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REVIEW

Sternal Wound Infections, Risk Factors and Management – How Far Are We? A Literature Review

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Sternal wound infection (SWI) is one of the potential complications post cardiac surgery, and despite refined surgical techniques such as smaller incisions, antibiotic therapy, and optimised glycaemic control, the incidence rate is between <1% in elective cases with low risk factors and as high as 25% in patients with extensive risk factors. The presence of SWI will increase the perioperative morbidity and mortality rates and prolong the patient's hospital stay, therefore the prevention and diagnosis with appropriate management of such adverse outcomes at an early stage is important to prevent further progression as it can be fatal when the mediastinal structures are affected. Currently, the diagnosis typically consists of three main stages: clinical, biochemical including microbiology studies and imaging studies. In the current health care system, the use of computed tomography (CT) and magnetic resonance imaging (MRI) is valuable to define mediastinal abnormalities and can also help find the source of a descending infection. Management is through methods such as antibiotic therapy, surgical debridement, reconstruction with soft tissue flap coverage, sternal plating, and sternectomy. In this literature review, we aim to summarise current literature evidence behind appropriately diagnosing such a catastrophe.

Keywords Surgical site infection • Sternal wound infection • Imaging • Cardiac surgery

Introduction

Surgical site infection (SSI) is one of the complications that could occur post cardiac surgery; it results in severe complications with significant morbidity and mortality rates with a decreased life expectancy [1,2]. The occurrence of SSI is between 1–3% depending on the definition of mediastinitis, risk factors for SSI, conduction of preventative measures, and intensity of surveillance [1]. An example of SSI is sternal wound infection (SWI), which leads to prolongation of hospital stay, therefore increasing hospital costs up to $62,000 in the USA [2]. Sternal wound infections have major clinical and economic consequences, the ideal protocol is based on recommendations for the prevention of infection in pre, post, and intraoperative periods to achieve the lowest morbidity and mortality rates related to this complication [2]. There are different classifications of SWIs which range from a spectrum of minor to major forms, where superficial infections to mediastinum can spread to the sternum, major vessels and the heart itself [3]. While the majority of sternal wound infections are caused by the Staphylococcus species, infections by other microorganisms have been reported [3].

There are several risk factors that are associated with sternal wound infection and they can be categorised under patient-related factors or procedural-related factors [3]. Table 1 is a summary of risk factors for sternal wound infections. Treatment options vary and there is no clear consensus about optimal surgical management of SWI [4].

Sternal wound infections following sternotomy can be classified into two major groups as infection of the deep

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Table 1 **Division of risk factors in superficial sternal wound complications and deep sternal infection into preoperative, intraoperative and postoperative risk factors [5,6].**

Preoperative	Intraoperative	Postoperative
BMI/Obesity	Number of grafts	Reoperation (bleeding)
Diabetes	Single/bilateral use of IMA	Ventilator support
COPD	Duration of surgery	Metabolic support
Peripheral Vascular disease	Type of surgery: CABG vs Valve surgery	IABP support

Abbreviations: COPD, chronic obstructive pulmonary disease; BMI, body mass index; IMA, internal mammary artery; CABG, coronary artery bypass grafting; IABP, intra-aortic balloon pump.

Table 2 **Classification of sternal wound infection stated by Jones et al. [12] in 1997 based on anatomical layer and a type including sepsis [10,12].**

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

or superficial layers (Table 2). Infection of the superficial layer involves the skin, subcutaneous tissue, and pectoralis fascia. On the contrary, infection of the deep layers is defined as being below the subcutaneous tissue such as bone and mediastinum (Figure 1) [6,7]. Furthermore, Oakley et al. [8]. have classified deep sternal wound infection (DSWI) further into five subgroups that are divided based on aspects such as the presence of risk factors, time of presentation, and whether previous surgical attempts have failed (Table 3) [8]. Greig et al. [9] in 2007 introduced another classification of SWI based on affected anatomical location (Table 4) [9]. This author is the first to have classified the extent of sternal wounds vertically [9,10].

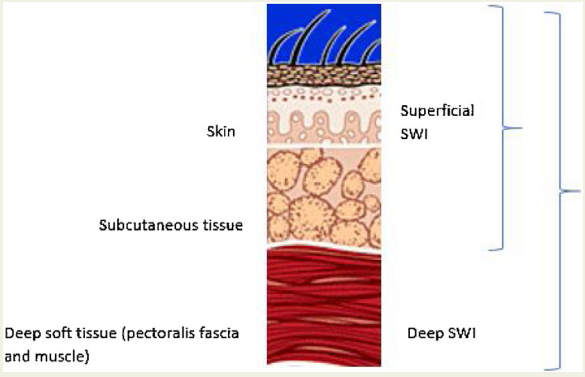

Figure 1 Anatomical layers in superficial and deep sternal wound infection (SWI) [11].

Overall, SWI after cardiac surgery is a life-threatening complication, therefore it is essential to have a standardised management plan [13]. Imaging tools such as computed tomography (CT) have been used for many years to evaluate pathological processes, allowing effective diagnosis of SWI [13]. This literature review will discuss sternal wound infection with regards to its clinical history, classification, risk factors, diagnosis, management, prevention, and treatment. In addition to this, the different imaging techniques used in the diagnosis of SWI will be highlighted and compared.

Natural History of Sternal Wound Infections

Surgical site infection (SSI) can prevent a wound from healing, leading to wound edges becoming further apart and abscess formation in deeper tissues [14]. An example of SSI is sternal wound infection (SWI) which can involve the sternum, mediastinum or the muscle, pectoralis fascia, and soft tissue. If it is deep SWI then the infection takes place below the subcutaneous tissue, in the bone or mediastinum, however, if it is superficial SWI then infection takes place in the skin, subcutaneous tissue and pectoralis fascia [6]. A typical patient who has a history of being immunocompromised, having poor wound healing and recurrent skin infections is likely to have SWI, regardless of timing of the

Table 3 Classification of post sternotomy sternal wound infection[1] in cardiac surgery [7].

Class	Description
Type I	Mediastinitis presenting within 2 weeks after operation in the absence of risk factor[2]
Type II	Mediastinitis presenting at 2 to 3 weeks after operation in the absence of risk factors[2]
Type IIIA	Mediastinitis type I in the presence of one or more risk factors[2]
Type IIIB	Mediastinitis type II in the presence of one or more risk factors[2]
Type IVA	Mediastinitis type I, II, or III after one failed therapeutic trial[3]
Type IVB	Mediastinitis type I, II, or III after more than one failed therapeutic trial[3]
Type V	Mediastinitis presenting for the first time more than 6 weeks after operation

[1]Wound infection linked with sternal osteomyelitis with or without infected retrosternal space.
[2]Risk factors observed in three or more major studies. Currently accepted risk factors for sternal wound infection include diabetes, obesity, and the requirement of immunosuppressive agents.
[3]The failed therapeutic trial includes any surgical intervention with intent to treat sternal wound infection.

Table 4 Classification introduced by Greig et al. [9] in 2007, which distinguishes the type of SWI (sternal wound infection) dependent on the affected anatomical location of the wound [9,10].

Type of surgical wound	Extension of sternal wound	Kind of retail recommended for reconstruction
Type A	The upper half of the sternum	Major pectoralis
Type B	The lower half of the sternum	Major pectoral combined with bipedicle abdominal rectus
Type C	The whole sternum	Major pectoral combined with bipedicle abdominal rectus

cardiac surgery [15]. Chest radiographic imaging and a positive wound culture are also ways in which SWI can be diagnosed [15].

Appropriate treatment of SWI can lead to complete eradication of infection, stabilisation, and full recovery of the patient. Treatment options include culture-directed antibiotic therapy, sternectomy, debridement, drainage, and wound closure using muscle or omental flaps [2]. If left untreated, SWI can lead to erosion of the sternal bone, cartilage damage, mediastinitis and in serious cases, death [5].

Risk Factors for Sternal Wound Infections

There have been numerous studies that display the risk factors of sternal wound infection which are either patient or procedure related factors [16,17]. Examples of patient-related factors include age, peripheral arterial occlusive disease, and chronic obstructive pulmonary disease (COPD). Furthermore, examples of procedural factors include the use of unilateral or bilateral internal thoracic arteries for coronary artery bypass grafting (CABG), duration of surgery, and postoperative complications [16,17].

Evidence to support the link between these risk factors and sternal wound infection is shown in a study by Lu et al. [18] that was carried out to highlight the risk factors for sternal infection post CABG [18]. Data was collected for a total of 4,288 prospective patients who underwent CABG surgery data between April 1997 and March 2001 [18]. Out of 4,288 patients, 109 patients (2.6%) developed SWI [18]. The study found that there were both patient and procedural related risk factors that are associated with postoperative SWI [18]. Examples of these risk factors include a body mass index $\geq 30\,kg/m^2$, peripheral vascular disease, poor left ventricular ejection fraction, and intra-aortic balloon pump (IABP) support postoperatively [18]. Furthermore, in the study, differences in sternal infection rate were not observed in factors such as age, sex, hypercholesterolaemia, hypertension, and renal dysfunction [18].

A similar study carried out by Meszaros et al. [16] evaluated whether the risk factors of sternal wound infection alter depending on the form of surgical procedure in cardiac operations [16]. The study reported risk factors associated with surgery and patient characteristics, for example, bilateral internal thoracic artery harvest, and COPD and diabetes, respectively [16]. These factors are summarised in Table 5.

Diagnostic Criteria for Sternal Wound Infections

There are specific clinical signs and symptoms, laboratory (including biochemical and microbiological) and radiological findings that help clinicians distinguish whether a patient has SWI or not [19]. In 2011, the National Institute for Health

Table 5 Common factors that do and do not predict the risks of SWI.

	Factors that predict risk of SWI	Factors that do not predict risk of SWI
Patient related	Body mass index ≥30 kg/m2	Age Sex
Disease related	Left ventricular ejection fraction Peripheral vascular disease COPD DM	Hypercholesterolaemia Hypertension Renal dysfunction
Treatment related	IABP support Bilateral internal thoracic artery harvest	

Abbreviations: SWI, sternal wound infection; COPD, chronic obstructive pulmonary disease; DM, diabetes mellitus; IABP, intra-aortic balloon pump.

and Care Excellence (NICE) guidelines in the UK set out specific signs to showcase whether a patient had SWI. Examples of investigations to be carried out include: signs of an elevated white cell count upon blood test, blood cultures, and taking swabs from sources of sepsis in the mouth or neck tissue [20]. Chest x-rays can also help diagnose sternal wound infection through detection of pneumomediastinum and air-fluid levels, lower lobe consolidation and/or pleural effusion, and lastly widening of pre-cervical retropharyngeal and paratracheal soft tissues [20]. In the current health care system, the use of computed tomography (CT) and magnetic resonance imaging (MRI) is valuable to define mediastinal abnormalities and can also help find the source of a descending infection [20].

As there are different classifications and subgroups of SWI it is important to have an imaging technique that can distinguish between superficial and deep sternal wound infection as management and outcomes of each group are subjective [21]. In the US health care system, the Centre for Disease Control and Prevention (CDC), there are three criterion that need to be met for diagnosis of deep sternal wound infection (DSWI) specifically: 1) the micro-organism is recovered from tissue from the mediastinum or culture from the fluid or non-culture based microbiological testing method 2) on anatomical or histopathological examinations there needs to be evidence of mediastinitis and, lastly 3) requirement of at least one symptom such as chest pain, fever, sternal ability and one symptom from mediastinal widening on imaging examination or infected drainage from mediastinal area [19]. This will be required during surgical interventions to help clinicians decide the most appropriate management of a patient [22]. The features that aid the diagnosis of SWI are summarised in Table 6.

Clinical Diagnosis

Sternal wound infection can be diagnosed by observing clinical signs and symptoms [19]. The majority of patients with SWI typically present within a 30-day period after cardiac surgery [19]. Symptoms can typically consist of low-grade fever and increased levels of inflammatory markers where reports of little or no recovery is taking place [19]. Signs such as erythema can also be seen as well as purulent drainage which occurs from the sternal wound [19,22]. Another way in which physicians can distinguish between DSWI and superficial sternal wound infection is

Table 6 Clinical, biochemical, microbiological and radiological features of SWI and DSWI.

Clinical		**Low grade fever** **Local erythema** **Purulent discharge from the sternal wound**
Biochemical		Persistent elevation of inflammatory markers (C reactive protein, erythrocyte sedimentation rate)
Microbiological		Wound aspirate culturing: coagulase negative staphylococci, *Staph aureus* or gram negative cocci
Radiological	CT	Mediastinal widening Presence of mediastinal fluid Parenchymal and sternal disruption Abscess Free gas production beneath sternal plate
	MRI	(Not feasible in the early evaluation of post cardiac surgery patients)
	US	Discrete fluid collection
	PET scan	(accurate identification of site of disease to guide management)

Abbreviations: CT, computed tomography; MRI, magnetic resonance imaging; US, ultrasound; PET, positron emission scan; SWI, sternal wound infection.

by using deep sternal wound aspirates to perform a culture test [22].

A study by Gårdlund et al. [23] aimed to describe the variation in clinical characteristics and microbiological aetiology in SWI [23]. A total of 9,957 cardiac surgery procedures were recorded between 1992–2000, and 126 (1.32%) patients developed SWI [23]. Out of 126 patients, 99 presented clinical signs of severe infection such as septic shock and high temperature (>38 degrees), 15 patients showed minor infection with a higher level of c reactive proteins or low-grade fever, and, lastly, 12 patients had no signs of infection, however, SWI was shown to be present when reoperation for sternal dehiscence occurred [23].

Microbiology

On physical examination, it has been a challenge to note the difference between SWI and DSWI [19]. In cases where there is a high probability of infection, it is advised to perform a bacteriological assessment of tissue from the sternal wound [19]. A study by Gårdlund et al. [23] concluded that sternal wound infection can be classified into three groups that have distinct postoperative and pathogenic outcomes [23]. The groups are: 1) sternal wound infection that is driven by coagulase-negative staphylococci and linked to chronic obstructive pulmonary disease and obesity; 2) sternal wound infection caused by *Staph aureus*, after perioperative contamination of the mediastinum and lastly; 3) sternal wound infection occurring during the postoperative period, caused by the spread of concomitant infection in other sites mainly by gram-negative rod [23]. The distinction of sternal wound infection is used to derive prophylactic countermeasures that can be a promising prospect in certain cases [23].

Radiology

Over the past decade, there has been a rapid expansion of knowledge in disease mechanisms, development, and progression which has been widely used for the evaluation of a therapeutic target [24]. Scientists and clinicians have been working towards reducing the time taken for a diagnostic conclusion to be made, allowing improved disease prevention and tailored therapeutic interventions [24]. For this to be possible nuclear medicine and radiology have played a promising role, together with meeting the increasing demands of diagnostic targets, pathophysiological knowledge, and treatment [24]. Examples of imaging modalities used to diagnose sternal wound infection include computed tomography, magnetic resonance imaging, positron emission tomography (PET) and ultrasound scan (US) [24]. The key focus on each imaging technique is to differentiate their suitability in analysing superficial and deep SWI.

US

Ultrasound (US) is a diagnostic tool that can perform a whole-body scan without transferring a patient to an imaging and interventional suite. This can prove highly beneficial for SWI patients in the intensive care units where infection control is a priority [28]. The US scan was first used as the medical diagnostic aid in the 1940s and the recent shift towards computer technology has led to the compaction of transducers allowing intraoperative and intravascular applications [29]. Ultrasound can now be used in the diagnosis, screening and treatment of the disease, therefore less use of the CT scan is now seen, leading to time efficient diagnoses, cheaper costs to health care, and above all, a better quality of patient care [30]. During an US, an example of a DWSI patient would show a discrete fluid collection in the suprasternal mass [15].

CT Scan

Radiographic imaging in sternal wound infection is an essential tool to support a clinical diagnosis, for surgical planning, and to deduce an optimal treatment [19,25]. The diagnostic tool that is most widely used by clinicians for sternal wound infection is a contrast-enhanced CT scan [19,25]. The CT scan is widely used for evaluating pathological processes in the mediastinum and therefore is beneficial to diagnose postoperative sternal wound infection [19,25]. In a CT scan for SWI, most typical signs to look for are a widening of the mediastinum, fluid build-up, parenchymal and sternal disruption, abscess formation and free gas production beneath the sternal plate (19,25). However, the drawback of the CT scan is that it does not provide information about the extent of mediastinal infection [25]. A study by Yamaguchi et al. reported that the sensitivity of CT for the diagnosis of sternal wound infection after the cardiac operation is at an unsatisfactory level [13]. The study found overlaps in the pathological appearance in 'normal' appearance and pathologically altered appearance of SWI therefore, reducing the reliability of the diagnosis via CT scan [13]. Due to this, a suggestion of using a comprehensive diagnostic strategy with various tools when signs of infection occur in the mediastinum can lead to a more reliable diagnosis [13]. A further study by Exarhos et al. [26] aimed to determine the diagnostic value of CT in the diagnosis of acute mediastinitis [26]. Computed tomographic findings were retrospectively studied in 40 patients. The sensitivity and specificity of CT in the first 17 days postoperatively was 100% and 33% respectively, and after 17 days, 100% and 90% [26]. This study concluded that CT is a highly sensitive imaging modality for mediastinitis [26].

MRI

Magnetic resonance imaging (MRI) is a non-invasive imaging modality and functions by using non-ionising radiation to produce a diagnostic image [24]. A radio wave antenna sends and receives signals to and from a patient's body which is positioned in a large, powerful magnet [24]. Advantages of using MRI in a patient with sternal wound infection include early detection through high spatial resolution and a highest soft tissue contrast (Figure 1) [24]. However, the use of MRI in sternal wound infection has drawbacks as fluid or air pockets produced postoperatively may remain and therefore disrupt the specificity of the findings [22]. In addition, for SWI patients the use of MRI is not permitted within the first 6 weeks due to sternal wires, heart valves, and

permanent pacemakers, therefore, using MRI early in the postoperative stage is not feasible [27].

PET Scan

Positron emission tomography (PET) scanning allows us to see 3D images of patients. It is a nuclear functional imaging tool that is used to identify abnormal metabolic processes, thus resulting in a conclusive diagnosis [31]. The mechanism behind PET involves gamma rays emitted indirectly by a tracer that are absorbed into the body through a biologically active molecule such as fludeoxyglucose [32]. In the case of late-occurring and recurrent sternal wound infection (SWI), PET-CT combined imaging can be advantageous in providing accurate knowledge of the site of disease, therefore being a desirable guide to adequate debridement [31].

Management of Sternal Wound Infection

For sternal wound infection, NICE guidelines, 2008, divided management into three phases: preoperative, intraoperative, and postoperative. A tailored approach is applied for each [14]. During preoperative management, the guidelines suggest giving intravenous (IV) antibiotic prophylaxis on starting anaesthesia for both clean-contaminated and contaminated surgery [14]. Antibiotic treatment in addition to prophylaxis should be given to patients undergoing surgery on a dirty or infected wound [14]. Intraoperatively, the management of SWI involves wound dressings to cover surgical incisions with an appropriate interactive dressing, antiseptic skin preparation, and maintenance of patient homeostasis [14].

The management of SWI postoperatively is dependent on the classification of the infection, the patient's clinical status, and the organisms that are detected in the cultures [8]. Treatment can, therefore, vary from a minor antibiotic therapy to a sternectomy in addition to a plastic surgery procedure [8]. For a deep infection, patients have necrotic material removed through surgical debridement, antibiotic therapy, drainage of all infected spaces and primary sternal closure [2,8]. Once the sternal debridement has taken place, the wound can be immediately closed if the patient is clinically stable, if the deep tissue is free from infection, and if the amount of sternum left over is enough to achieve stability [2]. In certain cases where the infection has not been eradicated, irrigation is said to be continued with the use of drainage tubes however, several studies have stated that there is a low chance of success and an increased rate of mortality with this method [2,33–35]. In cases of delayed closure where sternal re-wiring and dressing changes occur, it is proven that an increased level of accuracy is obtained through assessing the infection as well as reducing recurrent infections [36]. However, the drawback of this is a higher level of risk due to mechanical ventilation for example thrombosis, pneumonia, and muscle fatigue [12,33,37]. In addition, serious outcomes such as prolonged mobilisation and thoracic instability can occur [36]. For a superficial wound, an incision in the mediastinum is made to allow drainage of infected material, as well as allowing changes in dressing that fill the wound. Moreover, negative wound therapy can also be used in addition to packing [2].

Numerous studies have shown a negative result amongst the different management approaches to treat sternal wound infection [12,33,38]. This led to the increased interest shown in plastic procedures. Common examples that are used in DSWI include advancement or turnover of bilateral pectoralis muscle flaps [12,35]. In recent years, the Omentum flap has become an ideal method for the treatment of DSWI [39]. It acts to fill up cavities and cover infected artificial material allowing effective infection control [39]. It is mostly used in complex wounds with a chance of sternal loss, however, it also commonly used in patients with methicillin-resistant *Staphylococcus aureus* (MRSA), candida or diabetes mellitus [40–42]. Omentum flap is an alternative to pectoralis muscle use and has benefits such as an increase in immunological defence mechanisms, angiogenesis, and antimicrobial properties in dead space [38,40,43]. Although there is a reduction in mortality rates seen during this form of surgical management, it does not come without risk. Examples include trauma, flap-related morbidities such as hernias, and muscular pain [44]. The options of the management of SWI are summarised in Table 7.

Can We Prevent It?

In the case of SWI health boards have produced a set of guidelines to prevent wound infection from occurring that can be carried out preoperatively, intraoperatively, and postoperatively [2].

Before cardiac surgery, steps to prevent SWI include taking nasal swabs or polymerase chain reaction tests [2]. This is useful as most SWIs are caused by *Staphylococcus* species which arises in a majority of the patient's nasal flora [2]. *Staph aureus* is carried in 20–30% of the population and the patients who carry *Staph aureus* are three times more likely to be infected by *Staph aureus* postoperatively [2]. Other preventive measures that can be applied perioperatively include nasal disinfectants, preoperative bathing with chlorhexidine, smoking cessation, glycaemic control, and antibiotic administration [2].

Intraoperative preventative measures consist of antibiotic administration within 60 minutes of cardiac surgery, maintenance of glycaemic control, topical antibiotic application to areas of the cut, as well as adopting surgical techniques to avoid infection [2]. A study by Zerr et al. [45] included 8,910 patients who underwent cardiac operations between 1987 and 1993. A total of 1,585 (18%) of these patients were diabetic and, with an optimal diabetic control, the rate of deep wound infection was reduced from 2.4% to 1.5% [45]. Lastly, in terms of postoperative prevention methods, studies have suggested external chest support vests limiting chances of infection, antibiotics administration postoperatively for no longer than 2 days, and maintaining serum blood glucose

Table 7 Options of managing sternal wound infection (SWI).

	Surgical methods	Medical methods
Deep SWI	• surgical debridement and • drainage of all infected spaces • irrigation with drainage tubes • bilateral pectoralise muscle flaps • omentum flap	• antibiotic therapy
Superficial SWI	• Sternal incision for drainage and dressing • Negative wound therapy	• antibiotic therapy

levels in the ICU for a minimum of 1 day [2]. A study by Michael et al. [46] reported the clinical efficacy for primary reinforcement of the sternum with a new design of thorax support vest [46]. A total of 455 patients was started in September 2007 on the Posthorax® (Epple Inc., Vienna, Austria) sternum vest and a favourable outcome to prevent sternum instability after cardiac surgery was reported where one reoperation in patients treated with the sternum vest occurred in comparison to 16 in the control group [46]. The measures to prevent SWI are summarised in Table 8.

Zero Rates For Sternal Wound Infection Post Cardiac Surgery–Is it Fact or Fiction?

Sternal wound infection is a serious complication after surgery that costs health care systems around the world [47]. Although researchers and clinicians have a deep understanding of the pathophysiology of SWI and have developed effective surgical and non-surgical treatment options for SWI, it still causes financial instability, physical disabilities, and psychological impediment [47]. However, there are studies that have published a way in which the negative impact of SWI can be reduced [47]. An example of this is reported in a study by Raja et al. [47] at Harefield hospital that constructed a 5-year management plan, with the primary focus on pre-emption and prevention [47]. The strategy involves drawing attention to adjustable pre, intra, and post-operative risk factors as well as infection prevention and control [47]. The outcome has been positive where rates of SWI have dropped significantly which can result in complete elimination of SWI, otherwise known as a 'zero rate' [47].

However, a study by Kieser et al. [48] concluded that it is impossible to predict a 'zero rate' as a risk can never be completely eradicated [48]. The study attempted to introduce infection prevention measures, to help reduce DSWI in coronary artery bypass graft in 1,001 coronary artery bypass procedures [48]. They found the risk of infection was reduced close to a 'zero rate' through layers of infection prevention and that no single measure was critical [48].

To summarise, although the battle with SWI has been ongoing for many years, there are studies that show the prevalence at a local level is decreasing. To achieve complete eradication of SWI, there needs to be a national effort involving the institution to collaborate with practices and agencies, allowing a higher chance of elimination of SWI after cardiac surgery [47]. Harefield hospital has presented hope in this

Table 8 Possible measures to prevent sternal wound infection (SWI).

Preoperative measures	• nasal swabs or polymerase chain reaction tests for staphylococcus • species nasal disinfectants • preoperative bathing with chlorhexidine • smoking cessation • adequate glycaemic control • appropriate antibiotic therapy
Intraoperative measures	• prophylactic antibiotic administration within 60 minutes of incision • maintenance of appropriate glycaemic control • topical antibiotic
Postoperative measures	• External chest support vests • Postoperative antibiotics administration for no longer than 2 days • Adequate glycaemic control in the intensive care unit (ICU) for at least 1 day

Table 9 Concluding remarks on the diagnosis and the management of SWI.

Clinical awareness	Physicians should pay attention high-risk individuals in developing SWI • Patients who have a high BMI • Patients with multiple co morbidities including PVD, DM and COPD • Patients necessitating perioperative IABP support ventilatory support, receiving more grafts in CABG and receiving surgeries of longer duration
Timely diagnosis	Physicians should have a high degree of vigilance to detect the clinical features of SWI and arrange microbiological workup with imaging investigation such as CT and US with as less delay as possible
Appropriate treatment	Antibiotics should be offered with appropriate source control, with the consideration of the level of infection and the causative organisms.
Essential practices in prevention	Preoperative, intraoperative and postoperative measures are effective and important in preventing SWI. They include appropriate use of antibiotics, adequate glycaemic control and other measures.

Abbreviations: SWI, sternal wound infection; BMI, body mass index; PVD, peripheral vascular disease; DM, diabetes mellitus; COPD, chronic obstructive pulmonary disease; IAPB, intra-aortic balloon pump; CT, computed tomography; US, ultrasound; CABG, chronic obstructive pulmonary disease.

plan of action, through reducing SWI to less than 2% and completely removing mediastinitis in their practice [47].

Alternative Treatment With Hyperbaric Oxygen

There have been advocates promoting the use of hyperbaric oxygen (HBO) in the management of SWI alongside traditional treatments [49]. Oxygen is essential in the processes of wound healing, as demonstrated by the significant degree of oxygen extraction from the wound tissue which, in turn, facilitates a number of processes [50], such as leukocyte migration, collagen formation and vascular growth [51]. Hyperbaric oxygen therapy is the elevation of partial oxygen pressure as a form of treatment with the consideration of the risk of oxygen toxicity versus the degree of oxygen delivery. There is established evidence that favours the use of hyperbaric oxygen hand-in-hand with standard medical and surgical treatment of SWI [52]. Yet the hospital units which are able to provide hyperbaric oxygen treatment are limited–this has been a major factor that hinders the wider use of HBO in the routine management of sternal wounds.

Conclusion

In conclusion, despite the progress made with infection control and prevention, sternal wound infection is a concerning postoperative complication following cardiac surgery due to its impact on increasing postoperative hospital stay, morbidity, mortality, and costs [36]. With regards to choosing a gold standard imaging modality, CT and PET are promising however, the sensitivity of CT scans is not completely reliable and therefore it is not an ideal imaging technique to use by itself and results should be confirmed using other diagnostic tools [13]. Table 9 is a concluding remark that summarises the essential pointers in the diagnosis and the management of SWI. Further multicentre, large studies are required to establish the consensus on identifying optimal diagnostic measures for sternal wound infections.

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