	
>7 days after diagnosis	100 (16)	0 (0)	0 (0)	0 (0)	100 (42)	
Use of negative pressure therapy (VAC) (%)	104 (17)	9 (6)	8 (8)	29 (22)	58 (24)	<0.001
Flap type (%)						
Muscle and/or fascia	554 (91)	134 (94)	90 (92)	121 (92)	209 (87)	0.296
Omentum only	25 (4)	6 (4)	2 (2)	4 (3)	13 (5)	
Omentum and muscle/fascia	33 (5)	3 (2)	6 (6)	7 (5)	17 (7)	

* P values represent comparisons between flap timing groups using one-way analysis of variance test for continuous variables and Chi-square or Fisher's exact test for categorical variables.

** Bivariate comparison for debridement timing and flap timing variables unable to be performed due to the number of cells containing zero frequency counts.

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Table 3

Multivariable Logistic Regression Model of Mortality Outcomes in Flap Reconstruction Patients (N=612)

	Odds Ratio	95% CI	P
Flap Timing			
Same day of diagnosis		Reference	
1 – 3 days after diagnosis	0.85	0.25 – 2.87	0.794
4 – 7 days after diagnosis	2.94	1.09 – 7.93	0.033
>7 days after diagnosis	2.75	1.15 – 6.59	0.023
Flap Type			
Muscle and/or fascia		Reference	
Omentum only	2.56	0.86 – 7.61	0.092
Omentum and muscle/fascia	1.45	0.53 – 3.98	0.470
Age			
18–44	0.85	0.22 – 3.36	0.811
45–54	0.40	0.15 – 1.05	0.062
55–64		Reference	
65–74	1.78	0.91 – 3.51	0.093
75+	2.23	1.04 – 4.77	0.039
Timing of Debridement			
Same day of diagnosis		Reference	
1 – 3 days after diagnosis	0.84	0.37 – 1.89	0.675
4 – 7 days after diagnosis	0.45	0.17 – 1.19	0.108
>7 days after diagnosis	0.49	0.21 – 1.16	0.103
Length After Initial Cardiac Surgery			
1 – 7 days		Reference	
8 – 14 days	1.43	0.56 – 3.63	0.455
15 – 30 days	2.13	0.85 – 5.34	0.108
31 – 60 days	5.30	2.15 – 13.08	<0.001
61+ days	5.79	2.31 – 14.51	<0.001
Number of Comorbidities			
0 – 2 comorbidities		Reference	
3 – 6 comorbidities	0.57	0.23 – 1.40	0.222
+7 comorbidities	1.54	0.65 – 3.66	0.330
Bleeding/Transfusion after Initial Cardiac Surgery	2.81	1.60 – 4.93	<0.001

Table 4

Incidence Rate Ratios (IRR) of Number of Procedures, Number of Admissions, and Total Hospital Day Outcomes Based on Flap Timing (N=514)[#]

Flap timing	Number of Procedures				Number of Admissions				Total Hospital Days			
	IRR	95% CI	P		IRR	95% CI	P		IRR	95% CI	P	
Same day of diagnosis		Reference				Reference				Reference		
1 – 3 days after diagnosis	1.21	0.94 – 1.55	0.132		1.04	0.77 – 1.41	0.797		1.15	1.08 – 1.22	<0.001	
4 – 7 days after diagnosis	1.72	1.38 – 2.16	<0.001		1.19	0.90 – 1.57	0.229		1.43	1.35 – 1.52	<0.001	
>7 days after diagnosis	1.93	1.58 – 2.35	<0.001		1.17	0.91 – 1.51	0.216		1.37	1.30 – 1.45	<0.001	

[#] Control variables include age, flap type, timing of initial debridement, use of negative pressure therapy, timing of diagnosis, length of stay during the cardiac surgery encounter, number of comorbidities, occurrence of sepsis or bleeding after cardiac surgery.