Management of sterno-mediastinitis

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HSR Proceedings in Intensive Care and Cardiovascular Anesthesia 2012; 4(4): 233-241

ABSTRACT

With an incidence rate of 1-4 %, mediastinitis following cardiac surgery is a rarely occurring complication, but may show a mortality rate of up to 50 %. Risk factors for sternal instability are insulin-dependent diabetes mellitus, obesity, immunosuppressed state, chronic obstructive pulmonary disease, osteoporosis, history of radiation, renal failure, body height, smoking and nutritional state. The aim of this paper is to show an overview of this clinical picture, present the risk factors and elucidate the therapy options chronologically. As a result of interdisciplinary cooperation, a therapy concept has developed which is adapted to the patient individually. Therapy begins with the simplest measures and, if deemed necessary, this is then escalated step by step. The aim of the treatment is to bring the infection under control, which requires radical surgical debridement, removal of infected and necrotic tissue, removal of all foreign bodies (including wires and osteosynthesis material) and the removal of all infected, necrotic osseous material if necessary followed by vacuum-assisted closure therapy. The reconstruction of defects of the anterior chest wall is achievable using different muscle flaps. Mostly the muscle pectoralis major is used unilaterally or bilaterally with or without disinsertion of the tendon. Other options are the omental flap, the muscle latissimus dorsi flap or the muscle rectus abdominis flap. A combined approach comprising surgical debridement, short-term vacuum therapy and subsequent myoplastic coverage has proved successful and can be carried out with a high standard of safety.

Keywords: *sternotomy, sternal infection, therapeutic options, interdisciplinary cooperation.*

Presented at the 3rd Expert Forum of the Roland Hetzer International Cardiothoracic and Vascular Surgery Society on the occasion of the 6th Oriental Congress of Cardiology, Shanghai, May 25, 2012

INTRODUCTION

In the treatment of mediastinitis and sternal osteomyelitis, a change of treatment is emerging from open as well as vacuum and irrigation procedures toward combined procedures. The current gold standard is early and radical surgical debridement, followed by vacuum therapy and plastic surgery reconstruction.

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Sternal infections and mediastinitis can result from infections, tumors, injuries or as a consequence of radiotherapy.

The commonest cause of sternal wound infections is sternotomy. Median sternotomy is the standard access for cardiac surgery interventions.

Despite the undisputed advantages of this route of access, severe complications may occur, which lead to further interventions with an extended hospital stay and increased costs for the health system. Another consequence is a reduced long-term survival rate (1-3). Complications are principally divided into infection-induced vs. non-infection-induced and stable vs.

instable conditions. The most severe complication for the patient is mediastinitis with concomitant instability of the sternum.
An initially uncomplicated instability may cause an infection with subsequent mediastinitis. Mediastinitis accompanied by initially stable sternum conditions inevitably leads to instability sooner or later (4).

Incidence and risk factors

With an incidence of 1-4 %, postoperative mediastinitis and sternal osteomyelitis is rare (3, 5, 6). However, the complications arising as a result of perioperative infections show a significant mortality rate up to 50 % (3, 6), on average 10-25 % (7).
Considered as risk factors for this postoperative complication are insulin-dependent diabetes mellitus, obesity, immunosuppression, chronic obstructive pulmonary disease (COPD), sternal osteoporosis, irradiation of the operated area, use of bilateral internal thoracic arteries as bypass grafts, decreased or increased body mass, renal failure and inadequate surgical techniques Thoracic wall tumors may also lead to infections with subsequent mediastinitis (4, 6, 8-12). The diagnosis of postoperative mediastinitis or sternal osteomyelitis usually occurs in a clinical setting based on the typical signs of a local wound infection. The majority of patients show wound secretion accompanied by leukocytosis, an elevated C-reactive protein (CRP) value as well as elevated body temperature. Half of the patients have sternal instability in addition.
On the basis of clinical study, crepitation is apparent. Some patients, however, also arrive for admission with an open wound and in some cases with torn out and exposed sternal wires. In uncertain cases, a computed tomography (CT) or magnetic resonance tomography (MRT) may help in the decision-making process.

Figure 1 - *Deep sternal infection 6 weeks post surgery.*

Classification of mediastinitis

Mediastinitis (*Figure 1*) is defined in accordance with the guideline of the US Centers for Disease Control and Prevention (CDC) as an A3 infection. This means that the infection appears within 30 days or within one year in the case of implants and fulfills at least one of the following criteria:

- purulent secretion from the drainage tube connected to the organ or body cavity;
- spontaneous opening of the wound, reopening at temperatures over 38° or pain as well as isolation of pathogens from a culture taken under sterile conditions from the organ or body cavity;
- abscess or other sign of infection during the course of reoperation, clinical examination, histopathological examination or imaging procedures;
- diagnosis of the attending surgeon/physician (13).

Therapeutic options

There is currently no general consensus regarding appropriate postoperative surgical therapy for mediastinitis (7). The goal is to control the infection and to achieve prompt sternal stability with adequate soft tissue coverage (3, 11). Wound healing strategies comprise open wound treatment, vacuum

and irrigation drainage, vacuum-assisted closure therapy (VAC) and reconstruction using flap plasties.

Chronologically, the first procedure was open wound treatment. This includes reopening the sternum, surgical debridement, changing dressings with moist compresses up to spontaneous wound closure by granulation and epithelialization. Because of their high failure rate and a mortality rate of over 50 % due to sepsis, tissue erosion or direct injuries of the right ventricle caused by the sternum or sharp-edged fragments, these methods were dropped (4, 14).

Chronologically, this was then followed by vacuum and irrigation drainage. This also included reopening the sternum, surgical debridement of the entire area as well as removal of osteosynthetic material. This is followed by extensive irrigation of the wound and the insertion of a vacuum-irrigation system retrosternally. The sternum is then closed in the conventional manner, the soft tissues closing in layers (4, 5).

This is followed by continuous or intermittent irrigation, until three pathogen-free effluates are obtained from the irrigation fluid. If this does not succeed, the vacuum-irrigation therapy should be terminated after four weeks at the latest. The advantages of this technique are immediate sternal stability and soft tissue closure.

Disadvantages of the method are the creation of possible dead spaces (irrigation channels), the risk of catheter erosion of vital organs and the danger of systemic absorption of the vacuum-irrigation fluid or a tamponade. And there is little influence of infected soft tissue. Due to its high morbidity and mortality rate of up to 36 %, this method should now only be applied in exceptional cases.

Use of vacuum assisted closure therapy

A promising approach in the treatment of mediastinitis following heart surgery is the VAC -therapy, a secondary healing system. This was introduced by Argenta and Morykwas in 1997 (15, 16) and is based on the application of a uniform local vacuum of up to 120 mmHg in the wound area.

Chronic and partly also acute and sub-acute wounds are characterized by peripheral edema, which impedes microcirculation and lymph drainage. The uniform vacuum acting on the wound causes removal of fluid and a reduction of pressure in the local tissue. This leads to a dilatation of the capillaries and improves the flow properties of the blood, arterial blood flow, proliferation of granulation tissue and angiogenesis. Secretion and debris are continuously removed and the bacterial count drops (17). Recent publications show promising results, although the number of cases observed is limited and the underlying healing mechanisms are relatively unknown (18). VAC should be performed for a short a time as possible and serves as an interim measure until final soft tissue reconstruction. (19).

There are only a few contraindications described in the literature for the application of VAC. Thus, some patients report on pain if the system was installed near their chest wound.

In others, excessive growth of granulation tissue into the sponge occurred, above all when sponges were not changed in a timely fashion. Both disadvantages can be readily brought under control, however, if the pressure is applied slowly and does not drop below 120 mmHg and the sponge is changed regularly (15, 16, 20, 21).

Use of flaps

The reconstruction by flaps was introduced by Jurkiewicz in the early 80's.

The reconstruction of the anterior chest wall may be achieved by local pedicled or free flaps (*Figure 2*). For example:

1) musculus pectoralis major;
2) transposition of the greater omentum;

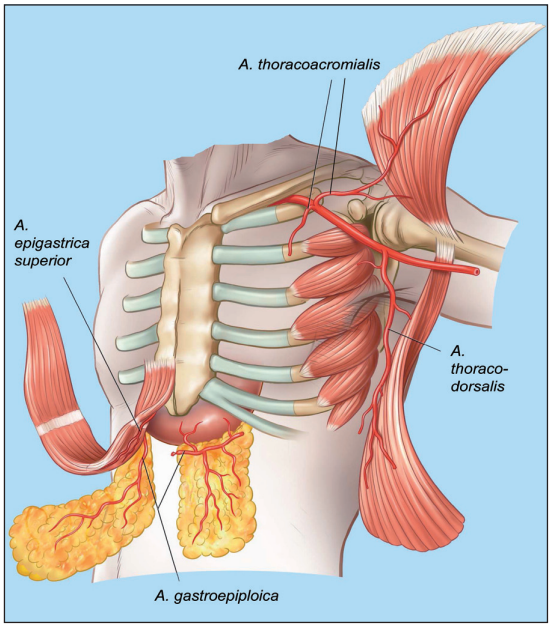

Figure 2 - *Options for flap plasties of the anterior chest wall.*

3) musculus latissimus dorsi;
4) musculus rectus abdominis.

These autologous tissues are ideally suited for covering surfaces with well-vascularized tissue, filling possible dead spaces as well as ensuring coverage of exposed parts of the sternum (4, 9, 22-24).

In principle, surgical reconstruction can be achieved by using autologous tissue or synthetic material. Most chest wall defects can be treated with local, musculocutaneous tissue, in infection-induced defects following sternotomy in particular using the pectoralis major (11).

Pectoralis muscle

Having excellent rotational capability, the pectoralis major offers the possibility of covering at least the upper two thirds of the sternum. The pectoralis major muscle can be used uni- or bilaterally. It is preferably dissected off the sternal origin, mobilized up to the humeral insertion and, if deemed necessary, detached there (4, 11, 14, 22, 25). Additional length is given by dissection of the flap from the costal origins and the clavicular part. But one has to keep in mind, that the pars clavicularis of the muscle stays untouched. Acting this way the pedicle can be completely isolated on the thoraco-acrominal trunk. With an intact ipsilateral internal thoracic artery, it can also be detached from the humeral insertion to perform a turn over flap. The dissection starts performing the tendon desinseration at the humerus, followed by the costal parts, the blood supply of the thoraco-acrominal trunk and is completed by raising the muscle from the clavicular part. The blood supply is guaranteed by the secondarily determined perforators of the internal thoracic artery. The pedicle can be turned into the sternal defect. Optically, it is not possible to avoid the formation of a protrusion, which some patients find disturbing (4, 11). In the presence of an advanced infection, parasternal vascularization is unreliable or destroyed.

For extensive defects, especially on the lower third of the sternum, pectoralis major flaps can also be dissected with the rectus muscle in continuity and be implemented as a so-called bridging flap. When doing this,

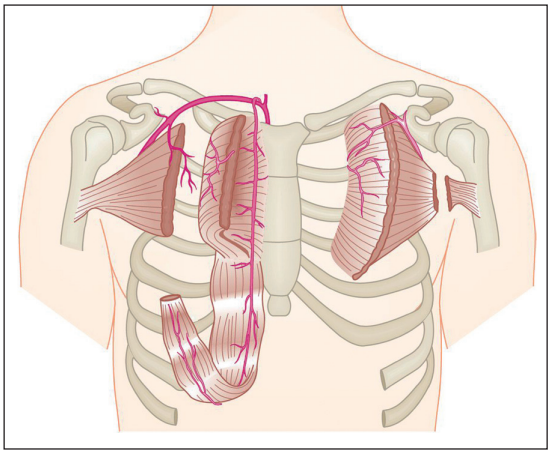

Figure 3 - *Therapeutic options to reconstruct defects with the pectoralis major.*

if possible, the ipsilateral internal thoracic artery should be intact (11, 24) (*Figure 3*). The distal section of the wound is at particular risk, as here the greatest force of gravity and most movement acts on the ribcage and the pectoralis muscles are by their nature least developed (4).

Omentum flap

The greater omentum (*Figure 4*) is perfused with blood by the gastro-epiploic vessels along the greater curvature of the stomach. It contains many immunologically active cells and shows anti-infective activity (4, 11, 26, 27). The greater omentum has a wide range; the mediastinum can be filled in satisfactorily. The flap can be pedicled via the right as well as via the left gastro-epiploic artery. Many surgeons prefer transpositioning of the greater omentum, above all, if foreign material lies exposed and irrigation channels have to be filled.

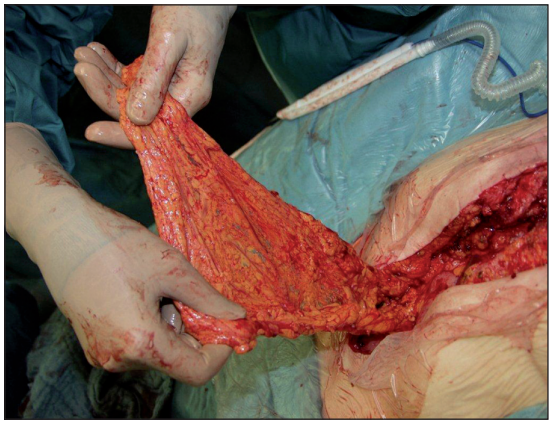

Figure 4 - *Greater omentum harvested.*

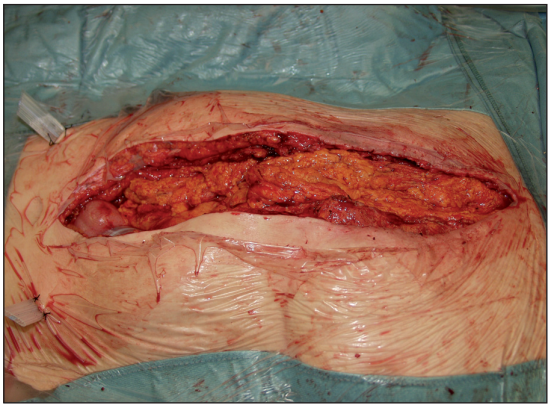

Figure 5 - *Transposition into the defect.*

Figure 6 - *12 days post surgery.*

Together with adequate surgical debridement, resolute intensive care as well as antibiotic monitoring, the method markedly improved the clinical results and concomitantly reduced the length of time in the prone position for the patient. It is, however, a two-cavity intervention with all the complication possibilities associated with this and a mortality rate of 12-36 % (27) (*Figures 5 and 6*).

Further problems, influencing the local zone of defect coverage, are the protracted secretion and possibly necessary skin transplants. Hernias also occur.

Latissimus dorsi muscle

This muscle receives its blood supply via the thoracodorsal artery and intercostal and lumbar perforators. The latissimus dorsi flap can be implemented as a pedicled, single or double flap as well as a free flap plasty (11, 14, 28).

The anterior thoracic wall can usually be readily reached by the pedicled muscle flap. There is a wide and reliable radius of rotation. The skin islets can measure a good 10

cm and can be oriented horizontally, vertically and obliquely. Whilst preparing the flap, the patient must be positioned onto his side so that repositioning may be necessary during the operation.
The donor side morbidity following pectoralis muscle is low. Effects on respiratory capacity are rare and are considered unproblematic. However, the effect on respiratory capacity is greater after using the rectus abdominis muscle as a reconstruction measure.
The donor side morbidity following latissimus dorsi plasty is a little higher, and there is the disadvantage of changing position during operation.

Rectus abdominis muscle

Some authors favor the sole use of the rectus abdominis muscle. For sternal reconstruction, they are suitable as cranially pedicled flaps (11). Hernias occasionally occur as a complication. This technique should only be applied in ipsilaterally intact internal thoracic arteries. Otherwise there is an increased danger of necrosis (*see the paragraph "Pectoralis muscle" and Figures 2 and 3*).
Along with the increased logistic investment, the following disadvantages of the muscle flap plasties also have to be considered (24):

- hematomas and seromas with subsequent revision;
- necrosis and wound healing disturbances;
- dysaesthesias in the operation area for a considerable time after the intervention;
- abnormal sternal mobility under stress such as cough or lateral position as a consequence of an unhealed sternotomy;
- tension and excessive distension in the distal scar area in female patients with mammary hyperplasia (29).

Concerns regarding restricted pulmonary function following reconstruction by means of muscle flaps could be dispelled (11, 14, 22, 24, 25). Postoperative pulmonary function tests show no relevant difference in comparison to the preoperative results.

Therapy algorithm

All aforementioned established procedures partially show high morbidity and mortality rates. Therefore, it continues to be important to develop alternative, safe therapeutic procedures. Common to all procedures, taking the central criteria (*Table 1*) into consideration, is the goal of bringing about healing of the sternal infection.
To achieve this, one should begin in the form of a "therapy ladder" (*Table 2*) with the simplest measure and then step-by-step escalate the therapy. In our patient collective, we use multistep therapy with phase-specific procedures and the following algorithm:

- complete removal of the infected and necrotic tissue and all foreign material, bacterial monitoring and antibiotic therapy;
- restabilization of the sternum depending on the findings and the time interval from the first operation;

Table 1 - *Central treatment criteria.*

- Radical surgical debridement of all infected and necrotic material, removal of all foreign bodies (osteosynthetic material)
- Bacteriological monitoring with antibiotic therapy according to an antibiogram
- Coverage of vital structures
- Re-establishment of functionality
- Stabilization of the bony skeleton
- Filling of empty body (residual) cavities
- Consideration of aesthetic aspects

Table 2 - *Therapeutic ladder.*

- Conservative approach, secondary wound healing
- Hydrotherapy, VAC therapy
- Direct wound closure
- Split skin flaps
- Local/regional flap plasties
- Free flap plasties
VAC = vacuum-assisted closure

- application of VAC;
- plastic surgery coverage after abatement of the infection parameters with pectoralis muscle plasty.

Radical, extensive debridement encompassing all infected structures is indispensable, also meaning that all osteosynthetic material has to be removed. A continuing infection can otherwise maintain progressive necrosis and in this way destroy tissue that is necessary for myoplastic coverage. The same applies for infected or necrotic bony parts of the sternum or the rib insertions. Partial or complete sternectomy may be necessary (11).
Non-infected, vital sternum parts should be preserved to improve thoracic stability and to avoid postoperative respiratory insufficiency. Subsequently, the entire wound must be extensively mechanically cleaned and irrigated. At each debridement swabs are taken and therapy is completed by administration of an antibiotic according to an antibiogram. With suitable wound conditions direct wound closure may be carried out. Otherwise VAC is recommended. The sponge selected for this should be as small as possible to avoid the soft tissues from shrinking, thereby facilitating later myoplastic reconstruction considerably.
Surgical debridement must be repeated until the site is decontaminated. Only then can final closure be carried out (22). A small bacterial load can, in individual cases, be accepted. In isolated cases, ruptures of the right ventricle may occur during these interventions. As long as no connective tissue plate has formed retrosternally, which as a general rule occurs after 6-8 weeks, fixation of the sternum or residual part of the sternum must be carried out.
According to our experience, restabilization of the sternum is therefore absolutely necessary, dependent on when the heart operation is performed, to prevent mechanical traumatization of the mediastinal structures, in particular of the right ventricle.
This may happen due to:

- continuos spreading infection;
- sharp ends of the sternum;
- increased or decreased intrathoracic pressure;
- adhesions between the sternum and the heart.

Complete rewiring need not be carried out, about 3-4 cerclages or cords being sufficient to prevent injury to the heart or vessels (4, 22, 27, 30, 31).
This is true for both planned revisions as well as for reconstructions. Therefore, in the VAC phase for every revision restabilization must be carried out once again. If as a result of severe osseous destruction secure refixation is not possible, rewiring according to Robicsek (4) may be considered. Further stabilization during VAC is achieved by means of a vacuum.
As a result of selective refixation only, the mediastinum can be well drained with maximum safety and reliability. Mobilization of the patient is thus possible in an uncomplicated fashion.
An accidental loss of vacuum as a result of detachment of the foil, disconnection of the VAC system or excessive mobilization can be corrected unproblematically without exposing the patient to the danger of a ruptured ventricle.
We dispense with covering the medial structures with compresses or membranes soaked in paraffin without refixation of the sternum. If the interval from the heart operation to treatment of the mediastinitis is longer than 6-8 weeks and if there is an adequate retrosternal connective tissue layer, refixation of the sternum becomes unnecessary.
In these cases, in consultation with the patient, stabilization of the sternum can be achieved by means of pseudarthrosis.

As a result of the myocutaneous plastic coverage, good additional stability is achieved by the muscle portions "growing into" the bony residual cavities (9, 11).

CONCLUSION

In our own patient collective, all patients showed a deep infection with the involvement of the sternum and/or the mediastinum. After an average of three debridements of the soft tissues and the sternum with the removal of the avital areas by means of sequesterectomy and partial resections the sternum lay relatively denuded.

From our point of view it is of immense importance to cover the remaining osseous sternum with well-perfused tissue and not adding protracted, secondary wound healing with the resulting presternal dysfunctional scar tissue. Furthermore, further stabilization is achieved as a result of myoplastic coverage.

The therapeutic algorithm, radical surgical debridement, VAC therapy serving as a conditioning and bridging treatment with additional myoplastic reconstruction, proved to be a save and reliable technique for treating deep sternal infections with good results, no recurrent infections and a justifiable risk (22).

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Cite this article as: Ennker IC, Ennker JC. Management of sterno-mediastinitis. HSR Proceedings in Intensive Care and Cardiovascular Anesthesia 2012; 4 (4): 233-241

Source of Support: Nil. **Conflict of interest:** None declared.

Acknowledgements: We thank Anne Gale, ELS (Editor in the Life Sciences), for editorial assistance.