

Mediastinitis Following Median Sternotomy A 4-Year Review

Rezayat Parvizi, MD; Mojtaba Varshochi, MD;
Sohrab Negargar, MD; Susan Hassanzadeh, MSc.

Abstract

Background- Purulent mediastinitis is an unusual complication of median sternotomy. This complication often occurs shortly, usually within two weeks, after surgery. This study has been planned to clarify the situation of life-threatening infectious complications after surgical operations at our center and to better the ways of prevention as much as possible.

Methods- In this study, all the patients who had undergone median sternotomy were observed over a 4-year period. The documentation of the diagnoses was completed, information about the patients including demographic characteristics, type of surgery, pre-, intra- and postoperative risk factors, clinical and laboratory findings, etiological diagnoses, responsible organisms, management methods and finally the outcome of the patients were collected and analyzed by a statistical software (SPSS-Win).

Results- This review comprised 2115 patients who had undergone median sternotomy. Thirteen of them (0.61%) suffered from post-surgical purulent mediastinitis. The type of surgery was 38% coronary artery bypass grafts (CABGs), 23% aortic valve replacement (AVR) + CABGs, and 23% valve replacement or repair. Forty-six percent of the mediastinitis patients were obese, 46% hypertensive, 38% smokers, 38% had a history of previous MI, 15% had preoperative creatinine > 1.2, and 15% needed preoperative intra aortic balloon pump. The mortality rate was 31%.

Conclusion- This complication is distinguished by its clinical manifestations and positive culturing from the mediastinum. Microbial etiology is influenced by the source of contamination and must be recognized for any center separately. A combination of antimicrobial therapy and surgical intervention has better results. A better evaluation of the patients' preoperative conditions, promotion of surgical techniques and preventive measures, and an early diagnosis of mediastinitis will be effective in the reduction of this complication. (*Iranian Heart Journal*. 2002, 2003; 3(2&3): 24-32)

Key words: mediastinitis < open heart surgery

Mediastinitis is an inflammation and infection of the space between the two pleural cavities in the thorax. Microorganism seeding during surgery and median sternotomy for access to the heart, great vessels and thoracic contents is one of the ways that infection involves this space. By reviewing 10 reports during 1970-1983, Sarr and colleagues showed that the overall incidence of mediastinitis was 4-5%.¹ Further reviews of 10 studies between 1986 and 1995 on more than 59,000 patients who had undergone

median sternotomy for open heart surgery indicated the average incidence was 1.3%.² The incidence of mediastinitis was decreased to 2.2%, 0.4% and 0.25% in the last studies³⁻⁵ and the lowest incidence rate, 0.15%, was reported by Blanchard et al. in 1995.⁵ In some conditions such as cardiac transplantation, the incidence of mediastinitis remarkably increases up to 7.5% due to immunosuppressive therapy.⁶ During outbreaks, its incidence can increase even up to 23.7%,⁷ and the use of mechanical devices such as artificial heart

can increase its incidence up to 35.7%.⁷ Although mediastinitis is not common after open heart surgery, its occurrence threatens the integrity of mediastinal great vessels, and sometimes causes fatal bleeding. On the other hand, it causes infection in aortic stitches, artificial grafts, prosthetic valves and can even result in septicemia.^{1,3,8} Different factors considered as the *preoperative* predisposing factors include diabetes mellitus, obesity, smoking, previous sternotomy, chronic obstructive pulmonary disease (COPD), large breast size, lengthy preoperative stay in the hospital, skin shaving method, low cardiac output state, emergency surgery, endocarditis, active infection in distant focuses, serum CRP and albumin level, and a history of previous radiation of mediastinum. The *intraoperative* factors include operation time, pump time, aorta clamp time, the kind of sternotomy saw, method of closing the sternal wound, high volume of bleeding during surgery, using internal mammary artery (IMA) especially bilaterally. The *postoperative* factors are redo sternotomy, a lengthy ICU stay, mechanical ventilation of more than 48 hours, tracheostomy, cardiopulmonary resuscitation (CPR), existence of infection in the site of the removal of saphenous vein, long persistence of inserted drains, and pacemaker wire and unstable hemodynamics.^{1-4, 7-19} Diagnosis is often clinical and easy, but sometimes paraclinical complementary methods are needed.¹³ Once mediastinitis occurs, another operation for pus drainage and debridement will be necessary. This operation entails a long ICU stay, which results in increased expense and mortality¹². The extent of surgery varies from a simple drainage procedure to advanced plastic surgery.²⁰ The cost to these patients will be at least three times as much as that to patients without this complication.^{4,20} Recognizing risk factors, preventive measures, an early diagnosis

and correct management can help its relative control. Unfortunately, the mortality rate of post surgical mediastinitis is about 14-55%.^{4,13,20}

Methods

This study includes all the patients who underwent sternotomy in our center between September 1996 and August 2000. Having undergone surgery on an either elective or emergency basis, the patients were observed for the appearance of any kind of infectious complications. Preoperative preparations were the same for all the patients. The patients received cefazolin as the chemoprophylaxis.

The selection of the patients:

For high-risk patients, infectious disease specialist consultation was carried out, and those patients who had one of the following characteristics were chosen as candidates for deep sternal wound infection:

- 1- Instability and sternal wound dehiscence,
- 2- Chest pain,
- 3- Body temperature $\geq 38^{\circ}\text{C}$.

These characteristics *in addition to* sternal wound purulent discharge *or* a positive culture of the wound *or* positive blood culture confirmed the diagnosis.

The patients who did not have apparent signs in the wound were further studied by imaging techniques (CXR and CT scan). Finally, the patients who were confirmed clinically for mediastinitis were chosen as candidates for re-exploring, and if pus was detected in mediastinum or there was a positive mediastinal culture, they entered the study as definite post surgical purulent mediastinitis.

Demographic characteristics, predisposing factors for infectious complications, clinical symptoms and signs, laboratory findings, etiological diagnoses, management methods and outcome of the patients were studied in all the mediastinitis cases. Our first goal was a case-control study so as to analyze the results and specially evaluate the influence of risk factors in creating mediastinitis, but because of the low number of patients in the

above-mentioned time period, we only managed to perform a descriptive expression.

Results

During 1996-2000, 2115 sternotomies were conducted in this center. This approach was done in 1155 cases for coronary artery bypass grafts (CABGs); in 665 cases for valve replacement, and in 295 cases for repairing the congenital heart disease and other surgical operations on the pericardium or heart. Table I shows demographic characteristics, the kind of operation and preoperative predisposing factors of the patients with mediastinitis.

Table I. Demographic characteristics, type of operation and preoperative predisposing factors of patients with mediastinitis.

Patient Age & Sex	Operation [*]	Predisposing factors ^{**}	LVEF % ^{***}
34/F	AVR, MVR	O	55
52/M	AVR, CABG	O, H, M	50
44/F	MVR		50
35/M	CABG	S, M	40
43/M	CABG	S-M-B	25
10/M	TOF [▲]	PS (2 yr ago)	
55/M	AVR, MV repair	S	40
52/M	MVR, CABG	O	5
73/M	CABG	S, H, C, RF	5
41/M	Pericardiectomy (CP) ^{▲▲}	S, H	55
65/F	CABG	O, D, H, M, B	35
63/M	CABG	O, H, M	45
63/F	MVR, CABG	O, H	60

* AVR = aortic valve replacement, MVR = mitral valve replacement, CABG=coronary artery bypass graft

** O=obese, D=diabetic, S=smoker, H=hypertensive, C=history of COPD, M=history of MI, E=history of endocarditis RF=renal, failure (Cr > 1.2).

B=need for balloon pump, PS=previous sternotomy

*** LVEF=left ventricular ejection fraction.

▲ Tetralogy of Fallot

▲▲ constrictive pericarditis

Except for one of the patients who was a child of 10, the average age of adults who had purulent mediastinitis was 51.6 ± 4.70 years and the male to female ratio was 2.25:1.

The excess weight in 85% of the cases was more than 10% and 45% of the cases were more than 30% overweight compared to the ideal body weight. The surgical operation in 23% of the mediastinitis cases were emergent. Their average preoperative hospitalization time was 10.6 (1-22) days. In all of the CABG patients, the internal mammary artery was used (87.5% left IMA and 12.5% bilateral); their average pump time was 162 (82-327) minutes. Twenty-three percent of the patients had a low cardiac output state on getting off the pump. In 7 patients (54%), the sternum was re-explored to control bleeding (once in 5 cases and twice in 2 cases). Thirty-one percent of the patients received more than 1000^{cc} blood in the operation room and ICU. Acute tubular necrosis (ATN) occurred in one patient (7.5%).

The average time between the primary operation and the diagnosis of mediastinitis was 9.3 (4-17) days, and the patients were under mechanical ventilation for 80 (11-432) hours before mediastinitis was recognized. The important clinical and laboratory findings of our patients are shown in Table II.

Table II. Important clinical and laboratory findings

Fever	92.5%
Purulent discharge	85%
Anorexia	85%
Local erythema	77%
Sternal dehiscence	61.5%
Chest pain	23%
Mild to moderate leukocytosis	92.5%
Mediastinal widening on CXR	23%

Chest CT-scan before re-exploring the sternum was necessary in 5 cases. These patients had multiple gas bubbles, air-fluid levels, soft tissue swelling, and concentrated collections behind the sternum.

Their mediastinitis having been diagnosed, each patient stayed in ICU for an average 40 (6-80) days. Before the patients went on antibiotics, the blood culture result was negative in 8 out of 13 mediastinitis cases (61.5%). The results of mediastinal fluid or pus culture, management methods and patients' outcome are shown in Table III.

Table III. Etiological diagnosis, management and outcome of patients complicated with purulent mediastinitis

Patients	Isolated organism	Surgical intervention	Antibiotic	Outcome♦
1	<i>C. albicans</i>	WD OI	VAN, GEN, RMP, AMB#	Dis. Morb.
2	<i>K. ozenae</i>	WD OI	CEF, AMK, CIP	Exp.
3	<i>E. aerogenosa</i>	WD CI	CEF, AMK, CIP	Dis. Morb.
4	<i>S. aureus (MR)</i>	WD CI	VAN, AMK, RMP	Dis. Imp.
5	<i>S. aureus (MR)</i>	WD OI	VAN, RMP, CIP	Dis. Imp.
6	<i>S. aureus (MR)</i>	WD CI	VAN, AMK, RMP	Exp.
7	<i>K. pneumoniae</i>	WD CI	CIP, AMK	Dis. Imp.
8	<i>S. epidermidis</i>	WD OI OP	VAN, RMP, CIP	Dis. Imp.
9	<i>C. freundii</i>	WD OI OP	CEF, CIP	Exp.
10	<i>S. epidermidis</i>	WD OI OP	VAN, RMP, CIP	Dis. Imp.
11	<i>S. aureus (MR)</i>	WD OI	VAN, RMP	Dis. P. Imp.
12	<i>P. aeruginosa</i>	WD OI	CEF, AMK, CIP	Exp.
13	<i>E. cloacae</i>	WD OI	CFX, AMK, CIP	Dis. Morb.

* WD=wound debridment, OI=open irrigation, CI=closed irrigation, OP=omentoplasty using omental flap

**VAN=Vancomycin, RMP=Rifampin, CIP=Ciprofloxacin, AMB=Amphotricin B, GEN=Gentamicin, AMK=Amikacin, CEF=Ceftazidim, CFX=Ceftriaxone

***MR=Meticillin resistant

The patient no.1 had been treated for along time as culture negative mediastinitis, but in spite of the primary relative clinical improvement, with failure of infection control in patient, the next studies showed candidal mediastinitis.

♦Dis. Morb=discharged with morbidity, Exp.=expired, Dis. Imp=discharged with improvement, Dis. P. Imp=discharged with partial improvement

After the diagnoses were confirmed, antibiotics were given intravenously for an average 34 (7-100) days. Mortality was 31% (4 cases). The patients who survived were followed up to at least 20 months and none of them relapsed. In two cases of the survivors, hearing threshold reduction due to drug-ototoxicity occurred and in one case subglottic tracheal narrowing due to prolonged intubation occurred.

Discussion

Mediastinal infection after median sternotomy always causes fear in cardiac surgical operation teams, but usually the kind of surgical operation on the heart does not have significant effects on mediastinitis incidence.^{1,15} Cheung and colleagues (1985) showed the high incidence of mediastinitis occurring in the valve replacement operations,²¹ but Grmoljez et al. (1975) reported that 9 out of 10 cases of post surgical mediastinitis occurred after coronary artery bypass grafts (CABGs) and only 1 case happened after mitral valve replacement.²² Although some reports have shown the high incidence in women²³ and some in men,^{3,4,17,24} it seems that age and sex do not have significant effects on the incidence of mediastinitis.¹⁶ The source of mediastinal infection is often topical and it occurs after a surgical wound is seeded by the flora of the patient's skin, the surgeon's hand and nasal flora,⁹ or surgical operation tools contamination.^{24,25} It is rarely secondary to bacteremia.²⁶ Predisposing and risk factors of post surgical mediastinitis have been studied with univariate and multivariate analyses in many literatures, but there is controversy over the influence of many of these factors. Arnold's study on the circulation and blood supply of 52 autopsied sternums using contrast media led to the theory of high probability of ischemia and susceptibility for sternal infection after using the internal mammary artery (IMA) as an arterial conduit, especially in the bilateral form.²⁷ This theory was confirmed by Grover and colleagues' (1994) study on more than 14000 cases of open-heart surgery.²⁸ But a recent study by Baskett et al. (1999) on 9771 patients has not confirmed the relationship between using this artery and the incidence of mediastinal infection.⁵ In the report of this group, the influence of diabetes mellitus, renal insufficiency, smoking, sex, age, reoperation, obesity, using steroid, post surgical long term mechanical ventilation, needing inotropes, the amount of bleeding and blood transfusion during and after surgery have been questioned as the post surgical mediastinitis

predisposition⁵ The bacteriologic pattern of post surgical mediastinitis in the published reports from different centers are various and sometimes the difference is quite remarkable. In a study by Ottinos et al. (1987), *Pseudomonas aeruginosa* has been discussed as the most common responsible organism in creating mediastinitis after open-heart surgery.¹⁶ But, according to general review articles, this organism is responsible for about 2% of mediastinitis cases.⁷ Although, polymicrobial mediastinitis has been shown in up to 40% of cases, according to general reviews polymicrobial mediastinitis does not include more than 10% of cases.⁷ Generally, gram positive cocci in 67% of cases and aerobic gram negative bacilli in 22-24% of cases are the causative organisms, and other cases of mediastinitis are created either polymicrobially or by other rare organisms.⁷ Among the gram positive cocci, *Staphylococcal (aureus or epidermidis)* is responsible for one-half to three-fourths of cases.^{5,29} According to Kutsal et al. report post surgical culture was negative in 64% of mediastinitis cases,¹⁴ but in most of recent reports, the percentage of negative culture cases has been reported as zero percent.^{3,5} Almost less than 2% of mediastinitis cases are caused by fungi (*Candida*),⁷ the mortality of which is twice that of bacterial cases.³⁰ Any increase in the incidence of mediastinitis by Gram-negative bacilli especially in cluster forms is an alarm for the contamination of the environment and tools, as well as probable defects in the sufficient controlling of their sterilization.³¹ But, the origin of Gram-positive cocci in comparison with the Gram-negative bacilli is usually endogenous. Ferrazzi et al. study confirmed this correlation. They observed that changing and improving the situation of the operating room caused a substantial decrease in the incidence of mediastinitis caused by Gram-negative bacilli. But, there was no improvement in the incidence of mediastinitis caused by Gram-positive cocci.³² The clinical manifestations of mediastinitis are mainly dependent on its causative mechanisms. Apart from some common symptoms and signs such as fever, chest

pain, respiratory distress, tachycardia, etc.⁷ the unusual appearance of surgical wounds gives a double help to recognize the post surgical mediastinitis, some of which are sternal tenderness, wound erythema and cellulitis, serousanguinous or purulent discharge of wound and sternal dehiscence.⁷ After fever, wound discharge is the most common sign of this infectious complication in 70-90% of patients.¹ The diagnostic value of purulent discharge is high when it is accompanied by sternal instability.¹ Diagnostic laboratory tests are sometimes helpful but they can be confusing because of the operation effects, especially the effect of pump on the acute phase reactants. For example, moderate and sustain leukocytes with shifting to the left and increasing of ESR are only indirect clues as to post surgical infectious complication. Some authors believe that sub-xyphoid or direct aspiration of the sternal wound is useful for the diagnosing of post surgical mediastinitis.⁷ Blood culture has shown simultaneous bacteremia in about 20% of cases.^{3,11,24} The value of epicardial pacemaker wire culture has been different in the diagnosis of post surgical mediastinitis.^{33,34} CXR does not have such diagnostic values.^{35,1} But in some cases, it may show mediastinal widening, air-fluid level and subcutaneous emphysema.⁷ Thoracic and mediastinal CT- scanning is the most valuable imaging technique to recognize mediastinitis from superficial infections and the loculated abscess behind the sternum.^{33,35,36,37,38,39} There are not such studies on the role of MRI and it should not be used in the presence of prosthetic valves. Mediastinitis management includes debridement, drainage and copious irrigation of the mediastinal cavity and suitable intravenous antibiotics. Although some cases of successful cure have been reported, using antibiotic therapy alone can have a high mortality rate. Surgical debridement alone will have at least a 39% management failure rate.⁴⁰ The cause of mediastinitis and the consideration of the spectrum of probable organisms are two most important criteria for empirical antimicrobial therapy. After radical debridement, it is necessary to

instate the open or closed drainage and irrigation system according to the patient's condition.¹ Using reconstructive surgery methods has shown an encouraging decrease in the mortality rate of patients with advanced mediastinitis (10% and zero).^{41,42}

Unfortunately, pectoral muscle flap, which was described by Jurkiewicz et al. for the first time,⁴² has a treatment failure rate of 25% (persistence of infection, subcutaneous infection and abscess formation),⁴³ and it may be followed by some unpleasant cosmetic effects and limitation in the movements of chest and shoulder.¹⁴ Lec et al. described the mediastinal omentoplasty in 1976.⁴³ Because of having a high blood supply and strong lymphatic system, omentum, can remove microorganisms, inflammatory exudates and destructed cells. It has more flexibility in comparison with muscle flaps, comes up to the sternal notch and most often completely fills the space behind the sternum. The superiority of this operation in comparison with muscle flap has been observed in recent studies, especially in the presence of artificial materials in mediastinum, such as aortic Dacron grafts.^{44,45} This method is even used successfully coincident with the primary debridement.⁴⁶ In 2-9.5% of cases, laparotomy and omentum removal is accompanied by some late complications, such as diaphragmatic hernia or the probability of intestinal obstruction. Choosing the surgical strategy is on the basis of the intensity and the stage of mediastinitis. In addition to surgical measures, using long-term and intravenous antimicrobial treatment is the main part of management in these patients. The duration of treatment is not exactly clear. Some authors have recommended intravenous therapy for 3 months, and some others have suggested a continuation of treatment with oral single-therapy up to 9 months.¹ Apart from antibiotic and surgical intervention, other supporting measures such as appropriate feeding programs, blood pressure controlling, prevention of peptic ulcers caused by stress, prevention of deep vein thrombosis and decubitus pressure ulcers,

appropriate chest physiotherapy, using mechanical ventilation when necessary, controlling mood disorders and anxiety, etc. are the important parts in the management of patients. The most appropriate method in the prevention of mediastinitis is to increase attention during surgical procedures. The crucial factors involved in the prevention of mediastinitis include: improvement in patient's nutrition and his respiratory tract function; promoting the immune system function;¹ decreasing hospitalization duration before surgery; eradicating less important infectious sources such as dental and urogenital infections; bathing with soap-containing disinfectants (e.g. hexachlorophene); preparing the patient's skin with iodine just before surgery;^{15,47} using prophylactic antibiotics;^{1,47,48} improving the operating room conditions; paying enough attention to the sterilization of the tools, using better surgical techniques specially decreasing sternal fractures; decreasing tissue trauma due to electrocautery; better sternum fixing techniques; decreasing operation and pump time; decreasing the use of bone-wax; recognizing nosocomial infectious outbreaks; taking aseptic cares after surgery, taking out the catheters and drains as soon as possible (like tracheal tubes, intravenous and arterial catheters and mediastinal drains), and using cricothyroidectomy instead of tracheotomy when long mechanical ventilation is needed.¹ The spread of infection to near spaces (pleura, pericardium, and peritoneum); vascular injuries and massive bleeding tendencies; contamination of artificial materials; septicemia; sternal osteomyelitis, and costochondritis can be the complications of post surgical purulent mediastinitis. Several factors have been studied in the prognosis of purulent mediastinitis, from which the interval between primary operation and the diagnosis of mediastinitis is the most important factor.^{15,49}

Conclusion

Due to high mortality rates and hospital cost, decreasing the incidence of the number of mediastinitis in our center is the research team's desire. But, in spite of the

promotion in technology of aseptic surgery and the suitable use of preventive methods, it is not feasible to reduce it to zero. It seems that the predisposition for post surgical mediastinitis is multifactorial and the accumulation of several risk factors is more effective than one factor by itself. On the other hand, the importance of technical factors is more remarkable in comparison with host factors. Increasing the knowledge and experience of medical teams in preventing mediastinitis and correct management after the occurrence requires so many studies on bacteriologic patterns and sources of contamination that they should be carried out at any center separately.

Acknowledgements

We wish to express our appreciation to Hejazy, MS; A. Afrasiabi, B. Nagili, M. Mosharkesh, and A. Nabati for their kind assistance and cooperation.

References

1. Sarr MG, Gott VL, Townsend TR. Mediastinal infections after cardiac surgery. *Ann Thorac Surg* 1984, 38:415-423.
2. Bitkover CY, Gardlund B. Mediastinitis after cardiovascular operations: A case-control study of risk factors. *Ann Thorac Surg* 1998; 65:36-40.
3. Munoz P, Menasalvas A, Bernaldo de Qviros et al. Post surgical mediastinitis: A case control study. *Clin Inf Dis* 1997, 25; 1060-1064.
4. El Oakley R, Paul E, Wong PS, et al. Mediastinitis in patients undergoing cardiopulmonary bypass: risk analysis and midterm results. *J Cardiovasc Surg* 1997, 38:595-600.
5. Baskett RJF, Mac Dougall CE, Ross DB. Is mediastinitis a preventable complication? A 10-year review. *Ann Thorac Surg* 1999; 67:462-465.
6. Trento A, Dummer GS, Hardesty RL, et al. Mediastinitis following heart transplantation: Incidence, treatment and results. *Heart Transplantation*. 1984, 3: 336-339.
7. Rupp Mc: Mediastinitis. In: Mandell GL, Bennett JE, Dolin R, (eds.). *Principles and Practice of Infectious Disease*. 5th ed. New York: Churchill, 2000, 941-949.
8. Ko W, Lazenby WD, Zelano JA, et al. Effects of shaving methods and intraoperative irrigation on suppurative mediastinitis after bypass operations. *Ann Thorac Surg* 1992, 53: 301-305.
9. Gayness R, Marosok R, Mowry-Hanley J, et al. Mediastinitis following coronary artery bypass surgery: A 3-year review. *J Infec Dis* 1991, 163: 117-121.
10. Hammermeister KE, Burchfiel C, Johnson R, et al. Identification of patients at greatest risk for developing major complications at cardiac surgery. *Circulation* 1990, 82 (suppl IV) 386-389.
11. Farinas MC, Peralta FG, Bernal JM, et al. Suppurative mediastinitis after open-heart surgery: A case-control study covering a seven-year period in Santander, Spain. *Clinic Infec Dis* 1995, 20: 272-279.
12. Newman LS, Szczukowski LC, Bain RP, et al. Suppurative mediastinitis after open-heart surgery: A case-control study of risk factors. *Chest* 1988, 94: 546-553.
13. Maroto LC, Aguado JM, Carrascal Y, et al. Role of epicardial pacing wire cultures in the diagnosis of post-sternotomy mediastinitis. *Clinic Infec Dis* 1997, 24: 419-421.
14. Kutsal A, Ibrisim E, Catav Z, et al. Mediastinitis after open-heart surgery: Analysis of risk factors and management. *J Cardiovasc Surg* 1991, 32: 38-41.
15. Culliford AT, Cunningham JN, Zeff RH, et al. Sternal and costochondral infections following open-heart surgery: A review of 2,594 cases. *J Thorac Cardiovasc Surg* 1976, 72: 714-725.
16. Ottino G, De Paulis R, Pansini S, et al. Major sternal wound infection after open heart surgery: A multivariate analysis of risk factors in 2,57; consecutive operative procedures. *Ann Thorac Surg* 1987, 44: 173-179.
17. Miholic J, Hudec M, Domanig E, et al. Risk factors for severe bacterial infections after valve

- replacement and aortocoronary bypass operation: Analysis of 246 cases by Logistic regression. *Ann Thorac Surg* 1985, 40: 224-228.
18. Farrington M, Webster M, Fenn A, et al. Study of cardiothoracic wound infection at St. Thomas' Hospital. *Br J Surg* 1985, 72: 759-762.
 19. Francen EJ, Maessen JG, Elenbass T, et al. Enhanced preoperative C-reactive protein plasma levels as a risk factor postoperative infections after cardiac surgery. *Ann Thorac Surg* 1999, 97: 134-138.
 20. Oakley RM, Wright JE. Postoperative mediastinitis: classification and management. *Ann Thorac Surg* 1996, 61: 1030-1036.
 21. Cheung RH, Craver JM, Jones EL, et al. Mediastinitis after cardiac valve operations: Impact upon survival. *J Thorac Cardiovasc Surg* 1985, 90: 517-522.
 22. Grmoljez PF, Barner HH, Willman VL, et al. Major complications of median sternotomy. *Am J Surg* 1975, 130: 679-681.
 23. Breyer RH, Mills SA, Hudspeth AS, et al. A prospective study of sternal wound complications. *Ann Thorac Surg* 1984, 37: 412-417.
 24. Ehrenkraz NJ, Pfaff SJ. Mediastinitis complicating cardiac operations: Evidence of postoperative causation. *Rev Infect Dis* 1991,13: 803-814.
 25. Andersen BM, Sqrlic D, Hotvedt R et al. Multiply beta-lactam resistant *Enterobacter cloacae* infections linked to the environmental flora in a unit for cardiothoracic and vascular surgery. *Scand J Infect Dis* 1989, 21: 181-191.
 26. Weinstein RA, Jones EI, Schwarzmans SW, et al. Sternal osteomyelitis and mediastinitis after open-heart operation: pathogenesis and prevention. *Ann Thorac Surg* 1976, 21: 442-444.
 27. Arnold M. The surgical anatomy of sternal blood supply. *J Thorac Cardiovasc Surg* 1972, 64: 596-610.
 28. Grover FL, Johnson RR, Marshall G, et al. Impact of mammary grafts on coronary bypass operative mortality and morbidity. *Ann Thorac Surg* 1994, 57: 559-569.
 29. Mossad SB, Serkey JM, Longworth DL, et al. Coagulase-negative staphylococcal sternal wound infections after open-heart operations. *Ann Thorac Surg* 1997, 63: 395-401.
 30. Weil RJ. Candidal mediastinitis after surgical repair of esophageal perforation. *South Med J* 1991, 84: 1052-1053.
 31. Siegman-Igra Y, Shafir R, Weiss J, et al. Serious infectious complications of midsternotomy. A review of bacteriology and antimicrobial therapy. *Scand J Infect Dis* 1990, 22: 633-643.
 32. Ferrazzi P, Allen R, Crupi G, et al. Reduction of infection after cardiac surgery. A clinical trial. *Ann Thorac Surg* 1986, 42: 321-325.
 33. Browdie DA, Bernstein RW, Agnew R, et al. Diagnosis of post-sternotomy infection: comparison of three means of assessment. *Ann Thorac Surg* 1991, 51: 290-292.
 34. Robicsek F. Post-sternotomy infection. *Ann Thorac Surg* 1991, 52: 896-900.
 35. Breatnach E, Delany DJ. The role of computed tomography in acute and subacute mediastinitis. *Clinic Radiol* 1986, 37: 139-145.
 36. Misawa Y, Fuse K, Hasegawa T. Infectious mediastinitis after cardiac operations: Computed tomographic findings. *Ann Thorac Surg* 1998, 622-624.
 37. Kay HR, Goodman LR, Teplick SK, et al. Use of computed tomography to assess mediastinal complications after median sternotomy. *Ann Thorac Surg* 1983, 36: 706-714.
 38. Carrol CL, Jeffrey RB, Federle M, et al. CT evaluation of mediastinal infections. *J Comput Assist Tomogr* 1987, 11: 449-454.
 39. Robicsek F. Post-sternotomy infection. *Ann Thorac Surg* 1991, 52: 898.
 40. Roberts JR, Smythe R, Weber RW, et al. Thoracoscopic management of descending necrotizing mediastinitis. *Chest* 1997, 112: 850-854.
 41. Jones G, Jurkiewicz MJ, Bostwick J, et al. Management of the infected median sternotomy wound with muscle flap. *Ann Surg* 1997, 225: 766-778.

42. L Gamel A, Younan NA, Hassan R, et al. Treatment of mediastinitis: Early modified Robicsek closure and pectoralis major advancement flaps. *Ann Thorac Surg* 1998, 65: 41-47.
43. Milano CA, Georgiade G, Muhlbaier LH, et al. Comparison of omental and pectoralis flaps for post-sternotomy mediastinitis. *Ann Thorac Surg* 1999, 67: 377-381.
44. Krabatsch T, Hetzer R. Post-sternotomy mediastinitis treated by transposition of the greater omentum. *J Cardiovasc Surg* 1995, 10: 637-643.
45. Yasuura K, Okamoto H, Morita S, et al. Results of omental flap transposition for deep sternal wound infection after cardiovascular surgery. *Ann Surg* 1998, 227: 455-459.
46. Heath BJ, Bagnato VJ. Post-sernotomy mediastinitis treated by omental transfer without postoperative irrigation or drainage. *J Thorac Cardiovasc Surg* 1987, 94: 355-360.
47. Sutherland RD, Martines HE, Guynes WA, et al. Postoperative chest wound infections in patients requiring coronary bypass: A controlled study evaluating prophylactic antibiotics. *J Thorac Cardiovasc Surg* 1977, 73: 644-647.
48. Myerowitz PD, Caswell K, Lindsay WG et al. Antibiotic prophylaxis for open heart surgery. *J Thorac Cardiovasc Surg* 1977, 73: 625.
49. Grossi EA, Culliford AT, Kriger KH, et al. A survey of 77 major infectious complications of median sternotomy: A review of 7,949 consecutive operative procedures. *Ann Thorac Surg* 1985, 40: 214-223.