Sternotomy Wounds: Rectus Flap versus Modified Pectoral Reconstruction

Steven P. Davison, M.D., D.D.S.
Mark W. Clemens, M.D.
Deana Armstrong, M.D.
Ernest D. Newton, M.D.
William Swartz, M.D.

Pittsburgh, Pa.; and Washington, D.C.

Background: Infected sternotomy wounds occur in 0.5 to 8.4 percent of open heart operations. They are complex problems, with a mortality rate of 8.1 to 14.8 percent despite flap closure. For closure, the pectoralis major flap has had considerable success. However, in providing coverage to the lower third of the sternum, it may be deficient. Modifications to improve closure have included a rectus flap or an anterior rectus fascia extension to the pectoralis flap.
Methods: This retrospective study of 130 consecutive sternotomy wounds compares 41 bilateral pectoralis major muscle flaps with a modified anterior rectus fascia extension against 56 rectus abdominis muscle flaps alone in addressing the lower third of the sternum following dehiscence.
Results: Pectoralis flaps with rectus fascia extension and rectus flaps have similar success, postoperative course, and morbidity and mortality rates. The pectoralis flaps with rectus fascia extensions prevented superior dehiscence, but this modification does not eliminate dehiscence of the distal third of the sternum.
Conclusions: The rectus muscle alone proved superior in coverage to the inferior sternum. Sternal wounds should be covered preferentially by a pectoralis flap to cover a superior infection and by a rectus flap if the dehiscence is localized to the distal third. (*Plast. Reconstr. Surg.* 120: 929, 2007.)

Median sternotomy is one of the most common operations performed today. It is the preferred approach to the anterior mediastinum and for surgical treatment of coronary artery disease. The sternum becomes infected postoperatively in 0.5 to 8.4 percent[1–19] of open heart operations, leading to the possible sequelae of osteomyelitis, dehiscence, and death. Sternotomy wounds are complex problems because of their proximity to the heart, lungs, and abdominal cavity and the lack of coverage to these vital organs following debridement. They have mortality rates of 8.1 to 14.8 percent.[1–3,6,10,14,17,18,20] Hospital stays are prolonged by a mean of 30 days, but can take 5.5 months, with up to four reoperations.[1,17,18,21] The cost of an infected sternotomy doubles to quadruples hospital expenses.[1,22,23] The significant morbidity and mortality associated with sternotomy infections has spurred a longstanding search for the most effective method of treatment.

The treatment options in the past ranged from leaving the wound open to heal by secondary intention to debridement and rewiring coupled with antibiotic irrigation therapy.[18,24,25] In the past quarter century, well-vascularized flaps have been shown to provide stable coverage to the sternotomy wound after radical debridement. In 1976, Lee et al. initiated the idea of an omental flap for closure of this deficit.[26] In 1980, Jurkiewicz et al. reported the use of pectoral muscle flaps.[4] These treatment strategies have increased long-term success from 50 percent[4,12,26] to now 90 to 99 percent.[1,2,5,17,27,28] The average length of hospital stay has dropped from 84 days to under 13 days.[2,4–6,9,17,29] Although the sternum is normally lacking muscular coverage, in treating an infected sternum, the use of muscle flaps has substantially reduced both hospital stay and mortality from this difficult problem. In addition, the muscle provides structural protection to the vital structures beneath following massive sternal debridement.

Pectoralis major and rectus abdominis have become first-line flaps,[30] with the pectoral favored between the two.[3,9] The omentum is generally thought of as a second-line treatment

From West Penn Hospital, Shadyside Hospital, and the Division of Plastic and Reconstructive Surgery, Georgetown University Medical Center.
Received for publication January 3, 2006; accepted February 17, 2006.

DOI: 10.1097/01.prs.0000253443.09780.0f

choice.[30] A major limitation of the pectoralis major flap has been coverage of the inferior third of the sternotomy wound.[7,8,14,31–35] It is the most common site for dehiscence after flap repair.[2,14,26,30,31,34–36]

In this study, the authors evaluated two different flap options that address the inferior third of the sternotomy wound. The two senior authors (S.P.D. and M.W.C.) have independently used either a rectus abdominis flap alone or a modified pectoralis major flap with anterior rectus sheath extension for coverage of dehisced sternotomy wounds. The purpose of this article is to compare these two treatment protocols in terms of efficacy and complications focusing on the lower third of the sternum.

PATIENTS AND METHODS

This is a retrospective review of two series of consecutive patients treated for infected sternotomy wounds. Each series used a different technique on a similar demographic patient population (age range, 52 to 86 years; mean, 67.5 years) at adjacent medical facilities. Both hospitals serve equal income populations.

Hospital records were reviewed for patients treated for sternal dehiscence/infection from January of 1985 to December of 1998. Chart review evaluated flap technique, postoperative success, recovery time, reoperation rate, morbidity, and mortality. A postdischarge written survey completed follow-up results. Follow-up was limited to 2 to 4 years (average, 2.8 years). Results were analyzed using the Fisher's exact test.

The rectus flap closure was based on the superior epigastric pedicle. The sternotomy incision was continued inferiorly 3 cm lateral to the umbilicus directly over the rectus. During rectus harvest, a skin bridge was preserved if possible; however, this was dependent on where the sternotomy incision ended. The anterior rectus sheath was opened and elevated from the underlying muscle. The rectus insertion to the pubis was sectioned at the ligament. The inferior epigastric artery was identified and clipped. Note that none of the rectus flaps were delayed or required supercharging; however, the authors advocate harvesting the deep inferior epigastric artery as an intraoperative "lifeboat" should the adequacy of rectus perfusion be in question. The lateral intercostal perforators were coagulated with bipolar electrocautery and the rectus was raised. The superior epigastric and as many of the superior anterior intercostal perforator arteries were preserved. The rectus sheath was closed, and a two-layer closure of the abdominal area was completed.

The pectoralis major flap, modified with anterior rectus fascia, was harvested through the midline sternotomy incision extended 5 cm inferiorly. A plane was developed between the pectoralis and the subcutaneous tissue bilaterally to the mid nipple line. Both pectoralis muscles were sharply elevated from their costal and sternal insertions, continuing the dissection in a subpectoral plane to allow bilateral advancement to the midline without tension. The humeral attachments of the pectoralis muscles were left intact and the thoracoacromial arteries were carefully preserved. The internal mammary artery perforators were clipped or coagulated. The insertion of the pectoralis muscles was released with preservation of the long thoracic artery to aid in a tension-free closure. In the inferomedial portion, the pectoral muscle was elevated in continuity with the anterior rectus fascia, leaving the rectus muscle undisturbed. The rectus fascia was lifted up with the pectoralis fascia. At least 5 cm of the anterior rectus fascia to the first imbrication was harvested. Inferiorly, the anterior rectus fascia is separated from the rectus (Fig. 1). The pectoralis muscles were imbricated medially. A two-layer closure of the subcutaneous tissue and skin complete the procedure. Both reconstruction techniques were used after aggressive staged debridement. Only very mild infections limited to superficial dermis and subcutaneous soft tissue were debrided and closed in one stage. Drains were used and intravenous antibiotics were given for 3 to 6 weeks after surgery.

RESULTS

A total of 130 patients with sternotomy wounds were treated, 107 with muscle flaps, 12 with omental flaps, and 11 with local wound management only. Average time to presentation was 7 to 10 days, with drainage (22 patients), dehiscence (15 patients), cellulitis (12 patients), and click (seven patients) the predominant symptoms. The most common organisms present in the 92 patients with positive cultures was *Staphylococcus aureus* in 55 patients (60 percent), mixed infection with *S. aureus* in 10 patients (11 percent), group D *Enterococcus* in 11 patients (12 percent), and *Serratia marcescens* in 10 patients (11 percent).

Modified pectoralis reconstruction was used in 41 patients and rectus reconstruction was used in 56 patients (Table 1). Success was defined as a healed wound and a discharged patient at 30 days postoperatively. This was attained in 85 percent

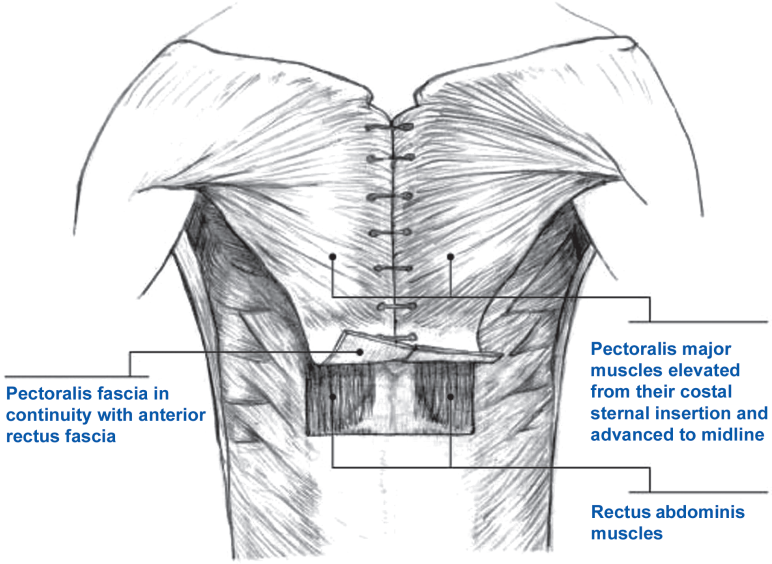

Fig. 1. In the modified pectoralis flap, the superior anterior rectus sheath is separated from the inferior portion of the sheath. The superior anterior rectus sheath is then left in continuity with the pectoralis muscle and fascia, giving continuous coverage to the lower third of the sternum.

Table 1. Morbidity and Mortality of 41 Modified Pectoral Flaps versus 56 Rectus Abdominis Flaps

Morbidity/Mortality	Pectoral/Rectus Fascia Extension (%)	Rectus Abdominis (%)
Superior dehiscence	0 (0)	8 (14.2)
Inferior dehiscence	6 (14.6)	0 (0)
Hematoma/seroma	6 (14.6)	2 (3.6)
Harvest complication	0 (0)	9 (16)
Hernia	0 (0)	1 (1.8)
Deep venous thrombosis	1 (2.4)	0 (0)
Death (unrelated to reconstructive surgery)	2 (4.9)	4 (7.1)

for the modified pectoralis patients and 86 percent in the rectus population. The average time for recovery was 14.4 and 15 days, respectively.

Modified pectoralis reconstruction had 34 percent morbidity, with inferior wound dehiscence in six patients, hematoma/seroma in seven patients, and deep venous thrombosis in one patient. Thirty-day mortality was two of 41.

Rectus reconstruction had 34 percent morbidity, with flap tip necrosis and superior dehiscence in eight patients, abdominal skin breakdown in nine patients, seroma/hematoma in two patients, and hernia in one patient. Mortality was four of 56.

The rectus group showed a statistically significant improvement in preventing dehiscence of the inferior third ($p = 0.0045$), and the pectoral series displayed a statistically significant advantage in preventing superior dehiscence ($p = 0.0192$). Without isolating the sites of dehiscence, there were no significant differences in success, morbidity, or mortality between groups ($p > 0.05$).

DISCUSSION

The advantage in wound closure and the decrease in mortality associated with vascularized flap closure in sternal wound infection is well documented by large studies.[2–9,14,18,26,30,34] The number of flap options discussed—pectoralis turnover or pedicle,[2–4,5,9,14,18,31,32,36,37] latissimus dorsi,[2,5,9,31] rectus abdominis,[2,5,7–9,37–39] or omental[9,14,26,30]—suggests that the ideal flap does not exist. A combination of flaps is sometimes required, particularly to deal with difficult areas such as the inferior third of the sternum. In this study, the authors evaluated a modification of the pectoralis major flap compared with the rectus abdominis flap to treat acute infections of the sternum, particularly the inferior third of the sternotomy.

The clinical course of these patients is typical of sternotomy infection and dehiscence, with a presentation delayed 10 days postoperatively.[1,6,17,29] The typical patient population presents with *S. aureus*,[1,3,5–7,11,18,34] and this was reiterated in our study as the most common organism (60 percent). *S. marcescens* involved 11 percent of cases in our study, possibly reflecting a trend in hospital colonization.

The considerable success of the pectoralis major flap has been extensively discussed.[40] It is based on the thoracoacromial artery, unaffected by the

harvesting of the internal mammary arteries for coronary graft. It is presently the favored muscle flap for covering infected sternotomy wounds.[3,9] A major limitation of the pectoralis major flap has been 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.[2,14,26,31,32,34–36] The pectoral and latissimus flaps alone are unsuccessful in this area.

The rectus abdominis flap has been advocated as an alternative to the pectoralis major flap. It is pedicled on the superior epigastric artery; however, it can survive in the absence of the internal mammary artery.[5,8,21,35] Coverage using the rectus abdominis is advocated based on its ease of dissection and its wide arc of rotation. It can easily cover the lower third of the sternum but can also reach as high as the sternal notch.[7] One presumed morbidity associated with this technique is hernia formation or protrusion of the peritoneum through the abdominal wall, described to occur in as much as 50 percent in some studies[9] but only found in 2 percent of our rectus flap patients. By leaving the rectus fascia in place with a two-layer closure, we significantly diminished this complication.

Both of these flaps have similar success rates for sternal wound closure at 30 days of 85 and 86 percent, with average recovery being 15 days, which is an improvement from results reported with other methods. Although the rectus group had a mortality rate double that of the pectoral group, the deaths in this series were all related to the patients' cardiac or cardiopulmonary status, not the procedure or surgical complications. This confirms and emphasizes the underlying risk factors these patients have and the serious nature of a sternal infection.[41]

The most significant finding was the difference in flap morbidities. The pectoralis-rectus fascial flap broke down at the inferior third (Fig. 2) in six of 41 patients. This was the area the rectus fascia modification was designed to protect. This area of the combination musculofascial flap contains only fascia and is by principle the weakest area of the closure. The wound dehiscence in the rectus flaps was at the distal tip of the rectus, leading to a superior wound defect (Fig. 3). In the area of the lower third of the sternum, the muscular flap of the rectus was significantly superior to the fascial coverage of the pectoral group, 0 percent and 15 percent dehiscence, respectively. This illustrates that the rectus flap is superior in obliterating the dead space and promoting healing in the lower third of the sternum. Salvage of either defect in six patients of each group was performed using the alternative flap.

Fig. 2. Wound dehiscence at the inferior third of the sternal reconstruction in a patient with modified pectoralis major flap reconstruction.

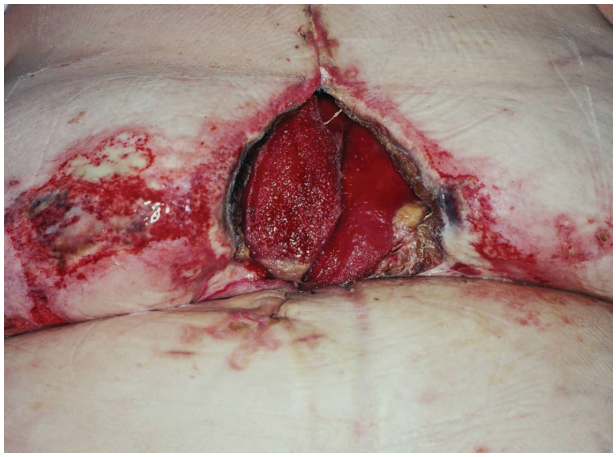

Fig. 3. The upper chest at the level of the inframammary fold is shown. Note the superior dehiscence of the rectus flap seen through the distal sternal incision.

The predominant complication in the pectoralis major flaps was hematoma and seroma formation, whereas in the rectus abdominis flap the problem in nine of 56 patients was abdominal wound breakdown (Fig. 4). Here, the skin and fat of the abdomen became necrotic because of the disruption and transposition of the major blood supply to this area. These patients were frequently obese, an independent risk factor for sternal wound dehiscence.[10,17,32] Harvesting the rectus muscle eliminates the zone 1 blood supply to the abdominal skin, perpetuating fat necrosis, and results in considerable donor-site morbidity. To pre-

Fig. 4. The superior abdominal wall of a morbidly obese patient is shown. Note fat necrosis along incision emphasizing compromised zone 1 vascular supply following rectus reconstruction.

vent this complication, endoscopic harvest of the rectus[42,43] may be used to preserve collateral supply and improve recovery time. Several studies have shown that the use of vacuum-assisted closure devices[23,44,45] as a bridge to flap closure of sternal wounds improves recovery time and success. Another recent study demonstrated the advantages of transverse plate fixation for stabilization of the sternal skeletal structure leading to earlier extubation, low incidences of recurrence, and more reliable healing.[45,46] Further studies are warranted to evaluate the efficacy of combining these techniques.

Patients now receiving coronary artery bypass grafting through a median sternotomy have complications preventing percutaneous transluminal coronary angioplasty. Although the rates of sternal infection are currently 0.5 to 8.4 percent, this rate is likely to climb because of this sicker patient population.

Of note is a recent article that stated that the omental flap is superior to the pectoral flap in preventing sepsis-related morbidity in a 33-patient study.[14] The disadvantage of this procedure is that it requires a laparotomy that could spread infection from the thoracic cavity to the abdomen, or possibly vice versa. This approach also leads to greater hernia formation. Because of these two possibilities, it is reserved for secondary closure after pectoral or rectus flaps have failed.

Operative Warning

A point deserving particular attention that was found by reviews of operative notes was that seven of 56 patients in whom a rectus abdominis was used had the right ventricle stuck to the underside of the right sternum at the time of debridement. Risk of rupture of the right ventricle at this time is substantial if the potential for this is not appreciated. The dissection of the sternum off the pericardium must be very carefully completed, especially when the planes are disturbed by infection.

CONCLUSIONS

A high rate of success (85 and 86 percent) was found in this study for closure of infected sternotomy wounds either with pectoralis major modified with rectus fascia extension or with a rectus abdominis flap. The complications of the pectoralis flap are located in the lower sternal area, with wound dehiscence and hematoma/seroma the most common complications. The major complications for the rectus abdominis flap group were donor-site necrosis, and if dehiscence did occur, it was located in the superior tip. The rectus abdominis flap is superior in addressing the lower third and should be used over the pectoral, with or without the anterior rectus fascia extension, if the infection is concentrated in this inferior region.

Mark Clemens, M.D.
Division of Plastic and Reconstructive Surgery
Georgetown University Medical Center
3800 Reservoir Road, NW
Washington, D.C. 20007
markclemens26@yahoo.com

ACKNOWLEDGMENT

The authors acknowledge Michael Javernick for assistance with the modified pectoral illustration.

DISCLOSURE

None of the authors has a financial interest in any of the products, devices, or drugs mentioned in this article.

REFERENCES

1. Smith, J. M., Glasser, R. S., Osborne, B., et al. Sternal wound complications after open heart surgery: Results from 3524 consecutive operative procedures. *Contemp. Surg.* 43: 197, 1993.
2. Jones, G., Jurkiewicz, M. J., Bostwick, J., et al. Management of the infected median sternotomy wound with muscle flaps: The Emory 20 year experience. *Ann. Surg.* 225: 766, 1997.
3. Pairolero, P. C., Arnold, P. G., and Harris, J. B. Long-term results of pectoralis major muscle transposition for infected sternotomy wounds. *Ann. Surg.* 213: 583, 1991.
4. Jurkiewicz, M. J., Bostwick, J., Hester, T. R., Bishop, J. B., and Craver, J. Infected median sternotomy wound: Successful treatment by muscle flaps. *Ann. Surg.* 191: 738, 1979.
5. Nahai, F., Rand, R., Hester, R., et al. Primary treatment of infected sternotomy wound with muscle flaps: A review of 211 consecutive cases. *Plast. Reconstr. Surg.* 84: 434, 1989.
6. Martin, R. D. The management of infected sternotomy wounds. *Ann. Plast. Surg.* 22: 243, 1989.

7. Iacobucci, J. J., Stevenson, T. R., Hall, J. D., and Deeb, G. M. Sternal osteomyelitis: Treatment with rectus abdominis muscle. *Br. J. Plast. Surg.* 42: 452, 1989.
8. Fernando, B., Muszynski, C., and Mustoe, T. Closure of a sternal deficit with the rectus abdominis muscle after sacrifice of both internal mammary arteries. *Ann. Plast. Surg.* 21: 468, 1988.
9. Ringleman, P. R., Vander-Kolk, C. A., Cameron, D., et al. Long-term results of flap reconstruction in median sternotomy wound infections. *Plast. Reconstr. Surg.* 93: 1208, 1994.
10. Ottino, G., De Paulis, R., Pansini, S., et al. Major sternal wound infection after open-heart surgery: A multivariate analysis of risk factors in 2,579 consecutive operative procedures. *Ann. Thorac. Surg.* 44: 173, 1987.
11. Culliford, A. T., Cunningham, J. N., Zeff, R. H., et al. Sternal and costochondral infections following open-heart surgery. *J. Thorac. Cardiovasc. Surg.* 72: 714, 1976.
12. Sarr, M. G., Gott, V. L., and Townsend, T. R. Mediastinal infection after cardiac surgery. *Ann. Thorac. Surg.* 38: 415, 1984.
13. Breyer, R. H., Mills, S. A., Hudspeth, A. S., et al. A prospective study of sternal wound complications. *Ann. Thorac. Surg.* 37: 412, 1984.
14. Lopez-Monjardin, H., De-la-Pena-Salcedo, A., Mendoza-Munoz, M., Lopez-Yanez-de-la-Pena, A., Palacio-Lopea, E., and Lopez-Garcia, A. Omentum flap versus pectoralis major flap in the treatment of mediastinitis. *Plast. Reconstr. Surg.* 101: 1481, 1998.
15. Robicsek, K. F. Postoperative sterno-mediastinitis. *Am. Surg.* 66: 184, 2000.
16. Fairchild, P. G., and Gantz, N. M. Mediastinal and sternal infections. *Card. Surg. State Art Rev.* 2: 407, 1988.
17. Yuen, J. C., Zhou, A. T., Serafin, D., and Georgiade, G. S. Long-term sequelae following median sternotomy wound infection and flap reconstruction. *Ann. Plast. Surg.* 35: 585, 1995.
18. Scullly, H. E., Leclerc, Y., Martin, R. D., et al. Comparison between antibiotic irrigation and mobilization of pectoral muscle flaps in treatment of deep sternal infections. *J. Thorac. Cardiovasc. Surg.* 90: 523, 1985.
19. Grossi, E. A., Culliford, A. T., Krieger, K. H., et al. A survey of 77 major infectious complications of median sternotomy: A review of 7,949 consecutive operative procedures. *Ann. Thorac. Surg.* 40: 214, 1985.
20. Weinstein, R. A., Jones, E. L., Schwarzmann, A. W. Sternal osteomyelitis and mediastinitis after open heart operation: Pathogenesis and prevention. *Ann. Thorac. Surg.* 21: 442, 1976.
21. Arnold, P. G., and Pairolero, P. C. Chest-wall reconstruction: An account of 500 consecutive patients. *Plast. Reconstr. Surg.* 98: 804, 1996.
22. Loop, F. D., Lytre, B. W., Cosgrove, D. M., et al. Sternal wound complications after isolated coronary artery bypass grafting: Early and late morbidity, mortality, and cost of care. *Ann. Thorac. Surg.* 49: 179, 1990.
23. Hersh, R. E., Jack, J. M., Dahman, M. I., Morgan, R. F., and Drake, D. B. The vacuum-assisted closure device as a bridge to sternal closure. *Ann. Plast. Surg.* 46: 250, 2001.
24. Shumacker, H. B., and Mandelbaum, I. Continuous antibiotic irrigation in the treatment of infection. *Arch. Surg* 86: 384, 1963.
25. Bryant, L. R., Spencer, F. C., and Trinkle, J. K. Treatment of median sternotomy infection by mediastinal irrigation with an antibiotic solution. *Ann. Surg.* 169: 914, 1969.
26. Lee, A. B., Schimert, G., Shaktin, S., and Seigel, J. H. 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* 80: 433, 1976.
27. Chase, C. W., Franklin, J. D., Guest, D. P., and Barker, D. E. Internal fixation of the sternum in median sternotomy dehiscence. *Plast. Reconstr. Surg.* 103: 1667, 1999.
28. Schulman, N. H., and Subramanian, V. Sternal wound reconstruction: 252 consecutive cases. The Lenox Hill experience. *Plast. Reconstr. Surg.* 114: 44, 2004.
29. Borger, M. A., Rao, V., Weisel, R. D., et al. Deep sternal wound infection: Risk factors and outcomes. *Ann. Thorac. Surg.* 65: 1050, 1998.
30. Hultman, C. S., Culbertson, J. H., Jones, G. E., et al. Thoracic reconstruction with the omentum: Indications, complications, and results. *Ann. Plast. Surg.* 46: 242, 2001.
31. Dejesus, R. A., Paletta, J. D., and Dabb, R. W. Reconstruction of the median sternotomy wound dehiscence using the latissimus dorsi myocutaneous flap. *J. Card. Surg.* 42: 359, 2001.
32. Solomon, M. P., and Granick, M. S. Bipedicle muscle flaps in sternal wound repair. *Plast. Reconstr. Surg.* 101: 356, 1998.
33. Nahai, F., Morales, L., Bone, D. K., and Bostwick, J. Pectoralis major muscle turnover flaps for closure of the infected sternotomy wound with preservation of form and function. *Plast. Reconstr. Surg.* 70: 471, 1982.
34. Pairolero, P. C., and Arnold, P. G. Management of recalcitrant median sternotomy wounds. *J. Thorac. Cardiovasc. Surg.* 90: 523, 1985.
35. Netscher, D. T., Eladoumikdachi, F., and Goodman, C. M. Rectus abdominis muscle flaps used successfully for median sternotomy wounds after ipsilateral internal mammary artery ligation. *Ann. Plast. Surg.* 47: 223, 2001.
36. Mathes, S. J. The principles of muscle and musculocutaneous flaps. In J. G. McCarthy (Ed.), *Plastic Surgery*, Vol. 1. Philadelphia: Saunders, 1990.
37. Russell, R. C., Feller, A. M., Elliott, L. F., et al. The extended pectoralis major myocutaneous flap: Uses and indications. *Plast. Reconstr. Surg.* 88: 814, 1991.
38. Solomon, M. P., and Granick, M. S. New reconstruction method for sternotomy wounds. *Perspect. Plast. Surg.* 8: 61, 1994.
39. Clarkson, J. H., Probst, F., Niranjan, N. S., et al. Our experience using the vertical rectus abdominis muscle flap for reconstruction in 12 patients with dehiscence of a median sternotomy wound and mediastinitis. *Scand. J. Plast. Reconstr. Surg. Hand Surg.* 37: 266, 2003.
40. AschermanJ., PatelS., Malhotra, S., and Smith, C. Management of sternal wounds with bilateral pectoralis major myocutaneous advancement flaps in 114 consecutively treated patients: Refinements in technique and outcomes analysis. *Plast. Reconstr. Surg.* 114: 676, 2004.
41. Ahumada, L. A., de la Torre, J. I., RayP. D., et al. Comorbidity trends in patients requiring sternectomy and reconstruction. *Ann. Plast. Surg.* 54: 264, 2005.
42. Dabb, R., Wrye, S., and Hall, W. Endoscopic harvest of the rectus abdominis muscle. *Ann. Plast. Surg.* 44: 491, 2000.
43. Sawaizumi, M., Onishi, K., and Maruyama, Y. Endoscopic-assisted rectus abdominis muscle flap harvest for chest wall reconstruction: Early experience. *Ann. Plast. Surg.* 37: 317, 1996.
44. Song, D. H., Wu, L. C., Lohman, R. F., Gottlieb, L. J., and Franczyk, M. Vacuum assisted closure for the treatment of sternal wounds: The bridge between debridement and definitive closure. *Plast. Reconstr. Surg.* 111: 92, 2003.
45. Agarwal, J. P., Ogilvie, M., Wu, L. C., et al. Vacuum-assisted closure for sternal wounds: A first-line therapeutic management approach. *Plast. Reconstr. Surg.* 116: 1035, 2005.
46. Cicilioni, O. J., Stieg, F. H., and Papanicolaou, G. Sternal wound reconstruction with transverse plate fixation. *Plast. Reconstr. Surg.* 115: 1297, 2005.