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EDITORIAL

Deep sternal wound infection after cardiac surgery: Evidences and controversies

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Abstract

Despite many advances in prevention and perioperative care, deep sternal wound infection (DSWI) remains a pressing concern in cardiac surgery, with a still relevant incidence and with a considerable impact on in-hospital mortality and also on mid- and long-term survival. The permanent high impact of this complication is partially related to the increasing proportion of patients at high-risk for infection, as well as to the many patient and surgical risk factors involved in the pathogenesis of DSWI. The prophylactic antibiotic therapy is one of the most important tools in the prevention of DSWI. However, the choice of antibiotic, the dose, the duration, the adequate levels in serum and tissue, and the timing of antimicrobial prophylaxis are still controversial. The treatment of DSWI ranges from surgical revision with primary closure to surgical revision with open dressings or closed irrigation, from reconstruction with soft tissue flaps to negative pressure wound therapy (NPWT). However, to date, there have been no accepted recommendations regarding the best management of DSWI. Emerging evidence in the literature has validated the efficacy and safety of NPWT either as a single-line therapy, or as a "bridge" prior to final surgical closure. In conclusion, the careful control of patient and surgical risk factors - when possible, the proper antimicrobial prophylaxis, and the choice of validated techniques of treatment could contribute to keep DSWIs at a minimal rate.

Key words: Risk factors; Sternotomy; Wound healing; Wound infection; Postoperative care

Core tip: Intensivists and cardiothoracic surgeons are commonly worried about surgical site infections due to increasing length of stay, costs, and mortality. In particular, deep sternal wound infection (DSWI) is a worrying complication after cardiac surgery, with a still relevant incidence. Unfortunately, DWSI appearance is related to a wide number of both patient and surgical factors. This review may be useful for guiding physicians to the knowledge of main risk factors and the choice of the appropriate management of DWSIs with the aim of reducing the rate of this potentially devastating complication in cardiac surgery patients.

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INTRODUCTION

Deep sternal wound infection (DSWI) is one of the most complex and potentially devastating complications following median sternotomy in cardiac surgery with a significant impact on both patient prognosis and hospital budgets[1-5]. Despite many advances in prevention, it still remains significant and ranges between 0.5% and 6.8%[6-10], with in-hospital mortality rates between 7% and 35%[2,3,7,9,11-13]. Moreover, mid- and long-term survival is significantly reduced in patients that have experienced DSWI. By the end of the first year, Filsoufi *et al*[6] found a 15% absolute survival difference between patients without DSWI and those who had developed this complication. In a 10-year follow-up study after coronary artery bypass grafting, the adjusted survival rate was 39% for patients who developed DSWI compared with 70% in patients who did not[14]. Excess costs arise primarily owing to additional antibiotic treatments and surgical procedures, as well as increased hospital length of stay[13,15].

The management of DSWI has progressed through long-lasting clinical experience. Commonly adopted strategies of treatment include surgical revision with primary closure, surgical revision with open dressings or closed irrigation, reconstruction with soft tissue flaps, and application of negative pressure wound therapy (NPWT)[16-18]. However, at the moment, there has been no general consensus regarding the appropriate management of DSWI.

DEFINITION

According to Centers for Disease Control and Prevention (CDC) guidelines, the definition of a DSWI requires positive culture results of surgical sites or drainage from the mediastinal area or evidence of infection during surgical re-exploration or fever, sternal instability, and positive blood culture results[19].

RISK FACTORS

Patient and surgical factors contribute to the risk of DSWI after cardiothoracic surgery. Patient factors include age[20-22], female sex[20,22,23], obesity[2,4,20,21,24-28], diabetes mellitus or hyperglycemia during the perioperative period[2,20,21,24,26-29], smoking tobacco[2,4,28-30], recent treatment with antibiotics[31], *Staphylococcus aureus* nasal carriage[32,33], skin infection anywhere on the body[31], chronic obstructive pulmonary disease[25,27], heart failure[2,34], kidney dysfunction[27,34], peripheral vascular disease[2,26], and emergent or urgent surgery[28,35].

The reason for the increased risk of DSWI in obese patients can be related to the poor perfusion of subcutaneous adipose layers with low levels of prophylactic antibiotics in this tissue. Gummert *et al*[24] found a 1.5-times increased adjusted risk of DSWI after cardiac surgery in patients with body mass index > 30 kg/m^2. Filsoufi *et al*[6] reported that obesity was associated with a more than 2-fold increased risk of DSWI.

Convincing evidence has emerged that the control of blood glucose levels during surgery and the immediate postoperative period with frequent monitoring and protocols for continuous intravenous administration insulin can decrease DSWI rate[36,37]. Researchers at the Mayo Clinic concluded that a 20 mg/dL (1.11 mmol/L) increase in the mean intraoperative blood glucose level correlated with an increase of more than 30% in adverse outcomes[38]. A large prospective study of diabetic patients undergoing cardiac surgery demonstrated that hyperglycemia was an independent risk factor for death, length of hospital stay, and infection rates, and found that a continuous insulin infusion reduced these risks[39].

Smoking tobacco can impair the tissue microcirculation and increase the risk of DSWI. Møller *et al*[40] showed that preoperative cessation of smoking 6-8 wk prior to operation significantly reduced the infection rate in a prospective randomized trial in orthopedic prosthesis surgery. Actually, the CDC guidelines recommend smoking cessation at least 30 d prior to surgery[19].

The patient's carriage of *Staphylococcus aureus* on skin and nares has been identified as an important risk factor for DSWI[32,33]. The Society of Thoracic Surgeons practice guidelines upon antimicrobial prophylaxis recommend routine 5-d mupirocin 2% nasal administration for all patients undergoing cardiac surgery in the absence of a documented negative testing for staphylococcal colonization[41]. However, concerns still remain about the extensive use of mupirocin because of lack of efficacy, risk of widespread high-level resistance, and costs[42-44]. A systematic review of the literature and meta-analysis by Kallen *et al*[45] demonstrated a 45% reduction in surgical site infections (SSIs) caused by *Staphylococcus aureus* with the use of preoperative mupirocin among cardiac surgery patients known to be colonized with *Staphylococcus aureus*. Of note, the only prospective, randomized, and double-blinded trial of mupirocin in cardiac surgery patients did not show benefit: No patients with poststernotomy mediastinitis caused by methicillin-resistant *Staphylococcus aureus* (MRSA) had identical isolates in preoperative and surgical-site cultures[46].

Surgical risk factors include prolonged duration of aortic cross clamp, cardiopulmonary bypass perfusion or overall surgery[22,26], use of internal mammary artery (IMA) grafts-especially bilaterally-[2,24,25,27,30], inadvertent paramedian sternotomy[47], use of bone wax, extensive use of electrocauterization[27], surgical procedures requiring prosthesis implant, use of intra-aortic balloon pump or ventricular assist device[23,27], postoperative bleeding[10], blood transfusions, re-exploration for bleeding[6,23,24,48,49], re-operation, postoperative respiratory failure with prolonged mechanical ventilation[2,6], and prolonged stay in intensive care unit (ICU)[4,24,26].

Controversial opinions still remain on the IMA harvest technique. The skeletonization harvest technique is already known to severely reduce the incidence of DSWI - particularly in diabetic and obese patients - because of the better preservation of collateral sternal blood flow and internal thoracic veins[50]. However, many cardiothoracic surgeons are reluctant to application this technique as it can easily lead to graft conduit damage[51]. Evidences also suggest the need for dosing adjustment following IMA harvesting as this significantly diminishes antibiotic penetration into the presternal tissue[52].

Level of concern has varied regarding to the risk of DSWI due to use of bone wax. Animal studies showed an increased risk of *Staphylococcus aureus* infections[53]; however, a prospective, randomized trial of 400 patients found no detrimental effects[54].

Finally, adherence to basic principles of care contributes to reduce the risk of DSWI. These mainly include reduced preoperative hospital stay, increased perioperative oxygenation, preoperative showering using antiseptic solution, hair removal over the operating site using scissors or a depilatory cream instead of shaving, and scrubbing of the operation site with a proper antiseptic solution and letting it dry[6,19,31,55]. Chlorhexidine-, alcohol- or povidone-iodine-based solutions can be used; indeed, the CDC guidelines do not recommend one antiseptic solution over the others[19].

PATHOGENS

Recent reports focused on a growing number of DSWIs caused by methicillin-resistant Gram-positive pathogens[56]. *Staphylococcus epidermidis* is one of the most common agents in poststernotomy mediastinitis when foreign materials such as prosthetic heart valve are implanted; moreover, approximately 75% of the *Staphylococcus epidermidis* strains are methicillin-resistant[57]. The other major pathogen in poststernotomy mediastinitis is *Staphylococcus aureus*. The latter microorganism has been increasingly associated with colonization of the patients' nares. National Nosocomial Infections Surveillance System reports that the rate of MRSA has risen from 30% in 1989 to 60% in 2005 in ICU patients with nosocomial infections and MRSA was the causative microorganism in a third of the patients with DSWI[58].

ANTIMICROBIAL PROPHYLAXIS

The advantages of proper antimicrobial prophylaxis in patients undergoing cardiac surgery have been clearly demonstrated[19,59,60]. However, the choice of antibiotic, the dose, the duration, the adequate levels in serum and tissue, and the timing of antimicrobial prophylaxis are still controversial[11,41,61].

The Society of Thoracic Surgeons Practice Guidelines on antimicrobial prophylaxis in cardiac surgery recommended that a cephalosporin should be given within 60 min from the skin incision and be continued for 24-72 h[41,61]. First generation (cefazolin), second generation (cefamandole and cefuroxime), and third generation (cefotaxime) cephalosporins have been shown to be effective in reducing SSIs in cardiac surgery; however, the superiority of one class over another has not been proven[62-64].

The frequent identification of MRSA as the cause of DSWI has brought the attention on vancomycin as the prophylactic drug of choice[10]. Engelman *et al*[41] stated that vancomycin is reserved mainly for patients with a history of type Ⅰ allergic reaction to β-lactam agents or in the setting of the institutional presence of a "high incidence" of MRSA (class ⅡB recommendation, level of evidence C). Vancomycin should be given with any of the following doses: 1000 mg, 1500 mg, or 15 mg/kg over 1 h, with completion within 1 h of the skin incision[41]. The reason for the 1-h infusion is related to the risk of histamine-release phenomenon characterized by extensive erythematous rash that involves the upper chest and face ("red man syndrome") that can be triggered by a rapid infusion of vancomycin[41,61]. Moreover, studies in the literature showed that the incidence of infection is decreased when the preoperative dose is administered within 1 h before surgical incision[11,65]. Regarding the duration, postoperative prophylactic antibiotics are given for 48 h or less (class ⅡA recommendation, level of evidence B)[61].

A meta-analysis comparing cephalosporins with glycopeptides as antimicrobial prophylaxis regimens found a higher frequency of postoperative SSIs and a trend toward an increased risk of Gram-positive SSI in the glycopeptide group but a lower frequency of SSIs caused by resistant gram-positive pathogens[66].

The relationship between timing of prophylactic antimicrobial administration and risk of infection is an additional field of debate. The 2011 American College of Cardiology/American Heart Association guidelines for cardiac surgery recommend that "Antibiotic prophylaxis should be initiated 30 to 60 min before surgery"[9]. Key studies have demonstrated that antimicrobial prophylaxis administered too late or too early reduces the efficacy of the antimicrobial prophylaxis and increases the risk of infection[10,11,65,67]; conversely, other reports do not clearly demonstrated the superiority of the 1-h window[68-70].

Ideally, short courses of antimicrobial prophylaxis are preferred over longer courses to reduce costs, drug toxicity, infection with *Clostridium difficile*, and the appearance of resistant pathogens[11,19,61,65,71]. However, the use of cardiopulmonary bypass, the hypothermia, the length of operation, the high mortality and costs of DSWI suggest to prolonging the antimicrobial prophylaxis in cardiac surgery. A 2011 systematic review and meta-analysis of the literature significantly favored longer-term antimicrobial prophylaxis of more than 24 h in these patients[72]. Similarly, Lador *et al*[73] showed that shorter duration of prophylaxis (⩽ 24 h) was associated with a higher rate of DSWI, surgical intervention for any kind of SSI, and endocarditis; whereas, no difference between 48 h *vs* longer durations was found for all outcomes.

There is absolutely no data for continuing antimicrobial prophylaxis until chest drains are removed[61]. Some studies highlighted the importance of weight-based antibiotic dosing in obese patients and the need for repeated doses during prolonged procedures (more than two half-lives of the drug) or in case of excessive blood loss during the procedure[11,74]. Other investigators reported that a cefazolin bolus followed by continuous infusion improved pharmacokinetic and pharmacodynamic values, including concentrations in the cardiac muscle[75].

MANAGEMENT

Debridement with primary closure has been the treatment of choice for a long time and, until now, it can be considered for infection localized to a small part of the sternum with little or no purulent drainage. Debridement is usually associated with the advancement of the pectoralis muscles and can be done in a single phase procedure or in a delayed closure with multiple open dressing changes followed by sternal re-wiring[17,76-78]. The latter treatment allows improved accuracy in assessing the extent of the sternal infection and reduces the risk of recurrent infection but carries on major disadvantages: Thoracic instability, prolonged immobilization, and mechanical ventilation with increased risk of complications such as thrombosis, muscular weakness, and pneumonia[17,76-79]. Concerns still remain about the need for obtaining negative cultures at the time of closure. Two recent studies found that the presence of positive tissue cultures did not affect the rate of recurrent infections[80,81].

An important step forward in the treatment of DSWI occurred with the introduction of continuous irrigation using closed chest catheter following revision. Further developments were achieved with antibiotic irrigation but several studies have reported high rates of failure and mortality[82-84].

The unsatisfactory results of these different approaches increased interest in plastic procedures as alternative treatments[6,79,84]. Bilateral pectoralis muscle flaps, as either advancement or turnover flaps, are the most usual plastic procedures in the dealing of DSWI[16,85]. This surgical management has a quite low mortality rate but carries a series of disadvantages, including additional surgical trauma and late flap-related morbidity such as muscular weakness, pain, and hernias[86]. An alternative plastic procedure to pectoralis muscle flaps is the use of omentum that promotes significant angiogenesis, immunologic function, and antimicrobial activity supporting tissue-generation promotion with great capacity to occupy dead space[6,87,88]. Usually, the use of omentum is considered in the case of complex wounds or when the defect is extremely wide with significant sternal loss. Specifically, a definite preference has been expressed for the use of omentum when the primary causative pathogen is particularly resistant, such as MRSA[80,89] and Candida[90] or when the patients suffering from diabetes mellitus[91].

However, complications occurred in up to 18% of patients treated with this approach[16,92].

Several recent studies, meta-analyses, and systematic reviews have validated the efficacy of NPWT in DSWI either as a single-line therapy, or as a "bridge" prior to final surgical closure[93-97]. This wound-healing technique is based on the application of continuous or intermittent negative pressure to a wound, which results in arteriolar dilatation and, subsequently, determines wound perfusion and granulation tissue proliferation[57,85,93]. *In vitro* and clinical studies designed to determine the effect of NPWT lent convincing evidence of efficacy and safety in term of decrease of edema, exudation, and microbial colonization as well as reduction of inflammatory cytokine release[57,85,98-100].

In case of diagnosis of DSWI, an early application of NPWT was associated to a faster healing and an increased likelihood of survival[18,97,101,102]. Moreover, several studies demonstrated shorter treatment duration and length of hospital stay, as well as lower costs in patients treated with NPWT[96,98,100,103]. NPWT was also successfully applied in the case of MRSA mediastinitis and as a temporizing treatment prior to secondary closure in mediastinitis due to Candida[90,104,105].

Conversely, other authors suggested that prolonged application of NPWT can result in chronic infection due to a shift in bacterial species and to an increased growth of some of them, such as *Staphylococcus aureus*[99,106]. Different studies have focused on factors that can predict failure of NPWT. Gdalevitch *et al*[107] found that positive blood cultures, wound depth of ⩾ 4 cm, and high degree of bony exposure and sternal instability are significant predictors of NPWT failure. Pericleous *et al*[108] highlighted also the importance of lung emphysema, corticosteroids, and advanced age. Finally, Gustafsson *et al*[109] stressed bacteremia or elevated plasma C-reactive protein levels as the most sensitive predictors of failure.

The positive effects of NPWT on complicated surgical wounds have triggered the interest in using NPWT also after closure of clean and sutured wounds to prevent SSIs in patients at high risk of developing DSWI[110]. The surgical incision management system (Prevena™ Incision Management System, Kinetic Concepts Inc., San Antonio, TX, United States) consists of a single-use NPWT that delivers negative pressure of 75-125 mmHg (10-16.7

KPa); this system holds the incision edges together, reduces lateral tension and edema, stimulates perfusion, and protects the surgical site from external infectious sources[110]. Grauhan *et al*[111] showed significant reduction of SSIs in obese patients (body mass index > 30 kg/m^2) with median sternotomy compared with patients treated with standard wound dressings. In general, retrospective studies and randomized controlled trials provided a substantial body of evidence that the use of this prophylactic wound dressing technique may reduce the incidence of wound infections[112-114].

CONCLUSION

Despite several progresses in prevention and perioperative care, DSWI is still a permanent concern in cardiac surgery because of its significant rate and relevant impact on length of hospital stay, costs, and mortality. The incidence of this complication is in part due to the increased number of patients at high-risk for infection because of advanced age and rate of relevant comorbidities in the population undergoing cardiac surgery. A rigorous attention to the details of preoperative, intraoperative, and postoperative management could contribute to keep DSWIs at a minimal rate.

REFERENCES

1 **Wang FD**, Chang CH. Risk factors of deep sternal wound infections in coronary artery bypass graft surgery. *J Cardiovasc Surg* (Torino) 2000; **41**: 709-713 [PMID: 11149637]

2 **Ridderstolpe L**, Gill H, Granfeldt H, Ahlfeldt H, Rutberg H. Superficial and deep sternal wound complications: incidence, risk factors and mortality. *Eur J Cardiothorac Surg* 2001; **20**: 1168-1175 [PMID: 11717023 DOI: 10.1016/S1010-7940(01)00991-5]

3 **Lu JC**, Grayson AD, Jha P, Srinivasan AK, Fabri BM. Risk factors for sternal wound infection and mid-term survival following coronary artery bypass surgery. *Eur J Cardiothorac Surg* 2003; **23**: 943-949 [PMID: 12829070 DOI: 10.1016/S1010-7940(03)00137-4]

4 **Abboud CS**, Wey SB, Baltar VT. Risk factors for mediastinitis after cardiac surgery. *Ann Thorac Surg* 2004; **77**: 676-683 [PMID: 14759458 DOI: 10.1016/S0003-4975(03)01523-6]

5 **Salehi Omran A**, Karimi A, Ahmadi SH, Davoodi S, Marzban M, Movahedi N, Abbasi K, Boroumand MA, Davoodi S, Moshtaghi N. Superficial and deep sternal wound infection after more than 9000 coronary artery bypass graft (CABG): incidence, risk factors and mortality. *BMC Infect Dis* 2007; **7**: 112 [PMID: 17888179 DOI: 10.1186/1471-2334-7-112]

6 **Filsoufi F**, Castillo JG, Rahmanian PB, Broumand SR, Silvay G, Carpentier A, Adams DH. Epidemiology of deep sternal wound infection in cardiac surgery. *J Cardiothorac Vasc Anesth* 2009; **23**: 488-494 [PMID: 19376733 DOI: 10.1053/j.jvca.2009.02.007]

7 **Kanafani ZA**, Arduino JM, Muhlbaier LH, Kaye KS, Allen KB, Carmeli Y, Corey GR, Cosgrove SE, Fraser TG, Harris AD, Karchmer AW, Lautenbach E, Rupp ME, Peterson ED, Straus WL, Fowler VG. Incidence of and preoperative risk factors for Staphylococcus aureus bacteremia and chest wound infection after cardiac surgery. *Infect Control Hosp Epidemiol* 2009; **30**: 242-248 [PMID: 19199534 DOI: 10.1086/596015]

8 **Tom TS**, Kruse MW, Reichman RT. Update: Methicillin-resistant Staphylococcus aureus screening and decolonization in cardiac surgery. *Ann Thorac Surg* 2009; **88**: 695-702 [PMID: 19632455 DOI: 10.1016/j.athoracsur.2009.02.010]

9 **Hillis LD**, Smith PK, Anderson JL, Bittl JA, Bridges CR, Byrne JG, Cigarroa JE, Disesa VJ, Hiratzka LF, Hutter AM, Jessen ME, Keeley EC, Lahey SJ, Lange RA, London MJ, Mack MJ, Patel MR, Puskas JD, Sabik JF, Selnes O, Shahian DM, Trost JC, Winniford MD. 2011 ACCF/AHA Guideline for Coronary Artery Bypass Graft Surgery. A report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. Developed in collaboration with the American Association for Thoracic Surgery, Society of Cardiovascular Anesthesiologists, and Society of Thoracic Surgeons. *J Am Coll Cardiol* 2011; **58**: e123-e210 [PMID: 22070836 DOI: 10.1016/j.jacc.2011.08.009]

10 **Bryan CS**, Yarbrough WM. Preventing deep wound infection after coronary artery bypass grafting: a review. *Tex Heart Inst J* 2013; **40**: 125-139 [PMID: 23678210]

11 **Bratzler DW**, Hunt DR. The surgical infection prevention and surgical care improvement projects: national initiatives to improve outcomes for patients having surgery. *Clin Infect Dis* 2006; **43**: 322-330 [PMID: 16804848 DOI: 10.1086/505220]

12 **Karra R**, McDermott L, Connelly S, Smith P, Sexton DJ, Kaye KS. Risk factors for 1-year mortality after postoperative mediastinitis. *J Thorac Cardiovasc Surg* 2006; **132**: 537-543 [PMID: 16935107 DOI: 10.1016/j.jtcvs.2006.04.037]

13 **Graf K**, Ott E, Vonberg RP, Kuehn C, Haverich A, Chaberny IF. Economic aspects of deep sternal wound infections. *Eur J Cardiothorac Surg* 2010; **37**: 893-896 [PMID: 19896860 DOI: 10.1016/j.ejcts.2009.10.005]

14 **Braxton JH**, Marrin CA, McGrath PD, Morton JR, Norotsky M, Charlesworth DC, Lahey SJ, Clough R, Ross CS, Olmstead EM, O'Connor GT. 10-year follow-up of patients with and without mediastinitis. *Semin Thorac Cardiovasc Surg* 2004; **16**: 70-76 [PMID: 15366690]

15 **Ennker IC**, Kojcici B, Ennker J, Vogt P, Melichercik J. [Examination of the opportunity costs and turnover situation in patients with deep sternal infections]. *Zentralbl Chir* 2012; **137**: 257-261 [PMID: 22194084 DOI: 10.1055/s-0031-1283762]

16 **van Wingerden JJ**, Lapid O, Boonstra PW, de Mol BA. Muscle flaps or omental flap in the management of deep sternal wound infection. *Interact Cardiovasc Thorac Surg* 2011; **13**: 179-187 [PMID: 21543366 DOI: 10.1510/icvts.2011.270652]

17 **Izaddoost S**, Withers EH. Sternal reconstruction with omental and pectoralis flaps: a review of 415 consecutive cases. *Ann Plast Surg* 2012; **69**: 296-300 [PMID: 22214791 DOI: 10.1097/SAP.0b013e31822af843]

18 **Steingrimsson S**, Gottfredsson M, Gudmundsdottir I, Sjögren J, Gudbjartsson T. Negative-pressure wound therapy for deep sternal wound infections reduces the rate of surgical interventions for early re-infections. *Interact Cardiovasc Thorac Surg* 2012; **15**: 406-410 [PMID: 22691377 DOI: 10.1093/icvts/ivs254]

19 **Mangram AJ**, Horan TC, Pearson ML, Silver LC, Jarvis WR. Guideline for Prevention of Surgical Site Infection, 1999. Centers for Disease Control and Prevention (CDC) Hospital Infection Control Practices Advisory Committee. *Am J Infect Control* 1999; **27**: 97-132; quiz 133-134; discussion 96 [PMID: 10196487 DOI: 10.1016/S0196-6553(99)70088-X]

20 **Dodds Ashley ES**, Carroll DN, Engemann JJ, Harris AD, Fowler VG, Sexton DJ, Kaye KS. Risk factors for postoperative mediastinitis due to methicillin-resistant Staphylococcus aureus. *Clin Infect Dis* 2004; **38**: 1555-1560 [PMID: 15156442 DOI: 10.1086/420819]

21 **Harrington G**, Russo P, Spelman D, Borrell S, Watson K, Barr W, Martin R, Edmonds D, Cocks J, Greenbough J, Lowe J, Randle L, Castell J, Browne E, Bellis K, Aberline M. Surgical-site infection rates and risk factor analysis in coronary artery bypass graft surgery. *Infect Control Hosp Epidemiol* 2004; **25**: 472-476 [PMID: 15242194]

22 **Berríos-Torres SI**, Mu Y, Edwards JR, Horan TC, Fridkin SK. Improved risk adjustment in public reporting: coronary artery bypass graft surgical site infections. *Infect Control Hosp Epidemiol* 2012; **33**: 463-469 [PMID: 22476272 DOI: 10.1086/665313]

23 **Lepelletier D**, Perron S, Bizouarn P, Caillon J, Drugeon H, Michaud JL, Duveau D. Surgical-site infection after cardiac surgery: incidence, microbiology, and risk factors. *Infect Control*

Hosp Epidemiol 2005; **26**: 466-472 [PMID: 15954485]
24 **Gummert JF**, Barten MJ, Hans C, Kluge M, Doll N, Walther T, Hentschel B, Schmitt DV, Mohr FW, Diegeler A. Mediastinitis and cardiac surgery--an updated risk factor analysis in 10,373 consecutive adult patients. *Thorac Cardiovasc Surg* 2002; **50**: 87-91 [PMID: 11981708 DOI: 10.1055/s-2002-26691]
25 **Diez C**, Koch D, Kuss O, Silber RE, Friedrich I, Boergermann J. Risk factors for mediastinitis after cardiac surgery - a retrospective analysis of 1700 patients. *J Cardiothorac Surg* 2007; **2**: 23 [PMID: 17511885 DOI: 10.1186/1749-8090-2-23]
26 **Fakih MG**, Sharma M, Khatib R, Berriel-Cass D, Meisner S, Harrington S, Saravolatz L. Increase in the rate of sternal surgical site infection after coronary artery bypass graft: a marker of higher severity of illness. *Infect Control Hosp Epidemiol* 2007; **28**: 655-660 [PMID: 17520536]
27 **Robinson PJ**, Billah B, Leder K, Reid CM; ASCTS Database Committee. Factors associated with deep sternal wound infection and haemorrhage following cardiac surgery in Victoria. *Interact Cardiovasc Thorac Surg* 2007; **6**: 167-171 [PMID: 17669800 DOI: 10.1510/icvts.2006.143479]
28 **Cayci C**, Russo M, Cheema FH, Martens T, Ozcan V, Argenziano M, Oz MC, Ascherman J. Risk analysis of deep sternal wound infections and their impact on long-term survival: a propensity analysis. *Ann Plast Surg* 2008; **61**: 294-301 [PMID: 18724131 DOI: 10.1097/SAP.0b013e31815acb6a]
29 **Risnes I**, Abdelnoor M, Almdahl SM, Svennevig JL. Mediastinitis after coronary artery bypass grafting risk factors and long-term survival. *Ann Thorac Surg* 2010; **89**: 1502-1509 [PMID: 20417768 DOI: 10.1016/j.athoracsur.2010.02.038]
30 **Ogawa S**, Okawa Y, Sawada K, Goto Y, Yamamoto M, Koyama Y, Baba H, Suzuki T. Continuous postoperative insulin infusion reduces deep sternal wound infection in patients with diabetes undergoing coronary artery bypass grafting using bilateral internal mammary artery grafts: a propensity-matched analysis. *Eur J Cardiothorac Surg* 2015; Epub ahead of print [PMID: 25825261 DOI: 10.1093/ejcts/ezv106]
31 **Gårdlund B**. Postoperative surgical site infections in cardiac surgery--an overview of preventive measures. *APMIS* 2007; **115**: 989-995 [PMID: 17931235 DOI: 10.1111/j.1600-0463.2007.00845.x]
32 **von Eiff C**, Becker K, Machka K, Stammer H, Peters G. Nasal carriage as a source of Staphylococcus aureus bacteremia. Study Group. *N Engl J Med* 2001; **344**: 11-16 [PMID: 11136954 DOI: 10.1056/NEJM200101043440102]
33 **Walsh EE**, Greene L, Kirshner R. Sustained reduction in methicillin-resistant Staphylococcus aureus wound infections after cardiothoracic surgery. *Arch Intern Med* 2011; **171**: 68-73 [PMID: 20837818 DOI: 10.1001/archinternmed.2010.326]
34 **Zhang L**, Garcia JM, Hill PC, Haile E, Light JA, Corso PJ. Cardiac surgery in renal transplant recipients: experience from Washington Hospital Center. *Ann Thorac Surg* 2006; **81**: 1379-1384 [PMID: 16564276 DOI: 10.1016/j.athoracsur.2005.10.045]
35 **Sakamoto H**, Fukuda I, Oosaka M, Nakata H. Risk factors and treatment of deep sternal wound infection after cardiac operation. *Ann Thorac Cardiovasc Surg* 2003; **9**: 226-232 [PMID: 13129420]
36 **Kramer R**, Groom R, Weldner D, Gallant P, Heyl B, Knapp R, Arnold A. Glycemic control and reduction of deep sternal wound infection rates: a multidisciplinary approach. *Arch Surg* 2008; **143**: 451-456 [PMID: 18490552 DOI: 10.1001/archsurg.143.5.451]
37 **Rogers SO**, Zinner MJ. The role of perioperative hyperglycemia in postoperative infections. *Adv Surg* 2009; **43**: 103-109 [PMID: 19845172]
38 **Gandhi GY**, Nuttall GA, Abel MD, Mullany CJ, Schaff HV, Williams BA, Schrader LM, Rizza RA, McMahon MM. Intraoperative hyperglycemia and perioperative outcomes in cardiac surgery patients. *Mayo Clin Proc* 2005; **80**: 862-866 [PMID: 16007890 DOI: 10.4065/80.7.862]
39 **Brown JR**, Edwards FH, O'Connor GT, Ross CS, Furnary AP. The diabetic disadvantage: historical outcomes measures in diabetic patients undergoing cardiac surgery -- the pre-intravenous insulin era. *Semin Thorac Cardiovasc Surg* 2006; **18**: 281-288 [PMID: 17395023 DOI: 10.1053/j.semtcvs.2006.04.004]
40 **Møller AM**, Villebro N, Pedersen T, Tønnesen H. Effect of preoperative smoking intervention on postoperative complications: a randomised clinical trial. *Lancet* 2002; **359**: 114-117 [PMID: 11809253 DOI: 10.1016/S0140-6736(02)07369-5]
41 **Engelman R**, Shahian D, Shemin R, Guy TS, Bratzler D, Edwards F, Jacobs M, Fernando H, Bridges C; Workforce on Evidence-Based Medicine, Society of Thoracic Surgeons. The Society of Thoracic Surgeons practice guideline series: Antibiotic prophylaxis in cardiac surgery, part II: Antibiotic choice. *Ann Thorac Surg* 2007; **83**: 1569-1576 [PMID: 17383396 DOI: 10.1016/j.athoracsur.2006.09.046]
42 **Reiss S**, Pané-Farré J, Fuchs S, François P, Liebeke M, Schrenzel J, Lindequist U, Lalk M, Wolz C, Hecker M, Engelmann S. Global analysis of the Staphylococcus aureus response to mupirocin. *Antimicrob Agents Chemother* 2012; **56**: 787-804 [PMID: 22106209 DOI: 10.1128/AAC.05363-11]
43 **Seah C**, Alexander DC, Louie L, Simor A, Low DE, Longtin J, Melano RG. MupB, a new high-level mupirocin resistance mechanism in Staphylococcus aureus. *Antimicrob Agents Chemother* 2012; **56**: 1916-1920 [PMID: 22252810 DOI: 10.1128/AAC.05325-11]
44 **Tenover FC**, Tickler IA, Goering RV, Kreiswirth BN, Mediavilla JR, Persing DH; MRSA Consortium. Characterization of nasal and blood culture isolates of methicillin-resistant Staphylococcus aureus from patients in United States Hospitals. *Antimicrob Agents Chemother* 2012; **56**: 1324-1330 [PMID: 22155818 DOI: 10.1128/AAC.05804-11]
45 **Kallen AJ**, Wilson CT, Larson RJ. Perioperative intranasal mupirocin for the prevention of surgical-site infections: systematic review of the literature and meta-analysis. *Infect Control Hosp Epidemiol* 2005; **26**: 916-922 [PMID: 16417031 DOI: 10.1086/505453]
46 **Harbarth S**, Huttner B, Gervaz P, Fankhauser C, Chraiti MN, Schrenzel J, Licker M, Pittet D. Risk factors for methicillin-resistant Staphylococcus aureus surgical site infection. *Infect Control Hosp Epidemiol* 2008; **29**: 890-893 [PMID: 18785849 DOI: 10.1086/590193]
47 **Zeitani J**, Penta de Peppo A, Moscarelli M, Guerrieri Wolf L, Scafuri A, Nardi P, Nanni F, Di Marzio E, De Vico P, Chiariello L. Influence of sternal size and inadvertent paramedian sternotomy on stability of the closure site: a clinical and mechanical study. *J Thorac Cardiovasc Surg* 2006; **132**: 38-42 [PMID: 16798300 DOI: 10.1016/j.jtcvs.2006.03.015]
48 **Sreeram GM**, Welsby IJ, Sharma AD, Phillips-Bute B, Smith PK, Slaughter TF. Infectious complications after cardiac surgery: lack of association with fresh frozen plasma or platelet transfusions. *J Cardiothorac Vasc Anesth* 2005; **19**: 430-434 [PMID: 16085245 DOI: 10.1053/j.jvca.2005.05.001]
49 **Banbury MK**, Brizzio ME, Rajeswaran J, Lytle BW, Blackstone EH. Transfusion increases the risk of postoperative infection after cardiovascular surgery. *J Am Coll Surg* 2006; **202**: 131-138 [PMID: 16377506 DOI: 10.1016/j.jamcollsurg.2005.08.028]
50 **Peterson MD**, Borger MA, Rao V, Peniston CM, Feindel CM. Skeletonization of bilateral internal thoracic artery grafts lowers the risk of sternal infection in patients with diabetes. *J Thorac Cardiovasc Surg* 2003; **126**: 1314-1319 [PMID: 14666001 DOI: 10.1016/S0022-5223(03)00808-0]
51 **Saso S**, James D, Vecht JA, Kidher E, Kokotsakis J, Malinovski V, Rao C, Darzi A, Anderson JR, Athanasiou T. Effect of skeletonization of the internal thoracic artery for coronary revascularization on the incidence of sternal wound infection. *Ann Thorac Surg* 2010; **89**: 661-670 [PMID: 20103378 DOI: 10.1016/j.athoracsur.2009.08.018]
52 **Andreas M**, Zeitlinger M, Hoeferl M, Jaeger W, Zimpfer D, Hiesmayr JM, Laufer G, Hutschala D. Internal mammary artery harvesting influences antibiotic penetration into presternal tissue. *Ann Thorac Surg* 2013; **95**: 1323-1329; discussion 1329-1330 [PMID: 23462262 DOI: 10.1016/j.athoracsur.2012.10.088]
53 **Bhatti F**, Dunning J. Does liberal use of bone wax increase the risk

of mediastinitis? *Interact Cardiovasc Thorac Surg* 2003; **2**: 410-412 [PMID: 17670085 DOI: 10.1016/S1569-9293(03)00180-4]
54 **Prziborowski J**, Hartrumpf M, Stock UA, Kuehnel RU, Albes JM. Is bonewax safe and does it help? *Ann Thorac Surg* 2008; **85**: 1002-1006 [PMID: 18291188 DOI: 10.1016/j.athoracsur.2007.10.036]
55 **Anderson DJ**, Kaye KS, Classen D, Arias KM, Podgorny K, Burstin H, Calfee DP, Coffin SE, Dubberke ER, Fraser V, Gerding DN, Griffin FA, Gross P, Klompas M, Lo E, Marschall J, Mermel LA, Nicolle L, Pegues DA, Perl TM, Saint S, Salgado CD, Weinstein RA, Wise R, Yokoe DS. Strategies to prevent surgical site infections in acute care hospitals. *Infect Control Hosp Epidemiol* 2008; **29** Suppl 1: S51-S61 [PMID: 18840089 DOI: 10.1086/591064]
56 **Hidron AI**, Edwards JR, Patel J, Horan TC, Sievert DM, Pollock DA, Fridkin SK; National Healthcare Safety Network Team; Participating National Healthcare Safety Network Facilities. NHSN annual update: antimicrobial-resistant pathogens associated with healthcare-associated infections: annual summary of data reported to the National Healthcare Safety Network at the Centers for Disease Control and Prevention, 2006-2007. *Infect Control Hosp Epidemiol* 2008; **29**: 996-1011 [PMID: 18947320 DOI: 10.1086/591861]
57 **Sjögren J**, Malmsjö M, Gustafsson R, Ingemansson R. Poststernotomy mediastinitis: a review of conventional surgical treatments, vacuum-assisted closure therapy and presentation of the Lund University Hospital mediastinitis algorithm. *Eur J Cardiothorac Surg* 2006; **30**: 898-905 [PMID: 17056269 DOI: 10.1016/j.ejcts.2006.09.020]
58 **National Nosocomial Infections Surveillance System**. National Nosocomial Infections Surveillance (NNIS) System Report, data summary from January 1992 through June 2004, issued October 2004. *Am J Infect Control* 2004; **32**: 470-485 [PMID: 15573054 DOI: 10.1016/j.ajic.2004.10.001]
59 **Kreter B**, Woods M. Antibiotic prophylaxis for cardiothoracic operations. Meta-analysis of thirty years of clinical trials. *J Thorac Cardiovasc Surg* 1992; **104**: 590-599 [PMID: 1387437]
60 **Spellberg B**, Blaser M, Guidos RJ, Boucher HW, Bradley JS, Eisenstein BI, Gerding D, Lynfield R, Reller LB, Rex J, Schwartz D, Septimus E, Tenover FC, Gilbert DN. Combating antimicrobial resistance: policy recommendations to save lives. *Clin Infect Dis* 2011; **52** Suppl 5: S397-S428 [PMID: 21474585 DOI: 10.1093/cid/cir153]
61 **Edwards FH**, Engelman RM, Houck P, Shahian DM, Bridges CR. The Society of Thoracic Surgeons Practice Guideline Series: Antibiotic Prophylaxis in Cardiac Surgery, Part I: Duration. *Ann Thorac Surg* 2006; **81**: 397-404 [PMID: 16368422 DOI: 10.1016/j.athoracsur.2005.06.034]
62 **Curtis JJ**, Boley TM, Walls JT, Hamory B, Schmaltz RA. Randomized, prospective comparison of first- and second-generation cephalosporins as infection prophylaxis for cardiac surgery. *Am J Surg* 1993; **166**: 734-737 [PMID: 8273859]
63 **Galbraith U**, Schilling J, von Segesser LK, Carrel T, Turina M, Geroulanos S. Antibiotic prophylaxis in cardiovascular surgery: a prospective randomized comparative trial of one day cefazolin versus single dose cefuroxime. *Drugs Exp Clin Res* 1993; **19**: 229-234 [PMID: 8174496]
64 **Townsend TR**, Reitz BA, Bilker WB, Bartlett JG. Clinical trial of cefamandole, cefazolin, and cefuroxime for antibiotic prophylaxis in cardiac operations. *J Thorac Cardiovasc Surg* 1993; **106**: 664-670 [PMID: 8412261]
65 **Cotogni P**, Passera R, Barbero C, Gariboldi A, Moscato D, Izzo G, Rinaldi M. Intraoperative vancomycin pharmacokinetics in cardiac surgery with or without cardiopulmonary bypass. *Ann Pharmacother* 2013; **47**: 455-463 [PMID: 23512663 DOI: 10.1345/aph.1R669]
66 **Bolon MK**, Morlote M, Weber SG, Koplan B, Carmeli Y, Wright SB. Glycopeptides are no more effective than beta-lactam agents for prevention of surgical site infection after cardiac surgery: a meta-analysis. *Clin Infect Dis* 2004; **38**: 1357-1363 [PMID: 15156470 DOI: 10.1086/383318]
67 **Classen DC**, Evans RS, Pestotnik SL, Horn SD, Menlove RL, Burke JP. The timing of prophylactic administration of antibiotics and the risk of surgical-wound infection. *N Engl J Med* 1992; **326**: 281-286 [PMID: 1728731 DOI: 10.1056/NEJM199201303260501]
68 **Weber WP**, Marti WR, Zwahlen M, Misteli H, Rosenthal R, Reck S, Fueglistaler P, Bolli M, Trampuz A, Oertli D, Widmer AF. The timing of surgical antimicrobial prophylaxis. *Ann Surg* 2008; **247**: 918-926 [PMID: 18520217 DOI: 10.1097/SLA.0b013e31816c3fec]
69 **Steinberg JP**, Braun BI, Hellinger WC, Kusek L, Bozikis MR, Bush AJ, Dellinger EP, Burke JP, Simmons B, Kritchevsky SB; Trial to Reduce Antimicrobial Prophylaxis Errors (TRAPE) Study Group. Timing of antimicrobial prophylaxis and the risk of surgical site infections: results from the Trial to Reduce Antimicrobial Prophylaxis Errors. *Ann Surg* 2009; **250**: 10-16 [PMID: 19561486 DOI: 10.1097/SLA.0b013e3181ad5fca]
70 **Hawn MT**, Richman JS, Vick CC, Deierhoi RJ, Graham LA, Henderson WG, Itani KM. Timing of surgical antibiotic prophylaxis and the risk of surgical site infection. *JAMA Surg* 2013; **148**: 649-657 [PMID: 23552769 DOI: 10.1001/jamasurg.2013.134]
71 **Bratzler DW**, Houck PM. Antimicrobial prophylaxis for surgery: an advisory statement from the National Surgical Infection Prevention Project. *Clin Infect Dis* 2004; **38**: 1706-1715 [PMID: 15227616 DOI: 10.1086/421095]
72 **Mertz D**, Johnstone J, Loeb M. Does duration of perioperative antibiotic prophylaxis matter in cardiac surgery? A systematic review and meta-analysis. *Ann Surg* 2011; **254**: 48-54 [PMID: 21412147 DOI: 10.1097/SLA.0b013e318214b7e4]
73 **Lador A**, Nasir H, Mansur N, Sharoni E, Biderman P, Leibovici L, Paul M. Antibiotic prophylaxis in cardiac surgery: systematic review and meta-analysis. *J Antimicrob Chemother* 2012; **67**: 541-550 [PMID: 22083832 DOI: 10.1093/jac/dkr470]
74 **Caffarelli AD**, Holden JP, Baron EJ, Lemmens HJ, D'Souza H, Yau V, Olcott C, Reitz BA, Miller DC, van der Starre PJ. Plasma cefazolin levels during cardiovascular surgery: effects of cardiopulmonary bypass and profound hypothermic circulatory arrest. *J Thorac Cardiovasc Surg* 2006; **131**: 1338-1343 [PMID: 16733167 DOI: 10.1016/j.jtcvs.2005.11.047]
75 **Adembri C**, Ristori R, Chelazzi C, Arrigucci S, Cassetta MI, De Gaudio AR, Novelli A. Cefazolin bolus and continuous administration for elective cardiac surgery: improved pharmacokinetic and pharmacodynamic parameters. *J Thorac Cardiovasc Surg* 2010; **140**: 471-475 [PMID: 20570290 DOI: 10.1016/j.jtcvs.2010.03.038]
76 **Schroeyers P**, Wellens F, Degrieck I, De Geest R, Van Praet F, Vermeulen Y, Vanermen H. Aggressive primary treatment for poststernotomy acute mediastinitis: our experience with omental- and muscle flaps surgery. *Eur J Cardiothorac Surg* 2001; **20**: 743-746 [PMID: 11574218 DOI: 10.1016/S1010-7940(01)00873-9]
77 **Fleck TM**, Koller R, Giovanoli P, Moidl R, Czerny M, Fleck M, Wolner E, Grabenwoger M. Primary or delayed closure for the treatment of poststernotomy wound infections? *Ann Plast Surg* 2004; **52**: 310-314 [PMID: 15156988]
78 **Wong CH**, Senewiratne S, Garlick B, Mullany D. Two-stage management of sternal wound infection using bilateral pectoralis major advancement flap. *Eur J Cardiothorac Surg* 2006; **30**: 148-152 [PMID: 16725333 DOI: 10.1016/j.ejcts.2006.03.049]
79 **Jones G**, Jurkiewicz MJ, Bostwick J, Wood R, Bried JT, Culbertson J, Howell R, Eaves F, Carlson G, Nahai F. Management of the infected median sternotomy wound with muscle flaps. The Emory 20-year experience. *Ann Surg* 1997; **225**: 766-776; discussion 776-778 [PMID: 9230817]
80 **Danner BC**, Zenker D, Didilis VN, Grossmann M, Stojanovic T, Seipelt R, Tirilomis T, Schöndube FA. Transposition of greater omentum in deep sternal wound infection caused by methicillin-resistant Staphylococci, with differing clinical course for MRSA and MRSE. *Thorac Cardiovasc Surg* 2011; **59**: 21-24 [PMID: 21243567 DOI: 10.1055/s-0030-1250373]
81 **Rodriguez Cetina Biefer H**, Sündermann SH, Emmert MY, Rancic Z, Salzberg SP, Grünenfelder J, Falk V, Plass AR. Negative microbiological results are not mandatory in deep sternal wound

infections before wound closure. *Eur J Cardiothorac Surg* 2012; **42**: 306-310; discussion 310 [PMID: 22290924 DOI: 10.1093/ejcts/ezr326]

82 **Calvat S**, Trouillet JL, Nataf P, Vuagnat A, Chastre J, Gibert C. Closed drainage using Redon catheters for local treatment of poststernotomy mediastinitis. *Ann Thorac Surg* 1996; **61**: 195-201 [PMID: 8561552 DOI: 10.1016/0003-4975(95)00921-3]

83 **Rand RP**, Cochran RP, Aziz S, Hofer BO, Allen MD, Verrier ED, Kunzelman KS. Prospective trial of catheter irrigation and muscle flaps for sternal wound infection. *Ann Thorac Surg* 1998; **65**: 1046-1049 [PMID: 9564925 DOI: 10.1016/S0003-4975(98)00087-3]

84 **Catarino PA**, Chamberlain MH, Wright NC, Black E, Campbell K, Robson D, Pillai RG. High-pressure suction drainage via a polyurethane foam in the management of poststernotomy mediastinitis. *Ann Thorac Surg* 2000; **70**: 1891-1895 [PMID: 11156090 DOI: 10.1016/S0003-4975(00)02173-1]

85 **Ennker IC**, Pietrowski D, Vöhringer L, Kojcici B, Albert A, Vogt PM, Ennker J. Surgical debridement, vacuum therapy and pectoralis plasty in poststernotomy mediastinitis. *J Plast Reconstr Aesthet Surg* 2009; **62**: 1479-1483 [PMID: 18996074 DOI: 10.1016/j.bjps.2008.05.017]

86 **Pairolero PC**, Arnold PG, Harris JB. Long-term results of pectoralis major muscle transposition for infected sternotomy wounds. *Ann Surg* 1991; **213**: 583-589; discussion 589-590 [PMID: 2039289 DOI: 10.1097/00000658-199106000-00008]

87 **De Brabandere K**, Jacobs-Tulleneers-Thevissen D, Czapla J, La Meir M, Delvaux G, Wellens F. Negative-pressure wound therapy and laparoscopic omentoplasty for deep sternal wound infections after median sternotomy. *Tex Heart Inst J* 2012; **39**: 367-371 [PMID: 22719146]

88 **Vyas RM**, Prsic A, Orgill DP. Transdiaphragmatic omental harvest: a simple, efficient method for sternal wound coverage. *Plast Reconstr Surg* 2013; **131**: 544-552 [PMID: 23142938 DOI: 10.1097/PRS.0b013e31827c6e2e]

89 **Hirata N**, Hatsuoka S, Amemiya A, Ueno T, Kosakai Y. New strategy for treatment of MRSA mediastinitis: one-stage procedure for omental transposition and closed irrigation. *Ann Thorac Surg* 2003; **76**: 2104-2106 [PMID: 14667661 DOI: 10.1016/S0003-4975(03)00744-6]

90 **Osada H**, Nakajima H, Morishima M, Su T. Candidal mediastinitis successfully treated using vacuum-assisted closure following open-heart surgery. *Interact Cardiovasc Thorac Surg* 2012; **14**: 872-874 [PMID: 22422875 DOI: 10.1093/icvts/ivs084]

91 **Stump A**, Bedri M, Goldberg NH, Slezak S, Silverman RP. Omental transposition flap for sternal wound reconstruction in diabetic patients. *Ann Plast Surg* 2010; **65**: 206-210 [PMID: 20606588 DOI: 10.1097/SAP.0b013e3181c9c31a]

92 **Schols RM**, Lauwers TM, Geskes GG, van der Hulst RR. Deep sternal wound infection after open heart surgery: current treatment insights. A retrospective study of 36 cases. *Eur J Plast Surg* 2011; **34**: 487-492 [PMID: 22162911 DOI: 10.1007/s00238-011-0573-2]

93 **Fleck TM**, Fleck M, Moidl R, Czerny M, Koller R, Giovanoli P, Hiesmayer MJ, Zimpfer D, Wolner E, Grabenwoger M. The vacuum-assisted closure system for the treatment of deep sternal wound infections after cardiac surgery. *Ann Thorac Surg* 2002; **74**: 1596-1600; discussion 1600 [PMID: 12440614]

94 **Immer FF**, Durrer M, Mühlemann KS, Erni D, Gahl B, Carrel TP. Deep sternal wound infection after cardiac surgery: modality of treatment and outcome. *Ann Thorac Surg* 2005; **80**: 957-961 [PMID: 16122463 DOI: 10.1016/j.athoracsur.2005.03.035]

95 **Raja SG**, Berg GA. Should vacuum-assisted closure therapy be routinely used for management of deep sternal wound infection after cardiac surgery? *Interact Cardiovasc Thorac Surg* 2007; **6**: 523-527 [PMID: 17669926 DOI: 10.1510/icvts.2007.157370]

96 **Damiani G**, Pinnarelli L, Sommella L, Tocco MP, Marvulli M, Magrini P, Ricciardi W. Vacuum-assisted closure therapy for patients with infected sternal wounds: a meta-analysis of current evidence. *J Plast Reconstr Aesthet Surg* 2011; **64**: 1119-1123 [PMID: 21256819 DOI: 10.1016/j.bjps.2010.11.022]

97 **Falagas ME**, Tansarli GS, Kapaskelis A, Vardakas KZ. Impact of vacuum-assisted closure (VAC) therapy on clinical outcomes of patients with sternal wound infections: a meta-analysis of non-randomized studies. *PLoS One* 2013; **8**: e64741 [PMID: 23741379 DOI: 10.1371/journal.pone.0064741]

98 **Fuchs U**, Zittermann A, Stuettgen B, Groening A, Minami K, Koerfer R. Clinical outcome of patients with deep sternal wound infection managed by vacuum-assisted closure compared to conventional therapy with open packing: a retrospective analysis. *Ann Thorac Surg* 2005; **79**: 526-531 [PMID: 15680828 DOI: 10.1016/j.athoracsur.2004.08.032]

99 **Bapat V**, El-Muttardi N, Young C, Venn G, Roxburgh J. Experience with Vacuum-assisted closure of sternal wound infections following cardiac surgery and evaluation of chronic complications associated with its use. *J Card Surg* 2008; **23**: 227-233 [PMID: 18435637 DOI: 10.1111/j.1540-8191.2008.00595.x]

100 **Vos RJ**, Yilmaz A, Sonker U, Kelder JC, Kloppenburg GT. Vacuum-assisted closure of post-sternotomy mediastinitis as compared to open packing. *Interact Cardiovasc Thorac Surg* 2012; **14**: 17-21 [PMID: 22108946 DOI: 10.1093/icvts/ivr049]

101 **Petzina R**, Hoffmann J, Navasardyan A, Malmsjö M, Stamm C, Unbehaun A, Hetzer R. Negative pressure wound therapy for post-sternotomy mediastinitis reduces mortality rate and sternal re-infection rate compared to conventional treatment. *Eur J Cardiothorac Surg* 2010; **38**: 110-113 [PMID: 20171898 DOI: 10.1016/j.ejcts.2010.01.028]

102 **Assmann A**, Boeken U, Feindt P, Schurr P, Akhyari P, Lichtenberg A. Vacuum-assisted wound closure is superior to primary rewiring in patients with deep sternal wound infection. *Thorac Cardiovasc Surg* 2011; **59**: 25-29 [PMID: 21243568 DOI: 10.1055/s-0030-1250598]

103 **Yu AW**, Rippel RA, Smock E, Jarral OA. In patients with post-sternotomy mediastinitis is vacuum-assisted closure superior to conventional therapy? *Interact Cardiovasc Thorac Surg* 2013; **17**: 861-865 [PMID: 23912622 DOI: 10.1093/icvts/ivt326]

104 **Modrau IS**, Ejlertsen T, Rasmussen BS. Emerging role of Candida in deep sternal wound infection. *Ann Thorac Surg* 2009; **88**: 1905-1909 [PMID: 19932259 DOI: 10.1016/j.athoracsur.2009.08.012]

105 **Morisaki A**, Hosono M, Sasaki Y, Hirai H, Sakaguchi M, Nakahira A, Seo H, Suehiro S, Shibata T. Evaluation of risk factors for hospital mortality and current treatment for poststernotomy mediastinitis. *Gen Thorac Cardiovasc Surg* 2011; **59**: 261-267 [PMID: 21484552 DOI: 10.1007/s11748-010-0727-3]

106 **Gaudreau G**, Costache V, Houde C, Cloutier D, Montalin L, Voisine P, Baillot R. Recurrent sternal infection following treatment with negative pressure wound therapy and titanium transverse plate fixation. *Eur J Cardiothorac Surg* 2010; **37**: 888-892 [PMID: 19775906 DOI: 10.1016/j.ejcts.2009.07.043]

107 **Gdalevitch P**, Afilalo J, Lee C. Predictors of vacuum-assisted closure failure of sternotomy wounds. *J Plast Reconstr Aesthet Surg* 2010; **63**: 180-183 [PMID: 19028156 DOI: 10.1016/j.bjps.2008.08.020]

108 **Pericleous A**, Dimitrakakis G, Photiades R, von Oppell UO. Assessment of vacuum-assisted closure therapy on the wound healing process in cardiac surgery. *Int Wound J* 2015; Epub ahead of print [PMID: 25728664 DOI: 10.1111/iwj.12430]

109 **Gustafsson R**, Johnsson P, Algotsson L, Blomquist S, Ingemansson R. Vacuum-assisted closure therapy guided by C-reactive protein level in patients with deep sternal wound infection. *J Thorac Cardiovasc Surg* 2002; **123**: 895-900 [PMID: 12019374 DOI: 10.1067/mtc.2002.121306]

110 **Dohmen PM**, Misfeld M, Borger MA, Mohr FW. Closed incision management with negative pressure wound therapy. *Expert Rev Med Devices* 2014; **11**: 395-402 [PMID: 24754343 DOI: 10.1586/17434440.2014.911081]

111 **Grauhan O**, Navasardyan A, Hofmann M, Müller P, Stein J, Hetzer R. Prevention of poststernotomy wound infections in obese patients by negative pressure wound therapy. *J Thorac Cardiovasc Surg* 2013; **145**: 1387-1392 [PMID: 23111014 DOI: 10.1016/j.jtcvs.2012.09.040]

112 **Atkins BZ**, Wooten MK, Kistler J, Hurley K, Hughes GC, Wolfe WG. Does negative pressure wound therapy have a role in preventing poststernotomy wound complications? *Surg Innov* 2009; **16**: 140-146 [PMID: 19460818 DOI: 10.1177/1553350609334821]
113 **Colli A**, Camara ML. First experience with a new negative pressure incision management system on surgical incisions after cardiac surgery in high risk patients. *J Cardiothorac Surg* 2011; **6**: 160 [PMID: 22145641 DOI: 10.1186/1749-8090-6-160]
114 **Grauhan O**, Navasardyan A, Tutkun B, Hennig F, Müller P, Hummel M, Hetzer R. Effect of surgical incision management on wound infections in a poststernotomy patient population. *Int Wound J* 2014; **11** Suppl 1: 6-9 [PMID: 24851729 DOI: 10.1111/iwj.12294]

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