Treatment of mediastinitis using an open irrigation and delayed sternal reconstruction with a pectoralis major muscle flap

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Background. **Mediastinitis is a very serious complication after cardiac surgery. To date, the optimal treatment of mediastinitis is still controversial: the "closed wound" procedures and the "open wound" treatments are the two conventional modalities reported in the literature.**

Methods. **Between January 1995 and December 2000, 20 patients, who had previously been submitted to cardiac surgery, were treated by a modification of the "open wound" treatment strategy for postoperative mediastinitis. All patients were scheduled for 2, 6, and 12-month clinical follow-up. The procedure performed consisted of three major steps: 1) early sternum reopening, followed by phase 2) including irrigation of the wound 3 times daily, and the final step 3) of delayed reconstructive surgery using the pectoralis major myocutaneous advancement flap closure technique. We prospectively analyzed the short- and long-term results of these procedures.**

Results. **The overall duration of hospitalization was 25 ± 10 days; no patient required intensive care unit permanency. Clinical success was achieved in all 20 cases (100%). No recurrences of local (such as fistulas or abscesses) or systemic infections were noted, and no patient required sternal reopening during follow-up. An optimal cosmetic result was obtained in all patients and only 2 cases had persistent sternal pain regressing at the 6-month follow-up control.**

Conclusions. **Our data suggest that for patients with severe mediastinitis, this treatment strategy is safe. The clinical and esthetic success rates are high, the recovery time rapid, and the rates of short- and long-term complications very low.**

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Introduction

Infection of the deep sternotomy wound with subsequent mediastinitis is a very serious complication after cardiac surgery. The incidence is reported to range between 1% to over 2.5%[1,2] and, in diabetic patients who undergo coronary bypass surgery with both internal mammary arteries harvested, the incidence exceeds 10%[1,3]. A mortality rate > 50% has been reported in several series and an effective treatment is considered able to reduce the mortality rates only to about 10%[2,3]. Moreover, the occurrence of mediastinitis negatively affects the length and cost of hospitalization[4]. Several factors have been associated with an increased risk of developing this complication. Diabetes mellitus, chronic obstructive pulmonary disease, chronic renal failure, obesity, smoking, and redo surgery are acknowledged among the preprocedural risk factors while intraoperative risk factors include the use of bilateral mammary artery grafts, prolonged postoperative mechanical ventilation, the extensive use of diathermy, the length of the procedure, the over-use of bone wax, and reopening for bleeding[2,5]. The standard treatment of this condition is still controversial; two main strategies are employed: 1) the "closed wound" approach (which may be vacuum-assisted), and 2) "open wound" treatment[1].

In this study we report the results obtained in patients treated with the "open wound" modified treatment strategy for postoperative mediastinitis.

Methods

Patients' characteristics. Between January 1995 and December 2000, 20 patients, representing 0.5% of the 3600 patients operated upon in our center during the same period, presented with postoperative mediastinitis. The indication for the initial median sternotomy was myocardial revascular-

ization in 16 patients and valve replacement in the remaining 4. The patients' characteristics are shown in table I. The mean age of the patients was 65 years (range 45-75 years). Twelve patients were male, 9 were diabetic (6 of whom were on an insulin regimen). Mediastinitis was diagnosed 12 ± 5 days after the intervention and the sternum was reopened in all cases within 1 to 9 hours of the diagnosis. The diagnosis of mediastinitis was made on the basis of the coexistence of fever, leukocytosis, and sternal instability or complete dehiscence (according to the criteria of the Centers for Disease Control and Prevention[6]) followed in all cases by the oozing of pus at the sternal reopening. We excluded from the analysis all the patients without wound pus. Eighteen patients with an infection of the superficial layers without sternum instability as well as 25 patients with sterile wound dehiscence were excluded from the study. The initial approach to closure of the sternum with the "open wound" technique was used in 15 cases (75%) while in the others an "open wound" strategy was used only after failure of a previously attempted closed approach (5 patients, 25%).

Procedural characteristics. The approach to mediastinitis consisted of a triple step approach.

Step I. Early sternal suture reopening. As soon as the diagnosis was made the initial step consisted of a prompt surgical reopening of the sternotomy in the operating room with the patient under mild anesthesia and moderate sedation. Necrotic debris and potentially infective material (including parts of the sternum) were removed together with the suture wires and sent to the microbiology laboratory for germ isolation. Sternal wound debridement was aggressive and associated with irrigation using large volumes of diluted povidone-iodine solution (betadine). The wound was left open and filled with gauze packs soaked in 10% chloramine solution.

Table I. Patients' preoperative and perioperative characteristics.

No. patients	20
Sex (M/F)	12/8
Age (years)	65 ± 14
Indication for surgery	
Myocardial revascularization	16 (80%)
CABG	15
OPCAB	1
Aortic valve replacement	2 (10%)
Mitral valve replacement	2 (10%)
Mediastinitis risk factors	
Diabetes	9 (45%)
Smoking	12 (60%)
Obesity	1 (5%)
Chronic renal failure	3 (15%)
Chronic obstructive pulmonary disease	5 (25%)
Ventilation > 24 hours	1 (5%)
Reoperation	1 (5%)
Revision for bleeding	4 (20%)
Use of one mammary artery	16 (100% CAD patients)
Use of both mammary arteries	1 (5%)
Prolonged operative time (> 4 hours)	5 (25%)

CABG = coronary artery bypass graft; CAD = coronary artery disease; OPCAB = off-pump coronary artery bypass.

Step II. Intermittent irrigation of the wound and medical support of the patient. Local treatment was carried out 3 times daily at the patient's bedside. The chloramine solution was poured into the wound and left *in situ* for about 30 min. The patient was invited to inhale deeply and to cough so as to allow sternal movement and more complete irrigation of the wound. The chloramine solution was then washed out and the wound was packed with sterile dry gauze. Surgical curettage of all necrotic-infective debris was done, especially during the initial days of the procedure. Once weekly we applied silver nitrate along the wound margins to avoid the growth of epithelial tissue into the wound.

All complications and/or comorbidity were treated during this period. Particular attention was given to the cardiovascular and respiratory states, the renal function, anemia and the nutritional and psychological states. The body temperature was monitored 3 times a day and every third day until complete blood cell counts, the coagulation profile, renal and liver function tests and blood germ isolation had been performed. Analgesia was administered, when necessary, with non-steroidal anti-inflammatory drugs. Oral anticoagulation was continued in those patients with prosthetic valves.

Once the patient's general conditions were considered optimal (including a body temperature < 37°C and a white blood cell count in the normal range) and local and systemic signs of infection were absent (macroscopic and microscopic sterility) the final step of sternal reconstruction was carried out.

Step III. Delayed sternal reconstruction with a pectoralis major muscle flap. As reported by Perkins et al.[7], the edges of the wound were resected and the pectoralis major myocutaneous advancement flap was elevated with no additional skin incision. The subpectoral fascia, which is relatively avascular, was dissected laterally over the pectoralis minor muscle. This allowed for adequate mobilization such that the muscle could be advanced to cover the sternal defect. A superior based flap was mobilized by elevating the sternocostal and manubrial origins and by dividing the perforators in the medial intercostal spaces using diathermy. The oscillating saw was used to cut the sternum and thin slices were removed at each side, taking care to reduce the wastage of viable bone to the minimum. No dissection of the underlying structures was necessary, thus doing away with time-consuming and potentially risky maneuvers. Diathermy was used to avoid leaving necrotic tissues as a possible site for future infection. Seven to 10 single 1G loop 4-0 metric polydioxanone

(PDS) sutures (Ethicon, Edinburgh, UK) were used for suturing. Sutures are made only through the outer cortex of the sternum in order to avoid puncture of the pleura which is commonly densely adherent to the posterior surface of the sternum. Having completed the reconstruction the stability of the structures was manually confirmed. The flaps were then easily advanced to the midline without tension. PDS absorbable monofilament 3G in interrupted sutures were used to approximate the pectoralis major muscle and the overlying fascia. The skin was then closed using an intradermal absorbable suture. Two closed high-pressure movable assisted drains were then placed below the subcutaneous and muscular flaps to prevent blood or fluid accumulation. The drains were removed when the volume of fluid drained during the preceding 24 hours dropped to < 10 ml.

Findings at bacterial *in vitro* growth and the choices of antibacterial treatment. Empiric antibacterial therapy (with teicoplanin 400 mg 3 times daily, and meropenem 500 mg 3 times daily) was started as soon as the diagnosis was made; however, drug therapy was subsequently modified according to the findings at the bacterial cultures of the material drawn during step I. In each case, a specific infectious agent was identified. The isolated germ was *Staphylococcus epidermis* in 15 cases (75%) and *Staphylococcus aureus* in the remaining 5 cases (25%). *Staphylococcus aureus* infections were treated with vancomycin 500 mg twice daily (instead of teicoplanin).

Endpoint definitions. Clinical success was defined as the absence, at the end of treatment and during follow-up, of signs of ongoing infection, sternal dehiscence, and wound reopening without any major complications. The definition of major complications included death, a non-fatal acute myocardial infarction, non-fatal stroke and sepsis. Secondary endpoints included the time to achieve regression of the fever and the normalization of the white blood cell count.

Minor complications were defined as the need for ambulatory care of the wound and included superficial infections, cutaneous fistulas, persistent sternal tenderness or durability, and a poor esthetic result. Patients were followed up for at least 12 months after the procedure with a scheduled office visit at 2, 6 and 12 months. Secondary analysis regarded the length of hospital stay and the duration of each treatment step.

Results

The overall hospital stay was 30 ± 12 days. The mean duration of step II was 15 ± 6 days while the mean length of hospitalization after sternal closure with the plastic flap procedures (step III) was 5 ± 2 days. The intraoperative time was 30 ± 10 min for step I and 100 ± 25 min for step III respectively. None of the patients were admitted to the intensive care unit. All 20 patients were extubated in the operating room and ventilatory support at the end of surgery was never necessary. All patients were mobilized on the first postoperative day and the drains were removed after 3 ± 1 days. After sternal reopening all patients became afebrile within 3 ± 2 days. The white blood cell count became normal after 5 ± 2 days. The wound became sterile after 11 ± 2 days. Intravenous antibiotic therapy was stopped at the time of hospital discharge and all the patients continued oral therapy for at least 24 days.

Clinical success was achieved in all 20 cases (100%). In particular, none of the patients died or had cardiac or neurologic complications during hospitalization or during follow-up. There were no recurrences of local (such as fistulas or abscesses) or systemic infections, and additional sternal reopening was never necessary. In all patients an optimal cosmetic result was obtained. Two patients (10%) had persistent sternal pain at 2 months of follow-up but not at the 6-month follow-up visit.

Discussion

The overall incidence of mediastinitis in clinical registries varies from 1% to over 2.5% of patients undergoing a median longitudinal sternotomy[1,2]. Interestingly, despite major improvements in surgical techniques and the decline in major adverse complications, over the past 30 years the incidence of mediastinitis has remained fairly constant[2,8]. Historically, the mortality associated with the current treatment modalities is very high, ranging between 15 and 50%[1-3]. Death is generally due to sepsis, endocarditis, hemorrhage or multiple organ failure (including acute respiratory distress)[2,4,9].

Moreover, in case of mediastinitis the costs of hospitalization increase significantly by a factor of approximately 3 compared to those of patients with an uncomplicated postoperative course[10]. Increased costs are primarily due to a prolonged hospital stay, to the recurrence of infections and to the need of repeat surgical procedures among these patients[10].

To date, the optimal treatment of mediastinitis is still controversial. There are two conventional treatment modalities reported in the literature[1,2]. The "closed wound" procedures and the "open wound" treatments. The "closed wound" procedure was introduced in cardiothoracic surgery by Durandy et al.[11] and was followed by a modified version proposed by Calvat et al.[12]. These techniques were associated with a shorter hospital stay and immediate sternum reconstruction, even though they were laden with a significant incidence of complications. Fistulas and abscesses occurred in about 20% of cases and were associated with persistent infections. The mortality reached 18%, and sternal reopening as bailout treatment was necessary in

over 13% of cases[11-13]. Continuous irrigation catheters used with the "closed" procedures further enhance the risk of infection, and are considered a very complex intervention worsening the conditions for the patient[12-14]. "Vacuum-assisted" closure techniques have been introduced into clinical practice only recently[15-19]. Although the available data are limited, this procedure appears to be associated with a high clinical success rate especially when compared with continuous irrigation closed treatment[16]. However, the patients must remain in bed for a mean period of 10-14 days without the possibility of walking and hence of increasing their respiratory capacity. Moreover, the treatment failure rate remains high[16-18] and the mortality reaches 10%[15-19]. None of these studies reported long-term follow-up data. For this reason, late complications such as fistulas, abscesses, wound tenderness or late dehiscence cannot be excluded.

Our data suggest favorable results with a logical strategy which is feasible in all patients with severe mediastinitis and without pericardial-pleural cavity communications. A three-step procedure was used to achieve a high clinical and esthetic success rate with very mild short- and long-term complications. Each step implies a different pathophysiologic meaning, and it is necessary to perform all steps in sequence if the final endpoints are to be reached. We believe that the excellent results may be attributed to the logical sequence of each step: a low-risk procedure in the presence of infection and sepsis and reconstruction only when the clinical conditions are good and the patients completely free of systemic and local infection. The muscle reconstruction allows for optimal cosmetic results. Even though in our study the different surgical techniques are not compared, it is noteworthy that the high success rate of treatment was maintained even during the long-term follow-up. Several authors[15,20] consider primary closed treatment as the first-line strategy for mediastinitis developing within 2-3 weeks after the initial surgical intervention. In our study the high success rate was obtained in patients in whom the mean time of mediastinitis after the initial surgery was 12 ± 5 days. On the other hand, some others[21] consider "open wound" techniques as being useful only in cases of moderate mediastinitis. However, our data suggest that it is feasible even in severe cases. As previously reported in the literature, "open wound" techniques were limited by a long hospital stay and by a considerable failure rate at follow-up[1,15,22]. For this reason, they were reserved only for those patients presenting with recurrent mediastinitis in whom the closed treatment approach had failed. In our series, however, the open intermittent irrigation strategy and the delayed sternal reconstruction with the pectoralis major muscle flap were used as first-line treatment with a 100% clinical success, a shorter hospital stay if compared to previous open treatment historical controls, and with a recovery time comparable to that of the "closed wound" techniques. The main differences between our results and those of other studies dealing with "open wound" treatment can be found in the evolution of step II, which was reported to be significantly longer than that of other strategies[21-23]. Several "open wound" treatments used different antiseptic solutions but the wound recovery time still remained longer than 30 days[24]; our data suggest that probably the overall contact time between the antiseptic solution and the sternal wound influences the rapidity of recovery of the wound more than the type of antiseptic solution.

"Vacuum-assisted" treatment modalities[15-19] and previous open[21-23] or closed treatments[12,13,20] had the disadvantage of heavy medical and nursing loads, while in our series no patient required intensive care unit permanency for respiratory or other discomforts. All patients were able to move about after 24 hours of step I, and in all cases cardiopulmonary rehabilitation was started within day 2. In fact, if compared with previous reports[10-19,25] our step I should be considered less invasive and more rapid with a short operative time. During step I, however, it is important to ensure that there is no communication between the mediastinal and pleural cavities, in view of the possibility of disseminating the infection and in order to avoid pneumothorax and the accidental introduction of antimicrobial solutions.

A high rate of failure following closed treatments may also be due to the impossibility of directly visualizing the wound and of simultaneously associating other therapies. We think that the optimal results obtained in our cases depend on the fact that the wound was rendered directly visible, and may also be related to the less vigorous curettage allowed by the "open" approach. Besides, the concomitant use of hyperbaric oxygen therapy in case of osteitis may have also contributed to decrease the risk of recurrent mediastinitis[26].

Even if the cosmetic results of a sternal wound could be considered as a primary endpoint in the evaluation of a strategy treatment, most series[21,22] do not consider the esthetic results as an endpoint, while other authors described a second intention wound recovery as the strategy for sternal closure. In our series all the patients were able to undergo muscle reconstruction with excellent short- and long-term cosmetic results and without complications. This reconstruction modality, which required a non-complex sequence of maneuvers, proved to be more advantageous than other reconstruction procedures (for example the transposition of material from other sites such as the omentum or other muscles)[27] in terms of cosmetic results and procedural complications. Ringelman at al.[15] reported a 7.5% primary early failure rate, a high rate of persistent pain or discomfort and an abdominal/thoracic contour scar abnormality present in about 85% of the 202 patients in whom the omentum or other muscle flaps were transposed. In our series no patient developed procedural complications, there were no periprocedural failures

and at 2 months of follow-up only 2 patients presented with a persistent sternal pain (which resolved within the 6-month follow-up visit) and no patient had developed a contour scar abnormality. The high-pressure drain system used in step III allowed us to avoid the accumulation of fluids and enhanced the sternal healing.

In conclusion, the treatment of mediastinitis using an open intermittent irrigation strategy and delayed sternal reconstruction with the pectoralis major myocutaneous advancement flap provides excellent short- and long-term results. No significant complications occurred. Such a strategy may prove to be a valid approach in every case of mediastinitis except for patients with mediastinal-pleural cavity communications.

Further studies will be necessary to directly compare the different approaches. The cost-effectiveness ratio of this approach should also be borne in mind, in view of the relatively shorter hospital stay observed in our study compared to historical controls.

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