

Research Article

## Analysis of the outcomes of figure-of-eight and double-loop sternal-closure (FUSION) techniques

### *Sekiz şeklinde kapama ve çift halka (FÜZYON) sternal kapama tekniklerinin sonuçlarının analizi*

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#### Abstract

**Aim:** To assess the benefit of a modified sternal closure (Figure-of-eight and double-loop sternal-closure, FUSION) versus conventional figure-of-eight wiring (FEW) technique in reducing sternal instability in obese patients undergoing coronary artery bypass grafting (CABG).

**Material and Methods:** We retrospectively analyzed 90 obese (body mass index  $\geq 30$  kg/m<sup>2</sup>) patients who underwent elective isolated CABG under median sternotomy between January 2023 and January 2024 at the Ankara Bilkent City Hospital. Patients were divided into two groups based on the sternal closure technique employed: 48 patients in the FEW groups and 42 patients in the FUSION group. Clinical follow-ups were conducted for two months postoperatively, and sternal instability was assessed through clinical examination, chest X-rays, and thoracic CT scans when necessary.

**Results:** Demographic and perioperative variables were similar among groups. Sternal instability occurred more frequently in patients in the FEW group (10.4%) than in those in the FUSION group (2.3%;  $p = 0.001$ ). Multivariate analysis showed that FEW technique (OR: 3.5; 95% CI: 2.4-5.3;  $p = 0.001$ ), COPD (OR: 3.5; 95% CI: 2.2-4.4;  $p = 0.05$ ), DM (OR: 2.3; 95% CI: 1.3-4.1;  $p = 0.05$ ), postoperative delirium (3.2; 95% CI: 2.1-4.8;  $p = 0.01$ ) and female gender (OR: 2.4; 95% CI: 1.8-5.5;  $p = 0.02$ ) were all independent factors for sternal instability.

**Conclusion:** The FUSION technique significantly reduced sternal instability in obese patients compared to the FEW techniques, indicating its potential as an effective preventive measure for high-risk populations.

**Keywords:** sternal closure, obesity, coronary artery bypass grafting, sternal instability

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## Öz

**Amaç:** Bu çalışmanın amacı, koroner arter baypas greftleme (KABG) ameliyatı geçiren obez hastalarda modifiye edilmiş bir sternal kapama yöntemi olan Figure-of-eight and doUble-loop Sternal-closure (FUSION) tekniğinin, geleneksel sekiz figürlü telleme (Figure-of-eight wiring, FEW) tekniğine kıyasla sternal instabiliteyi azaltmadaki etkinliğini değerlendirmektir.

**Gereç ve Yöntemler:** Ocak 2023 ile Ocak 2024 tarihleri arasında Ankara Bilkent Şehir Hastanesi'nde median sternotomi ile elektif izole KABG uygulanan, vücut kitle indeksi  $\geq 30$  kg/m<sup>2</sup> olan 90 obez hasta retrospektif olarak analiz edildi. Hastalar uygulanan sternal kapama tekniğine göre iki gruba ayrıldı: 48 hasta FEW grubunda, 42 hasta ise FUSION grubunda yer aldı. Postoperatif iki ay içinde klinik takipler gerçekleştirildi; gerekli durumlarda klinik muayene, akciğer grafisi ve toraks BT ile sternal instabilite değerlendirildi. İstatistiksel analizlerde Mann-Whitney U testi, ki-kare testi, Fisher's exact testi ve çok değişkenli lojistik regresyon kullanıldı.

**Bulgular:** Gruplar arasında demografik ve perioperatif değişkenler benzerdi. Sternal instabilite, FEW grubundaki hastalarda (%10,4) FUSION grubuna kıyasla (%2,3) daha sık görüldü ( $p = 0,001$ ). Çok değişkenli analizde; FEW tekniği (OR: 3,5; %95 GA: 2,4-5,3;  $p = 0,001$ ), KOAH (OR: 3,5; %95 GA: 2,2-4,4;  $p = 0,05$ ), diyabet (OR: 2,3; %95 GA: 1,3-4,1;  $p = 0,05$ ), postoperatif delirium (OR: 3,2; %95 GA: 2,1-4,8;  $p = 0,01$ ) ve kadın cinsiyet (OR: 2,4; %95 GA: 1,8-5,5;  $p = 0,02$ ) sternal instabilite için bağımsız risk faktörleri olarak belirlendi.

**Sonuç:** FÜZYON tekniği, obez hastalarda FEW tekniğine kıyasla sternal instabiliteyi anlamlı düzeyde azaltmıştır. Bu yöntem, yüksek riskli popülasyonlar için etkili bir koruyucu yaklaşım olabilir.

**Anahtar kelimeler:** sternal kapama, obezite, koroner arter baypas greftleme, sternal instabilite

## Introduction

The median sternotomy was first developed as the standard approach of cardiac surgery by Milton in 1897 (1). This method is utilized in various significant cardiac procedures, including coronary bypass, cardiac valve replacement, and other forms of open-heart surgeries. Achieving optimal sternal closure is crucial for ensuring stability, therefore decreasing the occurrence of postoperative complications, shortening hospital stays, and enhancing cost-effectiveness (2, 3). Complications related to sternal wounding present a serious threat to patients (4).

Preoperative patient-related risk factors include gender, age, obesity, diabetes mellitus (DM), smoking, and chronic obstructive pulmonary disease (COPD). Intraoperative risk factors include use of both internal thoracic arteries and prolonged bypass time. Risk factors for postoperative complications include reexploration and transfusion (5).

Conventionally, sternal closure is carried out by stainless-steel wires. There are various techniques for sternal closure, and the single-wire technique has been described with results, but only in obese patients, by Kiessling et al (6), the double-wire closure method based on the authors' own experiences as described by Saxena et al (7), and the systematic review by Shafi et al (8) comparing double-wire and figure-of-eight wire closure methods, representing a significant contribution to the available evidence.

In this retrospective study, we compared the figure-of-8 wire (FEW) closure method with Figure-of-eight and double-loop sternal-closure (FUSION) technique in obese patients undergoing coronary artery bypass grafting (CABG) through sternotomy.

The purpose of this study is to determine if this modified sternal closure technique can decrease the rate of sternal instability amongst obese patients in whom CABG is being performed and therefore improve the outcomes of this high-risk patient.

## Material and Methods

This retrospective study was designed and conducted at a single center, Ankara Bilkent City Hospital, Department of Cardiovascular Surgery, from January 2023 to January 2024. The study was approved by the Local Ethics Committee of Ankara Bilkent City Hospital with the approval number TABED 1-24-112. All procedures were conducted in accordance with the Declaration of Helsinki and local regulatory guidelines. Informed consent obtained from patients.

The inclusion criteria for this study encompassed obese individuals with a body mass index (BMI) of 30 kg/m<sup>2</sup> or higher who underwent elective isolated CABG surgery. These procedures involved the utilization of left internal mammary artery (LIMA) graft, median sternotomy, and extracorporeal circulation. Exclusion criteria for this study included other procedure than CABG, use of bilateral internal mammary artery, redo, emergency operation, and minimally invasive CABG.

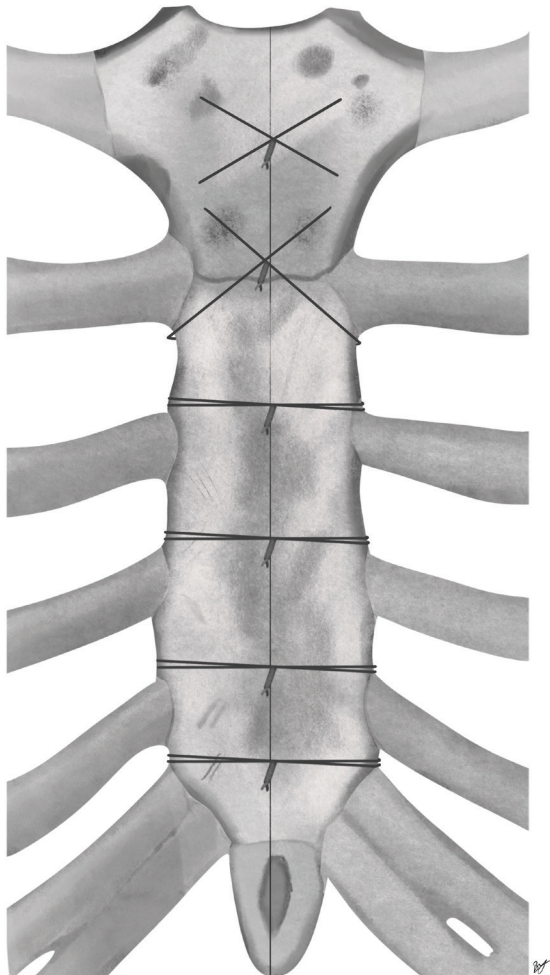
## Sternal closure technique

### Figure of eight wiring technique

In the figure-of-eight wiring (FEW) technique, stainless steel wires are passed transversely through the sternal halves in a crisscross manner, creating a “figure-of-eight” configuration.

### FUSION technique

We use two FEW over the manubrial area and at the level of the angle of Louis, and the double wire method in the other intercostal spaces (Figure 1). The sternum was closed with a 5mm/45 cm stainless steel surgical sternal wires (Doğsan, Trabzon/Turkey). Following surgery, the day of the operation, a chest brace was applied for 8 weeks.



**Figure 1.** Illustration of the FUSION technique.

Data collection relied on clinical follow-ups conducted for two months postoperatively. Routine chest X-rays were performed for one and two months postoperatively. Thoracic CT scans were performed when clinically indicated. Sternal instability considered detachment of sternum, breaking wire or sternum itself.

1456 patients underwent CABG were screened and obese patients were chosen. 90 patients (50 males and 40 females) were enrolled in this study. Within this group of obese patients 48 patients (28 males and 20 females) were treated with the figure-of-eight wire method and 42 patient (22 males and 20 females) with FUSION technique. The patients were classified into two groups for study: the FEW groups and FUSION group.

## Statistical Analysis

The data analysis was conducted using SPSS version 26 (SPSS Inc., Chicago, Illinois, United States). Continuous variables were presented as mean values  $\pm$  standard deviation (SD), while categorical variables were expressed as numbers and percentages. To compare outcomes between matched groups, the Mann-Whitney U test was utilized for continuous variables, while the chi-square test and Fisher's exact test were employed for categorical variables. A p-value of  $<0.05$  was considered statistically significant. Additionally, multivariate analysis (logistic regression) was performed to identify independent risk factors for sternal instability.

## Results

The demographic characteristics of the patients before and during surgery are summarized in Table 1. Preoperative, perioperative and postoperative data of the patients in both groups was statistically insignificant.

The average BMI rate of our patients is 33.4 in the FEW groups and 34.2 in the FUSION group. 65.5% of our patients are diabetic and smokers. There was no statistically significant difference between these results. During the postoperative follow-up period, sternal instability was noted in 5 patients (10.4%) in the FEW groups and 1 patient (2.3%) in the FUSION group (Table 2). There was statistical significance in disparity of prevalence of sternal instability between the groups.

The observed increase in sternal instability when using the FEW compared with the FUSION technique used in our institution for sternal approximation was 3.5-fold ( $p = 0.001$ ). Chronic obstructive pulmonary disease, diabetes mellitus, female gender and delirium were the factors found to be associated with higher rates of sternal instability (Table 3).

**Table 1.** Patient demographics and perioperative variables.

	FEW (n=48)	FUSION (n=42)	p
Age (y)	63.4 ±5.9	62.4 ±8.2	0.76
Males	28	22	0.45
Females	20	20	0.80
BMI (kg/m <sup>2</sup> )	33.4 ± 3.2	34.2 ± 2.2	0.67
Diabetes mellitus (n, %)	33 (68.7)	26 (61.9)	0.24
Chronic renal failure (n, %)	12 (25)	8 (16.6)	0.19
Peripheral arterial disease (n, %)	5 (10.4)	4 (9.1)	0.77
Smoking (n, %)	31 (64.5)	28 (66.6)	0.56
COPD (n, %)	8 (16.6)	10	0.54
Euro SCORE	2.32 ± 1.6	2.02 ± 1.4	0.45
CPB time (min)	91.6 ± 12.5	94.3 ± 16.2	0.32
Surgery time (min)	203.3 ± 18.6	215.2 ± 32.3	0.37
ICU stay [days] mean±SD	2.3 ± 1.6	2 ± 1.2	0.67
HLOS [days] mean±SD	7.1 ± 1.3	7.8 ± 1.4	0.72
Postoperative delirium (n, %)	16 (33.3)	15 (35.7)	0.64

BMI:Body Mass Index, COPD:Chronic Obstructive Pulmonary Disease, CPB:Cardiopulmonary Bypass, ICU: Intensive Care Unit, HLOS: Hospital Length of Stay

**Table 2.** Comparison between sternal closure techniques.

Sternal Instability	Yes	No	p
FEW (n=48, %)	5 (10.4)	43 (89.6)	0.001
FUSION (n=42, %)	1 (2.3)	41 (97.7)	
Total (n=90, %)	6 (6.6)	84 (93.4)	

FEW:Figure of Eight Wire, FUSION: Figure-of-eight and double-loop sternal-closure.

**Table 3.** Independent risk factors for sternal dehiscence.

	Odds Ratio	%95 CI	p
FEW vs. FUSION	3.5	2.4, 5.3	0.001
COPD	3.5	2.2, 4.4	0.050
DM	2.3	1.3, 4.1	0.050
Delirium	3.2	2.1, 4.8	0.010
Female	2.4	1.8, 5.5	0.020

FEW:Figure of Eight Wire, FUSION: Figure-of-eight and doUble-loop Sternal-closure, COPD: Chronic Obstructive Pulmonary Disease, DM:Diabetes Mellitus

## Discussion

Following median sternotomy, various wiring methods are employed to close the sternum. Sternal wires facilitate the approximation and fixation of the sternum. Postoperative sternal instability represents a significant complication, with potential occurrence in up to 8% of patients (9).

Moreover, sternal instability results breaking the wires, resulting cutting to the bone, and hence in sternal tissue infection that can be extended to mediastinitis (10). Mortality rates from untreated mediastinitis approach nearly 100%. The mortality from untreated mediastinitis is close to 100%. The incidence of these complications depends on certain risk factors, among which obesity, diabetes, osteoporosis,

immunosuppression and renal failure (11). However, key factor is the sternal closing technique. Surgical procedures are crucial in reducing sternal instability and disconnection. Various techniques have been devised to alleviate these complications (8, 12).

Molina et al (13) investigated the effect of sternal closure method on the incidence of sternal instability following cardiac surgery in obese patients. Obese (n = 1253) and non-obese (n = 1905) patients were compared, and sternum closure was based on the surgeon's preference: A) single wire through the bone, B) 8-shaped, or C) peristernal. The frequency of sternal dehiscence in obese patients was 6.4% (A: 6.3%, B: 6.2%, C: 7.8%), and 1.63% in non-obese

patients. These data suggest that obesity increases the risk of dehiscence. In our study, although the FUSION technique also showed decreased sternal instability with respect to the figure-of-eight technique in obese based on the risk factor of sternal instability in the postoperative follow-up period, this increase was of statistical significance. Previous reports have highlighted the superior outcomes of the double-wire technique over single-wire closure (14). We also found that postoperative delirium was a factor associated with sternal instability. Additionally, our results revealed the impact of COPD, DM and female sex on sternal instability. Reduction of sternal instability was achieved using FUSION technique and proprietary double wire technique.

In the study conducted by Loladze et al (14), an instability of the sternum was observed in the single-wire group in 16% and in 5% of the patients in the double-wire group at follow-up. The double-wire technique is intended to relieve tension in the sternum and to reduce the chance of wire cutting through bone. We hypothesize that employing double wires in this technique results in a more uniform distribution of pressure on the sternum, potentially reducing the likelihood of wire-induced sternum cutting. Additionally, we believe that incorporating the figure-of-eight wiring technique, encompassing the manubrium and the angle of Louis, reduces vertical sternum movement, consequently enhancing sternal stability. In this context, particularly in patients who may be prone to sternal instability, we were able to demonstrate that combining the FEW and double-wire techniques results in a superior approach that effectively enhances sternal stability.

FUSION technique is less susceptible to wire breakage during tightening compared to the figure-of-eight method. A study examining the utilization of double wires among sternal closure methods corroborates our findings (6). Obese patients impose greater mechanical stress on the sternum. Consequently, loosening of the wires due to this increased stress may lead to sternum cutting during breathing or coughing (14).

Losanoff et al (15) performed an experimental study to compare the tensile strength of one loop and two loops wire technique and found that double-wire technique was better than one-loop technique. Shafi et al (8) reported that the incidence of sternal instability was significantly higher with the single-wire technique compared to both the double-wire and FEW techniques. More specifically, sternal instability was noted in 14.7% of single-wire vs 4% double-wire closures.

These findings suggest a clear advantage of using double-wire configurations over single-wire closure in reducing sternal instability. In our series the incidence of sternal dehiscence with the FEW methods, widely used in our centre, was 10.4% and that achieved with FUSION method was 2.3%. FUSION technique aligns with the findings in literature and demonstrates a significant reduction in sternal instability.

### Limitations of the study

The most important limitation of our study is the limited number of obese patients in a single center and the retrospective screening. Therefore, prospective multicenter randomized studies may provide better results. Additionally, due to the unavailability of commercially manufactured double wires, we had to implement a looping technique using standard single wires. As a result, we acknowledge that this may not represent a true comparison with conventional double-wire techniques, and this limitation should be considered when interpreting our findings.

In conclusion, according to the results of our study, it has been observed that with FUSION technique sternal closure significantly reduces sternal instability compared to figure of eight in obese patients. It can be used as an important preventive measure against sternal instability for high-risk obese patients like our patient group.

### Ethics Approval

The study was reviewed and approved by the local Ethical Committee (TABED 1-24-112).

### Conflicts of Interest

The authors declare no conflicts of interest.

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### Author Contributions

Alp YILDIRIM: Conceptualization, Statistical analysis, Writing - Original Draft

Enis Burak GÜL: Data Curation, Writing - Review & Editing, Methodology

Serkan MOLA: Conceptualization, Supervision, Critical Review

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