Raymund E. Horch · Christian Willy
Ingo Kutschka *Eds.*

# Deep Sternal Wound Infections

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# Preface

Despite recent innovations in smaller incision and less invasive approaches to the heart, the median sternotomy still remains, by far, the most commonly used approach. This incision provides excellent anatomic access to all areas of the heart surface, intra-cardiac structures and the great vessels. The median sternotomy is also an incision that heals very well in most patients and with minimum morbidity.

While the future may see fewer open surgical valve repairs or replacements, and particularly in the aortic position, several large recent Trials (SYNTAX, EXCEL, NOBLE) have confirmed the superiority of CABG over stents for most patients with coronary artery disease and certainly those with more severe disease. However, this population also increasingly contains a higher proportion of patients whose co-morbidities, such as diabetes and obesity, may predispose to potentially major sternal wound problems. This is particularly so with the use of two internal mammary arteries which may offer patients, particularly those with Diabetes, better long term outcomes than a single mammary artery but at the cost of increased sternal wound healing problems. While advances in wound management have reduced the previously high mortality associated with sternal dehiscence, major wound complications can still lead to other important clinical problems and prolonged hospital stay, with their very expensive adverse economic sequelae.

The authors should therefore be congratulated on the content and timeliness of this current text book. It comprehensively covers all aspects of sternal wound management from pathophysiology and predispositions to diagnoses and treatment of complications. It reviews the latest invasions and technologies that may potentially reduce, or indeed prevent, sternotomy wound complications. The book makes ideal reading for all who are involved in the care of such patients.

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# Definition, Classification, and Epidemiology of Sternal Osteomyelitis

*Patrick Zardo and Ingo Kutschka*



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## 1.1 Definition

First coined by renowned French surgeon Auguste Nélaton in 1844 (Lima et al. 2014), the term »osteomyelitis« generally describes an infectious condition of the entire bone, although it is derived from the Greek words »ostéon« for bone, »myelós« for marrow, and »itis« for inflammation. Notwithstanding the technicality of »osteitis« being a more appropriate term from an etymological standpoint, osteomyelitis has established itself as a finite medical term to describe deep wound infections involving the bone and its surrounding tissue. In this book we will focus on locoregional infections of the sternum, a narrow flat bone that serves as a keystone of the rib cage and stabilizes the entire chest wall.

## 1.2 Classification

Osteomyelitis is a highly heterogeneous disease with a wide array of possible clinical presentations, symptoms, and treatment strategies. Owing to its complexity, more than ten classification systems were proposed over the past 40 years, none of which has been universally adopted. From a historical perspective, much is owed to a seminal *NEJM* publication by Waldvogel and colleagues in 1970 (Waldvogel et al. 1970), in which he classified the disease based on pathophysiological and chronological considerations. He distinguished between (a) acute forms with edema, pus formation, vascular congestion, and thrombosis of the small vessels and (b) a chronic onset with recurrence of formerly acute inflammation, large areas of ischemia, necrosis, and bone sequester. Additionally, a pathophysiological and etiological distinction was msade between hematogenous, contiguous, and vascular insufficiency-associated types. Hematogenous forms were related to seeding from a distant infective focus and most often found in children; contiguous types were either the result of direct inoculation (posttraumatic and postsurgical) or continuous spread from an adjacent infected site. Vascular insufficiency disease classically occurs in patients with diabetes or other forms of peripheral vascular disease.

In the 1980s Cierny and Mader were the first to propose a more holistic approach by taking clinical characteristics of afflicted patients into account (Cierny et al. 1985) (Tab. 1.1). Their primary aim was to allocate patients to either amputation or limb-salvage surgery based on the clinical performance status. By stratifying patients according to their comorbidity, matched treatment options could be formulated, thus helping to choose »low-risk treatment forms for high-risk patients.« Major drawbacks of this classification were a mainly subjective evaluation of a patient's intrinsic ability to deal with infection and a lack of clear-cut, objective criteria to classify someone as a »C host« deemed unsuitable for surgery.

Romanò and coworkers recently proposed an amalgamation of different classifications – including both aforementioned systems by Waldvogel and Cierny and Mader – into a single bone and joint infections classification, dubbed the »7-Item Comprehensive Classification System (7-ICCS)« (Romanò et al. 2011). Despite being useful for strictly descriptive purposes, the classification is complex and offers no guidance in selecting treatment modalities, a feature unfortunately found in most other classification systems as well. Thus the authors conclude that »the proposed system is intended for di-

**Tab. 1.1** Cierny and Mader classification of osteomyelitis (modified from Cierny et al. 1985)

| | |
|---|---|
| Anatomical type | |
| Medullary | Restricted to marrow |
| Superficial | Restricted to cortical bone |
| Localized | Clearly defined margins and preserved bone stability |
| Diffuse | Diffuse with bony instability before or after debridement |
| Host class | |
| A. Healthy | No to little comorbidity |
| B (L). Locally impaired | Chronic lymphedema, venous stasis, postradiogenic fibrosis etc. |
| B (S). Systemically impaired | Diabetes, malnutrition, chronic hypoxemia etc. |
| C. Poor clinical performance status | Treatment potentially worse than disease |

dactic and scientific purposes and may be potentially used to better compare patients and clinical series« (Romanò et al. 2011), which clearly limits its usefulness.

Most publications dealing with DSWI utilize a classification first proposed by El Oakley et al. which basically equates it to mediastinitis and differentiates between 5 types:

- Type I:
  Mediastinitis occuring during the first 2 postoperative weeks without patient-related risk factors
- Type II:
  Mediastinitis occuring 2–6 weeks after surgery
- Type IIIa:
  Type I with one or more patient-related risk factors
- Type IIIb:
  Type II with one ore more risk factors
- Type IVa:
  Type I–III after failed intervention
- Type IVb:
  Type I–III after more than one failed intervention
- Type V:
  Mediastinitis after more than 6 weeks post surgery

Sir Francis Robiszek proposes a different classification of sterno-mediastinitis and adds therapeutic considerations to each type:

- Type I: 3–5 days after surgery. Non-purulent secretions and lack of osteitis Either no bacterial contamination of the wound or detection of staphylococci. Treatment consists in redo-surgery, chest tube placement and Robiszek-Rewiring (if necessary).
- Type II: 1–3 weeks after sternotomy with massive symptoms. Redo -procedures are based around radical debridement with removal of all infected bone, cartilage and soft-tissue fragments. Muscle -flaps are encouraged. The incisional site is left open and will only be closed secondarily.
- Type III: 1 month–1year after sternotomy with chronic secretions and osteitis. Requires thorough debridement, sternal resection and muscle -flaps.

For practical purposes, we mainly differentiate between primary and secondary forms of sternal osteomyelitis (SO) with acute, subacute or chronic onset. While primary forms are exceptionally rare in children (Upadhyaya et al. 2005) and occur only when an underlying predisposition, such as immunodeficiency, iv drug abuse or acne fulminans is present in adults (Boll and Jurik 1990), secondary forms are common after cardiac surgery. Timing-wise acute forms are diagnosed within 2 weeks after onset, subacute forms within one to several months and chronic forms after several months (Lew and Waldvogel 2004, Carek et al. 2001). While acute osteomyelitis occurs predominantly in children and is rare (incidence 8/100.000 children/year in developed countries, (Peltola and Pääkkönen 2014)), subacute and chronic forms tend to manifest themselves mostly after surgical procedures in adults and are far more common. Postoperative infections can be further stratified according to the amount of time transpired after surgery. Early manifestation is generally defined as onset of infection within the first 4–12 weeks post-surgery, delayed within 3 months and 2 years after an operation and late manifestation is encountered 2 years after a procedure (Lew and Waldvogel 2004).

## 1.3 Epidemiology and Economic Considerations

Median sternotomy was first introduced in 1897 by Milton to access and excise tuberculous mediastinal lymph nodes and became the standard approach in cardiac surgery after being propagated by Julien since the late 1950s (Dalton et al. 1992). Postsurgical SO, a sequela of median sternotomy, is still a deleterious complication after open heart surgery and associated with mortality rates between 15 and 40% (Cobo et al. 1996; Lucet 2006). According to numerous studies, the incidence of SO varies between 0.5 and 3.6% (Abboud et al. 2004; Graf et al. 2010; Wang and Chang 2000) and correlates with patient or procedure-related risk factors.

Established independent risk factors for development of SO include diabetes, obesity, prior myocardial infarction, chronic obstructive pulmonary

disease, and aortic calcification as well as combined valve/coronary artery bypass graft (CABG) procedures, aortic surgery, cardiopulmonary bypass time, re-exploration for bleeding, and respiratory failure (Filsoufi et al. 2009).

Large observational studies underline the importance of diabetes as a risk factor for SO and mediastinitis (Filsoufi et al. 2009; Gummert et al. 2002), with other authors even demonstrating a positive correlation between hyperglycemia (>200 mg/dl) during the first 2 days after surgery and an increased incidence of deep wound infection (Furnary et al. 1999). Today the importance of perioperative blood glucose management has been largely recognized (Shine et al. 2007), even though intensive insulin therapy during cardiac surgery does not appear to reduce perioperative morbidity or mortality and may be associated with an increased risk for death and stroke (Gandhi et al. 2007). At this point there are no clear-cut guidelines for glycemic control during and after cardiac surgery (Haga et al. 2011).

Obesity negatively affects wound healing and is a risk factor for developing SO (Abboud et al. 2004; Filsoufi et al. 2009; Gummert et al. 2002). Patients with a body mass index (BMI) greater than 30 kg/m$^2$ have a 1.5- (Gummert et al. 2002) to twofold (Filsoufi et al. 2009) increased adjusted risk for deep sternal wound infection. Whether this is due to technical difficulties in operating on obese patients, prolonged operative time, or poor bioavailability of antibiotics in adipose tissue remains unclear (Filsoufi et al. 2009). Cardiopulmonary bypass (CPB) leads to hypoperfusion of adipose tissue, which in turn may predispose obese patients to subsequent infection (Filsoufi et al. 2009). Interestingly, a so-called obesity paradox exists, which refers to counterintuitive epidemiological evidence suggesting improved health outcomes for obese individuals in a variety of clinical situations (Adams et al. 2006). Johnson and coworkers described this in patients undergoing cardiac surgery, with overweight (BMI 25.0–29.9 kg/m$^2$) and moderately obese (BMI 30.0–34.9 kg/m$^2$) patients having improved outcomes following CABG and CABG/aortic valve replacement compared with patients with normal BMI (Johnson et al. 2015). Morbidly obese and underweight patients had significantly worse clinical outcomes.

Patients undergoing complex (combined CABG/ valve replacement, CABG/aortic operation) and/or long (>150 min CPB time) procedures have a significantly higher risk of developing deep sternal wound infection than those having standard CABG (Filsoufi et al. 2009; Kubota et al. 2013). The adjusted relative risk for postoperative SO rises from 1.9 to 2.4 (CABG vs. CABG/valve replacement) and correlates with procedure length (> 150 min; Filsoufi et al. 2009; Kubota et al. 2013). Additionally, patients who undergo complex and/or lengthy procedures are at risk for postoperative bleeding and consecutive re-exploration, which constitutes a further risk for deep sternal wound infection (Abboud et al. 2004; Filsoufi et al. 2009; Gummert et al. 2002).

Therapy for SO is complex, expensive, and often tedious. Afflicted patients require long hospital stays, antibiotic regimes, and repeated surgery. The length of stay for CABG patients increases from 16 to 34 days when infection occurs, and mortality can become as high as 40% (Cobo et al. 1996; Lucet 2006). Beside the aforementioned deleterious clinical implications, postoperative infection has economic ramifications as well: Overall costs rise from € 13,000 to € 36,000 (Graf et al. 2010) with healthcare insurance companies reimbursing € 27,000/CABG on average (Graf et al. 2011).

Although this book deals mainly with therapeutic options for deep sternal wound infections, prevention is always preferable to treatment. Coordinated efforts to minimize postoperative infections are mandatory to increase the safety of our patients and reduce intrahospital costs.

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