The SternaLock Blu Study

Sternal Closure Using Rigid Plate Fixation versus Conventional Wire Cerclage: Results from a Prospective, Randomized Multi-Center Study

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Introduction

Rigid fixation is the standard of care in all other specialties for the treatment of fractures and osteotomies except for the closure of sternotomies. Over the last decade, Zimmer Biomet has partnered with cardiothoracic surgeons to design and execute clinical studies focused on evaluating the clinical benefits of rigid plate fixation of the sternum (Figure 1). This research has shown improved sternal healing and lower post-operative pain is associated with rigid plate fixation with SternaLock compared to wire cerclage. Patients at high risk for sternal complications experienced:

- Nearly 3x more patients with sternal union at 6 months with SternaLock[1]
- 25% lower pain and narcotics use during hospitalization with SternaLock[1]

Despite this, wire cerclage remains the primary method of sternal closure due to a perceived low sternal complication rate and the low cost of wires. However, traditional 30-day outcome monitoring may contribute to an underreporting of sternal complications; leading to the current perception that wire cerclage is sufficient. As reimbursement transitions from a fee-for-service payment system toward value-based and risk sharing models, the length of outcome tracking will shift focus from 30 days to 90 or even 180 days; bolstering the importance of providing optimal patient care in a cost effective manner.

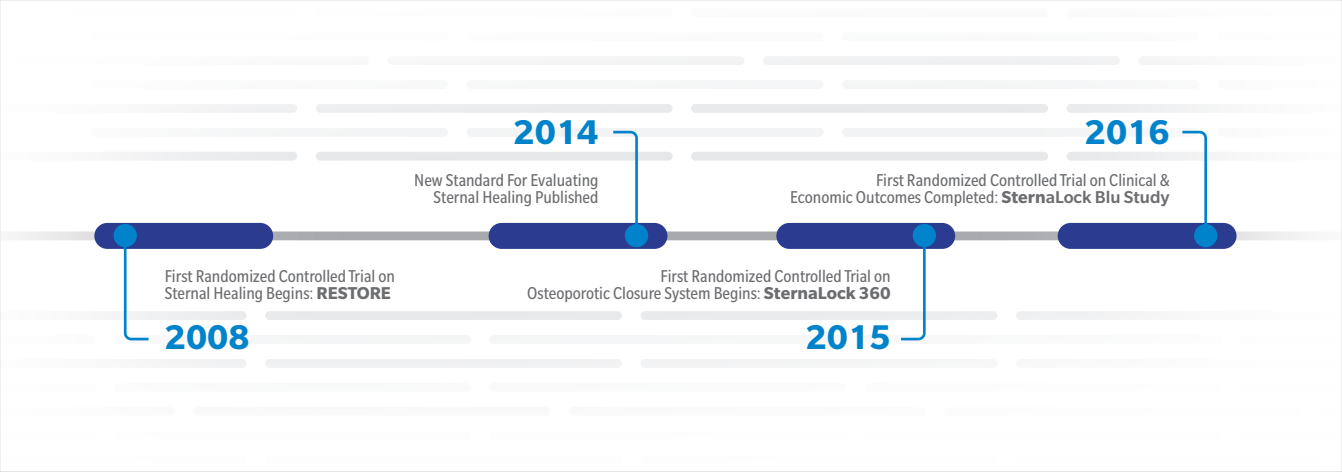


Figure 1. The SternaLock Blu study is Zimmer Biomet's latest scientific investigation, partnering with leading surgeons to further the understanding of the benefits of sternal closure with rigid plate fixation.

Objective

The objective of the SternaLock Blu study was to evaluate sternal healing, sternal complications, and health economic benefits of SternaLock Blu in patients undergoing elective cardiac surgery.[2, 3]

Study Design

This prospective, randomized, single-blinded, multi-center trial enrolled 236 patients undergoing elective cardiac surgery at 12 US centers between March 2013 and June 2015 (Figure 2). The study was sponsored by Zimmer Biomet and registered on clinicaltrials.gov (NCT01783483).

Patients were randomized (1:1) to sternal closure with either SternaLock Blu or wire cerclage. Patients randomized to SternaLock Blu received one plate on the manubrium and two "X" plates on the sternal body. Sternal closure with wire cerclage was pre-specified to require a minimum of 6 stainless steel wires per institutional/surgeon preference to allow for various wiring configurations.

The primary outcome measure was assessment of sternal healing by CT scans. Secondary outcomes included complications and an evaluation of overall costs at 3 and 6 months.

Study Design

Prospective, Randomized Controlled Trial

12 US Centers | 236 Patients

Median Sternotomy | **Elective Cardiac Surgery**

Inclusion

- ≥ 18 years
- < 40 BMI

Exclusion

- End Stage Renal Failure on Dialysis
- Severe COPD
- Pre-operative Narcotics
- Chronic Steroids
- Biologics Acting as Immunosuppressants
- Active Infection
- Emergent/Salvage Cardiac Acuity
- NYHA Class IV Heart Failure

Patients Blinded and Randomized at Time of Sternal Closure

SternaLock Blu 116 Patients

Plating configuration pre-specified using 3 sternal plates (1 manubrium, 2 sternal body)
Manubrium: (1) L, JL, Box or Hex plate
Body: (2) X plates

Wire Cerclage 120 Patients

Wiring configuration per institutional preference using a minimum of 6 wires

Follow-up

Hospital Index Admission: Baseline & Postoperative • Post-discharge: 3 weeks, 6 weeks, 3 months, & 6 months

Primary Endpoint: Sternal healing via CT scan at a radiology core lab

Secondary Endpoints: Sternal Complications, Health Economics core lab analysis

Figure 2. 236 patients undergoing elective cardiac surgery were randomized at 12 U.S. centers to sternal closure with SternaLock Blu or wire cerclage and evaluated for sternal healing, sternal complications, and health economics over 6 months.

Patient Demographics & Risk Factors for Sternal Complications

Demographic data and intraoperative variables were recorded for all patients and are presented in Table 1. Patient groups were well matched with no significant differences in demographics or risk factors for sternal complications. Although this study enrolled patients undergoing elective cardiac surgery, many presented with known sternal complication risk factors. Intraoperative variables and surgical procedures were also similar between the SternaLock Blu and wire cerclage treatment groups. Sternal closure time with SternaLock Blu was on average 2.6 minutes longer than wire cerclage (p=0.03).

Table1. Patient demographics, sternal complication risk factors, and procedure variables showed similarities between patient groups. SternaLock Blu sternal closure time was 2.6 minutes longer than wire cerclage.

	STERNALOCK® BLU	WIRE CERCLAGE	*P*-value
DEMOGRAPHICS			
Mean Age (yrs)	65.3 ± 13.0	65.7 ± 11.4	0.8
Gender Distribution (Male)	86 (74.1%)	91 (75.8%)	0.8
Height (cm)	172.2 ± 9.8	172.7 ± 9.9	0.6
Weight (kg)	85.6 ± 17.6	88.2 ± 16.5	0.2
BMI	28.8 ± 4.7	29.4 ± 4.6	0.3
Race (White)	103 (88.8%)	102 (85.7%)	0.5
Hypertension	86 (74.1%)	83 (69.2%)	0.4
Peripheral Artery Disease	12 (10.3%)	5 (4.2%)	0.1
Cerebrovascular Disease	10 (8.6%)	7 (5.8%)	0.4
RISK FACTORS FOR STERNAL COMPLICATIONS			
Diabetes	35 (30.2%)	44 (36.7%)	0.3
BMI ≥33	26 (22.4%)	29 (24.2%)	0.8
Chronic Lung Disease	22 (19.0%)	22 (18.3%)	0.6
Current Tobacco Use	14 (12.1%)	10 (8.3%)	0.3
Renal Failure	0 (0%)	2 (1.7%)	0.2
BIMA	7 (6.0%)	4 (3.4%)	0.4
Previous Sternotomy	8 (6.9%)	5 (4.2%)	0.4
INTRAOPERATIVE VARIABLES			
Isolated CABG	56 (48.3%)	57 (47.9%)	1.0
Isolated Valve	33 (28.5%)	33 (27.7%)	0.9
CABG/Valve	25 (21.6%)	28 (23.5%)	0.7
Mean # Bypass Grafts	2.7 ± 1.1	2.9 ± 1.1	0.4
Operative Time (hrs)	5.6 ± 1.8	5.6 ± 1.4	1.0
Sternal Closure Time (min)	18.9 ± 9.0	16.3 ± 9.3	0.03

Improved Sternal Healing

Sternal Healing Methodology

Three and 6 month CT scans were evaluated for sternal healing at a core radiographic laboratory according to a validated methodology using three independent radiologists.[4] Five *a priori* anatomic locations were selected by a radiologist for scoring. Two independent radiologists then scored the slices for sternal healing on a 6-point scale ranging from nonunion (0) to complete synthesis (5) as shown in Figure 3. Bias was minimized by attempting to choose slices that did not reveal the method of sternal closure. Sternal healing outcomes included two measures, CT Score and Sternal Union Rate. CT Score is the average score across all five locations for each patient in each treatment group. Sternal Union Rate is reported as the percentage of each treatment group with sternal union, where a sternal union is defined as a patient having an average healing score ≥3.

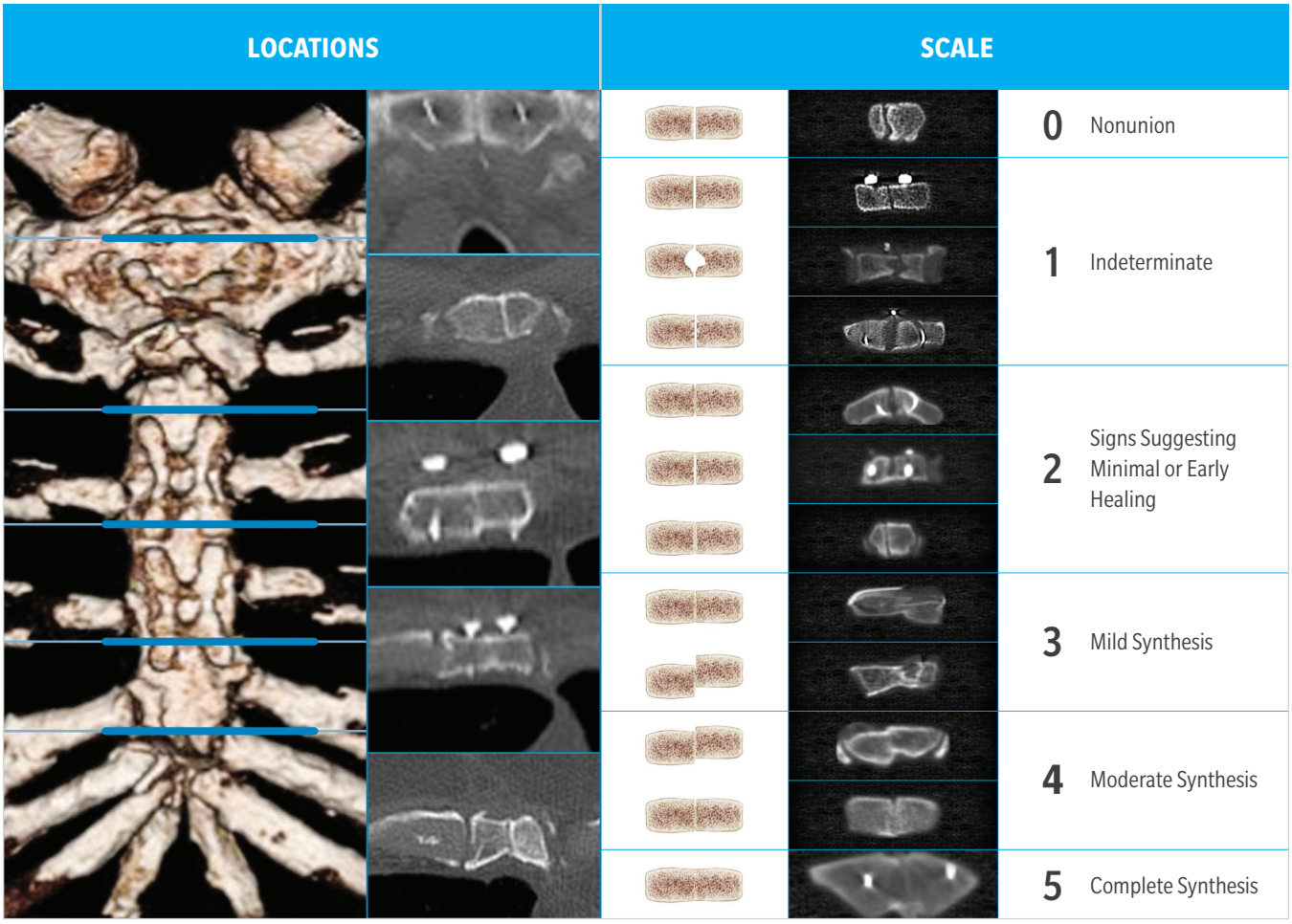


Figure 3. Sternal healing was assessed via CT scans at 5 *a priori* anatomic locations according to a validated method on a 6-point scoring scale.

Improved Sternal Healing

Sternal Healing Results

CT Score and Sternal Union Rate results are shown in Figure 4. **Patients treated with SternaLock Blu saw improved healing scores over wire cerclage patients at 3 and 6 months (p<0.0001 and p=0.0007, respectively).** Additionally, SternaLock Blu patients demonstrated a greater frequency of sternal union at 3 and 6 months (p<0.0001 and p=0.03, respectively). At 3 months, the number needed to treat (NNT) for preventing one sternal nonunion was 4 (90% CI 2.9 to 6.6). At 6 months, the NNT for preventing one sternal nonunion was 8 (90% CI 4.3 to 32.5). Differences in CT Score, Sternal Union Rate, and NNT between treatments groups were greater at 3 months indicating that closure with SternaLock Blu leads to improved healing faster when compared to wire cerclage.

More patients are healed with SternaLock Blu

- 2.6x more patients healed at 3 months
- 1.2x more patients healed at 6 months

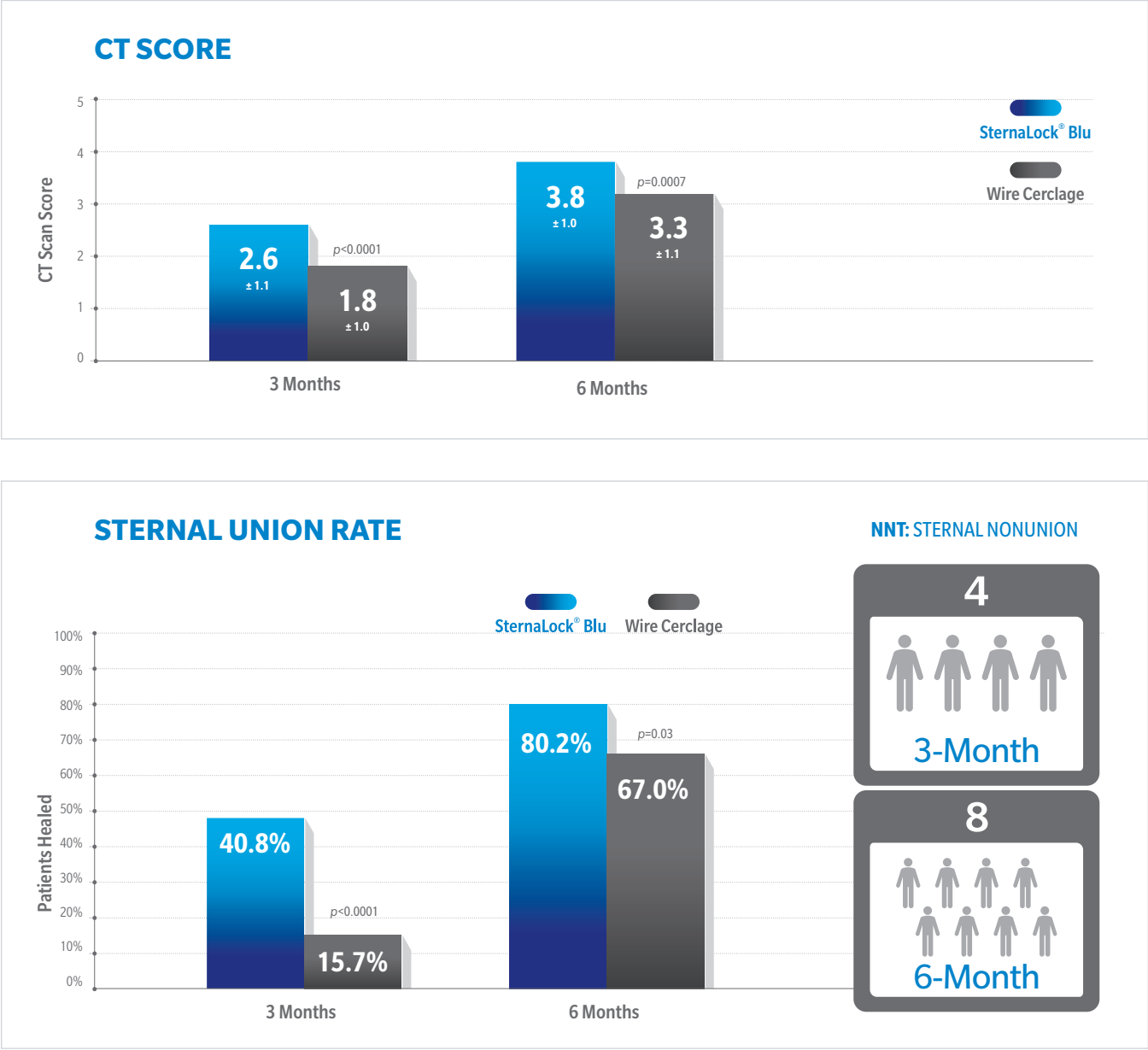


Figure 4. SternaLock Blu patients experienced significantly higher CT Scores and greater Sternal Union Rates at 3 and 6 months when compared to wire cerclage patients.

Improved Sternal Healing

Sternal Healing Predictors

Backwards stepwise linear regression was used to evaluate predictors of sternal healing (Figure 5). Of 16 possible demographic, sternal complication risk factors, and intraoperative variables, 4 predictors of sternal healing at 3 and 6 months were revealed:

Improved sternal healing
- Closure with SternaLock Blu

Impaired sternal healing
- Higher BMI
- Older patient age
- Smoking

The strongest of the four sternal healing predictors was closure with SternaLock Blu.

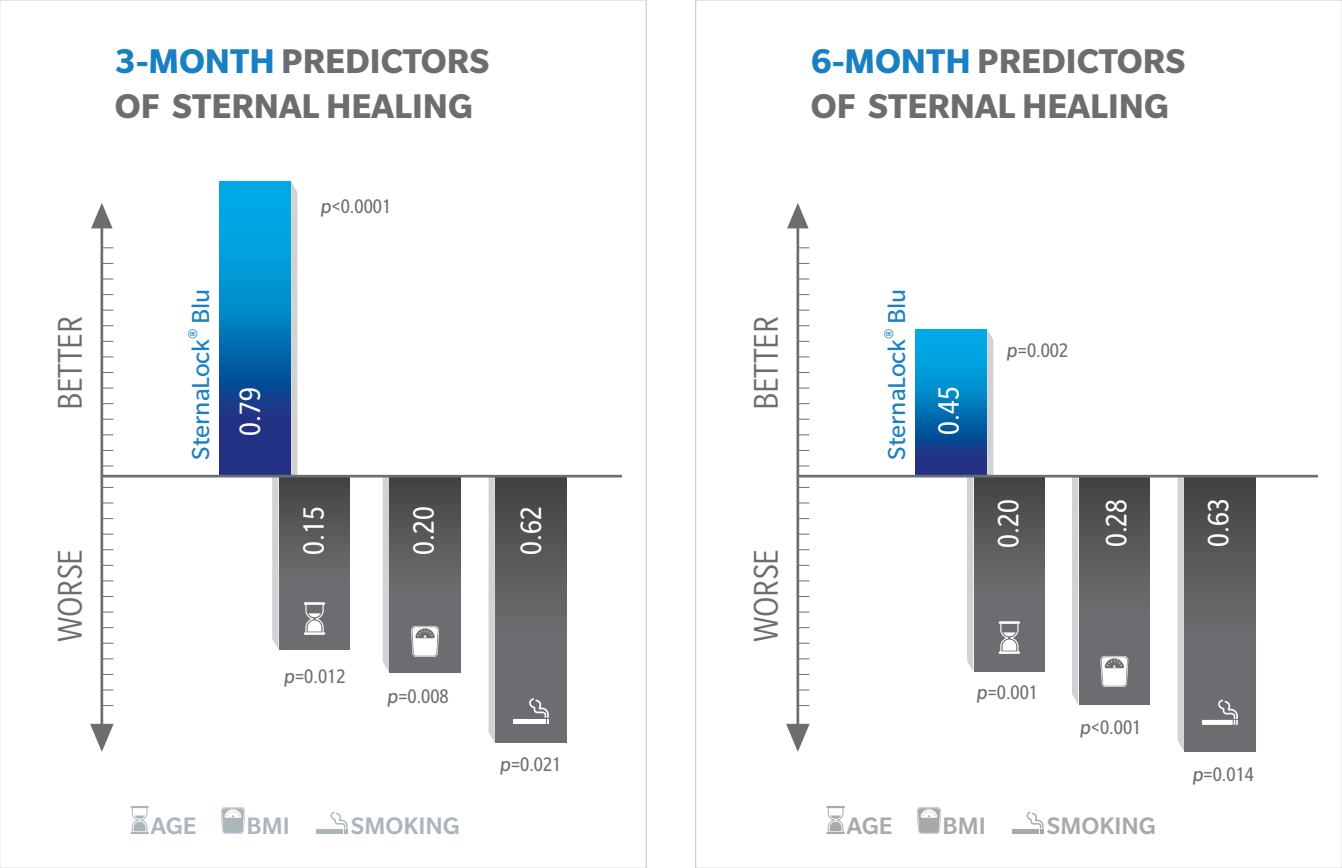


Figure 5. Three and 6-month linear regression models found closure with SternaLock Blu was the strongest predictor of improved sternal healing.

Conclusion

Sternal closure with SternaLock® Blu resulted in significantly improved sternal healing over wire cerclage.

Fewer Sternal Complications

Sternal Complications Methodology

Sternal complications and resulting readmissions and reoperations were detailed and followed as they occurred over 6 months. Sternal complications were defined as any adverse event related to the method of sternal closure, including deep or superficial wound infections as defined by the STS.

Sternal Complications Results

Sternal complications are broken down by type and time point in Figure 6. **Through 6 months, patients treated with SternaLock Blu experienced fewer sternal complications than patients treated with wire cerclage (0% vs. 5%, respectively, p=0.03).** Of the six wire cerclage sternal complications, half (2.5%) occurred beyond the conventional 30-day monitoring window, supporting the notion that perceived wire cerclage complication rates are artificially low. NNT analysis revealed that treatment of 20 patients with SternaLock Blu could prevent one sternal complication at 6 months when compared to wire cerclage (90% CI 12.1 to 57.8, Figure 6).

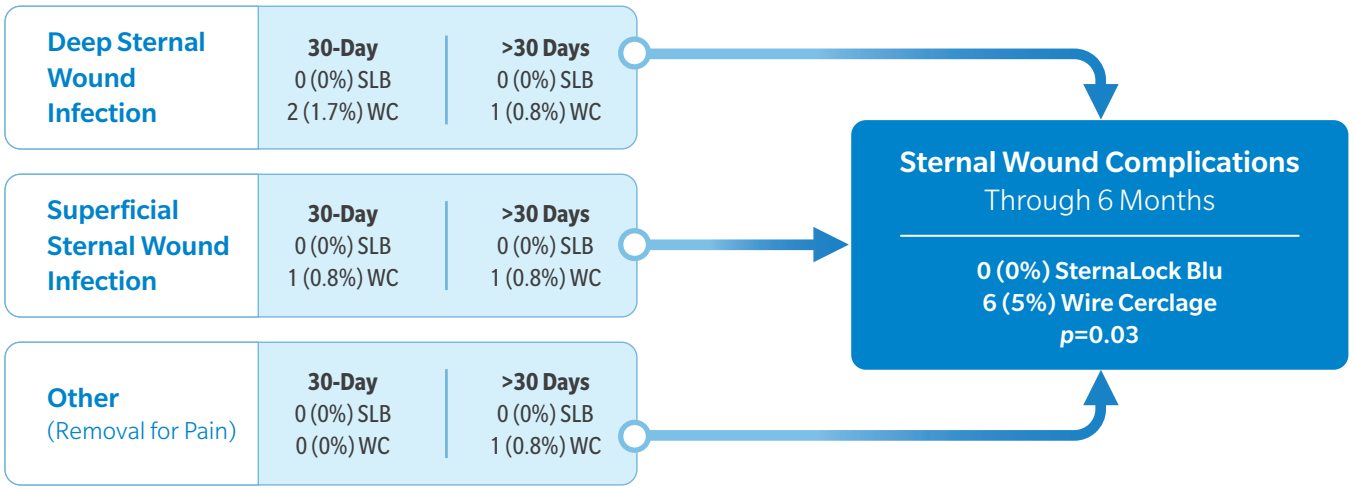
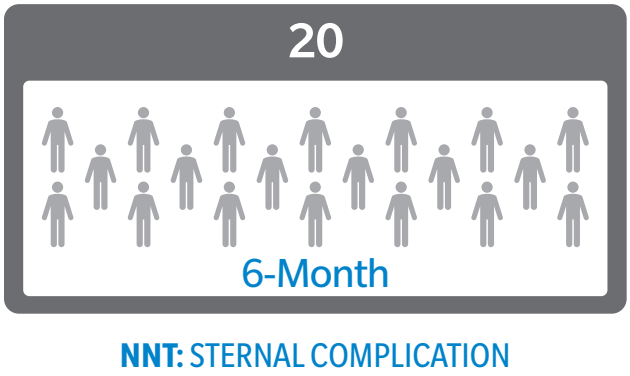


Figure 6. SternaLock Blu patients experienced significantly fewer sternal complications compared to wire cerclage patients over 6 months.



NNT: STERNAL COMPLICATION

Readmissions, reoperations, and length of stay related to sternal complications are presented in Table 2. Five wire cerclage patients accounted for 6 readmissions due to sternal complications. Three deep sternal wound infections, two superficial wound infections, and a single pain related removal occured in wire cerclage patients and led to **11 total reoperations**. Readmissions resulted in **an additional 94 days of hospitalization for wire cerclage patients.**

Table 2. Sternal closure with SternaLock Blu resulted in fewer sternal complication readmissions, reoperations, and hospital days.

	STERNALOCK® BLU	WIRE CERCLAGE
Readmissions Due to Sternal Complications (n)	0	6
Reoperations Due to Sternal Complications (n)	0	11
LOS for Sternal Complications Readmissions (days)	0	94

Fewer Sternal Complications

Sternal Complication Predictors

Exact logistic regression was used to determine the variables predictive of sternal complications and infections. Covariates considered included method of closure, diabetes, renal failure, smoking status, COPD, previous sternotomy, BIMA, age, gender and BMI. **In a multivariate model, sternal closure method was the only significant predictor of sternal complications and sternal wound infections (Table 3).**

When compared to SternaLock Blu:

- Sternal complications were 11.5x more likely with wire cerclage
- Sternal wound infections were 10.7x more likely with wire cerclage

Table 3. Sternal closure method was the only predictor of 6-month sternal wound complications. Wire cerclage was associated with an 11.5 times greater chance of a sternal complication and 10.7 times greater chance of sternal wound infection when compared to SternaLock Blu.

REGRESSION RESPONSE	WIRE ODDS RATIO	WIRE *p*-value
Sternal Complication	11.5	0.02
Sternal Wound Infection	10.7	0.03

Although BMI was not a significant predictor of sternal complications and infections, there was a trend towards increased sternal complications (OR=1.2 per unit increase BMI; p=0.10) and wound infections (OR=1.2 per unit increase BMI; p=0.07) in patients closed with wire cerclage. Figure 7 shows how the probability of a sternal complication and infection increases with increasing BMI in the wire cerclage group.

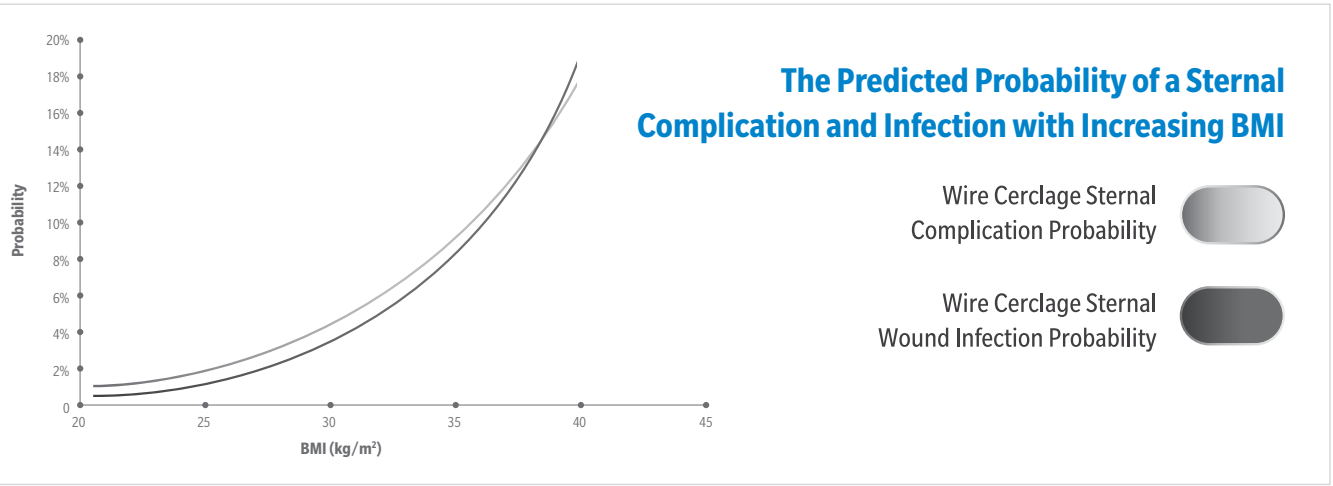


Figure 7. Probability of a sternal complication and sternal wound infection was correlated with increasing BMI for closure with wire cerclage.

Conclusion

SternaLock® Blu patients experienced significantly fewer sternal complications. Closure with SternaLock® Blu was the only significant predictor of fewer sternal complications and infections.

Proven Cost Savings

Health Economic Analysis Methodology

In order to compare the costs of SternaLock Blu to wire cerclage, detailed medical resource utilization and hospital billing data were collected for all patients starting from the time of randomization (i.e., sternal closure) through 6-month follow-up. The methods used for this analysis were similar to those used to evaluate the cost effectiveness of drug-eluting coronary stents and transcatheter heart valves. Total costs at discharge, 3 months, and 6 months were determined in order to reflect the payment periods for various reimbursement models including DRGs and bundled payments.

Health Economic Analysis Results

Index hospitalization, follow-up, and aggregate 3 and 6-month costs are shown in Tables 4 - 5. Initial hospital costs tended to be higher with SternaLock Blu than with wire cercalge, driven by the cost of sternal plates and screws. After discharge, there was a trend toward lower costs in patients treated with SternaLock Blu compared with wire cerclage. These reduced costs were primarily related to reduced sternal complications and outpatient resource utilization costs in the SternaLock Blu group.[3] In this study, the mean cost per patient of a sternal complication was $45,532 in patients treated with wire cerclage.

Total costs savings in patients treated with SternaLock Blu

- **Total 3-month costs were $1,888 less in patients treated with SternaLock Blu than patients treated with wire cerclage (p=0.5)**
- **Total 6-month costs were $1,646 less in patients treated with SternaLock Blu than patients treated with wire cerclage (p=0.6)**

Table 4. Three-month costs in patients treated with SternaLock Blu and wire cerclage.

	STERNALOCK® BLU COSTS	WIRE CERCLAGE COSTS	DIFFERENCE (SL - WIRES)	BOOTSTRAP *P*-value
Total Index Hospitalization Costs	$23,437 ± $12,421	$20,574 ± $14,102	$2,863	0.1
Total Follow-up Costs	$5,742 ± $15,148	$10,493 ± $24,625	-$4,751	0.06
Total 3-Month Costs	$29,179 ± $21,016	$31,067 ± $28,562	-$1,888	0.5

Table 5. Six-month costs in patients treated with SternaLock Blu and wire cerclage.

	STERNALOCK® BLU COSTS	WIRE CERCLAGE COSTS	DIFFERENCE (SL - WIRES)	BOOTSTRAP *P*-value
Total Index Hospitalization Costs	$23,437 ± $12,421	$20,574 ± $14,102	$2,863	0.1
Total Follow-up Costs	$9,002 ± $18,041	$13,511 ± $27,449	-$4,509	0.1
Total 6-Month Costs	$32,439 ± $24,124	$34,085 ± $30,916	-$1,646	0.6

SternaLock Blu is an Economically Dominant Solution

Technologies that improve outcomes without increasing costs and are considered "Economically Dominant", indicating a high degree of economic value.

Conclusions

Compared with wire cerclage, rigid plate fixation with SternaLock Blu resulted in:

- Significant improvements in sternal healing at 3 and 6 months.
- Significantly fewer sternal complications at 6 months.
- Proven cost savings over 6 months.

References

1. Raman J, Lehmann S, Zehr K, et al. Sternal closure with rigid plate fixation versus wire closure: a randomized controlled multicenter trial. The Annals of thoracic surgery. 2012;94(6):1854-1861.

2. CR 0712S (Clinical Study Report) SternaLock Blu Study, 2014-15, an evaluation of rigid plate fixation in supporting bone healing: a prospective, multi-center trial of 236 total patients undergoing full midline sternotomy.

3. CR 0712E (Economic Study Report) SternaLock Blu Study, 2014-15, an evaluation of rigid fixation in supporting bone healing; a prospective, multi-center trial of 236 total patients undergoing full midline sternotomy.

4. Stacy G, Ahmed O, Richardson A, Hatcher B, Raman J. Evaluation of sternal bone healing with computed tomography and a quantitative scoring algorithm. Open Medical Imaging Journal 2014;8:29-35.

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