The Heart Surgery Forum #2004-03114
7 (6), 2004 [Epub September 2004]
doi:10.1532/HSF98.200403114

Online address: www.hsforum.com/vol7/issue6/2004-03114.html

A Steel Band in Addition to 8 Wire Cerclages Reduces the Risk of Sternal Dehiscence after Median Sternotomy

Dr. Riess

Friedrich-Christian Riess,[1] Nizar Awwad,[1] Bettina Hoffmann,[1] Ralf Bader,[1] Hanns-York Helmold,[1] Christine Loewer,[2] Andreas G. Riess,[1] Niels Bleese[1]

Departments of [1]Cardiac Surgery and [2]Cardiac Anesthesia, Albertinen-Krankenhaus, Hamburg, Germany

ABSTRACT

Background: Sternal dehiscence after full median sternotomy may result in wound-healing disorders, including osteomyelitis. The consequences are extended hospitalization, plastic surgery, stress for the patient, and increased costs. Stable closure of the median sternotomy plays a crucial role in the avoidance of sternal dehiscence and osteomyelitis.

Methods: All patients who underwent full sternotomy from January 1999 until December 2001 were investigated with respect to the incidence of sternal dehiscence. Since January 2000, patients supposed to be at risk for sternum dehiscence were more frequently treated with an Ethicon steel band at the third intercostal space in addition to standard osteosynthesis with 8 wire cerclages.

Results: Since the introduction of this method, the incidences of sternal dehiscence and sternal wound infections decreased from 2.9% and 0.9 %, respectively, in 1999 to 0.3% and 0.2%, respectively, in 2001. This decline resulted in shorter postoperative hospital stays, less stress for the patients, and substantial reductions in postsurgical costs.

Conclusions: A steel band used in addition to standard osteosynthesis with 8 wire cerclages is a safe and effective procedure resulting in a statistically significant decrease in the frequency of sternal dehiscence.

INTRODUCTION

Wound-healing disorders of the sternum are among the most serious complications of cardiac surgery [Culliford 1976, Breyer 1984]. They often result in extended hospitalization, plastic surgery, stress for the patient, and substantial costs to the health care system. Risk factors for sternal dehiscence and sternal osteomyelitis are obesity, diabetes, pulmonary disease, and nicotine abuse [Nagachinta 1987, Baskett 1999, Jacob 2000, Gummert 2002]. Several special techniques have been suggested to increase stability during sternal osteosynthesis [Labitzke 1983, Johnston 1985, Tavilla 1991, Noyez 1993, Roux 1995] and to decrease the number of wound-healing complications. Not all of these techniques are satisfying with respect to ease of handling and the amount of time necessary to perform osteosynthesis. An antiseptic technique by the surgical, anesthesia, and perfusionist team is of high importance for the prevention of wound infection of the sternal area after open heart surgery [Ferrazzi 1986]. There is no prospective randomized study providing statistically significant proof that antibiotic prophylaxis can prevent sternal wound infection. However, perioperative prophylactic antibiotic therapy has been recommended for cardiac surgery to prevent sternal wound infection [Firor 1967, Myerowitz 1977] and today is part of the international standard in cardiac surgery [Dajani 1997, Simon 2000].

Stable closure of the median sternotomy seems to play the crucial role in the avoidance of the sternum dehiscence that can result in osteomyelitis. We have had a constant sternum dehiscence rate of approximately 3% for all of the patients who have undergone open cardiac surgery via a full sternotomy, and it was our aim to decrease the incidence of this potentially severe complication by using an osteosynthesis combining 8 wire cerclages and 1 additional steel band.

METHODS

All patients who underwent full median sternotomy from January 1999 until December 2001 were studied retrospectively with regard to the incidence of sternal dehiscence. Until December 1999, no steel band had been used. Since January 2000, patients supposed to be at risk for sternum dehiscence were more frequently treated with a steel band (tensioning device; Ethicon, Norderstedt, Germany) (Figures 1-7) at the third intercostal space in addition to standard osteosynthesis with 8 wire cerclages (USP 5/6; Ethicon). The operative technique is described in detail in the figure

Presented at the Fifth Annual Meeting of the International Society for Minimally Invasive Cardiac Surgery, New York, New York, USA, June 20-23, 2002.

Received April 21, 2003; received in revised form July 2, 2004; accepted July 8, 2004.

Address correspondence and reprint requests to: Friedrich-Christian Riess, Albertinen-Krankenhaus, Suentelstrasse 11 a, 22457 Hamburg, Germany; 00-49-40-5588-2445; fax: 00-49-40-5588-2421 (e-mail: Friedrich-Christian.Riess@albertinen.de).

© 2004 Forum Multimedia Publishing, LLC

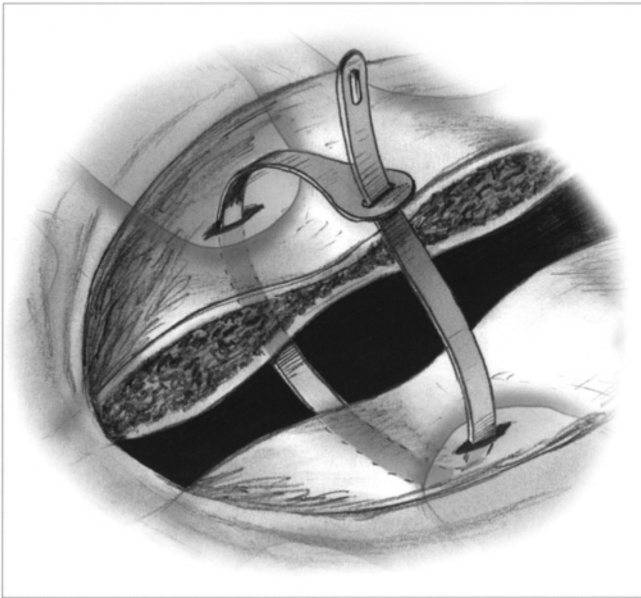

Figure 1. The steel band is run around the sternum through small incisions lateral to the sternum, most effectively in the third intercostal space. The steel band is then threaded through its slot. The bone is not penetrated.

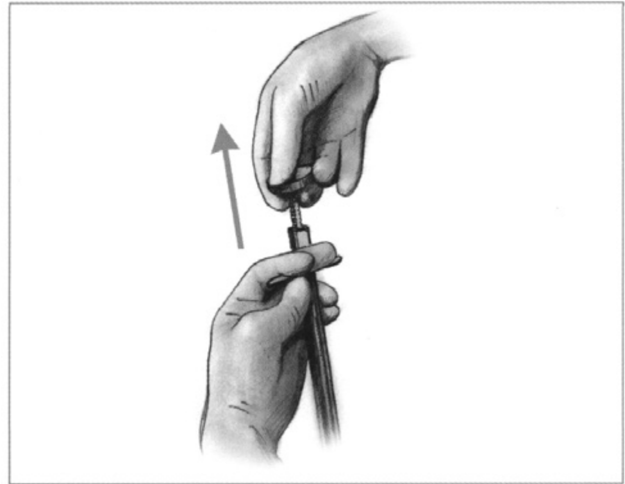

Figure 3. The set screw is then extracted from the tensioning device, which tightens the steel band around the sternum.

legends. We considered patients at high risk for sternum dehiscence, including patients with chronic obstructive lung disease, bilateral internal mammary artery (IMA) grafts, osteoporosis, insulin-dependent diabetes mellitus, and severe obesity. Patients who underwent operations in 1999 (group A), 2000 (group B), and 2001 (group C) were compared with respect to demographic data and clinical outcome, especially to the incidence of sternum dehiscence and/or sternum osteomyelitis in correlation with the number of steel bands used. Table 1 summarizes the demographic data for the 3 groups of patients who underwent cardiac surgery via a full sternotomy. Patients from 1999 were significantly younger than patients from 2000 (mean difference, 1.5 years; $P = .003$, Scheffé test) and 2001 (mean difference, 1.1 years; $P = .036$). Tests with all other variables showed no statistically significant differences. Concomitant diseases considered risk factors for sternum dehiscence or sternum wound-healing problems are shown in Table 2. There were no statistically significant differences between the 3 groups for the variables of diabetes and obesity; however, a statistically significant difference in the incidence of chronic obstructive pulmonary disease was found for the 3 groups of patients ($\chi^2 = 21.8$; $P < .001$).

Cardiac surgery was performed by means of cardiopulmonary bypass using a membrane oxygenator and cardioplegic arrest with modified blood cardioplegia (Table 3) or as

Figure 2. The narrow end of the steel band is inserted into the tensioning device and connected through an eyelet to the hook of the set screw.

Figure 4. The steel band receives its final tension adjustment through tightening of the nut, allowing both sides of the sternum to be adjusted in an infinite variety of ways.

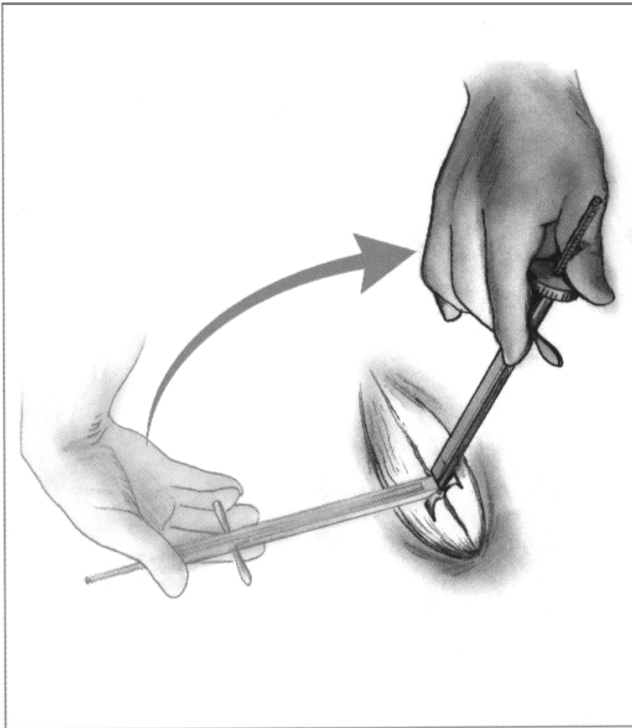

Figure 5. The tensioning device is turned down by bending the steel band near its slot.

an off-pump procedure without the use of cardiopulmonary bypass. In all patients, perioperative antibiotic prophylaxis was performed with cefazolin. Postoperative respiratory training avoiding increased stress to both arms was performed in all patients. In cases of sternal wound infection and osteomyelitis, the patients were intermittently treated with debridement of the open chest wound and mechanical ventilation in the intensive care unit.

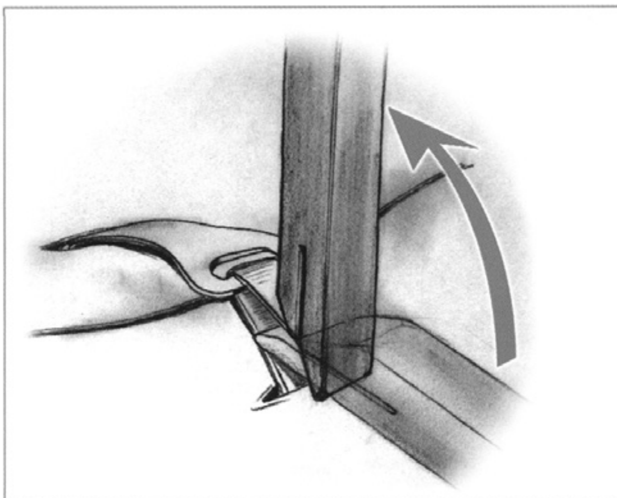

Figure 6. The steel band is released by unscrewing the nut approximately 1.5 cm. The tensioning device is now turned up again. The steel band is then detached from the tensioning device.

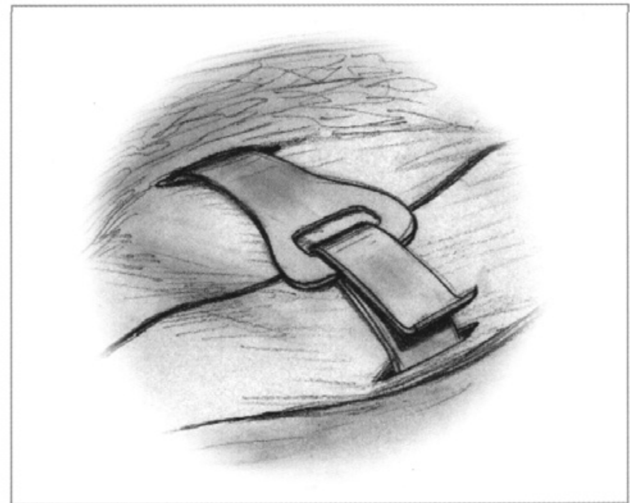

Figure 7. Finally, any excess portion of the steel band is clipped off with pliers.

Statistics

Differences in age were investigated with the Scheffé test. The variables of weight, length, chronic obstructive pulmonary disease, diabetes, obesity, and frequency of dehiscence were investigated with the χ^2 test according to the method of Pearson. Length of hospital stay was investigated by means of the Student *t* test. Variables are shown as the mean ± SD. A *P* value less than .05 was considered statistically significant.

RESULTS

The operative data for the patients who underwent cardiac surgery via full median sternotomy in 1999, 2000, and 2001 are shown in Table 3. There was a statistically significant difference (analysis of variance: F = 4.42; $P = .012$) in operation times for the 3 groups of patients. The results of the post hoc test demonstrated that the mean operation time for the 1999 patient group was significantly shorter than that of the 2001 patient group (mean difference, –11.09 minutes; $P = .003$). The mean operation time for the 2000 patient group was significantly shorter than that of the 2001 patient group (mean difference, –8.07 minutes; $P = .043$). The difference in mean operation time between the 1999 patient group and the 2000 patient group did not reach statistical significance. Until December 1999, no additional steel band had been used. Since January 2000, patients determined to be at risk for sternum dehiscence were treated more frequently with a steel band (Table 4). Since the introduction of this method, the incidence of sternum dehiscence and/or osteomyelitis decreased from 2.9% in 1999 to 0.3% in 2001 in correlation with the increased use of a steel band in addition to the standard sternum osteosynthesis using 8 wire cerclages. This difference was highly statistically significant (χ^2 value according to Pearson, 26.4; $P < .001$) Moreover, the wound infection rate decreased from 0.9% in 1999 to 0.2% in 2001. However, because of the small number of infections, this decrease did not reach statistical significance. The different pathologic species cultured from wound swabs are shown in Table 4.

© 2004 Forum Multimedia Publishing, LLC

Table 1. Demographic Data of Patients Who Underwent Cardiac Surgery via a Full Sternotomy*

Group	A	B	C
Year of operation	1999	2000	2001
Patients, n	1189	1174	1254
Age, y	64.2 ± 10.5 (20.0-88.0)†‡	65.6 ± 10.2 (23.0-88.0)†	65.2 ± 10.5 (20.0-90.0)‡
Female sex, % (n)	24.9 (296)	28.4 (333)	28.3 (355)
Weight, kg	79.6 ± 13.5 (42-140)	79.3 ± 13.6 (43-131)	78.4 ± 13.9 (42-132)
Length, cm	172.5 ± 8.3 (147-198)	172.1 ± 8.6 (144-200)	171.9 ± 8.7 (145-197)

*Data are presented as the mean ± SD (range) where appropriate.
†Mean difference, 1.5 years; *P* = .003, Scheffé test.
‡Mean difference, 1.1 years; *P* = .036, Scheffé test.

The numbers of sternal wound infections in patients with bilateral IMA grafts are shown in Table 4. In all of these patients, IMA preparation was performed with the pedicle technique.

Length of hospital stay was longer in all 3 groups for patients with sternal dehiscence than for patients without sternal dehiscence. However, this prolongation in hospital stay was statistically significant only for the 2001 patient group (Table 4).

The numbers of patients who underwent debridement of the open chest wound and mechanical ventilation in the intensive care unit are shown in Table 4. No sternal dehiscence or infection occurred in the patients with the additional steel band. The frequencies of risk factors in patients who underwent cardiac surgery via a full sternotomy and experienced consecutive sternum dehiscence and/or osteomyelitis are shown in Table 5.

DISCUSSION

Wound infections following median sternotomy are devastating complications in cardiac surgery. Most frequently, they are the result of an unstable osteosynthesis caused by sternal wires cutting into the cortical layers, resulting in a loss of tension and dehiscence [Wilson 1987, Zurbrugg 2000]. Patients at high risk of developing sternal dehiscence and wound infection are particularly those patients with immunosuppression, diabetes, obesity, and osteoporosis [Jacob 2000, Losanoff 2002]. Once dehiscence has occurred, the risk of wound-healing problems, including osteomyelitis of the sternum and mediastinitis, increases. Thus, the incidences of osteomyelitis reported in early studies were between 0.8% and 1.5% [Culliford 1976, Breyer 1984] and could increase to 8% when bilateral pedicled IMAs were used for coronary artery bypass grafting [Culliford 1976]. Risk factors for sternal wound infections are mistakes in aseptic management in the operating room, retrosternal hematoma [Engelman 1973, Wilson 1987], harvesting of both IMAs in a pedicled technique [Kouchoukos 1990, Baskett 1999], obesity [Wilson 1987], and diabetes [Kouchoukos 1990]. Despite good aseptic intraoperative management, contamination during surgery resulting in wound infections cannot completely be prevented [Ferrazzi 1986, Graber 1999, Wong 1999]. Endogenous contaminations by bacterial foci (nasopharyngeal space, gut) may result in sternal wound infections [Jacob 2000, Panknin 2000]. Once sternal dehiscence has occurred, especially in the case of additional wound infection, it results in prolonged hospital stays requiring plastic surgery, strain on the patient, and substantial costs to the health care system.

In our study, we compared 3 groups of patients who underwent full median sternotomy and cardiac surgery with respect to the risk of developing sternal dehiscence with and without wound infection. All 3 groups were comparable with respect to the demographic data, including concomitant dis-

Table 2. Concomitant Diseases in Patients Who Underwent Cardiac Surgery via Full Sternotomy in 1999, 2000, and 2001*

Group	A	B	C
Year of operation	1999	2000	2001
COPD, n	82 (6.9%)†	120 (10.2%)†	157 (12.5%)†
Diabetes mellitus, n	217 (18.7%)	212 (18.4%)	216 (17.3%)
Obesity (BMI>30), n	198 (16.8%)	199 (17.3 %)	203 (16.4%)

*COPD indicates chronic obstructive pulmonary disease; BMI, body mass index.
†χ^2 = 21.8; *P* < .001.

Table 3. Operative Data for Patients Who Underwent Cardiac Surgery via Full Sternotomy in 1999, 2000, and 2001

Group	A	B	C
Year of operation	1999	2000	2001
Operations, n	1189	1174	1254
Reoperations, n	95	92	123
Coronary bypass operations, n	779	734	757
Valve surgery, n	239	247	291
Combined surgery, n	130	138	154
Other operations, n	41	55	52
On-pump surgery, %	93.1	92.4	92.2
Off-pump surgery, %	6.9	7.6	7.8
Operation time, min*	243.1 ± 71.5†	246.1 ± 82.8‡	254.2 ± 82.1†‡

*Data are presented as the mean ± SD. F = 4.42, analysis of variance; *P* = .012.
†Mean difference, −11.09 minutes; *P* = .003, post hoc test.
‡Mean difference, −8.07 minutes; *P* = .043, post hoc test.

Table 4. Data for Patients Who Underwent Cardiac Surgery via Full Sternotomy in 1999, 2000, and 2001 and Developed Sternum Dehiscence with and without Osteomyelitis*

Group	A	B	C
Year of operation	1999	2000	2001
Osteosynthesis with wire cerclages, n	1189	1174	1254
Osteosynthesis with additional steel band, n	None	93 (7.9%)	438 (34.9%)
Sternal dehiscence, n	34 (2.9%)†	17 (1.5%)†	4 (0.3%)†
Sternal dehiscence and wound infections, n	11 (0.9%): *S aureus* (n = 5), *Enterococcus* (n = 2), *A viridans* (n = 1), *P aeruginosa* (n = 1), *S epidermidis*, (n = 2)	7 (0.6%): *S aureus* (n = 2), *Enterococcus* (n = 1), *P acnes*, (n = 1), *S epidermidis*, (n = 3)	3 (0.2%): *S aureus* (n = 1), cn staph (n = 1), *S hemolyticus* (n = 1)
Bilateral IMA graft and sternal infection, n	2/11	3/7	2/3
Sternal dehiscence in on-pump surgery, n	32	16	4
Sternal dehiscence in off-pump surgery, n	2	1	None
Hospital stay			
Without sternal dehiscence, d‡	12.4 ± 3.9 (n = 1155)	13.4 ± 10.7 (n = 1157)	11.5 ± 10.9 (n = 1250)§
With sternal dehiscence, d‡	14.8 ± 17.1 (n = 34)	15.7 ± 7.1 (n = 17)	24.8 ± 15.7 (n = 4)§
OCD, n	5/34	2/17	1/4
Hospital stay for patients with OCD, d	91, 26, 52, 26, 24	35, 32	31
Sternum resection, n	1	1	1
Plastic surgery (pectoralis flap), n	2	2	1

**S aureus* indicates *Staphylococcus aureus*; *A viridans*, *Aerococcus viridans*; *P aeruginosa*, *Pseudomonas aeruginosa*; *S epidermidis*, *Staphylococcus epidermidis*; *P acnes*, *Propionibacterium acnes*; *S hemolyticus*, *Staphylococcus hemolyticus*; cn staph, coagulase-negative staphylococcus; IMA, internal mammary artery; OCD, debridement of open chest wound.

†χ^2 according to Pearson, 26.4; $P < .001$.

‡Data are presented as the mean ± SD.

§Student *t* test: $t = 2.4$; $P = .015$.

eases and risk factors. Only chronic obstructive pulmonary disease was found to be significantly more frequent in the 2000 and 2001 patient groups than in the 1999 patient group. The following risk factors for sternal dehiscence and wound infection were considered: chronic lung diseases and severe obesity (body mass index >30) because of increased mechanical stress, osteoporosis of the sternum because of decreased stability of the bone, and bilateral pedicled IMAs and diabetes because of the increased ischemic risk to the sternal area (Tables 2 and 5).

Our experience shows that a stable closure after median sternotomy plays the crucial role in the avoidance of sternal dehiscence and osteomyelitis. Especially in patients with specific risk factors, the commonly used sternal osteosynthesis with wire cerclages may not result in adequate stability in the sternal area. The use of a steel band in the third intercostal space in addition to the common sternal closure with 8 wire cerclages increases the stability of the sternal osteosynthesis in our clinical experience. The increased size of the steel band (6 times wider than the customary wire cerclages) results in force being distributed more evenly throughout the bone, resulting in a higher stability of the area and promoting faster wound healing. The adaptation of the sternum by means of the tensioning device is infinitely variable; thus, optimal adaptation of the sternum is achieved. The technique is simple to perform, and the steel band can be removed without problems in cases of early or late reoperation. In our study, the incidence of sternal dehiscence decreased significantly from 2.9% in 1999 to 0.3% in 2001 in correlation with the increasing number of times a steel band was used (1999, n = 0; 2001, n = 438) in patients at risk for sternal dehiscence (Table 4). Moreover, the wound infection rate decreased from 0.9% in 1999 to 0.2% in 2001. However, this decrease did not reach statistical significance.

The numbers of sternal wound infections in patients with bilateral IMA grafts are shown in Table 4. In all of these patients, IMA preparation was performed with the pedicle technique and not with a skeletonized technique that we perform today in all of our coronary artery bypass grafting patients.

Table 5. Risk Factors in Patients with Sternum Dehiscence and/or Osteomyelitis after Cardiac Surgery via a Full Sternotomy*

Group	A	B	C
Year of operation	1999 (n = 34)	2000 (n = 17)	2001 (n = 4)
COPD, n	13 (38.2%)	4 (23.5%)	1 (25%)
Diabetes mellitus, n	12 (35.3%)	7 (41.2%)	2 (50%)
Obesity (BMI >30), n	10 (29.4%)	6 (35.3%)	1 (25%)
Overweight (BMI >25), n	26 (81.8%)	12 (72%)	2 (50%)

*COPD indicates chronic obstructive pulmonary disease; BMI, body mass index.

© 2004 Forum Multimedia Publishing, LLC

The length of hospital stay for patients with sternal dehiscence was longer for all 3 groups than for the patients without sternal dehiscence. However, this prolongation in hospital stay was statistically significant only for the 2001 patient group. A limitation of this result is the small number of patients.

A long hospital stay was observed for patients who underwent debridement of the open chest wound (Table 4). Because of the small number of these patients, there was only a minor effect on the mean hospital stay of all of the patients.

Table 5 demonstrates that the risk factors for sternal dehiscence, such as chronic obstructive pulmonary disease, diabetes, and obesity, are more frequently found in patients with sternal dehiscence and/or osteomyelitis.

CONCLUSION

Our data suggest that a steel band used in addition to the standard osteosynthesis with 8 wire cerclages is a safe and effective procedure that significantly decreases the rate of sternum dehiscence and infection. This technique helps to avoid an extended hospital stay, discomfort for the patient, and the necessity of plastic surgery and thereby helps to reduce their substantial costs to the health care system.

ACKNOWLEDGMENTS

We thank Christine Bardong for statistical analysis and Petra Schlizio for her skillful secretarial assistance.

REFERENCES

Baskett RJ, MacDougall CE, Ross DB. 1999. Is mediastinitis a preventable complication? A 10-year review. Ann Thorac Surg 67:462-5.

Breyer RH, Mills SA, Hudspeth AS, Johnston FR, Cordell AR. 1984. A prospective study of sternal wound complications. Ann Thorac Surg 37:412-6.

Culliford AT, Cunningham JN Jr, Zeff RH, Isom OW, Teiko P, Spencer FC. 1976. Sternal and costochondral infections following open-heart surgery: a review of 2,594 cases. J Thorac Cardiovasc Surg 72:714-26.

Dajani AS, Taubert KA, Wilson W, et al. 1997. Prevention of bacterial endocarditis: recommendations by the American Heart Association. JAMA 277:1794-801.

Engelman RM, Williams CD, Gouge TH, et al. 1973. Mediastinitis following open-heart surgery: review of two years' experience. Arch Surg 107:772-8.

Ferrazzi P, Allen R, Crupi G, Reyes I, Parenzan L, Maisonnet M. 1986. Reduction of infection after cardiac surgery: a clinical trial. Ann Thorac Surg 42:321-5.

Firor WB. 1967. Infection following open-heart surgery, with special reference to the role of prophylactic antibiotics. J Thorac Cardiovasc Surg 53:371-8.

Graber P, Zimmerli W. 1999. Antibiotikaprophylaxe in der Chirurgie. Schweiz Arzteztg 80:2921-6.

Gummert JF, Barten MJ, Hans C, et al. 2002. Mediastinitis and cardiac surgery: an updated risk factor analysis in 10,373 consecutive adult patients. Thorac Cardiovasc Surg 50:87-91.

Jacob HG, Borneff-Lipp M, Bach A, et al. 2000. The endogenous pathway is a major route for deep sternal wound infection. Eur J Cardiothorac Surg 17:154-60.

Johnston RH Jr, Garcia-Rinaldi R, Vaughan GD 3rd, Bricker D. 1985. Mersilene ribbon closure of the median sternotomy: an improvement over wire closure. Ann Thorac Surg 39:88-9.

Kouchoukos NT, Wareing TH, Murphy SF, Pelate C, Marshall WG. 1990. Risk of bilateral internal mammary artery bypass grafting. Ann Thorac Surg 49:210-7.

Labitzke R, Schramm G, Witzel U, Quisthout P. 1983. "Sleeve-rope closure" of the median sternotomy after open heart operations. Thorac Cardiovasc Surg 31:127-8.

Losanoff JE, Jones JW, Richman BW. 2002. Primary closure of median sternotomy: techniques and principles. Cardiovasc Surg 10:102-10.

Myerowitz PD, Caswell K, Lindsay WG, Nicoloff DM. 1977. Antibiotic prophylaxis for open-heart surgery. J Thorac Cardiovasc Surg 73:625-9.

Nagachinta T, Stephens M, Reitz B, Polk BF. 1987. Risk factors for surgical wound infections following cardiac surgery. J Infect Dis 156:967-73.

Noyez L, Verkroost MW, van Asten WN, Kaan GL, Lacquet LK. 1993. Sternal closure: comparison of two techniques. Cardiovasc Surg 1:643-5.

Panknin HT, Schwemmle K. 2000. Antibiotika in der operativen Medizin. Medizin im Dialog 1:1-4.

Roux D, Fournial G, Glock Y, Nottin R. 1995. New technique for sternal osteosynthesis. Ann Thorac Surg 60:1132.

Simon C, Stille W. 2000. Antibiotika-Therapie in Klinik und Praxis. 10th ed. Stuttgart, Germany: Schattauer Verlag.

Tavilla G, van Son JA, Verhagen AF, Lacquet LK. 1991. Modified Robicsek technique for complicated sternal closure. Ann Thorac Surg 52:1179-80.

Wilson APR, Livesey SA, Treasure T, Gruneberg RN, Sturridge MF. 1987. Factors predisposing to wound infection in cardiac surgery: a prospective study of 517 patients. Eur J Cardiothorac Surg 1:158-64.

Wong ES. 1999. Surgical site infections. In: Mayhall CG, editor. Hospital epidemiology and infection control. 2nd ed. Philadelphia, Pa: Lippincott Williams & Wilkins. p 189-210.

Zurbrugg HR, Freestone T, Bauer M, Hetzer R. 2000. Reinforcing the conventional sternal closure. Ann Thorac Surg 69:1957-8.