Does Sternal Cable System Prevent Sternal Complications after Revision Sternal Surgery?

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ABSTRACT

Objective: To determine the efficacy of a sternal wire system in secondary sternal dehiscence after repeat closure of the sternum, following surgical revision after open heart surgery.

Study Design: Case-control study.

Place and Duration of Study: Department of Cardiovascular Surgery, Zonguldak Bülent Ecevit University, Zonguldak, Turkey; and Turkey Yuksek Ihtisas Training and Research Hospital, Turkey, from January 2015 to May 2019.

Methodology: Patients, who underwent open heart surgery with median sternotomy, were included in this retrospective study. The patients were divided into two groups, according to the sternal closure material. The time of the sternal reconstruction surgery, because of sternal dehiscence, fracture, broken sternal wire(s) or cable(s) after the first revision surgery, was noted for each patient.

Results: A total of 389 patients were identified. Group 1 included 72 (50%) patients whose sternums were closed with a sternal cable system; and Group 2 included 72 (50%) patients whose sternums were closed with conventional steel wires after propensity matching. The duration of cardiopulmonary bypass, number of intra-aortic balloon pumps used, and number of extracorporeal membrane oxygenators used were significantly higher in Group 1 ($p = 0.007$, $p = 0.034$, and $p = 0.028$, respectively). The number of emergency operations was significantly higher in Group 2 ($p = 0.021$). There was no significant difference in terms of secondary sternal dehiscence between the groups ($p = 0.366$).

Conclusion: Application of the sternal wire system in revisional open heart surgery is not more effective than conventional steel wire at preventing secondary sternal dehiscence.

Key Words: *Sternal dehiscence, Sternal cable, Sternal wire, Open heart surgery, Postoperative revision.*

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INTRODUCTION

Median sternotomy has been the standard technique of cardiac exposure in open heart surgery for decades. The anatomy of the mediastinum can be exposed quickly by median sternotomy, it provides access to major vasculature in the mediastinum for central cannulation during cardiopulmonary bypass, and it is well tolerated by patients. Post-sternotomy healing complications, such as sternal wound infection and dehiscence, occur in about 0.5% to 5% of patients after cardiac surgery. Mortality rates related to these complications are reported to be between 15% and 50%.[1,2]

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The treatment costs of patients with sternal wound complications are approximately 2.8 times higher than patients without sternal wound complications.[2] The high-price sternum closure materials used in these patients contribute to the high costs.

There are many techniques for sternal closure, described in the literature; and many studies conducted about primary closure techniques of the sternum after open heart surgery;[3-6] but there are no studies focused on the secondary dehiscence of the sternum after repeat closure following surgical revision to the best of authors' knowledge.

Herein, the aim was to determine the effect of a sternal wire system on secondary sternal dehiscence after repeat closure of the sternum, following surgical revision in patients who underwent open heart surgery.

METHODOLOGY

Patients who underwent open heart surgery with median sternotomy at Zonguldak Bülent Ecevit University, Zonguldak, Turkey; and Turkey Yuksek Ihtisas Training and Research Hospital, Turkey, from January 2015 to May 2019, were evaluated in this retrospective study. Open heart and aortic surgeries without median sternotomy (with lateral thoracotomy, *etc*.), redo surgeries, sternal closure with any means other than a sternal cable system, and sternal wire were the exclusion criteria.

Patients were divided into two groups. Group 1 was the study group and included patients who underwent an early postoperative revision surgery and whose sternums were closed with a sternal cable system (RTI surgical cable system, pioneer surgical technology, Inc., Marquette, Michigan, USA). Group 2, as the control group, included patients whose sternums were closed with conventional steel wires (LVM stainless steel surgical cables), The time of the sternal reconstruction surgery because of a sternal healing complications, such as sternal dehiscence, sternal fracture, broken sternal wire(s) or cable(s), was noted for each patient.

A sternal cable system was used for sternal closure in these situations: if the patient was over 70 years, had diabetes and obesity (body mass index (BMI) >30), had bilateral internal mammary artery (IMA) graft harvesting performed or, had chronic obstructive pulmonary disease (COPD) or chronic kidney disease (CKD). The final decision for sternal cable application was made by the operating surgeon after the evaluation of the patient's sternal bone structure.

Revision surgery, performed within the first 24 hours postoperatively, is defined as early revision surgery. The decision for early postoperative revision surgery was made by the same surgeon who had performed the initial operation. Early postoperative bleeding and/or cardiac tamponade were accepted as the primary indications for early postoperative revision surgery.[7]

All patients wore sternal support vests (Orthocare sternicare plus™, Ankara, Turkey) during the hospitalisation period and were discharged with these supportive vests with recommendations on continuous wearing of these vests during the day, wound care, body hygiene and precautions to prevent sternal dehiscence.

Secondary sternal dehiscence is defined as the presence of broken sternal wire(s) or cable(s) documented in the antero-posterior and lateral chest radiogrammes, causing sternal dehiscence in physical examination after the primary revision surgery.

The sternal revision surgery was performed in the presence of sternal dehiscence in physical examination and sternal bone and wire fracture in the chest radiogram accompanied by superficial wound infection and severe complaints and discomfort of patients related with these sternal complications observed in the outpatient clinic follow-ups. Local ethical committee approval was obtained for data collection and study conduction. The study complied with the Declaration of Helsinki and its later amendments.

All of the primary operations were performed under general anaesthesia and with median sternotomy incision. Conventional cardiopulmonary bypass (CPB) with cardioplegia, on-pump beating heart (ONBHCAB) or off-pump (OPCAB) techniques were utilised with regard to the type of surgery and to patient-related attributes, such as left ventricle dysfunction, comorbidities, emergent surgery, *etc.* Sternotomy was closed either with a sternal cable system or sternal steel wires. Figure-of-8 and simple wire loop wiring techniques were used for sternal wire and cable application, according to the decision of the surgeon. Four figure-of-8 or minimum five simple wire/cable loops were placed according to the anatomy and structure of the patient's sternum.

Early postoperative revision operations were performed without CPB. Secondary sternal closure technique and material were chosen by the operating surgeon, regardless of the initial sternal closure system.

The statistical analysis of the data was done with statistical package for the social sciences (SPSS version 16.0 Inc., Chicago, IL, USA) software. Categorical data were expressed as numbers and percentages. Continuous data were presented as mean ± standard deviation (SDs). The Kolmogorov-Smirnov test was used to test the normality of the data distribution. In order to decrease the effect of selection bias and potential confounding, propensity score matching was performed using a one-to-one matching ratio and nearest neighbour matching algorithm. The propensity scores of the preoperative baseline characteristics variables were calculated using logistic regression analysis. The adequacy of the propensity score model was evaluated using the area under the ROC curve (C-index) and the Hosmer-Lemeshow goodness-of-fit test. The model yielded a C-index value of 0.752 and a Hosmer-Lemeshow goodness-of-fit Chi-square value of 1.63 ($p = 0.990$), which indicated that the model was well-calibrated. The categorical data were tested with the Chi-square and Fisher's Exact tests and the continuous data were tested with the independent samples t-test. P values <0.05 were considered as statistically significant.

RESULTS

A total of 389 patients, who had a median sternotomy, were identified. A total of 72 patients, who underwent early postoperative revision surgery and had their sternotomy closed with a cable system, were included in Group 1 as the study group; and their propensity score-matched pairs 72 patients who had their sternotomy closed with conventional steel wires, were included in Group 2 as the control group. The preoperative demographic characteristics are presented in Table I.

Postoperative data are presented in Table II. The duration of CPB was longer in Group 1 ($p = 0.007$). More patients needed intra-aortic balloon pump counter pulsation in the postoperative period in Group 1 ($p = 0.034$). More patients needed extracorporeal membrane oxygenation (ECMO) support in the postoperative period in Group 1 ($p = 0.028$). The number of emergency operations was significantly higher in Group 2 ($p = 0.021$).

Table I: Preoperative demographic data of the initial procedures (propensity matched).

		Group 1 (n=72)	Group 2 (n=72)	p-value
Male		37 (51.39)	29 (40.28)	0.181
Age (Mean ± SD)		64.21 ± 12.46	63.92 ± 10.62	0.880
BMI (Mean ± SD)		29.92 ± 4.55	29.83 ± 4.17	0.905
Preoperative EF		50.17 ± 8.31	49.30 ± 9.36	0.557
Hypertension		50 (69.44)	50 (69.44)	>0.999
Hyperlipidemia		16 (22.22)	22 (30.56)	0.257
COPD		15 (20.83)	15 (20.83)	>0.999
Diabetes mellitus		38 (52.78)	36 (50.00)	0.739
Medication for diabetes				0.484
	None	33 (46.48)	38 (52.78)	
	OAD	21 (29.58)	14 (19.44)	
	Insulin	11 (15.49)	15 (20.83)	
	OAD + Insulin	6 (8.45)	5 (6.94)	
Tobacco product smoking		30 (42.25)	29 (40.28)	0.810
Thyroid gland dysfunction		9 (12.50)	8 (11.27)	0.820
CKD stage				0.121
	Stage 1	16 (22.22)	28 (38.89)	
	Stage 2	41 (56.94)	30 (41.67)	
	Stage 4	3 (4.17)	1 (1.39)	
	Stage 5	0	1 (1.39)	
	Stage 3a	11 (15.28)	9 (12.50)	
	Stage 3b	1 (1.39)	3 (4.17)	
Preoperative diagnosis				0.628
	CAD	47 (65.28)	54 (75)	
	CAD + HVD	2 (2.78)	2 (2.78)	
	CAD + Carotid	3 (4.17)	1 (1.39)	
	HVD	10 (13.89)	6 (8.33)	
	Aorta disease	10 (13.89)	9 (12.50)	

The data is presented as numbers (%), if not mentioned otherwise. SD: Standard deviation; BMI: Body mass index; EF: Ejection fraction; COPD: Chronic obstructive pulmonary disease; OAD: Oral antidiabetics; CKD: Chronic kidney disease; CAD: Coronary artery disease; HVD: Heart valve disease; Carotid: Carotid artery disease

More patients needed inotropic agent support (adrenaline, dopamine or dobutamine) in the intensive care unit follow-up period in Group 1; but it was not statistically significant (p=0.062). There was no significant difference in terms of secondary sternal dehiscence between the groups (p = 0.366).

One patient had sternal cable rupture in Group 1 without sternal bone fracture two months after his sternal revision surgery.

DISCUSSION

The results of this study show that the rate of secondary sternal dehiscence after the early revision surgery is not affected by the sternal closure material, which is either wire or cable.

There are many risk factors related to postoperative sternal complications such as diabetes, obesity (BMI >30), older age (>75 years), CKD, postoperative revision surgery, harvesting bilateral IMA grafts, COPD and prolonged CPB.[8,9] In this study, the mean CPB time of the study group (Group 1) was significantly higher than the control group (Group 2); but the secondary dehiscence rates were similar.

Nezafati *et al*. used sternal implants to fix the sternum in 168 patients and compared the 12-month follow-up results of 158 patients with conventional sternal steel wires.[4] They reported better results with the sternal implants in terms of pain and sternal dehiscence, but had non-significant results in terms of sternal wound infection. Marasco *et al*. used the same sternal closure implants as the aforementioned study in their prospective randomized study including 118 patients.[10] They compared these implants and steel wires in terms of sternal movement and reported significantly more movement of the sternum and manubrium in the implant group. Both authors did not use the device on the secondary closure of the sternum and did not have any experience of the re-application of the device.

Table II: Postoperative data of the initial procedures.

	Group 1 (n=72)	Group 2 (n=72)	p-value
Emergency primary operation	6 (8.33)	16 (22.22)	0.021

CPB min (Mean ± SD)	139.57 ± 76.04	102.94 ± 85.46	0.007
XCL min (Mean ± SD)	61.79 ± 34.47	54.57 ± 59.05	0.372
LIMA	51 (71.83)	56 (77.78)	0.413
RIMA	1 (1.39)	1 (1.39)	>0.999
IABP	15 (20.83)	6 (8.33)	0.034
ECMO	6 (8.33)	0	0.028
ONBHCAB	3 (4.17)	5 (6.94)	0.719
OPCAB	6 (8.33)	5 (6.94)	0.754
Postoperative drainage ml (Mean ± SD)	635.14 ± 432.74	582.92 ± 486.41	0.515
Blood product transfusions units (Mean ± SD)			
FFP	2.79 ± 2.14	3.11 ± 3.00	0.462
RBC suspension	1.57 ± 1.34	2.08 ± 2.21	0.093
Platelet	0.67 ± 1.35	0.35 ± 1.28	0.148
Whole blood	0.10 ± 0.38	0.17 ± 0.65	0.436
MVS time hours (Mean ± SD)	88.90 ± 236.34	42.18 ± 45.41	0.104
Number of inotrope types			0.062
None	24 (33.33)	27 (37.50)	
One inotrope	16 (22.22)	18 (25.00)	
Two inotropes	19 (26.38)	7 (9.72)	
Three inotropes	13 (18.06)	20 (27.78)	
ICU stay days (Mean ± SD)	5.64 ± 11.46	4.88 ± 5.46	0.613
IHS days (Mean ± SD)	14.28 ± 17.28	12.76 ± 10.26	0.531
Mortality	11 (15.28)	18 (25.00)	0.146
Secondary sternal dehiscence	4 (5.56)	1 (1.39)	0.366

The data is presented as numbers (%), if not mentioned otherwise. SD: Standard deviation; CPB: Cardiopulmonary bypass; XCL: Aortic cross-clamp; LIMA: Left internal mammary artery; RIMA; Right internal mammary artery; IABP: Intra-aortic balloon pump; ECMO: Extra-corporeal membrane oxygenator; ONBHCAB: On-pump beating heart coronary artery bypass; OPCAB: Off-pump coronary artery bypass; FFP: Fresh frozen plasma; RBC: Red blood cell; MVS: Mechanic ventilator support; ICU: Intensive care unit; HIS: In-hospital stay.

Tunçay *et al*. used sternal clips to close the sternotomy of six patients with non-infectious sternal dehiscence.[11] They reported better outcomes and the cost-effectiveness of these clips as compared to conventional sternal wire closure, but they did not provide any data about the comparison of the costs of the device and the sternal wire. Moreover, they did not use the device on secondary sternal closure and had no data about the re-utilization of the device.

Dunne *et al*. and Oh *et al*. used the same cable system as the one used in this study.[6,12] Dunne *et al.* enrolled 273 patients and found non-significant differences between the results of cable and wire groups in terms of sternal wound infection. Oh *et al.* conducted their study on 392 patients and reported the cable system had no better clinical results than the conventional steel wire.[12] They did not use the cable system on secondary sternal closure.

Another method for sternal closure is, using the combination of the materials and systems in the market. Ata *et al*. used a sternal cable system and conventional steel wires in combination when closing the sternotomy in obese patients (BMI > 30) undergoing open heart surgery.[13] They reported a decrease in the incidence of sternal dehiscence in these patients.

In the recent guidelines for CABG surgery and meta-analyse of the largest clinical trials, total arterial revascularisation of the myocardium is a favourable technique.[14,15] But the main concern about total arterial revascularisation is the risk of sternal wound infection and dehiscence requiring reoperation after bilateral IMA graft harvesting.[16] The present authors think that the pros and cons should be well weighed before harvesting bilateral IMA grafts, especially in high risk patients (*i.e*. diabetics, obese, and patients with COPD); and if bilateral IMA graft harvesting is mandatory, conventional steel wires and high-price sternal cable devices can be considered as equals with regard to the incidence of postoperative sternal complications.

External support vests help keep the sternum intact and reduce the mechanical complications of sternal healing in the postoperative period. In their prospective randomised trial, Caimmi *et al*. reported better sternal healing,[17] lower incidence of mechanical sternal complications, shorter hospital stay, and better quality of life in patients using external support vests. Vos *et al*. also reported a significant reduction in deep sternal wound infections in patients using support vests.[18]

In this study, the sternal cable system was used in patients who had revision surgery because of postoperative sternal complications regardless of the primary sternal closure technique. In the authors' experience, the removal of the cable system was as easy as removing the sternal wires and re-application of the cable system was as easy as the first-time application.

The study was conducted retrospectively, which was a major limitation, but propensity score matching and building a model according to the propensity score were performed to overcome selection bias. It is not possible to have full knowledge of the patients' behaviours and how well they follow the recommendations on sternal care-taking precautions after they are discharged, so it is not possible to define the effect of the patients' behaviours on the occurrence of sternal dehiscence. Preoperative sternal bone densitometry and evaluation of patients for osteoporosis were not available because of technical difficulties.

CONCLUSION

Application of the sternal wire system in revisional open heart surgery is not more effective than conventional steel wires at preventing secondary sternal dehiscence. The authors think that more studies should be conducted to evaluate its related risk factors.

ETHICAL APPROVAL:
This study was conducted with the approval from the Ethics Committee of the Zonguldak Bülent Ecevit University, Turkey (Registry No. 2019-146-18/09).

PATIENT'S CONSENT:
No informed consent was taken, because the study was conducted with retrospective data collection technique.

CONFLICT OF INTEREST:
The authors declared no conflict of interest.

AUTHORS' CONTRIBUTION:
LA, EC: Data acquisition, interpretation and drafting.
AÖ: Analysis, critical revision and final approval.
AT: Conception and design.
GY: Analysis and interpretation.
UT: Final approval.

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