Postoperative Sternal Complications

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39.1 Introduction

The *median sternotomy*, developed at the end of the nineteenth century, is currently employed for access to the heart in >90 % of all procedures in cardiac surgery. It is technically simple to perform and offers an excellent view *of* all structures relevant to the cardiac surgeon for any procedure. The sternal closure as the final step in a trans-sternal cardiac surgical procedure is technically *straightforward* and usually well tolerated by the patient. However, with the increasing number of *elderly and more complex* patients *undergoing cardiac surgery*, sternal complications may pose *greater* challenges to cardiac and plastic surgeons in greater numbers than ever before.

In the literature, the overall incidence of sternal complications after cardiac surgery is reported to be between 0.2 and 10 %; however, clear-cut definitions of a sternal complication are lacking. In Germany the reported range is smaller *at* 1–4 %. There is a large spectrum from mild to life-threatening complications ending in septic circulatory shock. Comprehensive classifications of septic sternal complications have been suggested by El Oakley and Wright (1996; ◘ Table 39.1) as well as from the US Centers for Disease Control and Prevention (CDC; Mangram et al. 1999), but these are rarely applied *clinically*. Commonly, a more or less detailed description of sternal instability and infection is given; usually, soft tissue damage, involvement of the bone structure, and the mediastinum are analyzed, as well as *sepsis* may be reported.

◘ **Table 39.1** Classification of the mediastinitis after surgery with a heart-lung machine according to El Oakley and Wright (1996)

Type	Finding
I	Mediastinitis presenting within 2 weeks after the operation in the absence of risk factors
II	Mediastinitis presenting at 2–6 weeks after the operation in the absence of risk factors
IIIA	Mediastinitis type I in the presence of one or more risk factors
IIIB	Mediastinitis type II in the presence of one or more risk factors
IVA	Mediastinitis type I, II, or III after one failed therapeutic trial
IVB	Mediastinitis type I, II, or III after more than one failed therapeutic trial
V	Mediastinitis presenting for the first time more than 6 weeks after the operation

Definition of the mediastinitis according to the Centers for Disease Control and Prevention (CDC; Mangram et al. 1999):

- Cultural evidence of pathogen from mediastinal tissue or fluid
- Clinical picture of a mediastinitis during surgical revision
- Chest pain or sternal instability or fever (>38 °C) *plus* secretion of pus
- Cultural evidence of pathogens from the blood or drainage fluid

At least one of the situations has to be given.

The *pathogenesis* of sternal complications in general is not completely understood and awaits further elucidation.

Primary aseptic sternal instability is *typically a* mechanical problem. Increased *lateral force* at the *sternal edges* and *failure of the closure technique* may lead to this problem.

In infected sternal instability, the pathogenesis is discussed rather controversially. On the one hand, it is presumed that sternal instability promotes wound infection; on the other hand, a sternal dehiscence may also develop secondarily as a consequence of a local osteomyelitis. Another hypothesis is based on inadequate drainage of the mediastinum with retrosternal accumulation of retained *fluid* (El Oakley and Wright 1996).

The following *risk factors* have been demonstrated in numerous studies:

- Obesity
- Diabetes mellitus
- Osteoporosis
- Chronic-obstructive lung disease
- Prolonged ventilation time
- Bilateral use of the internal mammary artery during coronary bypass surgery

Interestingly, the risk factors had additive effects (Eagle et al. 2004; El Oakley and Wright 1996). *The use of bilateral internal mammary arteries* is discussed quite controversially, as the sternal perfusion is reduced by >90 %. Accordingly, the *potential* benefit of the arterial revascularization is opposed by an increased risk for sternal complications (Seyfer et al. 1988). Whether the application of bone wax *promotes* sternal instabil-

ity is also *unclear* (Nelson et al. 1990; Prziborowski et al. 2008).

The *mortality* of infectious sternal complications has decreased due to the effectiveness of currently available broad-spectrum antibiotics and the experience with various treatment options. There is still a high percentage of significant comorbidity, and mortality still ranges between 5 and 50 % (Domkowski et al. 2003). *Another important* issue with sternal complications is the significantly prolonged hospital stay; costs are increased and *long-term survival may be* reduced (Sjogren et al. 2006).

39.2 Diagnostics

39.2.1 Sternal Instability

Isolated sternal instability is *nonunion of the sternal edges* without an associated infection. In contrast to infected sternal instability, noninfected instability is less frequent and may occur very early, almost immediately after surgery. The patients present with a macroscopically unremarkable wound and complain about ongoing or recurrent pain and/or crepitation. The laboratory *evaluation is unremarkable*. In obvious cases, diagnosis can be established by palpation, but a thoracic computed tomography *scan is helpful in confirming the diagnosis*. In the latter, a significant gap, i.e., dehiscence, is visible in the sternum, which can be localized. It often affects the whole length of the sternum. *Loosened* sternal wires can be recognized as an underlying cause, quite often combined with a *fractured sternum in one or multiple sites*.

39.2.2 Wound Healing Disorder

Wound healing disorders after sternotomy are usually the consequence of a soft tissue infection. Obese and diabetic patients are at increased risk for wound healing disorders. Perioperatively administered antibiotics may not fully *penetrate the adipose tissue*, and thick skin folds *may be* difficult to *prepare for surgery*. In *diabetic* patients, it *has been clearly* demonstrated that strict control of the blood glucose level *postoperatively* reduces the incidence of sternal infections (Zerr et al. 1997). Poorly healing soft tissue wounds *may develop following reoperative* surgeries or after multiple surgical revisions via the same *site* which lead to considerable soft tissue trauma and *ischemia* (The Parisian Mediastinitis Study Group 1996).

A visual diagnosis can be made in 70–90 % of wound infections by identifying *an erythematous*, often wet, and discharging wound, in most cases 9–11 days after surgery (Wouters et al. 1994). Painful induration and fluctuating abscess/edema are not uncommon. Laboratory serum parameters and blood cultures can *support the* diagnosis, but not exclude it.

A chest X-ray is of little help. Depending on the depth of infection, superficial and deep sternal wound disorders *can be* distinguished. Superficial wound disorders involve only the subcutaneous *tissues*, whereas deep infections also affect the sternal bone. The predominant microorganisms are *Staphylococcus aureus* and *Staphylococcus epidermidis which* usually respond well to intravenous and/or local antibiotics. Less often involved are enterococci, *E. coli*, *Klebsiella oxytoca*, *Propionibacterium acnes*, and others.

39.2.3 Infected Sternal Instability

The combination of sternal instability and sternal wound infection is much more frequent than an isolated, aseptic sternal *dehiscence*. The order of the underlying pathological mechanisms is unclear (see ► Sect. 39.1, "Introduction"). The risk factors are similar to those of any sternal wound healing disorders:

- Significant obesity (frequently associated with an osteoporotic sternum)
- Prolonged stay in the intensive care unit
- Obstructive airway disease
- Poor patient compliance *regarding sternal precautions* during mobilization
- Advanced age
- Impaired renal function
- Emergent operation

These risk factors have been outlined in the guidelines for mediastinitis after aortocoronary bypass surgery by the American College of Cardiology (ACC) and the American Heart Association (AHA) (Eagle et al. 2004). The need for dialysis and diabetes mellitus was considered to be of less importance.

Diagnosis is generally simple to establish. The patients complain about local or diffuse chest pain

and sternal crepitation. Deep in the wound, the sternal bone and/or wires can be reached with a small probe, while pus or suspicious fluid may *be expressed*. There may be signs of systemic infection and the overall clinical condition of the patient can *rapidly decline*. If the diagnosis remains uncertain, a computed tomography *scan* of the chest may *provide confirmation*. In any case, wound swabs for microbiology culture should always be taken to determine the involved microorganisms, preferably before any therapy with antibiotics is initiated.

39.3 Indication for Surgery

A limited local instability, with an otherwise stable sternum, can be *managed conservatively*, particularly when *asymptomatic*. Instability involving the majority or the whole sternum and complete sternal dehiscence are a clear-cut indication for surgical revision. Nonsurgical therapy is only employed when patients suffer no or minimal discomfort, and redo surgery is considered a *very* high-risk procedure.

Any wound drainage almost always requires *surgical intervention* and intravenous antibiotic treatment after material for cultures has been taken. *Intravenous antibiotic treatment alone is not sufficient*. Nevertheless, it is important to determine the underlying organism as well as antibiotic sensitivities to be able to successfully treat difficult microorganisms like the methicillin-resistant *Staphylococcus aureus* (MRSA). *For superficial infections, reopening and debridement of the wound and conservative treatment modalities can be an effective approach*. However, abscess formation, fluid retention, and necrosis always mandate surgical intervention.

39.4 Surgical Therapy

39.4.1 Sternal Instability

During surgical revision the sternal wound is reentered. If the sternal wires are only loosened without an evident infection, they can be simply retightened. *Wires that have dehisced must be removed and the sternal edges prepared for reapproximation*. Even if the sternum is only partially dehisced, it is favorable to reopen the sternum completely *so new wires can be placed accurately*.

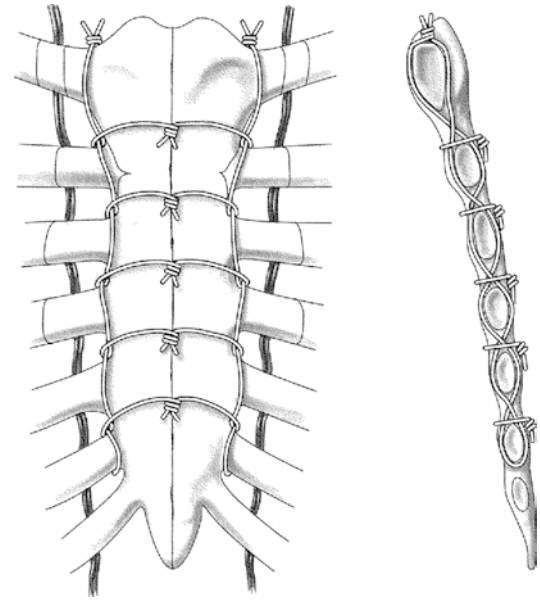

Fig. 39.1 Robicsek technique for rewiring of an unstable sternum

In any case it is important to keep attention not to lacerate mediastinal structures (e.g., coronary bypass graft) when preparing the sternal edges for reclosure.

Restabilization of the sternum can be achieved with different surgical techniques as no gold standard *has yet been defined*.

39.4.1.1 Rewiring

The sternal edges are approximated using single wires as with primary sternal closures or with two additional wires weaved through the intercostal spaces parasternally (Fig. 39.1) (Robicsek et al. 1977). The consolidated sternal edges are then reapproximated with sternal wires in various configurations (simple wires, wire loops, figure of eight) or with peristernal bands (e.g., Parham).

39.4.1.2 Plate Fixation

There are two possibilities for plate fixation of the sternum:

- A large 0.5 mm thick malleable titanium alloy plate with lateral perforations for suturing which is available in different sizes and shapes

can be placed onto the sternum, the Astudillo-Ley prosthesis (Astudillo et al. 2001). The sternal fragments are fixed to the plate with wires and sutures which renders the reconstructed sternum stable enough for careful rehabilitation.

- Alternatively, angle-stable titanium plates, as used in trauma surgery, can be transversely screwed to the ribs across the sternum (◘ Fig. 39.2). The advantage of this technique is that excellent stability is achieved, even in the case of extensive sternal destruction. However, the surgical expenditure and complexity are much larger as compared to the other techniques. There are also newer fixation systems using titanium plates which are primarily intended for prophylaxis during primary procedures of high-risk patients. *A significant reduction in postoperative sternal wound infections was achieved using rigid plate fixation in a high-risk patient population as compared to simple closure with wires* (Song et al. 2004). *High-risk patients closed with wires had a 14.8% incidence of mediastinitis* ($n = 207$) *as compared to 0% in the plating group* ($n = 45$).

If *extensive fragmentation* of the sternum is present which is commonly also associated with significant osseous defects, immediate sternal restabilization can be *difficult*. Bone sequesters require extensive debridement to remove all destroyed and potentially infected sternal tissue. Small osseous defects can be covered with unilateral or bilateral pectoralis muscle flaps (Jurkiewicz et al. 1980). *This becomes much more complex if* the whole sternum has to be resected. If there is no formation of granulation tissue within the mediastinum, reconstructive coverage of the defect by a plastic surgeon becomes necessary. Therefore, it is *advantageous* to preserve as much of the sternum as possible, especially if that *segment* provides local stability. For thoracic stability the manubrium is the most important and at times sufficient to allow for definitive treatment.

◘ **Fig. 39.2** Sternal plating

39.4.2 Wound Healing Disorders

A successful therapy of a sternal wound infection requires not only adequate antibiotic treatment but also mechanical elimination of the infection site to start with. *Infected superficial wounds* can be cleaned by excision of necrotic tissue and extensive rinsing with H_2O_2 (is controversially discussed for cell toxicity), polyvinylpyrrolidone-iodine, or other disinfecting solutions and thereafter closed again. Simple interrupted sutures are most suitable for that since a wound can be partially reopened in the case of a local reinfection. Also Penrose drains can be placed beforehand for 24–48 h.

Deep wound infections are more difficult to treat, since continuation of the infection directly into the sternum or via the sternal wires cannot be visually judged for sure. As in superficial cases of infection, the soft tissue must be radically and completely cleaned by necrosectomy and rinsing. Once this is done, a larger soft tissue defect remains which may be still closed directly, employing small wound drains if deemed necessary or possible. Tension at the wound edges can be relieved by mobilization of the pectoral muscles. In the presence of a large defect and extensive infection with uncertain spread, the negative-pressure wound therapy (NPWT), also called vacuum-assisted closure (VAC), has become a very popular therapy: the whole wound or the infected part of the wound remains open and it is filled out with an open-cell foam dressing or gauze. A drainage is placed over the foam and the wound is finally sealed with an occlusive film drape. With applied intermittent or continuous vacuum pressure to the drain (about 100 mmHg), the wound bed is cleaned, the wound edges are retracted, and granulation is stimulated. With sufficient granulation the wound can be closed at a second stage or further be treated conservatively.

Cowan could demonstrate that the need for surgical interventions is less and the hospital stays are shorter with vacuum therapy (Cowan et al. 2005).

39.4.3 Infected Sternal Instability

A wound *infection* with associated sternal instability poses the greatest challenge to the surgeon and to the patient. There are no standardized treatment concepts, but in all cases *complete eradication* of the infection in any tissue is the most important.

The first step is to open the infected wound and *debride* all necrotic tissue. All wires or other closure materials are *removed* and the sternum is separated. The mediastinum is inspected for evidence of *infection*. If there is suspicion of a mediastinitis, the mediastinum is rinsed with several liters of sodium chloride or Ringer's solution. H_2O_2 (see above for caution ► Sect. 39.4.2, "Wound Healing Disorders") and polyvinylpyrrolidone-iodine can be used as well.

In the case of extensive infection, implantation of a *closed chest tube drainage with irrigation system* is commonly utilized, with the irrigation tube being placed behind the manubrium and the drains placed subxiphoid (Shumaker and Mandelbaum 1963). *This approach provides a single-stage closure and has a low failure rate* (Merrill et al. 2004). Another option, especially used in recurrent mediastinal infection or in patients after cardiac transplantation, is to mobilize the greater omentum which can be prepared as a pedicled flap to cover the mediastinum. However, this technique requires a combined thoracic and abdominal *approach* which was associated with a significantly higher risk in elderly patients when *first described* (Lee et al. 1976).

Prior to *closure* the sternal edges are trimmed with curettes, Volkmann's spoon, or a sternal saw. The pectoral muscle is mobilized (Jurkiewicz et al. 1980). Stabilization techniques are similar to those described for aseptic sternal dehiscence (see ► Sect. 39.4.1, "Sternal Instability"), but it seems advantageous to minimize the use of implants. Nevertheless, *rigid fixation* of the sternal edges is the prerequisite for uncomplicated wound healing. Depending on the soft tissue conditions, it is decided whether the wound can be closed primarily or has to be *left* partially or totally open. If primarily left open, definite closure follows once the bottom of the wound is clean and fresh granulation tissue *is formed*. For the latter circumstance, the vacuum-assisted closure (VAC) technique can be used since they are highly efficient, easy to care, and comfortable for the patient. This has become more commonly used for complex open soft tissue wounds following sternal closure with excellent results (Sjogren et al. 2006).

In conclusion, there are several options to stabilize an unstable sternum at present. Infected sternal wounds are reopened and aggressively cleaned. An infected sternal instability can be treated in two ways, with a closed chest drainage and irrigation system with primary closure of the wound or with a vacuum therapy and a secondary sternal closure.

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