

Multifilament Cable Wire versus Conventional Wire for Sternal Closure in Patients Undergoing Major Cardiac Surgery

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Background: Stainless steel wiring remains the most popular technique for primary sternal closure. Recently, a multifilament cable wiring system (Pioneer Surgical Technology Inc., Marquette, MI, USA) was introduced for sternal closure and has gained wide acceptance due to its superior resistance to tension. We aimed to compare conventional steel wiring to multifilament cable fixation for sternal closure in patients undergoing major cardiac surgery. **Methods:** Data were collected retrospectively on 1,354 patients who underwent sternal closure after major cardiac surgery, using either the multifilament cable wiring system or conventional steel wires between January 2009 and October 2010. The surgical outcomes of these two groups of patients were compared using propensity score matching based on 18 baseline patient characteristics. **Results:** Propensity score matching yielded 392 pairs of patients in the two groups whose baseline profiles showed no significant differences. No significant differences between the two groups were observed in the rates of early mortality (2.0% vs. 1.3%, $p=0.578$), major wound complications requiring reconstruction (1.3% vs. 1.3%, $p>0.99$), minor wound complications (3.6% vs. 2.0%, $p=0.279$), or mediastinitis (0.8% vs. 1.0%, $p=1.00$). Patients in the multifilament cable group had fewer sternal bleeding events than those in the conventional wire group, but this tendency was not statistically significant (4.3% vs. 7.4%, $p=0.068$). **Conclusion:** The surgical outcomes of sternal closure using multifilament cable wires were comparable to those observed when conventional steel wires were used. Therefore, the multifilament cable wiring system may be considered a viable option for sternal closure in patients undergoing major cardiac surgery.

Key words: 1. Multifilament cable wire
2. Conventional wire
3. Sternal closure
4. Cardiovascular surgery
5. Complication

INTRODUCTION

Median sternotomy, which was re-introduced by Julian in 1957, remains the standard method of accessing the heart and great vessels [1]. It provides excellent exposure of the heart, which allows a range of heart operations to be performed,

and is well tolerated by most patients [2]. However, wound complications, such as sternal instability or infection, may occur after median sternotomy. These complications have been reported to occur in 0.3%–5.0% of cases, and are associated with a significant mortality rate of 14%–47%, with an especially high risk of mortality in cases of mediastinitis [3].

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Received: September 11, 2014, Revised: November 28, 2014, Accepted: December 1, 2014, Published online: August 5, 2015

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Furthermore, the rate of re-exploration for bleeding following cardiac surgery has been reported to be approximately 2.0%–7.0%, and the causes of postoperative bleeding can be multi-factorial [4]. A stable sternal approximation is believed to be the most important factor for preventing these complications. Various bone fixation materials and sternal closure techniques have been developed in order to maximize sternal stability; however, the advantages and disadvantages of each technique have been poorly described to date. The current standard technique for sternal closure is cerclage with stainless steel wires. Recently, a multifilament cable wiring system (Pioneer Surgical Technology Inc., Marquette, MI, USA) was introduced for sternal closure, and has become increasingly popular due to its superior resistance to tension. However, no comparative studies have been conducted to analyze the outcomes of these two different sternal closure techniques. Therefore, we aimed to compare conventional steel wiring to fixation using multifilament cables for sternal closure in patients undergoing major cardiac surgery.

METHODS

1) Patients

From January 2009 to October 2010, 1,354 patients underwent major cardiac surgery via median sternotomy at the Asan Medical Center, Seoul, Korea. Among these patients, 781 (57.7%) underwent sternal closure using the multifilament cable wiring system, while the remaining 573 patients (42.7%) underwent sternal closure using conventional stainless steel wires. Data were collected through a retrospective chart review. The decision to use multifilament cable wires in a given patient was influenced by that patient's demographic profile (age, gender, diabetes status, and osteoporosis status) and surgical factors (the type of surgery, the presence of an intraoperative sternal fracture, and the use of the bilateral internal thoracic artery). However, the choice was ultimately made at the discretion of the operating surgeon, reflecting his or her individual attitude regarding the use of multifilament cable wires.

2) Surgical technique

The multifilament cable group consisted of 781 patients, in whom 1.0-mm multifilament stainless cables (Pioneer Surgical

Technology Inc.) were deployed in a figure-of-eight fashion around the sternum. In 755 of these patients (96.7%), conventional stainless steel wires were added around the manubrium and the lower part of the sternal body. A median of two multifilament cable wires were used for sternal closure (range, 1–4), while a median of three conventional stainless steel wires were used in the procedure (range, 1–8).

The conventional wire group consisted of 573 patients in whom a median of seven standard stainless steel wires (range, 4–12) were used for sternal closure in a simple interrupted fashion: two to three pieces were used around the manubrium and four to five pieces were used around the sternal body. The steel wires were tightened by twisting with a large needle driver.

3) Definitions and follow-up

The primary outcomes of interest were early death and sternotomy-related complications, including sternal bleeding, sternal wound complications, and mediastinitis. Sternal bleeding was defined as postoperative bleeding requiring re-exploration that was ultimately determined to have originated in the sternum. Sternal wound complications were divided into major and minor wound complications. Major wound complications were defined as infections or dehiscence that required a major procedure, such as flap interposition, to be performed in the operating room. Among patients with major wound complications, those who showed sternal instability with bony involvement or had live organisms isolated from the mediastinum were diagnosed with mediastinitis. Minor wound complications were defined as less severe problems that were treated with medication or bedside wound revision and showed no sign of bacterial involvement.

Clinical follow-up was conducted every three to six months on an outpatient basis. All patients underwent follow-up, and the median follow-up duration was 27.5 months (interquartile range, 22.4–32.9 months).

4) Statistical analysis

Categorical variables are shown as frequencies and percentages, and continuous variables are expressed as means \pm standard deviation or medians with ranges. In order to decrease the effect of treatment selection bias and potential con-

Table 1. Baseline patient demographics

Characteristic	Multifilament cable group (n=781)	Conventional wire group (n=573)	p-value
Female gender	285 (36.5)	222 (38.7)	0.340
Age (yr)	61.3±11.0	59.3±12.4	0.053
Diabetes mellitus	214 (27.4)	156 (27.2)	0.930
Body mass index (kg/m ²)	24.1±3.2	23.9±3.1	0.690
Hypertension	367 (47)	253 (44)	0.300
Chronic renal failure	16 (2.05)	20 (3.49)	0.092
Cerebrovascular accident	21 (2.69)	15 (2.61)	0.930
Prior cardiac surgery	25 (3.20)	17 (2.97)	0.810
Preoperative left ventricular ejection fraction	56.3±10.6	56.4±10.7	0.920
Operative profiles			
Valve	475	341	0.450
AV	147 (18.8)	115 (20.1)	
MV	124 (15.9)	80 (14)	
Tricuspid valve	4 (0.5)	5 (0.9)	
AV+MV	31 (5.6)	32 (4.0)	
CABG	387	292	0.001
Off-pump coronary artery bypass	279 (35.7)	159 (27.7)	
Conventional CABG	46 (4.6)	36 (8.0)	
On-pump beating CABG	79 (10.1)	76 (13.3)	
Aorta	56	57	0.190
Ascending aorta replacement	17 (2.2)	18 (3.1)	
Hemi-arch replacement	39 (5.0)	39 (6.8)	
Valve + CABG	42 (5.38)	28 (4.87)	0.690
Atrial septal defect, ventricular septal defect	18 (2.30)	11 (1.91)	0.900
Others	5 (0.6)	14 (2.4)	0.008
Aortic cross cross-clamp time (min)	97.7±44.8	86.6±39.6	0.580
Cardiopulmonary bypass time (min)	139.9±76.9	215.6±115.3	0.190
Bilateral internal mammary artery	36 (4.6)	16 (2.8)	0.115

Values are presented as number (%) for categorical variables and as mean±standard deviation for continuous variables. AV, aortic valve; MV, mitral valve; CABG, coronary artery bypass grafting.

founding, we carried out adjustments for the differences in the baseline characteristics between the two groups by applying propensity score matching. The propensity scores were calculated using multiple logistic regression analysis. The adequacy of the propensity score model was evaluated using the C-statistic and the Hosmer-Lemeshow test. The model yielded a C-statistic of 0.592 and a Hosmer-Lemeshow goodness-of-fit p-value of 0.466, which indicated that the model was well-calibrated with reasonable discrimination. In order to identify propensity score-matched pairs (one to one matches), the greedy 5-to-1 digit matching algorithm was used. After the propensity score matching, the data of the two groups were compared using the paired t-test or the Wilcoxon signed

rank test for continuous variables, and using the McNemar test or the marginal homogeneity test for categorical variables.

All reported p-values were two-sided, and p-values <0.05 were considered to indicate statistical significance. SAS ver. 9.1 (SAS Institute Inc., Cary, NC, USA), was used for statistical analyses.

RESULTS

Table 1 summarizes the baseline characteristics, comorbidities, and procedure-related parameters of all patients. In comparison with the patients in the conventional wire group, the patients in the multifilament cable group tended to be older

Table 2. Baseline patient demographics (propensity-matched)

Characteristic	Multifilament cable group (n=392)	Conventional wire group (n=392)	p-value
Female gender	159 (40.6)	162 (41.3)	0.828
Age (yr)	60.6±12.1	60.1±12.0	0.588
Diabetes mellitus	112 (28.6)	107 (27.3)	0.691
Body mass index (kg/m ²)	23.9±3.3	23.9±3.1	0.974
Hypertension	182 (46.4)	168 (42.9)	0.315
Chronic renal failure	12 (3.1)	13 (3.3)	0.839
Cerebrovascular accident	9 (2.3)	12 (3.1)	0.518
Prior cardiac surgery	9 (2.3)	14 (3.6)	0.398
Preoperative left ventricular ejection fraction	56.0±11.2	56.9±9.8	0.839
Operative profiles			
Valve			0.996
AV	84 (21.4)	84 (21.4)	
MV	57 (14.5)	58 (14.8)	
Tricuspid valve	4 (1.0)	3 (0.8)	
AV+MV	21 (5.4)	22 (5.6)	
CABG			0.992
Off-pump coronary artery bypass	110 (28.1)	108 (27.6)	
Conventional CABG	33 (8.4)	33 (8.4)	
On-pump beating CABG	54 (13.8)	52 (13.3)	
Aorta			0.835
Ascending aorta replacement	11 (2.8)	13 (3.3)	
Hemi-arch replacement	27 (6.9)	30 (7.7)	
Valve + CABG	20 (5.1)	21 (5.4)	0.873
Atrial septal defect, ventricular septal defect	5 (1.3)	7 (1.8)	0.923
Others	5 (1.3)	1 (0.3)	0.217
Aortic cross-clamp time (min)	47.8±48.6	48.4±52.2	0.877
Cardiopulmonary bypass time (min)	154.5±82.0	98.4±148.0	0.183
Bilateral internal mammary artery	17 (4.3)	14 (3.6)	0.629

Values are presented as number (%) for categorical variables and as mean±standard deviation for continuous variables. AV, aortic valve; MV, mitral valve; CABG, coronary artery bypass grafting.

Table 3. Early operative outcomes

Variable	Multifilament wire group	Conventional wire group	p-value
Early mortality	5 (1.3)	8 (2.0)	0.578
Sternal bleeding (reoperation)	17 (4.3)	29 (7.4)	0.068
Sternal wound complications	19 (4.9)	12 (3.3)	
Major wound complications	5 (1.3)	4 (1.3)	1.00
Mediastinitis	4 (1.0)	3 (0.8)	1.00
Minor wound complications	14 (3.6)	8 (2.0)	0.279

Values are presented as number (%).

(61.3±11.0 years vs. 59.3±12.4 years; p=0.053), had a lower prevalence of chronic renal failure (2.1% vs. 3.5%; p=0.092), and were more likely to undergo off-pump coronary artery bypass graft surgery (Table 1).

Propensity score matching yielded 392 pairs of patients for whom no significant difference existed in the baseline profile, including age, body mass index, history of previous cardiac surgery, and the rate of bilateral internal mammary artery use

Table 4. Multivariable risk factor analysis for sternal wound complications (logistic regression)

Variable	Univariate analysis	Multivariable analysis		
	p-value	Odds ratio	95% confidence interval	p-value
Hypertension	0.16			
Cerebrovascular accident	0.10			
Redo sternotomy	0.16			
Body mass index	0.26			
Bilateral internal mammary artery	<0.001	5.17	2.19–12.20	<0.001

Only variables with $p < 0.30$ on univariate logistic regression analysis were incorporated into the multivariable analysis.

Table 5. Management of sternal wound complications and mediastinitis

Variable	Multifilament cable group	Conventional wire group	p-value
Vacuum-assisted closure application or wet dressing	4 (1.0)	6 (1.5)	0.752
Sternal reconstruction	7 (1.8)	3 (0.8)	
Titanium plate+tissue flap	2 (0.5)	0 (0.0)	0.499
Muscle flap	4 (1.0)	3 (0.8)	1.00
Omental flap	1 (0.3)	0	1.00

Values are presented as number (%).

between the two matched groups (Table 2).

The occurrence of postoperative complications is summarized in Table 3. In the propensity score-matched cohort, no significant differences were observed between the two groups regarding the rates of early mortality (1.3% in the multifilament cable group vs. 2.0% in the conventional wire group; $p=0.578$), major wound complications requiring reconstruction (1.3% in the multifilament cable group vs. 1.3% in the conventional wire group; $p=1.00$), minor wound complications (3.6% in the multifilament cable group vs. 2.0% in the conventional wire group; $p=0.279$), or mediastinitis (1.0% in the multifilament cable group vs. 0.8% in the conventional wire group; $p=1.00$). The patients in the multifilament cable group tended to have fewer sternal bleeding events than those in the conventional wire group, but this discrepancy only reached a marginal level of statistical significance (4.3% vs. 7.4%; $p=0.068$). On multivariable analysis, the use of the bilateral internal mammary artery was the only significant risk factor for sternal wound complications (odds ratio, 5.17; 95% confidence interval, 2.19–12.20; $p < 0.001$) (Table 4).

The management of sternal wound complications or mediastinitis is summarized in detail in Table 5. Sternal wound complications requiring sternal reconstruction occurred in 10

patients; two patients underwent sternal fixation with a titanium plate and autologous tissue flap, while the other eight patients received an autologous tissue flap, using either omentum ($n=1$) or muscle ($n=7$). No significant differences were observed between the two groups in the rate of sternal wound complications requiring vacuum-assisted closure, the use of wet dressing, or sternal reconstruction.

DISCUSSION

Complications from median sternotomy have been reported to occur in approximately 0.3%–5.0% of cases, and are associated with significant morbidity and mortality [5]. The loosening and failure of sternal fixation is associated with compromised wound healing, and may lead to sternal wound dehiscence. Infection is also associated with wire loosening [6]. Although a variety of sternum closure techniques have been developed, the primary consideration in choosing a technique should be its effectiveness in ensuring the rigid closure of the sternum, which restores the stability of the sternum and promotes its primary healing. Several sternum closure techniques have been reported to prevent sternal dehiscence, but no consensus yet exists about an ideal method. Wangsgard et al. [7]

reported that the figure-of-eight stainless-steel cable system and the dynamic sternal fixation plate system are expected to show a lower failure rate both in situations involving lateral distraction and in situations with longitudinal shear cyclic loading, in comparison to the figure-of-eight stainless-steel wire system. Furthermore, the figure-of-eight stainless-steel cable system has the best ability to resist failure, especially in high cycle numbers. Khasati et al. [8] compared two different sternal closure methods (simple wire versus figure-of-eight), and found that the figure-of-eight method had no significant benefit over the simple wire method. Cohen and Griffin [9] performed a biomechanical study of three sternal closure techniques (figure-of-eight stainless steel wires, stainless steel plates, and figure-of-eight stainless steel cables). Both the plate system and the stainless steel cable system showed significant advantages over the figure-of-eight stainless steel wire system [9]. Although many previous studies have reported sternum closure techniques that have been claimed to be ideal for sternal fixation, few comparative clinical studies have been conducted to analyze the outcomes of different sternal closure techniques in practice.

The Pioneer sternal cable has been reported to have a fatigue strength approximately ten times stronger than standard steel wires [10]. The cable wire hugs the bone uniformly in a figure-of-eight fashion, which may decrease the possibility of loosening, micro-motion, potential postoperative malunion, and resultant compromised wound healing. In this context, it is worth noting that the multifilament cable group in this study experienced less sternal bleeding, even though this association did not attain statistical significance. We speculate that this finding may be due to the greater fatigue strength and the higher resistance to stress of the multifilament cable wires. The resultant higher tension in the bone union and more stable fixation of the sternum may lead to a lower likelihood of bleeding from the sternal bone marrow and adjacent structures [7]. The cable wires are also easy to handle and may decrease the time required for sternum closure. However, despite all these putative advantages, surgeons must avoid over-tensioning cables, as they may break, and the multifilament cable wire may cut through soft bone tissue that is not protected and immobilized.

In the present study, 1,354 elective open heart surgery pa-

tients were separated into two groups depending on which sternal closure technique was employed. The size of the cohort was sufficiently large to power the statistical analysis. Propensity scoring was used to match important differences in the baseline risk profiles that may otherwise have confounded the outcomes. Since multiple surgeons performed the relevant operations in our institution, rigorous statistical adjustments were made to minimize the effects of individual surgeons on the outcome. In this study, multifilament cable wires were not found to have a clear clinical advantage over conventional steel wires. Instead, the results of our study showed no significant differences in the clinical outcomes between the two groups, except for a slight tendency for less sternal bleeding in the multifilament cable group, as described above. The multifilament cable wires may intuitively be thought to hold the sternum more tightly, leading to less bleeding than was observed among patients in whom conventional wires were used. However, further studies are necessary to improve our understanding of the mechanism by which multifilament cable wires result in less bleeding, as well as to identify the subsets of patients in which the benefits of this technique can be maximized.

This study has several limitations. The accuracy of this retrospective review depended on the availability of information in the patients' medical records. A particularly important qualification is that we were not able to determine the precise origin of sternal bleeding. The non-randomized design may have affected our results due to unmeasured confounders, procedural bias, or detection bias, even with the use of rigorous statistical adjustment. Moreover, conventional stainless steel wires were also used to close the sternum in the cable wire group, which rendered this cohort heterogeneous to some extent, thus potentially making our results somewhat ambiguous.

In conclusion, the clinical outcomes of sternal closure using multifilament cable wires were comparable to those observed when conventional stainless steel wires were used. Therefore, the new multifilament cable fixation system may be considered a viable option for sternal closure in patients undergoing major cardiac surgery.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

ACKNOWLEDGMENTS

This study was supported by a Grant of the Samsung Vein Clinic Network (Daejeon, Anyang, Cheongju, Cheonan; Fund No. KTCS04-029).

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