POSTOPERATIVE MEDIASTINITIS IN CARDIAC SURGERY - PATHOPHYSIOLOGY, RISK FACTORS AND PREVENTION

DONATO D’AGOSTINO*, CARMELA LACATENA*, LUIGI SANTACROCE**
*Section of Cardiac Surgery, Department of Emergency and Organ Transplantations “Aldo Moro”, University of Bari, Italy - °School of Nursing, University of Bari at Taranto, Italy - **Section of Health Professions, Ionian Department, “Aldo Moro” University of Bari at Taranto, Italy

ABSTRACT

Infective complications of the surgical site, namely the sternal wound, and its most severe form that is mediastinitis, represent in cardiac surgery a major problem in terms of morbidity and mortality, with great suffering of the patient, increase the length of hospital stay and the related costs.

In literature they have been identified in numerous studies the major risk factors predisposing to the development of sternal infections and mediastinitis, respectively divided into pre-operative, intra-operative and post-operative.

Knowledge of these risk factors enable clinicians, who are in charge of the patients undergoing cardiac surgery, to take all possible measures to control these risk factors, and therefore prevent, as much as possible, these specific complications, for the best clinical outcome.

Key words: Cardiac surgery, Mediastinitis/Postoperative/Surgical, Sternal wound infection/Risk factor, Surgical wound infection, Postoperative complications, Staphylococcus spp.

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Definition and classification

Infective complications of surgical site in cardiac surgery, i.e. the sternal wound, in patients undergoing cardiac surgery, and their most severe form, that is mediastinitis, represent a severe complication with enormous impact on morbidity and mortality.

The onset of this complication requires prolonged therapeutic treatments with antibiotics, surgical reoperations or both, with great suffering of patients affected by the complication itself, which causes a significant prolongation of hospital stay, hence with increased costs, increasing anyway the risk for mortality.

The incidence of surgical site infection in cardiac surgery varies between 0.9 and 20%, according to different international case studies, with an average incidence of about 10%.(1,2,3)

According to the classification made by the Centers for Disease Control and Prevention (CDC) in Atlanta, which is widely used in the literature by various authors in different studies published in this area(3,10), the infectious complications that can affect the surgical site after sternotomy, can be categorized into 2 groups:

1) Infections of the superficial layers of the sternal wound, i.e. “Superficial Sternal Wound Infection” (SSWI) when the infection affects only the skin and the subcutaneous tissue at the site of incision.

2) Infection of the deep layers, i.e. “deep sternal wound infection” (DSWI), or post-sternotomy mediastinitis, which occurs when the infection...
involves the deep layers, i.e., muscle tissue, bone and mediastinum. These were in turn classified by Oakley-Wright\(^{11}\) (Table 1) into several types (from I to V), in relation to the time of onset, the presence / absence of risk factors (considered to be diabetes, obesity and immunodepression by disease or by drugs) and to previous ineffective treatments.

Table 1: Classification of Post Sternotomic Mediastinitis in Cardiac Surgery.

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
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<tbody>
<tr>
<td>Type I</td>
<td>Mediastinitis presenting within 2 weeks after operation in the absence of risk factors(^a)</td>
</tr>
<tr>
<td>Type II</td>
<td>Mediastinitis presenting at 2 to 3 weeks after operation in the absence of risk factors(^a)</td>
</tr>
<tr>
<td>Type III A</td>
<td>Mediastinitis type I in the presence of one or more risk factors(^a)</td>
</tr>
<tr>
<td>Type III B</td>
<td>Mediastinitis type II in the presence of one or more risk factors(^a)</td>
</tr>
<tr>
<td>Type IV A</td>
<td>Mediastinitis type I, II, or III after one failed therapeutic trial(^a)</td>
</tr>
<tr>
<td>Type IV B</td>
<td>Mediastinitis type I, II, or III after more than one failed therapeutic trial(^a)</td>
</tr>
<tr>
<td>Type V</td>
<td>Mediastinitis presenting for the first time more than 6 weeks after operation</td>
</tr>
</tbody>
</table>

\(a\). Wound infection associated with sternal osteomyelitis with or without infected retrosternal space.

\(b\). Risk factors identified in three or more major studies. Currently accepted incremental risk factors for mediastinitis are diabetes, obesity, and the requirement of immunosuppressive agents.

\(c\). Failed therapeutic trial includes any surgical intervention with intent to treat mediastinitis.

According to the guidelines of the CDC, the presence of mediastinitis requires at least one of the following criteria:\(^{10}\):

1) isolation of an organism from tissue culture or mediastinal liquid;

2) evidence of infection of the tissues at the surgical exploration of the patient.

3) presence of at least one of the following clinical signs: chest pain, sternal instability and / or fever (\(> 38^\circ\) C) over the following signs:

- Finding of purulent secretions in the mediastinum
- Positive blood culture or positive culture from mediastinal tissue or fluid.
- Signs of infection detectable by computerized axial tomography of the mediastinum (CT-Scan).

**Etiology**

It is commonly believed that the germs responsible for the sternal wound infection are of endogenous origin, from the skin or surrounding tissues or transferred by health professionals\(^{24,10}\).

In about 80%, they are represented by gram-positive cocci, especially staphylococci, both Staphylococcus aureus coagulase-negative staphylococci, and to a lesser extent by enterococci. In about 20% of cases they are gram-negative bacilli (Pseudomonas, Enterobacter) or fungi. In severe infections it is possible to find a polymicrobial flora or superinfection by opportunistic germs that appear later during treatment. The frequency of such isolation is not well established and the percentages of bacterial isolation may vary in different conditions. We must also consider that the pathogens that cause surgical site infections do not respond to single configuration in the literature but are subject to change depending on centers and nations.

The study of Tegnell et al.\(^{2}\), for example, it showed that coagulase-negative Staphylococcus was very important in determining sternotomic postoperative infections, reporting a rate of 64% compared to other studies where the incidence was much lower, around 40% (39.6% and 46%)\(^{3,3}\).

A major study from Karolinska Institutet\(^{4}\) analyzed 9557 consecutive cardiac surgical procedures and it showed that coagulase-negative Staphylococcus was isolated in 46% of cases of mediastinitis, Staphylococcus aureus in 26%, and
Gram-negative in 18% of cases. The authors show that in patients with sternal dehiscence and mediastinitis, Staphylococcus coagulase-negative was isolated more frequently (44/80; 55%) than in patients with sternal stability (10/38; 26%) (p = 0.003). Staphylococcus aureus was isolated more frequently in patients with sternal stability (18/38; 47%) than in patients with sternal dehiscence (13/80.16%) (p < 0.001). The Gram-negative mediastinitis were present with similar frequency in patients with sternal instability or instability.

From these considerations, the authors distinguish three different types of mediastinitis, according to their pathogenesis:

1) *mediastinitis by Staphylococcus coagulase-negative*: in sternal dehiscence associated with obesity and, sometimes with chronic obstructive pulmonary disease; In such cases, the bacteria would reach a minimum dehiscence skin and hence the infection would be disseminated to the mediastinum after sternal dehiscence and then the interruption of its natural barrier;

2) *mediastinitis by Staphylococcus Aureus*: in these cases the mechanism of mediastinitis be attributed to perioperative contamination by the surgeon or the staff room, the patient himself or by air conducts of the operating room;

3) *infectious mediastinitis from other sources, in the majority of cases by Gram-negative*.

Other authors, such as the U.S. group at Washington University School of Medicine, identified Staphylococcus aureus as the causative organism for superficial and deep infections, ie mediastinitis, with similar percentages of incidence (54% and 41% mediastinitis and superficial infections).

**Incidence**

In mediastinitis that are carried out after interventions in cardiac surgery, in most cases the cause is represented by the sternal wound infection. While the incidence of post-sternotomy infections considered altogether, between superficial and deep, reported in the literature, it varies, in the different studies from 0.9 to 20% (1-3), on the other hand the incidence of deep infections of sternal wound, ie of mediastinitis, varies between 0.4% and 5%, with an average incidence of about 1%, according to recent studies (1-3,11,12,13).

The variation of incidence in different studies is probably due in part to the different classifications and in part to the different mode of surgery and the method of follow-up (3). In one of the most extensive retrospective studies, Loop and colleagues (34) have reported an incidence of 1.1% of 6,504 patients. This appears to be higher in some subgroups of patients, such as immunosuppressed individuals (15).

The incidence of dehiscence sternal wound is generally higher than that of mediastinitis. Bryan et al. (16) have shown that in 60% of patients who had a complication of median sternotomy it was a sternal dehiscence. The treatment of this complication through a sternal synthesis, generally produces excellent results in the short and long term (16). On the other hand the mediastinitis is associated with a high mortality rate, variable in the literature between 14% and 47% (11,16). Also from the point of health care spending, american studies have shown that the cost for patients with post-operative infection of the deep tissues is equal to 2.8 times that for patients with uncomplicated postoperative course (2-3).

**Pathogenesis**

As it regards the sternal wound dehiscence after cardiac surgery, considered as partial or total opening of the wound, which can involve the skin layers until the muscle fascia, crossing it, because the origin is usually attributable to suturing technique of the superficial layers that is not perfect and over the same points, to bacterial infection of the skin layers or below. It is important to do this premise because as regards the deeper infections ie mediastinitis, clinical evidence universally observed, confirmed by the data of the literature, shows that the more frequent primary cause, in most cases, is represented precisely by the infection of the sternal wound to the skin.

Next to this that is the most frequent occurrence, it has been reported by some authors other modes of occurrence of post-surgical mediastinitis:

- In some studies it is reported that the sternal wound infection can start with an area of localized osteomyelitis of the sternum with minimal external signs, then a situation similar to the primary osteomyelitis of other bones (17,18). The failure of sternal points appears after a few days as an effect, rather than as a cause of wound infection.
- Other authors believe that sternal instability, after the skin lesion, with suction of bacteria in the layers more deep, is the key event in the genesis of sternal wound infection (19).
- Another hypothesis for the pathogenesis of mediastinitis is represented by an inadequate mediastinal drainage, with formation of a large retrosternal collection that behaves as a culture medium for
bacterial growth. In the early stages of deep wound infection, the mediastinum is bordered by a thin layer of fibrin and the mediastinal structures are inflamed and mobilized. Osteomyelitis is usually confined to the margins of the sternal wound and debridement of the wound at this stage reveals the underlying bone still healthy. On the other hand, chronic mediastinitis evolves in a few weeks and is characterized by the formation of processes which extend in the posterior mediastinum, particularly for the presence of foreign materials; the structures of the mediastinum are soon covered by a thick fibrous rind that prevents their passage in the anterior mediastinum.

**Diagnosis**

The diagnosis of mediastinitis can be made early (7-10 days), late (10-30 days), very late (> 30 days). In most cases the onset of sternal infection is insidious and delayed. The symptoms that patients present is characterized by minor symptoms such as pain, redness and serous secretion, which have an average duration of 20 days. The lack of classic symptoms of the infection may be an explanation for the long time interval between the primary and the new cardiac surgery hospital stay for surgical reintervention to treat the infection.

The clinical presentation of mediastinitis can be very different. The mediastinitis can cause postoperative fever, even if the conditions of the wound may appear good; they may be the cause of otherwise unexplained difficult post-surgical recovery; They may be the cause of postoperative bacteremia; in these cases, the prognosis may be more severe. They are very helpful diagnostic imaging techniques such as CT-Scan and scintigraphy with labeled leukocytes.

**Risk factors**

They have been identified in the literature, mainly retrospective case-control studies, many risk factors predisposing to the onset of superficial and deep sternal infections wound after heart surgery, which can be distinguished into three groups:

a) Pre-operative risk factors: Diabetes mellitus, obesity, smoke and chronic obstructive broncho-pulmonary disease (COPD), advanced age, weakening of the immune system, and use of corticosteroid drugs. NYHA functional class III or IV, previous cardiac surgery.

b) Intra-operative risk factors: duration of intervention, type of surgery, duration of extracorporeal circulation, deep hypothermia or circulatory arrest, number of units of blood transfused, withdrawal of the two internal mammary arteries in revascularization, peri-operative antibiotic prophylaxis, emergency interventions that do not allow proper preparation of the patient, methods of hair removal, use of bone wax, closing technique of the sternum, use of intra aortic balloon pump (IABP).

c) Post-operative risk factors: intensive care time greater than 5 days and intubation with mechanical ventilation for a period more than 24 hours, tracheotomy, prolonged use of inotropic agents, reoperation for bleeding, contamination and wound infection sternotomy due to not careful management of the wound dressing itself.

**Focus on risk factors for the prevention**

The strategy for the prevention of sternal infections site in heart surgery patients can be realized on the basis of identification and accurate analysis of predictors of risk of developing complications, that several studies have so far provided. In this way, being able to identify patients who present those risk factors, you can try, where possible, to eliminate them, or at least mitigate, keeping them “under control” as much as possible, in order to reduce the risk of mediastinitis.

Lets analyse below, among risk factors found in the several studies, those considered to be most relevant, analyzing them specifically, with the relative considerations.

**As regards pre-operative risk factors:**

- An increased risk of mediastinitis in diabetic patients undergoing cardiac surgery for myocardial revascularization, who had blood glucose levels > 200 mg / dl in pre-operative, has been demonstrated by several authors. The increase of mediastinitis in diabetic patients must therefore direct prevention strategies targeted to control blood glucose. In this regard insulin therapy in continuous intravenous infusion in pre-operative, aimed at maintaining blood glucose levels <150 mg/dl, it reduces the risk of mediastinitis in about 66% of patients with diabetes.

- Also a US study at Washington University School of Medicine, conducted on 1,980 consecutive patients undergoing cardiac surgery for “revascularization”, shows how obesity (with “body mass index” > 30), obesity, no association of diabetes if not late, is a determining risk factor, statistically significant (P = <0.001), for the increase of superficial...
infections, while the concomitance of diabetes and obesity is determining risk factor, statistically significant (P = <0.001), for the increase of deep infections, i.e. mediastinitis (p = <0.001)\(^{(8)}\). Based on this evidence, among the strategies of prevention of post-operative surgical wound infections it could be included, in clinical processes, weight loss, with a diet targeted and monitored.

- Other risk factors are pre-operative smoking and COPD. The increased risk in smokers can be due to increased pulmonary complications, sternal wound colonization by the flora of the nasopharynx, and to reduced immune responses\(^{(21,22,23)}\). For these risk factors, for the purposes of prevention, it might suggest to quit smoking, as well as interventions to reveal the presence of Staphylococcus Aureus (Swab cultures nasopharyngeal and bronchial sputum) and to eradicate it with vaccines\(^{(9)}\) and antibiotic prophylaxis prior to surgery.

- Other authors have emphasized advanced age, previous steroid therapy, previous mediastinal irradiation, type of intervention, if it is re-operation as major risk factors\(^{(17,24,25)}\).

As regards intra-operative the risk factors:

- In this context it is crucial to consider how to constant feedback in literature, in all the studies in this field, the evidence that the operative technique has a central role in the pathogenesis of mediastinitis. An imperfect surgical cut of the sternum, in fact, is a big risk for the development of wound complications. Shafir et al.\(^{(26)}\), for example, they have identified in a para-median sternotomy, and / or otherwise incorrect, the main cause of complication of the surgical wound. The closure of the sternum in these cases should be reinforced, for example, according to the technique of Robicsek or even by internal fixation of the sternum\(^{(27)}\).

- Other studies have also shown that there is an increase incidence of mediastinitis when are used, in patients undergoing CABG, the internal mammary arteries (IMA) bilaterally. In fact, this condition causes a reduction, albeit transient, of the vascularization of the sternal region and it also causes a greater trauma of that region, which exposes the patient to an increased risk of dehiscence and wound infection\(^{(5,9)}\). More recent studies, however, suggest that in selected cases, judicious use of bilateral IMA grafts can not be an independent risk factor for wound infection\(^{(14,28,29)}\). The increased incidence of sternal wound infection observed in the use of bilateral IMA is probably due to the cumulative effects of several risk factors, for example, the increase in operative time, increased use of diathermy\(^{(30)}\), increased pulmonary complications due to unilateral or bilateral pleurotomy\(^{(31,32,33)}\) and increased incidence of reoperations for bleeding\(^{(28)}\).

- Deep hypothermia; circulatory arrest. They cause vasoconstriction and then a reduced oxygen supply to the surgical site\(^{(4)}\).

- Blood transfusions; This increase in risk might be attributed to the immunosuppressive effects of transfused blood\(^{(1,5,8)}\).

- Excessive use of diathermy or wax, to reduce the bone tissue resistance to infection\(^{(30,34)}\). The wax for the bone is a not-biodegradable material which inhibits bone healing and acts as pabulum for bacterial growth\(^{(35)}\).

As regards the risk factors post-operative:

- Excessive postoperative bleeding and a second sternotomy for bleeding are also risk factors for sternal wound infection\(^{(14,36,26)}\).

- Prolonged use of inotropic agents, which cause vasoconstriction and relative hypoperfusion of the surgical site\(^{(5)}\).

- The presence of a hematoma at the site of the surgical wound may create a culture for bacterial growth and however compromises its healing\(^{(8)}\). Therefore it will be good practice to evacuate early hematomas present.

- Blood transfusions; This increase in risk might be attributed to the immunosuppressive effects of transfused blood. It will be advisable therefore limit the number of transfusions, consistent with the clinical management of the patient correctly and within the limits of safety\(^{(40)}\).

- Prolonged postoperative mechanical ventilation; For this we recommend extubation as early as possible, even the latter, of course, as part of the overall optimization postoperative course of the patient\(^{(21,22,23)}\).

Role of nursing care

In reference to the documentation produced by the CDC\(^{(10)}\) on the guidelines for the prevention of surgical site infections, it is necessary to emphasize the main points regarding the nursing management of the patient and, particularly:

In the pre-operative phase

- Trichotomy: preoperative hair removal should be minimal, concerning only the area of surgical incision. It must proceed in such a practice immediately before the intervention (2–4 h from beginning of surgery) preferably with an electric razor (clipper) (Recommendation 1 / A) to avoid skin trauma.
• Pre-operative shower: in this regard it must be remembered that the use of chlorhexidine reduces to 9 times the bacterial cutaneous, while the use of povidone-iodine reduces the bacterial population colonizing the skin of only 1.3 times. Recommended application of chlorhexidine: a shower in the evening before surgery and a shower in the morning after the trichotomy, if this is to be effected.

In the post-operative phase

• Management of the sternotomic wound dressing. This type of activity performed by the nursing staff is of fundamental importance. It requires particular attention since, because of its location immediately below the mouth and nose of the patient, is easily exposed to endogenous contamination from the patient himself and to irritation. These include nasal colonization by Staphylococcus Aureus, vomiting and pulmonary secretions. Moreover it is important, in prevention cured by the nurses, also pay attention to any possible external sources of infection, including material for endotracheal intubation and catheters.

In the context of cardiac surgery, as the morbidity and mortality is significantly associated with the infection of the sternotomy, it is essential to avoid the latter, emphasize the importance of the optimization of nursing care for the purpose of an optimal clinical recovery of the patient.

In summary we have to consider that as in practical cardiac surgery, the sternal dehiscence is a major complication because it increases significantly the mortality of patients who may suffer it, is very important the role that has prevention in this area, to avoid or at least reduce the risk that this dangerous complication occurs. It is based first of all on the correct and complete clinical management of the patient in all the three phases of his hospitalization (pre-, intra-, and post-operative) by the entire team of the cardiac center that takes charge of the patient. The assessment and, when possible, the correction of predisposing factors to the dehiscence, optimizing the aseptic management of the patient and surgical field, a precise surgical section of the sternum by the operator, and the proper management of wound dressing after surgery, are crucial to prevent or at least reduce significantly the risk of this complication.

Next to this, however, after the patient’s discharge from the hospital it is necessary to implement an optimal monitoring of the state of the wound healing and, for this purpose, the possible onset of complications of the sternal wound should be well monitored both by the patient, both by doctors of the territory. To accomplish this, however, it is essential on the one hand, proper medical training, also addressed to doctors outside the hospital, in order to prompt identify the sternal wound complications and simultaneously, on the other hand, action is needed to education aimed towards the patient on the perceived clinical symptoms and its timely reporting, because aggressive and early treatment can reduce mortality. Is essential, also for this purpose, that the patient is aware of his clinical condition after surgery and that is also instructed on how to treat sternal wound in the recovery period (wound dressing, if necessary, avoid tearing or excessive tension, recognize the indices of inflammation, use of tenso-elastic sternal brace in the first weeks after surgery, etc.) in order to collaborate himself to safeguard the full and proper healing of surgical wound and osteo-synthesis of sternotomy, without the onset of the dreaded infectious complications.

Conclusions

The post-sternotomy mediastinitis is still one of the most dangerous complications that may arise in the postoperative course of patients undergoing cardiac surgery. Patients affected by this complication are forced to undergo a postoperative course very regrettable, if it is always the same burdened with high risk of mortality. Considering the large number of patients that are currently undergoing this type of surgery in hospitals around the world, we understand very well how important it can be, by all health professionals who are in charge of these patients (cardiac surgeons, anesthesiologists, nurses etc) to focus every day, all their efforts to try to prevent as much as possible this dangerous complication or, in the case of the unlikely event of it, detect it and treat it as quickly and as effectively as possible.

Finally we must consider that hospital infections, taken together, are a phenomenon that is constantly evolving and now represent an important indicator of quality in health care in general.

It must therefore be made quickly, based on the best scientific evidence, all those standards of care (procedural, behavioral, structural, and organizational) that implement an effective prevention.
References


Corresponding author
Prof. DONATO D’AGOSTINO
Corso Vittorio Emanuele, 143
70122 - Bari
(Italy)