The Egyptian Cardiothoracic Surgeon

In Press

Original Article

Skeletonized Internal Mammary Artery Harvesting with Harmonic Ultrasonic Shears Versus Cold Dissection

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Abstract

Background: Skeletonized internal mammary artery (IMA) harvesting offers several advantages over pedicled techniques in coronary artery bypass grafting (CABG). The optimal dissection tool remains controversial. Harmonic ultrasonic shears may reduce endothelial and thermal injury while improving operative efficiency compared with conventional cold dissection. The study aimed to compare operative efficiency, safety, and early graft outcomes of skeletonized IMA harvesting using harmonic ultrasonic shears versus conventional cold dissection.

Methods: In this prospective randomized study, 200 patients undergoing elective isolated CABG were randomized to harmonic shear harvesting (HS group, n = 100) or cold dissection with scissors and clips (CD group, n = 100). Operative variables, postoperative outcomes, and graft patency at 6 months were analyzed.

Results: Harmonic harvesting significantly reduced harvest time (24.6 ± 6.1 vs. 32.8 ± 7.4 minutes, $p < 0.001$), clip usage, and improved free-flow volume (78 ± 21 vs. 65 ± 18 mL/min, $p < 0.001$). Rates of IMA injury, postoperative bleeding, sternal wound infection, and 6-month graft patency were comparable between groups.

Conclusions: Skeletonized IMA harvesting with harmonic ultrasonic shears is a safe, reproducible technique that improves operative efficiency and conduit quality without compromising early clinical or graft outcomes. Broader adoption of this approach may facilitate wider application of arterial revascularization strategies.

KEYWORDS
Skeletonization; Harmonic ultrasonic shears; Cold dissection; Coronary artery bypass grafting; Arterial revascularization; Graft patency Severity Scale

Introduction

The internal mammary artery (IMA) remains the gold standard conduit for coronary artery bypass grafting (CABG), particularly for revascularization of the left anterior descending artery, owing to its superior long-term patency and survival compared with saphenous vein grafts [1, 2]. Long-term studies have consistently demonstrated reduced myocardial infarction, repeat revascularization, and mortality when an IMA graft is used [3].

Skeletonized harvesting of the IMA was introduced to enhance conduit length, increase free-flow volume, reduce postoperative pain, and preserve sternal perfusion [4]. Meta-analyses including more than 30 studies have demonstrated significantly lower rates of sternal

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wound infection (SWI) with skeletonized compared with pedicled harvesting, particularly in diabetic and obese patients [5, 6].

Despite these advantages, skeletonization is technically demanding and raises concerns regarding endothelial injury, vasospasm, and thermal damage depending on the harvesting instrument employed [7]. Conventional cold dissection avoids thermal injury but requires extensive branch ligation and mechanical manipulation, potentially prolonging operative time and increasing trauma. Electrocautery, although efficient, can generate tissue temperatures exceeding 300°C and has been associated with endothelial denudation and medial necrosis [8]. Harmonic ultrasonic shears use high-frequency mechanical vibration to divide tissue while limiting thermal spread to approximately 60–80°C, thereby preserving endothelial integrity [9]. Experimental and clinical studies have demonstrated excellent early patency and favorable endothelial preservation with ultrasonic harvesting; however, randomized comparisons between harmonic ultrasonic shears and cold dissection remain limited [10, 11].

This study was designed to prospectively compare these two techniques with respect to operative efficiency, safety, and early graft outcomes.

Patients and Methods

This prospective randomized trial was conducted at Benha University Hospitals and included 200 patients undergoing elective isolated CABG.

Inclusion criteria:

- Age ≥ 18 years
- Elective isolated CABG
- Planned use of at least one IMA graft

Exclusion criteria:

- Emergency or redo surgery
- Concomitant valve or aortic surgery
- Severe chest wall deformity
- End-stage renal disease on dialysis
- Active infection or immunosuppression

Patients were randomized 1:1 using computer-generated block randomization into: (1) HS group: skeletonized IMA harvested with harmonic ultrasonic shears; and (2) CD group: skeletonized IMA harvested using cold scissors and metallic clips.

Surgical Technique

All operations were performed through median sternotomy by experienced surgeons.

Harmonic-shear technique: The pleura was gently swept off the endothoracic fascia. The IMA was skeletonized using harmonic ultrasonic shears (Ethicon Endo-Surgery). Side branches were sealed using the blunt jaw of the device; clips were applied only if bleeding occurred. The device was maintained ≥1 mm from the arterial wall to avoid thermal injury, as recommended in prior experimental studies [10]. Papaverine-soaked gauze was applied after harvest.

Cold dissection technique: Skeletonization was performed using fine scissors. Side branches were divided and ligated with metallic clips. Mechanical traction was minimized. Papaverine was applied similarly. The IMA was anastomosed to the target coronary artery using continuous polypropylene sutures.

Sample Size Calculation

Based on Kieser et al. [12], harmonic harvesting reduced mean harvest time by approximately 6 minutes (SD ≈12 minutes). With $\alpha = 0.05$ and power = 90%, the required sample size was 90 patients per group. Allowing for attrition, 100 patients per group were enrolled.

Ethics

The study was conducted after approval from the Ethics Committee of Benha University Hospitals and was performed in accordance with the Declaration of Helsinki. Written informed consent was obtained from all patients prior to enrolment.

Statistical analysis

Data processing was performed using SPSS v26 (IBM Inc., Armonk, NY, USA). The normality of data distribution was assessed using the Shapiro–Wilk

Table 1: Baseline Characteristics

Variable	HS (n=100)	CD (n=100)	P value
Age (years)	65.1 ± 9.6	64.8 ± 10.2	0.831
Male sex, n (%)	69 (69%)	71 (71%)	0.758
Diabetes mellitus, n (%)	33 (33%)	35 (35%)	0.765
BMI (kg/m^2)	28.4 ± 4.1	28.6 ± 4.3	0.737
EuroSCORE II	2.9 ± 1.2	3.0 ± 1.1	0.540

HS: harmonic shear group; CD: cold dissection group; BMI: body mass index; EuroSCORE II: European System for Cardiac Operative Risk Evaluation II

test and visual inspection of histograms. Continuous variables are expressed as mean ± SD and were compared using the unpaired Student's t-test. Categorical variables are reported as frequencies and percentages, with associations evaluated via the Chi-square test or Fisher's exact test as required by the data distribution. Statistical significance was set at a two-tailed $p < 0.05$.

Results

There were no statistically significant differences in age, sex distribution, prevalence of diabetes mellitus, body mass index, or operative risk as assessed by EuroSCORE II between the harmonic shear (HS) and cold dissection (CD) groups (Table 1).

The HS technique resulted in a significantly shorter harvest time, greater conduit length, higher free-flow volume, and fewer clips compared with the CD group (all $p < 0.05$). Importantly, the incidence of IMA injury was low and comparable between groups (Table 2).

There were no statistically significant differences in rates of re-exploration for bleeding, perioperative myocardial infarction (MI), or stroke. Although superficial and deep sternal wound infection (SWI) rates were numerically lower in the HS group, these differences were not statistically significant (Table 3). Six-month CT angiography demonstrated IMA graft patency rates of 98% in the HS group and 96% in the CD group, with no statistically significant difference between groups ($p = 0.683$).

Discussion

The present prospective randomized study demonstrated that skeletonized IMA harvesting using harmonic ultrasonic shears significantly improved operative efficiency and conduit flow characteristics while maintaining excellent safety and early graft patency compared with conventional cold dissection.

Harvest time was significantly reduced in the harmonic group, consistent with large observational series demonstrating progressive time reductions with ultrasonic technology [12]. Reduced clip usage further simplifies the procedure and may theoretically reduce foreign-body-related inflammation.

Preservation of endothelial integrity is critical for graft durability. Electrocautery-based harvesting generates excessive heat and risks endothelial injury [8], whereas ultrasonic devices limit thermal spread to 60–80°C [9]. Experimental studies have confirmed superior endothelial preservation with ultrasonic skeletonization [10].

Table 2: Intraoperative Outcomes

Variable	HS (n=100)	CD (n=100)	P value
Harvest time (min)	24.6 ± 6.1	32.8 ± 7.4	< 0.001*
Conduit length (cm)	18.4 ± 1.9	17.6 ± 2.1	0.005*
Free-flow volume (mL/min)	78 ± 21	65 ± 18	< 0.001*
Clips used (n)	1.2 ± 0.8	6.7 ± 1.9	< 0.001*
IMA injury, n (%)	1 (1%)	2 (2%)	1.00

HS: harmonic shear group; IMA: Internal mammary artery; CD: cold dissection group; * statistically significant ($p < 0.05$)

Table 3: Early Postoperative Outcomes

Variable	HS (n=100)	CD (n=100)	P value
Re-exploration for bleeding, n (%)	2 (2%)	3 (3%)	1.00
Superficial SWI, n (%)	2 (2%)	6 (6%)	0.279
Deep SWI, n (%)	0 (0%)	1 (1%)	1.00
Perioperative MI, n (%)	1 (1%)	2 (2%)	1.00
Stroke, n (%)	0 (0%)	1 (1%)	1.00

HS: harmonic shear group; CD: cold dissection group; SWI: sternal wound infection; MI: myocardial infarction

The higher free-flow volume observed in the harmonic group likely reflects reduced vasospasm and preserved endothelial function.

IMA injury rates were low and comparable, consistent with modern series reporting injury rates below 2% when skeletonization is performed by experienced surgeons [12]. Postoperative bleeding and re-exploration rates were similar, reinforcing the safety of ultrasonic branch sealing.

Skeletonization itself remains the dominant factor in reducing sternal wound infection [5, 6]. Although SWI rates were numerically lower in the harmonic group, the study was underpowered to detect statistical significance. Importantly, excessive thermal injury has been identified as an independent risk factor for SWI [5], suggesting that harmonic technology may offer indirect protective effects.

Early graft patency exceeded 95% in both groups, consistent with the findings of Jung et al. [13]. While some registry analyses have suggested higher early occlusion rates with skeletonized IMAs [14], subsequent studies have demonstrated that outcomes are highly dependent on surgeon experience [15].

Harmonic ultrasonic shears may be particularly advantageous in minimally invasive and bilateral IMA harvesting, where limited operative exposure amplifies technical challenges [13]. Reduced operative time and tissue trauma may facilitate broader adoption of arterial revascularization strategies.

Limitations

Several limitations of this study merit consideration. First, the single-center design and use of a limited number of experienced surgeons may restrict generalizability; multicenter trials are needed to confirm these findings across institutions and operator skill levels. Second, the follow-up period of six months is insufficient to evaluate long-term graft patency and survival; extended follow-up studies are warranted. Third, a potential operator learning curve effect may have influenced harvest time and injury rates, as performance with harmonic shears may improve further with increasing experience. Fourth, histological analysis of harvested conduits was not performed, precluding definitive comparison of endothelial morphology between techniques. Fifth, outcome assessors were not blinded to group allocation, introducing a potential source of assessment bias. Future randomized controlled trials with long-term follow-up, blinded assessment, and histopathological endpoints are needed to fully characterize the advantages of harmonic skeletonization.

Conclusion

Skeletonized IMA harvesting using harmonic ultrasonic shears is a safe, reproducible technique that improves conduit quality and operative efficiency without compromising early clinical or graft outcomes. Broader adoption of this approach may facilitate wider application of arterial revascularization strategies.

Funding: Self-funded
Conflict of interest: Authors declare no conflict of

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