Int Surg 2017;**102:**189–195
DOI: 10.9738/INTSURG-D-15-00029.1

Limited Bilateral Advancement of the Sternocostal Head of Pectoralis Major for Sternal Reconstruction: Preserving the Axillary Fold

Warren M. Rozen[1–3], Ken G. W. Teo[3], Gausihi Sivarajah[3], Rafael Acosta[3]

[1]*Monash University Plastic and Reconstructive Surgery Group (Peninsula Clinical School), Department of Surgery, Monash University, Clayton, Australia*

[2]*Department of Surgery, School of Medicine and Dentistry, James Cook University Clinical School, Townsville Hospital, Townsville, Australia*

[3]*Department of Plastic and Reconstructive Surgery, Geelong Hospital, Geelong, Australia*

The introduction of well-vascularized flaps for infected sternotomy wound reconstruction has improved mortality rates dramatically. Multiple variations of the pectoralis major flap have been described in this context. However, unresolved limitations of this flap include poor cosmesis and problematic coverage of the inferior third of the sternotomy wound. We describe an approach to address these issues. The humeral attachments are preserved and bilateral muscles are advanced in a limited fashion. The left sternocostal head is advanced medially and rotated anticlockwise, using this portion to fill the upper half of the sternum while the caudal portion of the right pectoralis muscle is used as a turnover flap at the lower half of the wound. In all 25 patients, the anterior axillary fold was preserved bilaterally and the infection completely resolved. Complications included 3 cases of hematoma, 2 cases of coagulopathy, and 1 late bone sequestrum (aseptic). Although the study had a limited sample size, we had a high rate of success and few complications. With the preservation of bilateral axillary folds, good cosmesis, and adequate wound coverage, we recommend this modification of the pectoralis major flap in even complicated cases of mediastinitis.

Key words: Sternotomy wound infection – Medistinitis – Pectoralis major flap – Limited bilateral advancement – Turnover flap

Corresponding author: Warren Rozen, Monash University Plastic and Reconstructive Surgery Group (Peninsula Clinical School), Department of Surgery, Monash University, Level 5, E Block, Monash Medical Centre, 246 Clayton Road, Clayton, Victoria 3168, Australia.
Tel.: 0061 39784 7368; Fax: 0061 39784 7568; E-mail: warrenrozen@hotmail.com

In 1957, Julian *et al*[1] first described the median sternotomy for use in cardiac surgery. It provides good access to the anterior mediastinum but carries the risk of becoming infected postoperatively in 0.5% to 8.4% of open heart surgeries, leading to the possible sequelae of dehiscence, osteomyelitis, and death.

The treatment options in the past for sternotomy infections ranged from leaving the wound open to heal by secondary intention to debridement and rewiring coupled with antibiotic irrigation therapy.[2–5] In 1976 Lee *et al*[6] initiated the concept of an omental flap for closure of this deficit, followed in 1980 by Jurkiewicz *et al*[7] reporting on the use of pectoral muscle flaps. The use of well-vascularized flaps has improved mortality rates from 70% in early studies involving conservative treatment[8] to 5% and 10% in recent reports.[9]

Pectoralis major and rectus abdominis have become first-line flaps, with the pectoral being the preferred one.[9–13] The omentum is generally considered a second-line treatment choice.[10] Multiple variations of the pectoralis major flap in sternotomy wounds have been described. However, unresolved limitations of this flap include poor cosmesis and problematic coverage of the inferior third of the sternotomy wound.

We describe a technique that addresses these issues. By using the caudal half of pectoralis major bilaterally with limited advancement, we achieved wound closure with preservation of the anterior axillary fold and good coverage of the inferior third of the sternotomy wound.

Surgical Anatomy

The pectoralis major, a large, flat muscle, has two heads of origin: the clavicular head, which arises from the medial half of the clavicle and inserts into the bicipital groove of the humerus, and the sternocostal head, arising from the anterior surface of the sternum, the upper six costal cartilages, and the aponeurosis of the external oblique muscle over the costal attachment of the rectus abdominis.[13] The rounded appearance of the anterior axillary fold is formed as the lower sternocostal and abdominal fibres course upwards and laterally to be inserted progressively higher into the posterior lamina of the tendon (Fig. 1).

The blood supply, according to the classification of Mathes and Nahai, is a type 5 circulation, with one dominant vascular pedicle and a number of secondary segmental pedicles.[14–17] The dominant

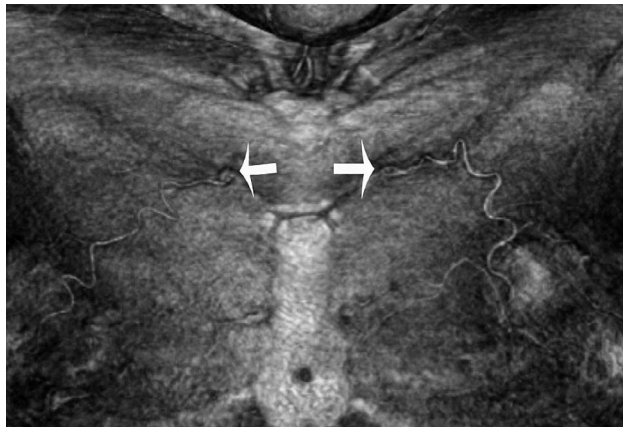

Fig. 1 Computed tomographic angiogram of the chest wall, demonstrating the segmental vascular supply to the pectoralis major muscles via the internal thoracic (internal mammary) artery perforators.

pedicle is based on the thoracoacromial artery, and the secondary segmental pedicles are based on the internal mammary artery. The secondary pedicles are located 2 to 3 cm lateral to the sternal border (Fig. 2). In addition, there are branches of the lateral thoracic and intercostal arteries that contribute to the blood supply.[16,17]

The motor innervation is via the lateral and medial pectoral nerves, supplying the upper part of the muscle and lower third respectively.[18] The medial nerve accompanies the thoracoacromial pedicle and its branches. Branches of the lateral nerve pass either

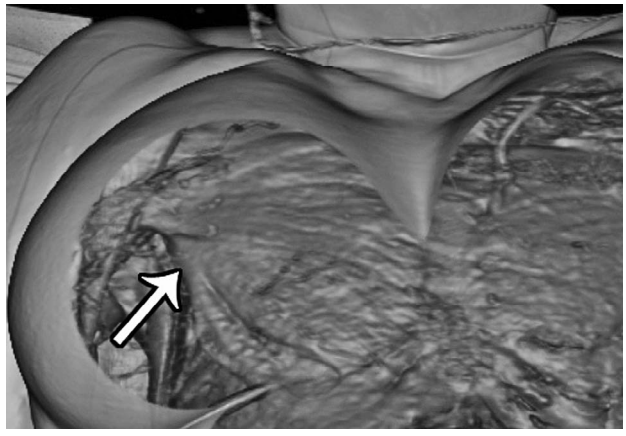

Fig. 2 Computed tomographic angiogram of the lateral chest wall, demonstrating the sternocostal fibers of the pectoralis major muscle encroaching upon its tendon in the axilla.

Fig. 3 Dehisced sternal wound showing the defect after debridement, pulsatile lavage, and application of a suction-assisted closure—intraoperative view prior to reconstruction.

Fig. 4 Intraoperative view of the use of the left pectoralis major muscle in covering the sternoclavicular and sternal portion of the defect.

lateral to or through the pectoralis minor muscle and into the pectoralis major muscle.[16,17]

Operative Technique

Prior to the procedure, as described by Godina,[19,20] infected sternal wounds require early radical debridement involving the removal of foreign bodies and the excision of nonviable tissue. Subsequently, pulsatile lavage is performed with 6 to 9 L of normal saline, secondary debridement occurs, and a suction-assisted dressing (*e.g.*, vacuum-assisted closure) is applied to eliminate dead space. Given skeletal stability, this process is then repeated in 24 to 48 hours.

Preoperative imaging with computed tomography (CT), and in particular CT angiography, can delineate the anatomy of the pectoralis major muscle, musculotendinous unit, and vascular anatomy. This can be used to establish the remaining vascular pedicles after serial debridements, and help select the side of choice for turnover versus advancement based on the vascular anatomy (Figs. 1 and 2).

The left pectoralis major muscle is harvested through the existing wound. The skin and subcutaneous tissue are dissected off the muscle medially to laterally to the axillary border. By blunt dissection, the fibers of the muscle are undermined and elevated from the underlying ribs and pectoralis minor muscle. The thoracoacromial pedicle is identified, after lateral dissection, and followed on the undersurface of the muscle. The intramuscular perforator branches are then divided. Both sets of nerves are also visualized and separated to preserve the motor supply to the lateral one third of pectoralis major. Muscular fibers attached close to the clavicular origin are divided to facilitate flap transposition; attachments to the sternum are cut medially, caudally, and laterally. Most of the caudal portion of the left pectoralis major is divided up to the cranial level and then across to the tendon, keeping the attachment of the superior portion of the muscle to the humerus. The sternocostal head is advanced medially and rotated anticlockwise, with this portion used to fill the sternoclavicular and sternal portion of the defect.

The right pectoralis major muscle fibers are detached at the same level as those on the left; however, perforator vessels are maintained and the caudal portion is instead advanced and folded over into the lower end of the wound as a turnover flap (Figs. 3–7). Two drains are placed subcutaneously at the lower end of the dissected left chest, and two drains are placed on the right chest—one above and the other below the muscle. The skin is directly closed over the flaps. Wounds were dressed with Collatamp (gentamicin-impregnated Gelfoam), active drainage, and Op-Site film. A breast girdle was worn for support and pain control. In addition, patients had epidural catheters and intravenous or oral analgesia for pain management. They were continued on long-term intravenous antibiotics.

Fig. 5 The use of the right pectoralis major as a turnover flap for the caudal end of the wound.

Results

The study population (n = 32) comprised a 5-year period (1996–2001). A total of 18 of these patients had osteonecrosis, 6 had osteomyelitis, 5 had mediastinitis, and 3 had superficial infection of the presternal region. In addition to the technique, early diagnosis, early debridement, antibiotic therapy, and pain control were required to achieve a successful outcome.

Risk factors for sternal wound infection included use of the left internal mammary artery (80%) and diabetes (68%), as well as nonsymmetrical osteotomy, history of smoking, reexploration, and postoperative bleeding. Wound microbiology revealed coagulase-negative *Staphylococcus* in 65% of patients, *Staphylococcus aureus* in 30% of patients, and mixed organisms in the remaining 5% of patients.

In all patients, the anterior axillary fold had been preserved bilaterally and the infection completely resolved (Fig. 8). Complications included 3 cases of hematoma, 2 cases of coagulopathy, and 1 late bone sequestrum (aseptic). No deaths were reported in the patient group studied.

Fig. 7 Intraoperative photograph with primary closure over the pectoralis major flaps.

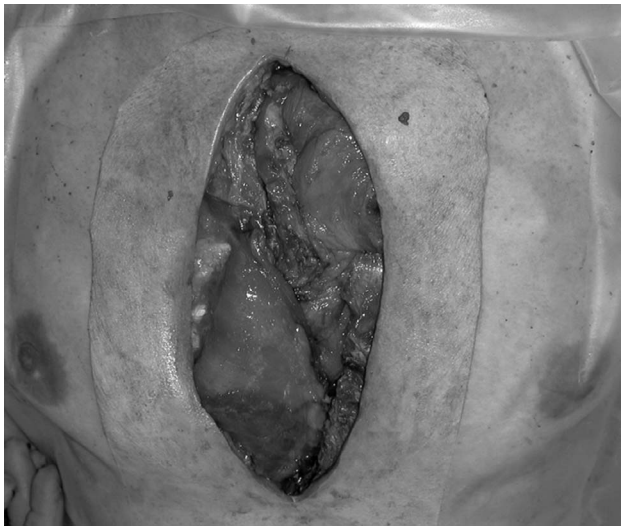

Fig. 6 Full sternal coverage, with both flaps inset.

Fig. 8 Postoperative result of patient at 1-month follow-up.

Discussion

Deep sternal wound infection is a rare but devastating complication. It occurs in approximately 1% to 3% of patients following median sternotomy.[16,17] Commonly accepted risk factors for the development of sternum wound complication are diabetes, obesity, history of smoking, reexploration, mediastinal hematoma, and immunosuppressive medications.[2,3,21,22] In our patients, diabetes was present in 68% of patients. It should be noted that 80% of our patients with infected wounds had their left internal mammary artery harvested—this large number could be a confounding result rather than a significant risk factor, because the left internal mammary artery is increasingly being used for grafting. The literature is inconclusive in this respect—some studies reported that harvesting the left and right internal mammary arteries may compromise sternal vascularity[21,23,24] and predispose a patient to sternal infection, whereas no significant difference was seen in others.[25,26]

Pairolero and Arnold classified sternal wounds into 3 categories based on the timing of presentation of infection[11,12,27] Type I wounds occur in the first few days postoperatively and are characterized by serosanguineous drainage without cellulitis, osteomyelitis, or costochondritis. These wounds respond well to intravenous antibiotics and wound debridement. Direct closure with suction drainage of the mediastinum is usually the only treatment required. Type II wounds occur within the first few weeks and are characterized by purulent drainage, cellulitis, mediastinal suppuration, and positive cultures. There is usually associated fulminating mediastinitis and osteomyelitis, although costochondritis is rare. Patients in this group are optimally treated by drainage, debridement, and immediate or delayed flap closure. Type III wounds occur months to years later and are characterized by the presence of chronic draining sinus tracts, localized cellulitis, osteomyelitis, costochondritis, or retained foreign body, but mediastinitis is rare. Debridement and extensive resection of the sternum and costal cartilages followed by flap obliteration of the mediastinum are necessary. The key in treating types II and III wounds is the obliteration of the dead space within the mediastinum.

Greig *et al*[8] introduced an anatomic classification of types II and III sternal wounds to aid in the choice of flap for reconstruction. Wounds in the upper half of the sternum were classified as type A. Wounds in the lower half of the sternum were classified as type B, and wounds involving the whole sternum were classified as type C.

Multiple approaches for sternal wound reconstruction have been described. The greater omentum was transplanted into the sternal defect, with its immunological properties further accelerating wound healing.[28,29] However, this procedure requires laparotomy, which can lead to additional complications in septic and critically ill patients. It also does not improve sternal stability and frequently necessitates skin transfer.

Another option is the transfer of the rectus abdominis muscle, but this technique requires extensive dissection and may result in postoperative abdominal hernia formation.[30] The previous use of mammary arteries may compromise blood supply,[31,32] and substernal chest tube placement at the primary operation commonly affects the rectus abdominis muscles and may impair the results of the muscle transfer. The use of latissimus dorsi muscle flaps for coverage of such defects and chest stabilization is limited by the required large incisions and the resulting functional impairment.[2] It is also difficult to perform because of the need to change the position of the patient during the procedure. Furthermore, only the most distal part of the muscle can be used for wounds in the lower half of the sternum, and this has a less reliable blood supply. The limitations of the aforementioned flaps have allowed the pectoralis major flap to gain increasing acceptance for sternal wound reconstructions.

Several variations of the pectoralis major muscle flap for sternal wound reconstruction have been described. It can be transposed into the mediastinum based on either the thoracoacromial pedicle as an advancement flap (unilateral or bilateral), or as a turnover flap based on perforators of the internal mammary artery. Nahai *et al*[16,17] described a modification of the turnover pectoralis major flap by dividing the muscle medial to the thoracoacromial pedicle and using only the medial two thirds of the pectoralis major for coverage of the sternotomy wound. By preserving the thoracoacromial pedicle, this modification attempts to reduce loss of the anterior axillary fold and functional deficits. Other techniques used to increase preservation of muscle motor function have been described by Tobin *et al*[33–37] and Morain.[38] Tobin *et al*[33–37] described splitting the pectoralis major into sternocostal, external, and clavicular segments, and preserving the thoracoacromial pedicle. The sternocostal segment can be advanced into the mediastinal wound,

and the muscle segments can be reapproximated in a V-Y fashion. Morain[38] split the pectoralis major segmentally, leaving some of the segments intact to preserve muscle function for smaller defects requiring only a small portion of muscle.

The major limitation of these techniques is the problematic coverage of the inferior third of the sternotomy wound. Studies have shown that the lower portion of wounds near the xiphisternum is the most common site of dehiscence after flap repair.[6,11,12,27,31,32,39–43]

This technique preserves the axillary fold and addresses this pertinent issue of inferior wound coverage by preserving the humeral attachments and advancing bilateral muscles in a limited fashion. The left sternocostal head is advanced medially and rotated anticlockwise, using this portion to fill the upper half of the sternum while the caudal portion of the right pectoralis muscle is used as a turnover flap at the lower half of the wound.

Of note, if the right internal mammary artery has been used for coronary grafting, the technique that uses the right pectoralis muscle as a turnover flap based on perforators of the right internal mammary artery will not be appropriate. Although the study had a limited sample size, we had a high rate of success and few complications. With the ability to preserve bilateral axillary folds, achieve good cosmesis and establish adequate wound coverage, we recommend this modification of the pectoralis major flap in all, and even complicated, cases of mediastinitis.

Acknowledgments

The content of this article has not been submitted or published elsewhere. There was no source of funding for the article. The authors declare that there is no source of financial or other support, or any financial or professional relationships that may pose a competing interest. All authors contributed to the preparation of this manuscript. Warren M. Rozen and Ken G. W. Teo are equal first authors.

References

1. Julian OC, Lopez-Belio M, Dye WS, Javid H, Grove WJ. The median sternal incision in intracardiac surgery with extracorporeal circulation: a general evaluation of its use in heart surgery. *Surgery* 1957;**42**(4):753–761
2. Bryan AJ, Lamarra M, Angelini GD, West RR, Breckenridge IM. Median sternotomy wound dehiscence: a retrospective case control study of risk factors and outcome. *J R Coll Surg Edinb* 1992;**37**(5):305–308
3. Bryant LR, Spencer FC, Trinkle JK. Treatment of median sternotomy infection by mediastinal irrigation with an antibiotic solution. *Ann Surg* 1969;**169**(6):914–920
4. Scully HE, Leclerc Y, Martin RD, Tong CP, Goldman BS, Weisel RD *et al*. Comparison between antibiotic irrigation and mobilization of pectoral muscle flaps in treatment of deep sternal infections. *J Thorac Cardiovasc Surg* 1985;**90**(4):523–531
5. Shumacker HB, Mandelbaum I. Continuous antibiotic irrigation in the treatment of infection. *Arch Surg* 1963;**86**(1):384–387
6. Lee AB Jr, Schimert G, Shaktin S, Seigel JH. Total excision of the sternum and thoracic pedicle transposition of the greater omentum: useful stratagems in managing severe mediastinal infections following open heart surgery. *Surgery* 1976;**80**(4): 433–436
7. Jurkiewicz MJ, Bostwick J, Hester TR, Bishop JB, Raver J. Infected median sternotomy wound: successful treatment by muscle flaps. *Ann Surg* 1979;**191**(6):738–744
8. Greig A, Geh J, Khanduja V, Shibu M. Choice of flap for the management of deep sternal wound infection - an anatomical classification. *J Plast Reconstr Aesthet Surg* 2007;**60**(4):372–378.
9. Kouchoukos NT, Wareing TH, Murphy SF, Pelate C, Marshall WG. Risks of bilateral internal mammary artery bypass grafting. *Ann Thorac Surg* 1990;**49**(2):210–215
10. Hultman CS, Culbertson JH, Jones GE, Losken A, Kumar AV, Carlson GW *et al*. Thoracic reconstruction with the omentum: indications, complications and results. *Ann Plast Surg* 2001; **46**(3):242–249
11. Pairolero PC, Arnold PG. Management of recalcitrant median sternotomy wounds. *J Thorac Cardiovasc Surg* 1984;**88**(3):357–364
12. Pairolero PC, Arnold PG, Harris JB. Long-term results of pectoralis major muscle transposition for infected sternotomy wounds. *Ann Surg* 1991;**213**(6):583–589
13. Ringleman PR, Vander-Kolk CA, Cameron D, Baumgartner WA, Manson PN. Long-term results of flap reconstruction in median sternotomy wound infections. *Plast Reconstr Surg* 1994;**93**(6):1208–1214
14. Mathes SJ, Nahai F. Classification of the vascular anatomy of muscles: experimental and clinical correlation. *Plast Reconstr Surg* 1981;**67**(2):177–187
15. Mathes SJ, Eshima I. The principles of muscle and musculocutaneous flaps. In: McCarthy JG, ed. *Plastic Surgery.* Philadelphia, PA: WB Saunders, 1990:379–411
16. Nahai F, Morales L, Bone DK, Bostwick J. Pectoralis major muscle turnover flaps for closure of the infected sternotomy wound with preservation of form and function. *Plast Reconstr Surg* 1981;**70**(4):471–474
17. Nahai FR, Rand RP, Hester TR, Bostwick J III, Jurkiewicz MJ. Primary treatment of the infected sternotomy wound with

muscle flaps: a review of 211 consecutive cases. *Plast Reconstr Surg* 1989;**84**(3):434–441
18. Moosman DA. Anatomy of the pectoral nerves and their preservation in modified mastectomy. *Am J Surg* 1980;**139**(6): 883–886
19. Godina M. Early microsurgical reconstruction of complex trauma of the extremities. *Plast Reconstr Surg* 1986;**78**(3):285–292
20. Godina M. *A Thesis on the Management of Injuries to the Lower Extremity.* Ljubljana, Slovenia: Personova Druzba, 1991
21. Hazelrigg SR, Wellons HA Jr, Schneider JA, Kolm P. Wound complications after median sternotomy: relationship to internal mammary grafting. *J Thorac Cardiovasc Surg* 1989;**98**(6): 1096–1099
22. Sarr MG, Gott VL, Townsend TR. Mediastinal infection after cardiac surgery. *Ann Thorac Surg* 1984;**38**(4):415–423
23. Grossi EA, Esposito R, Harris LJ, Crooke GA, Galloway AC, Colvin SB *et al*. Sternal wound infections and use of internal mammary artery grafts. *J Thorac Cardiovasc Surg* 1991;**102**(3): 342–347
24. Zacharias A, Habib RH. Factors predisposing to median sternotomy complications. *Chest* 1996;**110**(5):1173–1178
25. Galbut DL, Traad EA, Dorman MJ, DeWitt PL, Larsen PB, Kurlansky PA *et al*. Bilateral internal mammary artery grafts in reoperative and primary coronary bypass surgery. *Ann Thorac Surg* 1991;**52**(1):20–27
26. Smith JM, Glaser RS, Osborn BJ, Buckley DC, Rath R, Schreiber JT. Sternal wound complications after open-heart surgery: results from 3524 consecutive operative procedures. *Contemp Surg* 1993;**43**(1):197–202
27. Pairolero PC, Arnold PG. Management of infected median sternotomy wounds. *Ann Thorac Surg* 1986;**42**(1):1–2
28. Seguin JR, Loisance DY. Omental transposition for closure of median sternotomy following severe mediastinal and vascular infection. *Chest* 1985;**88**(5):684–690
29. Yasuura K, Okamoto H, Morita S, Ogawa Y, Sawazaki M, Seki A *et al*. Results of omental flap transposition for deep sternal wound infection after cardiovascular surgery. *Ann Surg* 1999; **227**(3):455–459
30. He GW, Ryan WH, Acuff TE, Bowman RT, Douthit MB, Yang CQ *et al*. Risk factors for operative mortality and sternal wound infection in bilateral internal mammary artery grafting. *J Thorac Cardiovasc Surg* 1994;**107**(1):196–200
31. Solomon MP, Granick MS. Bipedicle muscle flaps in sternal wound repair. *Plast Reconstr Surg* 1998;**101**(2):356–360
32. Solomon MP, Granick MS. New reconstruction method for sternotomy wounds. *Perspect Plast Surg* 1994;**8**(1):61–65
33. Tobin GR, Mavroudis CA, Howe WR, Gray LA Jr. Reconstruction of complex thoracic defects with myocutaneous and muscle flaps: applications of new refinements. *J Thorac Cardiovasc Surg* 1983;**85**(2):219–228
34. Tobin GR. Closure of contaminated wounds: biologic and technical considerations. *Surg Clin North Am* 1984;**64**(4):639–652
35. Tobin GR. Pectoralis major muscle–musculocutaneous flaps for chest wall reconstruction. *Surg Clin North Am* 1989;**69**(5): 991–1006
36. Tobin GR. Pectoralis major segmental anatomy and segmentally split pectoralis major flaps. *Plast Reconstr Surg* 1985;**75**(6): 814–824
37. Tobin GR. Segmentally split pectoral girdle muscle flaps for chest-wall and intrathoracic reconstruction. *Clin Plast Surg* 1990;**17**(4):683–696
38. Morain WD, Colen LV, Hutchings JC. The segmental pectoralis major muscle flap: a function-preserving procedure. *Plast Reconstr Surg* 1985;**75**(6):825–830
39. Dejesus RA, Paletta JD, Dabb RW. Reconstruction of the median sternotomy wound dehiscence using the latissimus dorsi myocutaneous flap. *J Cardiovasc Surg (Torino)* 2001;**42**(3): 359
40. Jones G, Jurkiewicz MJ, Bostwick J, Wood R, Bried JT, Culbertson J *et al*. Management of the infected median sternotomy wound with muscle flaps: the Emory 20 year experience. *Ann Surg* 1997;**225**(6):766–776
41. Lopez-Monjardin H, De-la-Pena-Salcedo A, Mendoza-Munoz M, Lopez-Yanez-de-la-Pena A, Palacio-Lopea E, Lopez-Garcia A. Omentum flap versus pectoralis major flap in the treatment of mediastinitis. *Plast Reconstr Surg* 1998;**101**(6):1481–1485
42. Netscher DT, Eladoumikdachi F, Goodman CM. Rectus abdominis muscle flaps used successfully for median sternotomy wounds after ipsilateral internal mammary artery ligation. *Ann Plast Surg* 2001;**47**(3):223–228
43. Thurer RJ, Bognolo D, Vargas A, Isch JH, Kaiser GA. The management of mediastinal infection following cardiac surgery: an experience utilizing continuous irrigation with povidone-iodine. *J Thorac Cardiovasc Surg* 1975;**68**(6):962–968