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Prevention, Classification and Management Review of Deep Sternal Wound Infection

Khaled E. Al-Ebrahim,[1] Ebrahim K. Al-Ebrahim[2]

[1]Department of Surgery, King Abdulaziz University, Jeddah, Saudi Arabia; [2]Faculty of Medicine, King Abdulaziz University, Jeddah, Saudi Arabia

ABSTRACT

Sternal wound complications are significant problems in cardiac surgery and cause challenges to surgeons as they are associated with high mortality, morbidity, and a tremendous load on the hospital budget. Risk factors and preventive measures against sternal wound infection need to be in focus. Classification of different types of sternotomy complications post cardiac surgery is important for specific categorization and management. Reviewing the literature, a variety of classifications was introduced to help understand the pathophysiology of these wounds and how best to manage them. Initial classifications were based on the postoperative period of the infectious process and risk factors. Recently, the anatomical description of sternal wound, including the depth and location, was shown to be more practical. There is a lack of evidence-based surgical consensus for the appropriate management strategy, including type of closure, choice of sternal coverage post sternectomy, whether primary, delayed and when to use reconstructive flaps.

INTRODUCTION

Background

The median sternotomy provides an excellent approach for cardiac surgery. It was first described by Milton in 1897 [Dalton 1992]. Sternal dehiscence, sepsis, and tissue loss complicate this approach. It increases the patient's morbidity and mortality. Deep sternal wound complications occur in 0.8% to 1.5% of patients and as high as 8% in obese or diabetic patients and when bilateral internal mammary arteries are used, with a morbidity rate of up to 50% causing prolonged hospital stay and a mortality rate of 14%-47% [Farsky 2011; Cutrell 2016; Pairolero 1984]. In the United States, approximately 700,000 open heart surgeries are performed each year, leading to nearly 8,300 cases of deep sternal wound infections [Cutrell 2016].Treating mediastinitis considerably increases the cost of care and several surgical procedures may be required for its management. Use of the appropriate antibiotic regimen and early debridement are the initial lines of management [Pairolero 1984; Sears 2016; Schiraldi 2019; Kubota 2013]. Mechanical dehiscence can be corrected with debridement and approximation of the wound edges. For correction of major complex defects, various techniques have been described, including muscle, musculocutaneous, omentum, and skin flaps and recently the fasciocutaneous flap including the pectoralis major muscle fascia [Sears 2016; Schiraldi 2019; Kubota 2013; Zahiri 2012; Salehi 2007; Weinand 2013].

Risk factors

Risk factors for sternotomy wound complications include older age, increased body mass index, smoking, and presence of comorbidities such as low immunity, diabetes mellitus, irradiation, reoperation, and chronic lung and kidney disease. Long operation time and bilateral use of internal mammary arteries in obese and diabetic patients contribute to a higher risk of complications. Postoperative factors include prolonged ventilator support, inotropes, delayed chest closure, and tracheostomy [Farsky 2011; Cutrell 2016; Pairolero 1984; Sears 2016; Schiraldi 2019; Kubota 2013; Zahiri 2012; Salehi 2007].

Table 1. Classification reported in 1996 by El Oakley, based on postoperative period of the infectious process and the presence of clinical risk factors

Classification	Description
Type I	Mediastinitis present in up to 2 weeks after the operation in the absence of risk factors
Type II	Mediastinitis present in 2 to 6 weeks after surgery in the absence of risk factors
Type IIIA	Mediastinitis type I in the presence of one or more risk factors
Type IIIB	Mediastinitis type II in the presence of one or more risk factors
Type IVA	Mediastinitis type I, II or III after treatment failure
Type IVB	Mediastinitis type I, II or III after failure of one or more treatments
Type V	Mediastinitis present for the first time after 6 weeks post-operatively

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Correspondence: Khaled E. Al-Ebrahim, Department of Surgery, King Abdulaziz University, Jeddah, Saudi Arabia, P.O. Box 80215, Jeddah 21589, Saudi Arabia; ++6401000; fax: ++6401238 (e-mail: dr.k.ebrahim@gmail.com).

Table 2. Classification proposed by Jones in 1997 based on anatomical site plus a type including sepsis

Classification	Depth	Description
Type 1a	Superficial	Skin and subcutaneous
Type 1b	Superficial	Exposure of sutured deep fascia
Type 2a	Deep	Bone exposure, sternum with stable steel suture
Type 2b	Deep	Bone exposure, sternum with unstable steel suture
Type 3a	Deep	Necrotic bone exposure or fractured, unstable sternum, exposed heart
Type 3b	Deep	Type 2 or 3 with septicemia

Table 3. Classification proposed by Greig in 2007, considering the regional location of the wound

Wound type	Site of sternal wound	Recommended flap for reconstruction
Type A	Upper half sternum	Pectoralis major
Type B	Lower half sternum	Combined pectoralis major and rectus abdominis bipedicled flap
Type C	Whole sternum	Combined pectoralis major and rectus abdominis bipedicled flap

Prevention

Lazar et al nicely summarized all preventive measures in open heart surgery to avoid or minimize sternal wound complications [Lazar 2016].

Preoperative control of blood glucose, meticulous disinfection, compliance with sterility principles, the topical use of antimicrobials on the sternum and prophylactic perioperative antibiotic, including intra-nasal mupirocin, are effective with reducing the incidence of postoperative sternal wound infection [Schiraldi 2019; Lazar 2016; Yusuf 2018; Abu-Omar 2017; Khanlari 2010]. Öztürk and colleagues in their meta-analysis showed that preoperative coexisting diseases, such as pulmonary HT, malignancy, heart failure, hepatic and neurological diseases, and dyslipidemia, may not be risk factors for the development of mediastinitis after cardiac surgery [Öztürk 2015].

Sternal stability is the cornerstone and most important factor with proper healing. Identification of high-risk cases preoperatively and application of the proper sternal closure technique is of crucial importance [van Wingerden 2014; Anger 2012; Al-Ebrahim 2003; Robicsek 2000; Fawzy 2011; Al-Ebrahim 1996]. Several reinforced sternal closure techniques were reported to overcome or prevent sternal instability, which is the major contributing factor for wound complications [Anger 2012; Al-Ebrahim 2003; Robicsek 2000; Fawzy 2011; Al-Ebrahim 1996; Singh 2011]. Type of sternal closure depends on the quality of the sternum. Osteoporosis, multiple fractures, and bone loss necessitate reinforced closure using Robicsek technique, plates, or bilateral wavy or straight longitudinal wires [Anger 2012; Al-Ebrahim 2003; Robicsek 2000; Fawzy 2011].

Table 4. Classification proposed by Anger and colleagues based on anatomical changes, considering the depth and location of the surgical wound.

Classification	Affected tissues	Wound location as the vertical extension
Type I	Skin and subcutaneous tissue	Partial/total Upper lower
Type II	Exposure of the sternum or ribs	Partial/total Upper lower
Type III	Bone loss of sternum or ribs	Partial/total Upper lower
Type IV	Exposed mediastinum	Partial/total Upper lower

Diagnosis

Clinical, laboratory and radiological investigations are important for the diagnosis of sternotomy wound complications. According to the Center for Disease Control and Prevention (CDC), deep sternal wound infection (DSWI) is diagnosed by one of the following criteria: Identification of organism(s) from mediastinal tissue or fluid, evidence of mediastinitis on gross anatomic or histopathologic exam and the patient has at least one of the following signs or symptoms: fever (>38.0°C), chest pain, or sternal instability, and at least one of the following: purulent drainage from mediastinal area or mediastinal widening on imaging test [Sears 2016; Schiraldi 2019; Kubota 2013; Zahiri 2012; Salehi 2007]. The clinical diagnosis is supported by laboratory and radiology findings. Radiographic abnormalities on chest radiograph include widening of the mediastinum, mediastinal air–fluid levels, pneumomediastinum, and pleural effusion. Computed tomography (CT) findings include dehiscence, fluid collections, wire displacement, and retrosternal collection [Zahiri 2012; Salehi 2007]. El Oakley and colleagues in 1996 classified different types of mediastinitis, according to time of presentation postoperatively [El Oakley 1996]. Coagulase-negative staphylococci and S. aureus are the most common pathogens. When infection persisted after surgical and antibiotic treatments, Gram-negative rods, especially enterobacteriaceae, were found more often [Pairolero 1984; Salehi 2007]. Because of their high concentration in cancellous bones, fosfomycin and rifampicin proved to be effective in methicillin resistant staph aureus osteomyelitis [Yusef 2018]. Antifungal therapy can be added in the absence of clinical improvement on a broad-spectrum antibiotic, even if no fungi are isolated [Abu-Omar 2017; Öztürk 2015; Tewarie 2019; Khanlari 2010]. In a recent study in our institution, the most common pathogen identified was coagulase negative staphylococcus epidermidis followed by S. aureus, pseudomonas and klebsiella [Elassal 2020].

Classifications

Reviewing the literature, looking for classification of post sternotomy, trans sternal, complications or mediastinitis, eight articles were found [Pairolero 1984; El

Table 5. AMSTERDAM classification (Assiduous Mediastinal Sternal Debridement & Aimed Management)

Type	Sternal stability	Bone viability & stock	Reconstruction	Staging of reconstruction
1	Stable	Reasonable	NPWT	(class I, level B)
2a	-	-	Local muscle flap	Primary (class II, level B)
2b	-	-	Muscle or omentum flap	Delayed (class I, level B)
3a	Unstable	Viable & sufficient	Rewiring/osteosynthesis	Primary Delayed (class IIb, level B)
3b	-	-	Rewiring/osteosynthesis and muscle or omentum flap	Primary Delayed (class IIb, level B)
4a	-	Necrotic & insufficient	Muscle flap	Primary Delayed (class IIb, level B)
4b	-	-	Omentum flap	(class IIb, level B)
4c	-	-	Muscle and Omentum flap	(class IIb, level B)

Oakley 1996; Jones 1997; Greig 2007; Anger 2015; Rupprecht 2013]. Pairolero and Arnold in 1984 introduced the first classification based on postoperative time of establishment of the infection, dividing it into three types. Type I, in the first week, was characterized by serosanguinous drainage only. Type II, between 2 to 6 weeks, was characterized by purulent drainage, cellulitis, mediastinal suppuration, and positive cultures, frequently associated with fulminating mediastinitis and osteomyelitis. Type III, after 6 weeks to years, included fistulas and chronic osteomyelitis [Pairolero 1984]. Subsequently, in 1996, El Oakley and Wright classified mediastinitis, according to time of presentation and presence of risk factors [El Oakley 1996] (Table 1). Jones and colleagues in 1997 reported the first classification based on the affected anatomical site, superficial to deep, looking at sternal stability and presence of septicemia and advocated single-stage debridement and closure to reduce hospital stay and cost [Jones 1997] (Table 2). Greig et al classified wounds into upper and lower sternum, according to the lower margin of the pectoralis major muscle and indicating the type of reconstruction necessary for the management of deep sternal infection and dehiscence [Greig 2007] (Table 3). Anger and colleagues in 2015 combine the Jones and Greig classifications, dividing it into skin and subcutaneous tissues, exposed sternum, bone loss, and mediastinitis [Anger 2015] (Table 4). In 2013, Rupprecht and Schmid proposed a classification of three types. Type I, noninfected sternal instability, is treated by rewiring, classical or Robicsek, or plating according to sternal bone status. Type II, deep sternal wound infection without sternal instability, is managed by debridement, antibiotics and either primary closure, if the wound is clean, or delayed primary after NPWT using either muscle or omental flaps. For Type III, deep sternal wound infection with sternal instability, they recommended continuous antibiotic tube irrigation with closure of the wound or leaving the mediastinum open, packed with towels or using NPWT. Later on, soft tissue reconstruction is achieved with pectoral flaps [Rupprecht 2013]. Based on meta-analysis and evidence-based reconstructive procedures, van Wingerden proposed a classification of post sternotomy mediastinitis, looking mainly at sternal stability, sternal bone viability and stock, including management for the first time [van Wingerden 2014] (Table 5). Most of their studies were categorized as class II B evidence, where there is conflicting evidence or a divergence of opinion, or both, about the usefulness/efficacy of a procedure based on systematic reviews, clinical trials, cohort studies and case series. In Type 1, there is minimal bone loss and a relatively stable sternum at debridement, available evidence favors wound management through the application of negative pressure wound therapy (NPWT). In Type 2, there is sufficient bone stock and the sternum is relatively stable. Direct closure, by mobilization of the pectoralis muscle, is done either primarily, without a conservative management (Type 2A) or delayed (Type 2B). In Type 3A, the sternum is unstable with sufficient bone stock left. The sternum is closed with wires and plates followed by NPWT. Type 3B sternal closure is supported with flap coverage. Type 4 is loss of sternal stability and viability. This is managed by debridement and muscle flap closure in 4A, greater omentum in 4B, and by both in 4C. Recently, Schiraldi and colleagues proposed a treatment algorithm based on their meta-analysis, from plastic surgery view, and according to Rupprecht and Schmid classification. They introduced Perforator and microsurgical free flaps as an important tool for reconstructive surgeons in fragile patients for whom extensive procedures should be avoided [Schiraldi 2019]. Table 6 collectively summarizes all previous classifications, including management in a simplified manner. All old classifications were descriptive without a management plan. Van Wingerden, Shiraldi, and Rupprecht included a management plan to the staging of infection to help standardize treatment. The author summarized the main points of management in Table 6.

Management

The optimal treatment of DSWI is still controversial, and it was impossible to combine the results of the different classifications analyzed herein to obtain collective evidence of the selected treatment. The most important two points to be dealt with in DSWI is sternal instability and degree of infection. Old surgical modalities introduced in the 1960s involved wound debridement, primary sternal closure, and mediastinal catheter irrigation with antibiotic or antiseptic solution proved to be unsatisfactory these days [Al-Ebrahim 2009; Yusuf 2018; Abu-Omar 2017; Öztürk

Table 6. Summarizes previous classifications and management

Classification	Anatomical depth	Surgical procedure
I	deep sternal wound infection reaching the sternum without sternal instability	# surgical debridement +/- NPWT followed by wound revision and direct closure or using fasciocutaneous pectoral flap
II	Sternal instability without infection	# debridement and primary sternal closure either standard rewiring /reinforced /plates
III	Deep sternal infection with sternal instability with MINOR tissue/ bone loss (<50%)	# debridement +/- NPWT followed by primary sternal closure/direct or using fasciocutaneous pectoral flap or pectoralis muscle flap
IV	Deep sternal infection/mediastinitis and MAJOR bone loss (>50%)	#debridement/NPWT/Delayed primary closure (>72hours) In #upper sternal defects: pectoralis major flap # lower or whole sternum defect: Pedicled rectus abdominis or great omentum

2015; Tewarie 2019]. Although several surgical options exist in current practice, there is a lack of consensus on optimal surgical management and when reconstructive flaps are needed [Öztürk 2015; Tewarie 2019]. Proper antibiotics based on sensitivity for at least six weeks and adequate debridement is essential for deep sternal infection [Abu-Omar 2017; Öztürk 2015; Tewarie 2019; Khanlari 2010]. In deep sternal infection and unstable sternum, an aggressive approach and early surgical intervention is recommended. This includes debridement of all necrotic tissues and sternal closure or flap coverage [Al-Ebrahim 1996; Al-Ebrahim 2009; Yusuf 2018; Abu-Omar 2017]. The amount of bone loss and feasibility to approximate wound edges after debridement are the two most important factors in decision making, regarding use of reconstructive flaps or primary closure. If the wound is clean and approximation is possible, direct sternal closure, either standard or reinforced, is the ideal solution. Tewarie and colleagues reported superior results, using bilateral pectoralis major muscle flap to the omental flap technique, in patients without sternal bone necrosis, with relatively low recurrence and mortality risks [Tewarie 2019]. Anger and colleagues described a new surgical technique to repair dehiscence using fasciocutaneous flaps from the pectoralis major fascia in 21 patients [Anger 2012]. In our institution, this procedure was adopted in patients with no or minimal bone loss with good results and proved to be less invasive, fast, and effective. The Cologne-Merheim approach algorithm presents a coverage strategy based on wound size and depth. Small wounds up to 6 cm are to be covered by unilateral or bilateral musculocutaneous pectoralis flaps. Unilateral pedicled pectoralis flaps are used for medium wounds (between 7 cm and 12 cm), while in large wounds (>13 cm), a left pedicled latissimus dorsi flap is recommended [Weinand 2013]. Negative pressure wound therapy (NPWT) was introduced as a bridge to surgical closure in patients with persistent deep sternal infections [Weinand 2013; Debreneci 2008; Dickie 2006] in the 1990s. It provides continual drainage of bacteria and exudates by negative wound pressure, thus enhancing microcirculation and tissue granulation [Weinand 2013; Debreneci 2008; Dickie 2006]. This is usually implemented when primary closure is not feasible, and the sternum is relatively stable. Early closure within 48 hours after adequate debridement is recommended. Delayed primary closure is superior to a late secondary closure as this is associated with the risk of secondary infection and emergence of multi-resistant microorganisms or fatal exanguination from erosion to the exposed right ventricle, great vessels, and bypass conduits [Berdajs 2011; Singh 2011]. The most devastating picture of dehiscence is mediastinitis and major or complete bone loss that cannot be approximated. Plastic coverage is needed following adequate debridement.

The sternal wound is divided vertically into upper and lower parts, according to the inferior insertion of the pectoralis major muscle [Greig 2007]. In major upper sternal defects, more than 50% bone loss, pectoralis major is the muscle of choice and can be mobilized on both sides or freed from the humeral attachment to cover the gap. In lower or whole sternal major gap, pedicled rectus abdominis, latissimus dorsi or greater omentum can be used to fill the space [Berdajs 2011; Davison 2007; van Wingerden 2011; Botianu 2019; Greig 2007; Anger 2012; Tewarie 2019] From 2005 to 2019, 30 cases of deep sternal wound infection were reported and among them, three cases of complete sternal necrosis secondary to osteomyelitis were treated in our hospital with negative pressure wound therapy, followed by rectus abdominis flap [Elassal 2020; Al-Ebrahim 2020]. Elassal et al reported that objective wound classification is helpful to organize the range of sternal wound complications and enables us to adopt the proper treatment strategy. Use of fasciocutaneous pectoral flap is a favorable and less invasive modality for most reconstructive procedures, and it avoids unnecessary use of the more invasive muscle or omental flaps [Elassal 2020].

Epigastric herniation, bleeding, necrosis, and contamination of the peritoneal cavity are serious complications of omental flaps [Botianu 2019; Tewarie 2019]. Pedicle rectus abdominis blood supply has to be secured and usually the right one is harvested in case the left internal mammary is used. Greater omentum or latissimus major is preferred when bilateral mammaries are used. Clear preference has been expressed for the use of omentum, instead of muscle, in cases where the primary causative organism is particularly resistant, such as methicillin resistant staph aureus [van Wingerden 2011; Botianu 2019]. A dedicated and highly specialized team for management of sternal wound complication is important in all cardiac centers to have proper evaluation and selection of the appropriate closing or covering procedure. This team must be experienced in all types of muscle flap harvesting and laparoscopic great omentum mobilization.

CONCLUSION

An international classification based on evidence from numerous centers and a large volume of patients, from both cardiothoracic and plastic reconstructive surgeons, is needed for further categorization and selection of the most appropriate surgical strategy. Prevention is the main cornerstone in the management of this complication. All risk factors must be taken into consideration before operating on those patients. A multidisciplinary team, consisting of cardiothoracic surgeons, plastic surgeons, intensivists, infectious disease specialists, and clinical microbiologists, is needed for the management of complicated deep sternal infection.

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