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Early and Mid-Term Outcomes of Quadruple Attack Technique for Sternal Osteomyelitis and Chronic Sinus Formation After Cardiac Surgery

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Abstract

Background: Sternal osteomyelitis with chronic sinus tract after cardiac surgery is a serious complication, and early management is crucial. The aim of this study is to report our experience with the "Quadruple Attack" technique, which involves intravenous (IV) antibiotics, surgical debridement, vacuum therapy, and hyperbaric oxygen sessions for management of this condition.

Methods: This prospective study was performed at Cardiothoracic Surgery Department, Ain Shams University in Egypt between March 2020 and August 2024 and included 52 patients who underwent the quadruple attack technique for the management of sternal osteomyelitis with a chronic sinus tract.

Results: The mean age was 49.6 ± 9.23 years. 12 (23.1%) patients were hypertensive, while 17 (32.7%) of patients had diabetes. 44 (84.6%) of patients had satisfactory healing, 8 patients (15.4%) had re-sternotomy and resection of the sinus tract, while 5 patients (9.6%) required sternectomy and musculocutaneous flaps.

Conclusion: Our quadruple attack technique for the management of sternal osteomyelitis with a chronic sinus tract after cardiac surgery is promising, with encouraging mid-term outcomes in selected patients with a non-dehisced sternum.

KEYWORDS

Sternal osteomyelitis; Sternal sinus; Cardiac Surgery

Introduction

Sternal osteomyelitis with chronic sinus tract after cardiac surgery is a serious complication, and early management is crucial [1]. The incidence varies across centers, countries, and eras, and has been reported to range from 0.2 to 8% [1, 2]. However, the mortality rate varies from 8 to 45%, and it is associated with increased medical costs, prolonged hospital stay, and reoperation [2]. The potential complications like septicemia and spread of infection into the mediastinum, grafts, prosthetic valves, and suture lines, make it an extremely challenging complication [1].

Surgical debridement and vacuum therapy are frequently needed when antibiotics alone cannot control the infection, and sternectomy may also be required, in addition to a musculocutaneous flap in severe cases for optimum healing. Patients with deep sternal wound infection can benefit from hyperbaric oxygen therapy, especially in terms of in-hospital mortality [3].

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Despite being a common complication after cardiac surgery, its management is still a subject of ongoing studies. Thus, we report our experience with the “Quadruple Attack” technique, which involves intravenous (IV) antibiotics, surgical debridement, vacuum therapy, and hyperbaric oxygen sessions for management of this condition.

Patients and Methods

Study settings

This retrospective cohort study was conducted from March 2020 through August 2024 and included 52 patients who received our quadruple attack technique for the management of sternal osteomyelitis and chronic sinus tract. All patients were evaluated clinically and radiologically to confirm the diagnosis and exclude sternal dehiscence, as patients with sternal dehiscence are not suitable for hyperbaric oxygen therapy. The study was approved by the local ethics committee, and the need for patient consents was waived due to the retrospective design.

Technique

The clinical diagnosis was based on the patient's history, clinical examination, and radiological findings, including a chest computed tomography (CT) scan with a fistulogram. All patients underwent laboratory investigations, including white blood cell count, inflammatory markers, and a sternal wound swab for culture and sensitivity. Intravenous (IV) antibiotics were administered based on the culture results. Table I summarizes the demographic and clinical characteristics of the included patients.

All patients underwent the quadruple attack technique, which included IV antibiotics, surgical debridement, vacuum-assisted therapy, and hyperbaric oxygen sessions. IV antibiotics, selected according to culture and sensitivity results, were continued for at least six weeks. Nineteen cases (36.5%) had methicillin-resistant Staphylococcus aureus (MRSA), 13 cases (25%) had Pseudomonas aeruginosa, 9 cases (17.3%) had Escherichia coli, while 11 cases (21.2%) had negative cultures. Patients with negative cultures received broad-spectrum antibiotics (vancomycin and meropenem). None of the patients developed antibiotic toxicity.

Surgical debridement was performed after initiating IV antibiotics. All necrotic tissue was resected, and the sternal wires associated with the sinus tract were removed. Tissue and bone cultures were obtained during debridement, and antibiotics were modified or continued as indicated by the culture reports.

Vacuum-assisted therapy was applied with a target negative pressure of 125 mmHg, using an intermittent cycle (5 minutes on, 2 minutes off), and was repeated two to three times weekly. None of the patients developed VAC-related complications such as bleeding.

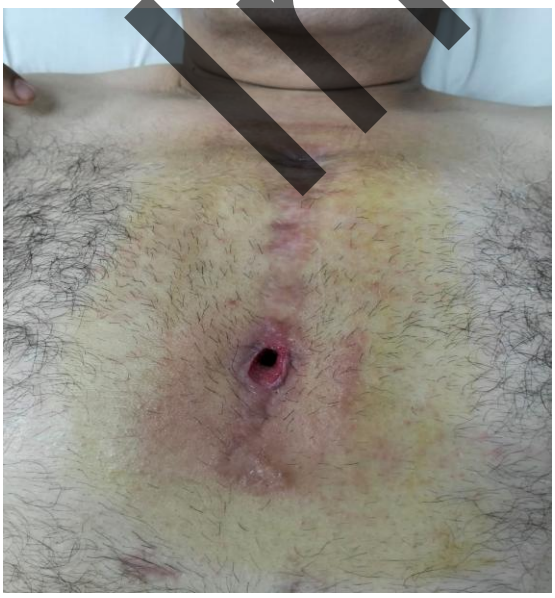

Figure 1: The sternal wound after 1 week of therapy

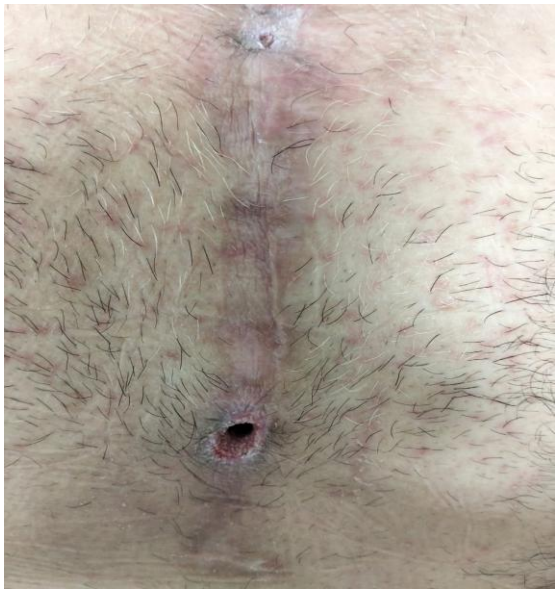

Figure 2: The sternal wound after 2 weeks of therapy

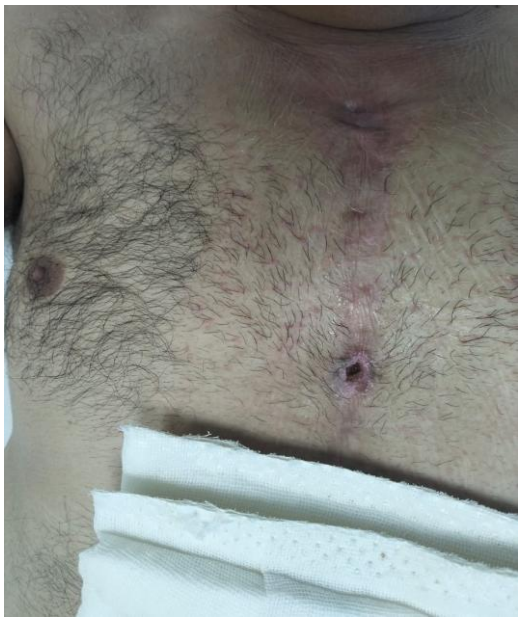

Figure 3: The sternal wound after 4 weeks of therapy

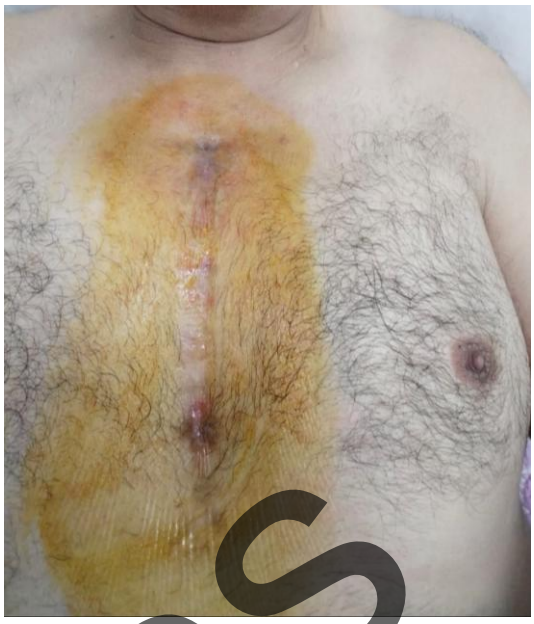

Figure 4: The sternal wound after 6 weeks of therapy

Hyperbaric oxygen therapy consisted of a total of 20 sessions delivered three times weekly. A single session in the hyperbaric chamber lasted approximately 70 minutes and included three stages: first, a slow compression phase (also called "immersion"), during which pressure in the chamber was increased. This phase lasted 5 to 10 minutes until the target pressure of 2.4 ATA was reached. Second, the main treatment stage lasted approximately 55 minutes, during which the chamber maintained the pressure required for oxygen to dissolve into the blood, supporting immune mechanisms and accelerating the regeneration of damaged tissues and organs. Third, the slow decompression phase, which equalized the pressure in the hyperbaric chamber, lasted 5 to 10 minutes.

Patients with sternal dehiscence or contraindications to hyperbaric oxygen therapy were excluded from this protocol. All patients tolerated hyperbaric oxygen therapy without barotrauma or oxygen toxicity, except for one patient who developed ear discomfort during the 11th session and did not complete the full 20 sessions.

Data and outcomes

The study collected comprehensive demographic and clinical data from the patient cohort. These data included the age, gender, and the mean time elapsed since the primary cardiac surgery. An analysis of relevant comorbidities included diabetes mellitus, hypertension, and dyslipidemia. Furthermore, patients presented with renal impairment and a history of atrial fibrillation were included.

The study outcomes included satisfactory healing (defined as the absence of drainage or sinus, radiographic resolution on CT, normalization of inflammatory markers, and no need for further intervention at one year). The need for escalation of therapy to a redo sternotomy and resection of the sinus tract or the need for a more extensive sternectomy followed by musculocutaneous flap reconstruction were reported.

Statistical analysis

Data were presented as means and standard deviations for continuous variables, and as counts and percentages for categorical variables.

Results

Among the 52 patients who underwent this technique, the mean interval since the original open-heart surgery was 19.73 ± 6.14 months (Table 1). Satisfactory healing, defined as the absence of drainage or sinus, radiographic resolution on CT, normalization of inflammatory markers, and no need for intervention at one year, was achieved in 44 (84.6%) patients. Criteria for escalation, prompting redo sternotomy or sternectomy with flap reconstruction, included persistent sinus or discharge and persistent

radiological findings of sternal osteomyelitis. The time from the initial debridement to escalation was after six weeks of combined therapy. Eight patients (15.4%) required a redo sternotomy and resection of the sinus tract extending deep to the sternum, and 5 (9.6%) of these patients required musculocutaneous flaps performed by the plastic surgery team. Table 2 summarizes the early postoperative outcomes of the included patients.

Table 1: Demographic and Clinical Characteristics of the Patients Who Received the Quadruple Attack Technique. Data is presented as mean ± SD for quantitative variables and number (%) for qualitative variables

Variable	Value
Age (Years)	49.6 ± 9.23
Sex (Males)	33 (63.5%)
Time since primary surgery (Months)	19.73 ± 6.14
Diabetes mellitus	17 (32.7%)
Hypertension	12 (23.1%)
Dyslipidemia	9 (17.3%)
Renal impairment	3 (5.8%)
Atrial fibrillation	14 (26.9%)

At the one-year follow-up, all patients remained asymptomatic with satisfactory healing, as defined above.

Figure 1 shows the sternal wound after one week of therapy. Figure 2 shows the sternal wound after two weeks of therapy. Figure 3 shows the sternal wound after four weeks of therapy. Figure 4 shows the sternal wound after six weeks of therapy.

Table 2: Early postoperative outcomes for the included patients

Variable	Value
Satisfactory healing	44 (84.6%)
Resternotomy and resection of the sinus track	8 (15.4%)
Sternectomy and myocutaneous flap	5 (9.6%)

Discussion

Sternal osteomyelitis with a chronic sinus tract following cardiac surgery remains a significant challenge for surgeons. A total of 52 patients with sternal osteomyelitis and chronic sinus tract following cardiac surgery were treated with the "Quadruple Attack" technique, which combines IV antibiotics, surgical debridement, vacuum-assisted therapy, and hyperbaric oxygen. The mean age of the cohort was 49.6 ± 9.23 years, and the mean interval since the primary surgery 19.73 was since ± 6.14 months. Diabetes mellitus was present in 32.7% of patients, and 26.9% had a history of atrial fibrillation. The treatment protocol achieved satisfactory healing in 44 patients (84.6%). Treatment escalation was required in 8 patients (15.4%), who underwent a redo sternotomy and resection of the sinus tract. Of these, 5 patients (9.6% of the total cohort) ultimately required a more extensive sternectomy with musculocutaneous flap reconstruction. At the one-year follow-up, all patients who achieved satisfactory healing remained asymptomatic.

Olimpiu Bota and colleagues conducted a study to pathologically examine resected sternal specimens from patients with osteomyelitis. They used a score from 0 to 5 to describe the intensity of sternal inflammation and found it in 76.6% to 93.6% of specimens. Notably, the left hemisternum sections were more prone to inflammation, particularly in cases where the left internal mammary artery had been harvested. This study demonstrated that deep sternal wound infection can cause widespread inflammation of the sternum and that harvesting the left internal mammary artery may exacerbate the infection [4].

Wen-Kuang Yu and colleagues performed a retrospective study to evaluate the effect of hyperbaric oxygen therapy on sternal infection and osteomyelitis after cardiac surgery. Twelve patients who underwent surgical debridement and received antibiotics were selected, six of whom also received additional hyperbaric oxygen therapy. No treatment-related complications occurred in patients who received this additional modality. Comparisons between the two groups showed that ICU stay and mechanical ventilation duration were significantly shorter in patients who

received adjunctive hyperbaric oxygen therapy. In-hospital mortality was also significantly lower in this group. The study concluded that, in addition to surgical debridement and antibiotics, hyperbaric oxygen therapy may be considered an adjunctive, safe modality to improve outcomes in patients with sternal infection and osteomyelitis after cardiac surgery [5].

In our series, we administered hyperbaric oxygen therapy three times weekly for a total of 20 sessions. Brett B. Hart noted that 20 to 40 sessions are typically required to achieve a sustained therapeutic benefit [6]. To investigate the diagnosis, management, and prevention of chronic sternal osteomyelitis with sinus formation after cardiac surgery, Guo and associates conducted a study involving 53 patients. They found that surgical debridement should be performed as soon as the diagnosis is confirmed, and that a combined-modality approach, including surgical debridement, musculocutaneous flap reconstruction, and an intermediate-thickness free skin graft, is both effective and safe [7]. Accordingly, we believe that a multi-modality approach is essential for managing this potentially serious condition.

The broader surgical literature on deep sternal wound infection (DSWI) and mediastinitis, including classification systems, timing of flap coverage, and outcomes comparing vacuum-assisted therapy followed by flap versus early flap reconstruction, is extensive. A more thorough contextualization of our findings within this framework would help position our protocol relative to established approaches and reported success and recurrence rates. Alebrahim and colleagues, in a review of this topic, found a lack of evidence-based surgical consensus regarding the appropriate management strategy, including the type of closure, choice of sternal coverage post-sternectomy, and whether to perform primary or delayed reconstructive flaps [8]. In all our patients, once complete healing of the sternotomy incision was achieved, without a sinus tract or discharge, they fully recovered and returned to normal activity. In other words, ethical and patient-centered outcomes, such as pain control, quality of life, time to functional recovery, and return to activity, would add meaningful context beyond simple wound closure.

Implications

The findings of this study suggest that the "Quadruple Attack" technique is a safe and promising multidisciplinary approach for managing post-sternotomy osteomyelitis in patients without sternal dehiscence. The high rate of satisfactory healing (84.6%) and the absence of major complications, such as antibiotic toxicity or VAC-related bleeding, support the feasibility and tolerability of this combined modality. By integrating hyperbaric oxygen therapy with standard surgical and antimicrobial care, this protocol may help reduce the need for more aggressive surgical interventions like sternectomy and flap reconstruction, as only 15.4% of patients required such escalation. These results contribute to the ongoing effort to standardize care for a condition with limited evidence-based consensus.

Limitations

This study is limited by the relatively small number of cases included and the relatively short one-year follow-up period. Further research involving a larger patient cohort and a longer follow-up duration is advisable.

Conclusion

Our quadruple technique for the management of sternal osteomyelitis with a chronic sinus tract after cardiac surgery is promising, with encouraging mid-term outcomes in selected patients with a non-dehisced sternum.

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