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# Rigid Sternal Fixation Versus Modified Wire Technique for Poststernotomy Closures

## A Retrospective Cost Analysis

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**Background:** Rigid sternal fixation (RSF) has been shown to reduce sternal wound complications in high-risk patients. However, the higher initial cost continues to deter its use. This study evaluates the cost of caring for high-risk sternotomy patients who underwent RSF compared with those who underwent sternal closure with a modified wire technique (MWT).

**Methods:** A retrospective single institution review of high-risk patients who underwent MWT (n = 45) and RSF (n = 30) for primary sternal closure from 2006 to 2009 was conducted. Total hospital cost, revenue, and net cost associated with surgery and subsequent care were analyzed.

**Results:** Overall rates of wound dehiscence and wound infections (superficial and deep) were higher in MWT patients (n = 14, 13, and 7, respectively) than RSF patients (n = 3, 2, and 0, respectively;  $P < 0.05$ ). Modified wire technique patients also required more operations (mean  $\pm$  SEM:  $0.4 \pm 0.1$  vs  $0.1 \pm 0.1$ ;  $P = 0.045$ ), and had longer follow-up time ( $55.0 \pm 9.1$  vs  $13.4 \pm 10.5$  days;  $P = 0.004$ ). Overall, the hospital suffered a greater loss caring for MWT patients (US \$18,903  $\pm$  2,160) than RSF patients (US \$8,935  $\pm$  2,647). Modified wire technique patients who developed a complication had higher costs associated with their operative hospitalization, outpatient care, and home health than RSF patients (total net loss: US \$41,436  $\pm$  7327 vs US \$10,612  $\pm$  4,258;  $P = 0.034$ ).

**Conclusions:** In high-risk patients, RSF is associated with lower rates of infections, including the “never event” mediastinitis, compared with MWT. Moreover, despite the initial higher cost, RSF affords an overall lower cost of care compared with MWT in patients at high-risk for developing sternal complications.

**Key Words:** sternotomy, rigid sternal fixation, wire cerclage, cost analysis

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Median sternotomy is the preferred incision for access to the mediastinum, with over one million sternotomies being performed annually worldwide. Although there have been numerous innovations to find the ideal sternal closure technique, there is no consensus how to reduce rates of mortality, morbidity, and shorter hospital stays in a cost-effective manner.<sup>1</sup> Wire cerclage introduced by Milton in 1897 as a method for primary sternal closure, providing a simple, rapid, and

inexpensive means of closing the sternum was later popularized by Julien and colleagues in 1957 and remains the most commonly used method for primary median sternotomy closure by cardiac surgeons today.<sup>2–4</sup> Although rare, with an incidence of 3.5%, poststernotomy wound complications, including dehiscence, mediastinitis, osteomyelitis, and sternal wound infections remain dreaded problems associated with higher morbidity, longer hospital stays, and an increased mortality of 15% to 22%.<sup>4–6</sup> Significant effort has been dedicated to the development of adjunct therapies to wire cerclage to help prevent poststernotomy wound complications including the use of retention sutures to reinforce skin closure, incisional negative pressure wound therapy, as well as modified wire techniques (MWTs), such as “figure-of-eight,” and Robicsek weaves to reinforce the sternal closure.<sup>7–11</sup> Unfortunately, none of these wire modifications have been proven to decrease the incidence of poststernotomy wound infections.<sup>9,12,13</sup>

Rigid plate fixation has been embraced by orthopedic, hand, maxillofacial and neurosurgeons for many years as a superior technique to wire fixation, affording greater stability and resulting in decreased incidences of nonunions, malunions, and infections.<sup>3,4,14–16</sup> Rigid sternal fixation (RSF) is a relatively novel technique in cardiac surgery, introduced just over a decade ago.<sup>4</sup> Studies performed in cadavers have shown that sterna closed with rigid sternal plates have greater resistance to force and less lateral movement than sterna closed with wire cerclage.<sup>17,18</sup> Additionally, RSF affords greater sternal stability and has been shown to decrease the incidence of mediastinitis in high-risk patients.<sup>4,15,19</sup> A prospective multicenter randomized controlled study in patients deemed high risk for the development of sternal wound complications found that RSF resulted in significantly higher rates of sternal union and bone healing based on computed tomography at both 3 and 6 months. In addition, this study found that RSF resulted in lower rates of postoperative pain compared with wire cerclage with decreased narcotic usage in RSF patients.<sup>3</sup>

Despite evidence that rigid plate fixation of the sternum is superior, cardiac surgeons continue to embrace traditional wire cerclage and MWTs for primary sternal closure.<sup>3</sup> A large component for the hesitation in adopting RSF is hypothesized to be cost with wire cerclage costing US \$16 to US \$41 per 10 m of wire compared with US \$2000 to US \$2500 for 3 titanium plates and screws used for RSF.<sup>3</sup> In addition, some cardiac surgeons believe that their MWTs perform comparably to more costly plate fixation. Although cardiac surgeons understand that deep surgical chest infections after coronary artery bypass grafting cost an additional US \$20,000 in hospital costs compared with those without surgical infections, questions remain.<sup>6</sup> Will RSF perform significantly better than MWTs to justify their higher initial costs and result in lower cost of care? To answer these questions, our study retrospectively reviewed our single-institution experience with MWT and RSF in high-risk sternotomy patients and their associated cost of care.

## METHODS

After IRB approval was obtained, a single-institution retrospective chart review of high-risk sternotomy patients from 2006 to 2009 was conducted. Patient data were retrieved from the University of California, Davis Cardiothoracic Surgery database and electronic medical record, including age, sex, body mass index, and the presence

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of any traditional preoperative risk factors: obesity (body mass index  $\geq 30$  mg/kg<sup>2</sup>), diabetes mellitus, chronic obstructive pulmonary disorder (COPD), renal failure with or without dialysis, and chronic immunosuppression. High-risk patients were determined by the presence of 3 or more these risk factors.<sup>5,20</sup> Patients were included in this analysis if sternal closure was performed by rigid fixation of the sternum or any form of wire closure altered from the standard intercostal cerclage method, that is, MWT. Patients who underwent salvage RSF were excluded from this study.

All patients received preoperative antibiotics within 30 minutes of incision, consisting of either cefazolin intravenous or another antibiotic at the discretion of the operating surgeon for  $\beta$ -lactam allergic individuals. In cases lasting greater than 4 hours, cefazolin was redosed. All patients had preoperative hair clipping with an electric clipper, and preoperative surgical skin preparation was performed with either 7.5% betadine solution or 2.5% chlorhexidine gluconate with 70% isopropyl alcohol solution. During the operation, the presence of any traditional intraoperative risk factors for poststernotomy wound complications were noted: off midline sternotomies, cardiac bypass time greater than 2 hours, or any transverse sternal fractures. The use of a MWT was also noted including retention sutures, wire cerclage in a figure-eight configuration, or use of a modified Robicsek weave.

Patients were followed up clinically in the hospital and outpatient settings by the cardiac surgical team. Clinical outcomes evaluated included the incidence of any poststernotomy wound complications (sternal instability, wound dehiscence, superficial wound infection, and deep wound infection), length of hospital stay, follow-up time including outpatient care, and 90-day mortality. For patients who developed a poststernotomy wound complication, the number of additional operations (including reconstructive flaps), and hospitalizations, and use of negative pressure wound therapy (V.A.C. Therapy, Kinetics Concepts, Inc., San Antonio, TX) were also noted.

Cost data provided by the Institutional Finance Department included total hospital revenue and total hospital cost (direct and indirect) for all hospitalizations (operative and subsequent), outpatient visits, and home health aid for wound care accumulated for the care of a patient as a result of their surgery and/or poststernotomy wound complications. The total net hospital loss or profit was calculated from the total hospital cost and the total hospital revenue received.

### Statistical Analysis

Descriptive univariate analysis was performed using the Student *t* test and the 2-sided Fisher exact test. All continuous variables were

expressed as mean  $\pm$  standard error of the mean. A *P* value less than 0.05 was considered to be statistically significant.

## RESULTS

Over the 4-year period of this study, 1057 patients underwent a median sternotomy at our institution. Of these patients, 273 (25.8%) fulfilled the traditional criteria (or having 3 more risk factors as stated above) of being high-risk for poststernotomy wound infections, but only 45 (4.3%) of these patients actually received a MWT for primary sternal closure, and 30 (2.8%) high-risk patients received RSF. Three patients had a MWT complicated by a poststernotomy wound complication, and later received RSF as a salvage procedure. They were included in the MWT arm, but excluded from the RSF arm of the study. Patient demographics are detailed in Table 1. Overall, both cohorts were equally matched in risk factors for poststernotomy wound complications (*P* > 0.05).

### Clinical Outcomes

Clinical outcomes are summarized in Table 2. The overall incidence of poststernotomy wound complications was 28% in this high-risk patient population, 16 (35.6%) MWT patients versus 5 (16.7%) RSF patients, *P* = 0.115. There was a significant difference in the number of wound complications with MWT patients having greater rates of wound dehiscence (14, 31%), as well as superficial (13, 29%), and deep infections (7, 15.6%) compared with RSF patients (3, 10.0%; 2, 6.7%; and 0, 0%; *P* = 0.04, 0.02 and 0.04, respectively). The use of outpatient negative pressure wound therapy was higher in the MWT group (11, 24.4%) and RSF (2, 6.7%), trending toward statistical significance (*P* = 0.063). The number of additional operations was greater in MWT patients ( $0.4 \pm 0.1$ ) than RSF patients ( $0.1 \pm 0.1$ , *P* = 0.045). Additionally, MWT patients had an overall longer follow-up time ( $55 \pm 9.1$  days), after their initial surgery than RSF patients ( $13.4 \pm 10.5$ , *P* = 0.004). Furthermore, when we looked at the type of coronary artery bypass grafting that patients received including internal mammary artery harvesting versus saphenous vein grafting only, we found that 13 (43%) of the RSF patients and 31 (69%) of the MWT patients had internal mammary artery harvesting. Of note, no patients had bilateral internal mammary harvesting. Of these patients 1 patient (7.7%) in the RSF group and 4 patients (12.9%) in the MWT group had sternal dehiscence. Internal mammary artery harvesting was found to be not statistically significant as a cause for sternal dehiscence in either group with *P* value of 0.294 in the MWT group and 1.0 in the RSF group.

**TABLE 1.** Demographic and Intraoperative Risk Factors

	Modified Wire Technique, N = 45	Rigid Sternal Fixation, N = 30	<i>P</i>
Age (mean $\pm$ SEM), y	64 $\pm$ 1.7	59.6 $\pm$ 2.2	0.113
Female sex, n (%)	30 (66.7%)	15 (50.0%)	0.160
BMI (mean $\pm$ SEM), kg/m <sup>2</sup>	36.0 $\pm$ 1.1	33.9 $\pm$ 1.6	0.264
Diabetes mellitus, n (%)	36 (80.0%)	19 (63.3%)	0.121
Chronic obstructive pulmonary disease, n (%)	13 (28.9%)	7 (23.3%)	0.436
Renal failure, n (%)	8 (17.8%)	5 (16.7%)	1.000
Chronic immunosuppression, n (%)	0 (0%)	2 (6.7%)	0.157
Off midline sternotomies, n (%)	1 (2.2%)	4 (13.3%)	0.151
Cardiac bypass time >2 h, n (%)	43 (95.6%)	29 (96.7%)	0.129
Transverse sternal fractures, n (%)	8 (17.8%)	9 (30.0%)	0.265

Patient demographics and intraoperative risk factors between the 2 cohorts, Modified Wire Technique (N = 45) and Rigid Sternal Fixation (N = 30).

BMI, body mass index.

**TABLE 2.** Clinical Outcomes

	Modified Wire Technique, N = 45	Rigid Sternal Fixation, N = 30	P
Any poststernotomy wound complication n, (%)	16 (35.6%)	5 (16.7%)	0.115
Sternal instability, n (%)	4 (9%)	1 (0.03%)	0.642
Wound dehiscence, n (%)	14 (31.0%)	3 (10.0%)	0.048
Superficial infection, n (%)	13 (29.0%)	2 (6.7%)	0.020
Deep wound infection, n (%)	7 (15.6%)	0 (0%)	0.016
90 d Mortality, n (%)	5 (11.0%)	1(3.0%)	0.392
Length of hospital stay (mean ± SEM), d	21.0 ± 4.3	11.7 ± 1.9	0.095
Follow-up time after surgery (mean ± SEM), d	55.0 ± 9.1	13.4 ± 10.5	0.004
No. hospitalizations (n, mean ± SEM)	1.3 ± 0.2	1.2 ± 0.1	0.700
Negative pressure wound therapy, n (%)	11 (24.4%)	2 (6.7%)	0.063
No. additional operations (n, mean ± SEM)	0.4 ± 0.1	0.10 ± 0.1	0.045
No. reconstructive flaps	4 (8.9%)	0 (0%)	0.145

Clinical outcomes between the 2 cohorts, Modified Wire Technique and Rigid Sternal Fixation. “n” is the number of patients the complication was present. P value less than 0.05 is significant.

**Cost Analysis**

**All Patients**

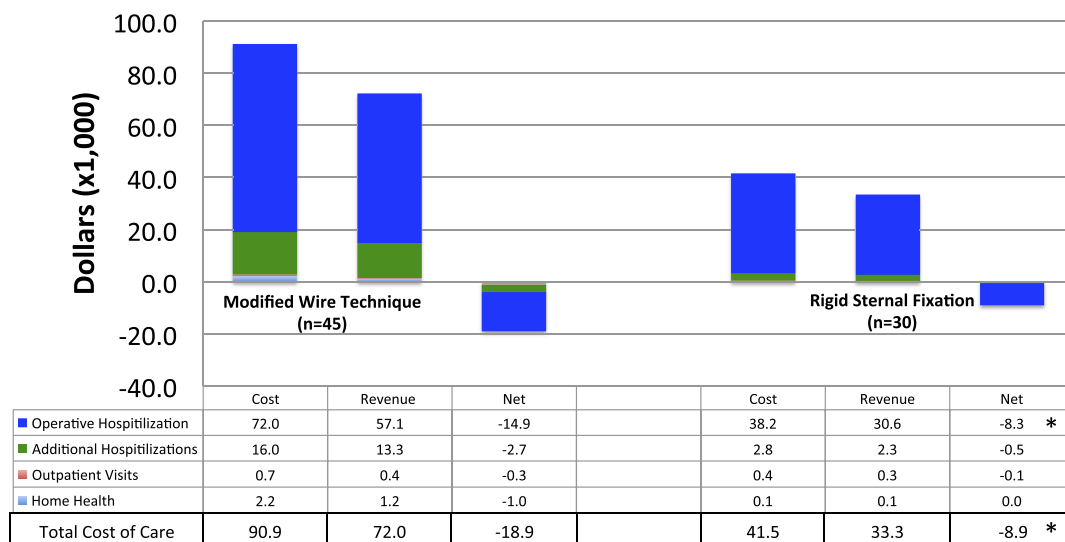
The itemized hospital cost, revenue received, and calculated net profit or loss for all high-risk sternotomy patients is summarized in Figure 1. Most of the cost of care for all patients is accounted for in the operative hospitalization. Modified wire technique patients had greater net negative costs (US \$14,925 ± 1486) associated with their operative hospitalization compared with RSF patients (US \$8309 ± 1927, P = 0.008). On average, the net loss for the total cost of care was US \$18,903 ± 2160 (range, -US \$221,509 to US \$37,025) for MWT patients compared with RSF patients with a net

calculated loss of US \$8935 ± 2647 (range, -US \$60,040 to \$89,411; P < 0.001).

**Patients Without Poststernotomy Wound Complications**

The itemized hospital cost, revenue received, and calculated net profit or loss stratified for high-risk sternotomy patients who did not develop a poststernotomy wound complication is summarized in Figure 2. After total revenue was collected and all hospital costs are deducted, there was no significant difference in net loss between MWT patients (US \$9887 ± 2331) than the RSF patients (US \$5466 ± 5315; P = 0.428). Of note, the net loss is greater in the MWT group than the

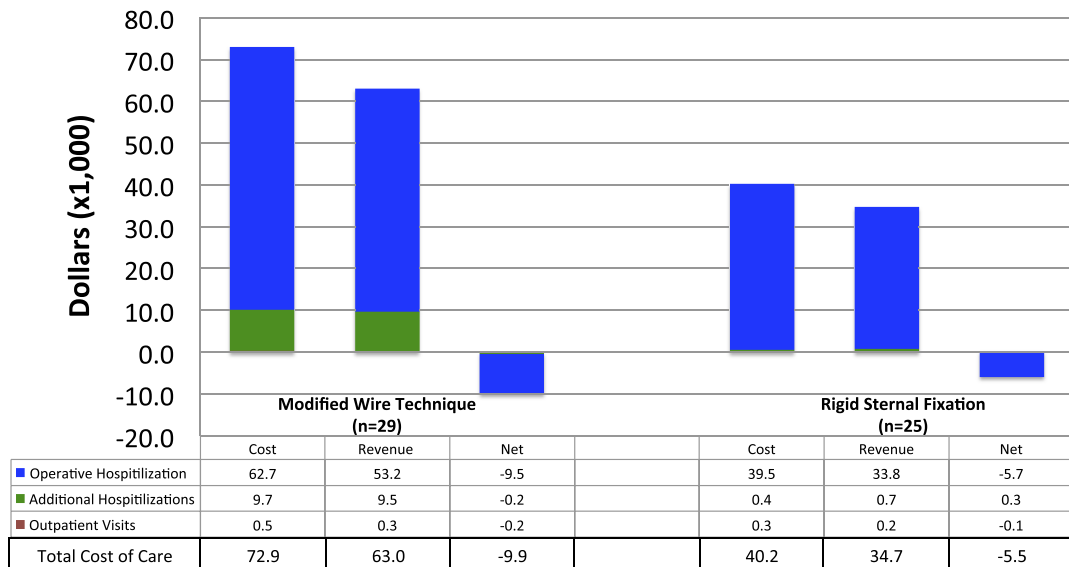
**Mean Cost of Care of All High-Risk Sternotomy Patients**



\* P-value <0.05

**FIGURE 1.** Bar graph depicting the mean cost of care of all high-risk sternotomy patients comparing the Modified Wire Technique cohort (N = 45) and the Rigid Sternal Fixation cohort (N = 30). Cost is itemized into the operative hospitalization, additional hospitalizations, outpatient visits, and home health for each cohort. The net values were compared between each group with a P value less than 0.05 as significant.

### Mean Cost of Care of High-Risk Sternotomy Patients Without Post-Sternotomy Wound Complications

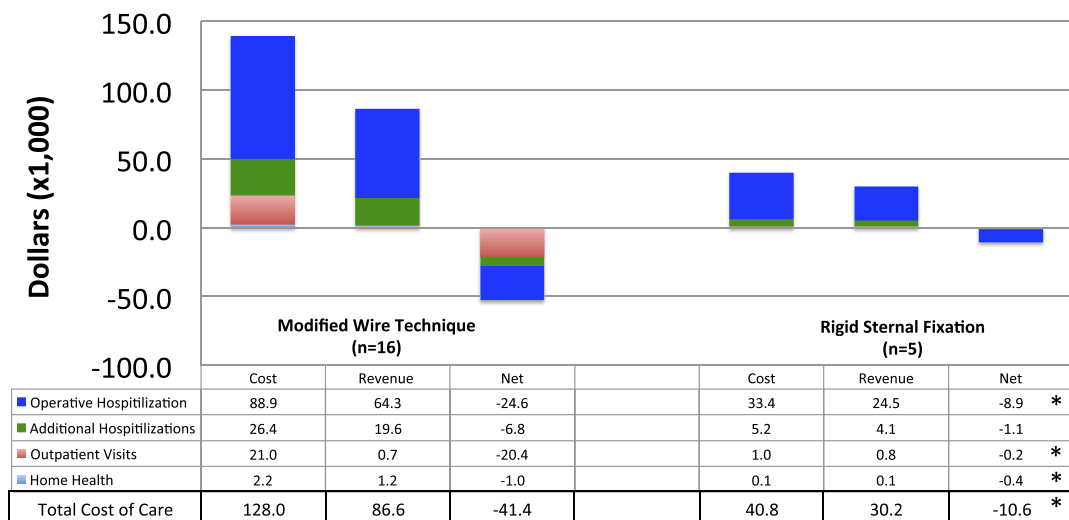


**FIGURE 2.** Bar graph depicting the mean cost of care for high-risk sternotomy patients without poststernotomy wound complications comparing the Modified Wire Technique cohort (N = 29) and the Rigid Sternal Fixation cohort (N = 25). Cost is itemized into the operative hospitalization, additional hospitalizations, and outpatient care for each group. The net values were compared between each group with P value less than 0.05 as significant.

RSF group even when there are no complications. Further analysis was completed looking specifically at the 2 groups without postoperative complications. The number of risk factors in the 2 groups were matched

at an average of 3.4 risk factors for MWT patients and 3.7 risk factors for RSF patients. Additionally, the median length of stay (LOS) and the intensive care unit LOS (ICU LOS) were found for each group

### Mean Cost of Care of High-Risk Sternotomy Patients With Post-Sternotomy Wound Complications



\* P-value <0.05

**FIGURE 3.** Bar graph depicting the mean cost of care for high risk sternotomy patients with poststernotomy wound complications comparing the Modified Wire Technique cohort (N = 16) and the Rigid Sternal Fixation cohort (N = 5). Cost is itemized into the operative hospitalization, additional hospitalizations and outpatient care for each group. The net values were compared between each group with P value less than 0.05 as significant.

without complications. The median LOS for MWT group was 9 days, and the median LOS for the RSF group was 8 days. There was no statistical difference between these 2 groups for LOS with a  $P$  value of 0.430. Furthermore, the median ICU LOS for MWT group was 5.5 days, and for the RSF group, 4 days. Again, findings were not statistically significant with a  $P$  value of 0.358. Most likely the reason why the RSF group had a smaller net loss than the MWT group, when there were no postoperative complications, was due to a longer LOS secondary to increased pain as well as a longer ICU LOS for the MWT group. This, however, is likely not reflected in our data due to our very small sample size. These findings have been corroborated in other studies with larger sample sizes including results that RSF patients have shorter median hospital stays, shorter intubation times, quicker postoperative recovery and less postoperative pain compared to patients with wire cerclage closures.<sup>3,15</sup>

### Patients With Poststernotomy Wound Complications

The itemized cost of care stratified for high-risk sternotomy patients who developed a poststernotomy wound complication is summarized in Figure 3. The total net cost of care was greater for MWT patients (US \$41,436 ± 7327) than RSF patients (US \$10,612 ± 4258;  $P = 0.034$ ). A calculated greater net loss from the operative hospitalization was noted in the MWT patients (US \$24,450 ± 2283) than the RSF patients (US \$8872 ± 3889;  $P = 0.003$ ).

When evaluating outpatient care for MWT versus the RSF groups, MWT (US \$20,352 ± 14,352) patients accumulated a greater net loss for outpatient care visits compared with their RSF counterparts RSF (US \$187 ± 52;  $P < 0.001$ ).

Of the patients who developed poststernotomy wound complications, 11 (24.4%) MWT and 2 (6.7%) RSF ( $P = 0.063$ ) patients required negative pressure wound therapy in the outpatient setting. Modified wire technique had greater net costs associated with home health assistance (US \$1092 ± 526) than RSF patients (US \$442 ± 179;  $P = 0.004$ ).

The total cost of care stratified per complication for each cohort is summarized in Table 3. Seven MWT patients developed multiple poststernotomy complications including sternal dehiscence and deep wound infections for a total of 20 complications in this cohort. One RSF patient developed more than 1 complication for a total of 6 complications for this cohort. Subsequently, on average, the hospital had a calculated net loss of US \$41,436 ± 7327 for each complication that an MWT patient developed compared with US \$10,612 ± 4,258 ( $P = 0.034$ ) for each complication that an RSF patient developed, a difference of US \$30,824.

## DISCUSSION

Despite multiple studies showing RSF is a superior technique to traditional wire cerclage in preventing poststernotomy wound complications in high-risk sternotomy patients, the technique has not been embraced by cardiac surgeons in large part due to the upfront costs of titanium plates and screws.<sup>3,4,15,16</sup> In this study, we performed a thorough retrospective cost analysis of the total cost of care for each

high-risk patient who underwent RSF and compared it with each high-risk patient who underwent an MWT. We not only focused on the operative costs of surgery but also the management and cost of care of any subsequent poststernotomy wound complication.

We report a poststernotomy wound complication rate of 28% in a subset of high-risk sternotomy patients that comprised only 7.1% of all of our median sternotomy patients, selecting for patients at *highest* risk (3 or more risk factors) for the development of poststernotomy complications. Our infection rates found in RSF patients are comparable to those in Song's study. Similar to our study, patients were defined as high-risk if they had 3 or more established historical risk factors, including COPD, renal failure, diabetes, obesity or immunosuppression. This group was matched to a high-risk group of patients who underwent wire cerclage closure, with 14.8% ( $n = 28$ ) of these patients developing mediastinitis. This is very similar to our MWT mediastinitis rate of 15.6% ( $n = 7$ ). Furthermore, like Song's study, our study also found a mediastinitis rate of 0% in RSF patients.

The high-risk nature of these patients is further confirmed by their high cost of care. Our data show that the hospital suffers a net loss in caring for these patients, even in those that do not develop poststernotomy complications. This is potentially due to the additional needs of patients with comorbidities, such as insulin therapy and monitoring for diabetes patients or potentially longer intubation periods with closer monitoring for COPD patients. These specificities cannot be teased out from the finance data. We believe this is reflective of the significant comorbidities present within these patients that can independently affect postoperative care and costs. The cost of care for this subset of very high-risk median sternotomy patients in our study is not reflective of the care of the other 93% of median sternotomy patients.

Like previously published series, the results of our study show high-risk sternotomy patients, or patients at higher risk for post sternotomy complications, can benefit from RSF over wire cerclage closure.<sup>14</sup> The hospital can reduce the cost of postoperative complications by treating patients with RSF instead of wire techniques. The greatest contribution to this decreased cost is in the initial operative hospitalization. On average, the hospital can save approximately US \$9000 per patient by using RSF at the initial operative hospitalization. This reduction in cost is likely reflective of the higher incidence of deep wound infections in MWT patients requiring additional operations, such as flap reconstruction (4 of 7 patients).

Furthermore, although there was no significant difference in the costs for additional hospitalizations, outpatient care, and home health assistance for the 2 cohorts overall, when stratified for patients who developed a poststernotomy complication, MWT patients did have higher costs for outpatient care and home health assistance. This is consistent with our finding that MWT patients have a longer follow-up period after surgery than their RSF counterparts. Our data demonstrate that RSF results in lower complication rates than MWT and when complications did occur in the RSF cohort they were less complex (superficial infections, 6.7%, as opposed to deep infections, eg, mediastinitis, 0%) than those that developed in the MWT (29.0% and 15.6%) cohort, thus more amenable to local wound care therapies. The lack of difference in costs between the 2 groups (Fig. 2) may be due to our small sample size. However, the differences noted when stratified for postoperative complications speaks to the high-risk target population of our study, reminding that high-risk populations such as these benefit most from RSF.

For patients who developed poststernotomy wound complications, our study shows that an MWT complication is approximately US \$77,000 more expensive in direct and indirect costs than a RSF complication without much revenue gain. Ultimately, it costs the hospital US \$33,000 more to care for a complication after an MWT than after RSF. The cost of care for a poststernotomy wound complication is even more relevant because mediastinitis is now classified as a preventable, nonreimbursable "never event" by Medicare.<sup>21</sup> The difference in cost

**TABLE 3.** Cost Per Complication

	Modified Wire Technique, N = 20	Rigid Sternal Fixation, N = 6
Revenue	US \$65,812	US \$21,194
Cost	US \$106,798	US \$29,483
Net profit/loss	−US \$40,986	−US \$8,289

The total cost of care stratified per complication for each cohort (MWT N = 20 versus RSF N = 6) with calculated net loss per technique.

between RSF and MWT in patients who did develop poststernotomy wound complications was statistically significant with regard to their operative hospitalization, outpatient visits, home health, and the total cost of care (Fig. 3). This small subset of high-risk patients ultimately increases the net loss to the hospital, a loss that could be decreased by plating this patient population. Although there is increased revenue associated with care of MWT patient complications, the hospital suffers a greater net loss overall compared with RSF patients, despite the higher initial cost of their plates. Although hospital LOS was not statistically different between the MWT ( $21.0 \pm 4.3$  days) and RSF ( $11.7 \pm 1.9$  days), it did trend toward significance ( $P = 0.095$ ) and perhaps with greater numbers, this might have been significant. Moreover, an increased LOS increases hospital costs.

We acknowledge limitations of our study due to its retrospective nature. However, all but 1 study to date evaluating postoperative complications between RSF versus wire cerclage are retrospective.<sup>3</sup> Although our patient numbers may be considered small, especially given the overall rare incidence of poststernotomy infections, we focused on a very high-risk population, demonstrating significant differences in complication rates between the MWT and RSF groups. Furthermore, our 2 patient cohorts have no statistically significant differences and are similarly matched in traditional risk factors for poststernotomy wound complications. This smaller subpopulation of very high-risk patients is the group with the most to benefit from RSF.

Our cost analysis is also limited by the data that our finance department is able to provide. Although we could exclude additional hospitalizations, outpatient visits, and outpatient wound care therapy for other complications aside from poststernotomy wound complication, such as saphenous vein harvest site wounds, we could not itemize the costs of the initial operative hospitalization. Thus, it is possible the operative hospitalization data could contain costs pertaining to other wound complications. However, poststernotomy wound complications tend to be much more severe, morbid, and costly than all other complications occurring after sternotomy. For example, leg infections after greater saphenous vein harvest are generally amenable to antibiotics and local wound care, thus contributing little to overall costs of the initial operative hospitalization.

There are differing views on figure-of-eight sternal closures versus simple or interrupted sternal wire closure. Figure-of-eight suturing is thought to redistribute shearing forces better than simple cerclage and thus less likely to cut the sternum.<sup>11</sup> A review by Khasati et al showed no difference in outcomes between figure-of-eight wire closures versus simple wire techniques.<sup>8</sup> Although some cardiothoracic surgeons use figure-of-eight wires routinely, we included this in our group of MWT because it differed from the traditional single simple wire placed in the peristernal location. Traditional wire cerclage technique as defined in Raman et al's prospective randomized multicenter trial as well as Song et al's was simple peristernal cerclage. Thus, any alteration from this definition is considered a MWT by these authors.<sup>3,4</sup>

New less expensive sternal fixation devices have entered the market with greater ease of application for cardiac surgeons than plates and screws. One such device, the sternal ZipFix (ZF), is a biocompatible poly-ether-ether-ketone cable-tie or band that encircles the sternum through an intercostal space, providing broader peristernal implant-to-bone contact than wire, better distributing force making it less likely to cut through the bone. The ZF system has comparable postoperative infection rates to wire cerclage closures; however, it is faster and easier to use than both plates and wire cerclage.<sup>22,23</sup> Although the ZF system is 5 to 8 times more expensive than conventional wires, it is expected to decrease with time and is still substantially less expensive than plates.<sup>23</sup> A study comparing total hospital costs between the ZF, sternal plating, and wire cerclage closure at our institution is planned, evaluating the potential cost effectiveness of the ZF system.

Poststernotomy wound complications, including mediastinitis, are highly morbid and costly. Our review confirms that RSF significantly decreases the incidence of mediastinitis in high-risk sternotomy patients when compared with various MWTs. We have also shown that despite higher initial costs compared to wires, RSF is the more cost-effective technique in this high-risk patient population and should be strongly considered in the treatment of these challenging and costly patients.

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