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REVIEW ARTICLE

Sternal wound closure in the current era: the need of a tailored approach

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Abstract

Objective Median sternotomy remains the most common access to perform cardiac surgery procedures. However, the experience of the operating surgeon remains a crucial factor during sternal closure to avoid potential complications related to poor sternal healing, such as mediastinitis. Considering the lack of major randomized controlled trials and the heterogeneity of the current literature, this narrative review aims to summarize the different techniques and approaches to sternal closure with the aim to investigate their reflections into clinical outcomes and to inform the choice on the most effective closure method after median sternotomy.

Methods A literature search through PubMed, Embase, EBSCO, Cochrane database of systematic reviews, and Web of Science from its inception up to April 2019 using the following search keywords in various combinations: sternal, sternotomy, mediastinitis, deep sternal wound infection, cardiac surgery, closure.

Results Single wire fixation methods, at present, seems the most useful method to perform sternal closure in routine patients, although patients with a fragile sternum might benefit more from a figure-of-eight technique. In high-risk patients (e.g. chronic pulmonary disease, obesity, bilateral internal mammary artery harvesting, diabetes, off-midline sternotomy), rigid plate fixation is currently the most effective method, if available; alternatively, weave techniques could be used.

Conclusion The choice among the sternal closure techniques should be mainly inspired and tailored on the patient's characteristics, and correct judgement and experience play a pivotal role. A decisional algorithm has been proposed as an attempt to overcome the absence of specific guidelines and to guide the operative approach. This operative approach might be used also in non-cardiac procedure in which median sternotomy is required, such as in case of thoracic surgery.

Keywords Sternal · Mediastinitis · Sternotomy · Coronary artery bypass grafting

Introduction

Although the current trend in cardiac surgery is to create a subspecialty with dedicated team and training for each procedure [1, 2], there is paradoxically a paucity of research addressing one common aspect of most procedures: what is the most effective method of sternal closure after median sternotomy? The major randomized trials and guidelines do not describe the details of the closure techniques and the experience of the operating surgeon in this crucial part of the operation [3, 4]. On the other hand, the basic and clinical research on sternal closure methods is populated by few small-sized clinical trials and several observational, very heterogeneous studies. The relevance of sternal wound complications is particularly important in the postoperative recovery and might influence patient's course in the

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rehabilitation facilities, by reducing mobility and requiring specific measures such as antibiotics, support vests or, in extreme cases, reoperation. This article intends to review the current literature on the different techniques and approaches to sternal closure with the aim to investigate their reflections into clinical outcomes and to inform the choice on the most effective closure method after median sternotomy.

Methods of sternal closure

Stainless-steel wire sutures

The primary sternal closure method is currently fixation using stainless-steel wire sutures. This contrasts with other specialities where rigid fixation has been adopted. This is due to numerous factors such as the low cost, decreased training requirements and the relatively low rate of complications [5].

Single wire

The use of a single stainless-steel wire is common in sternotomy closure. These sutures can be passed around the sternal body (parasternal) or pass through the body (transsternal) (Supplementary Fig. 1). It has been demonstrated that the use of six or fewer wires had a 4.2% rate of sternal wound infection, compared to 0.4% when utilizing seven or more [6]. The addition of sutures caudally on the sternum strengthens the fixation and results in a reduction in the incidence of sternal wound infections, highlighting the relationship between a good bony union and infection [7].

Double wire

The addition of a second wire allows for further resistance to the tearing through the sternum, better distributing the forces acting upon the sternum (Supplementary Fig. 1). This has been demonstrated in cadaveric studies showing double wiring to be more biomechanically stable compared to a single wire technique [8]. In obese patients the use of a double wire was shown to be a dependable method in reducing sternal dehiscence when compared to a single wire [9], but those results were not replicated in literature.

Figure-of-eight

Further modifications of the single wire technique have been developed to decrease the incidence of bone cutting. The figure-of-eight pattern (Supplementary Fig. 2) makes the attempt of increasing the surface area of wire that is in contact with the sternum and increasing the length of bone which the wire would have to cut through to tear the bone. Additionally, the shearing forces emitted on the sternum are oblique or horizontal in contrast to the perpendicular forces of the single wire method. This results in a decreased rate of wire fracture or loosening [10]. Despite being a commonly used technique in sternal closure, the evidence behind the figure-of-eight suture is debated. In a study of 98 patients undergoing CABG there was no significant difference in rates of sternal dehiscence found between the figure of eight group and the single wire group [11]. A study compared the figure-of-eight model with the single wire method by creating a biological sternotomy closure model utilizing porcine sternums. It was demonstrated that failure of the single wire model required a higher biomechanical force than the figure-of-eight model, thus suggesting that the single wire method is more robust than the figure-of-eight [12]. A meta-analysis compared 111 studies which consisted of either biomechanical testing of sternal wires or clinical papers reviewing the authors own experience of each technique. It was stated that the figure-of-eight wire method was not superior to the single wire method in sternal closure [13]. Conversely, an observational register study examined 7835 patients with the figure-of-eight method and 2122 patients with the single wire method. In 0.06% of patients undergoing the figure-of-eight wiring reoperation due to sternal dehiscence was required compared to 0.66% in the single wired group, concluding that figure-of-eight is a superior closure method [14]. At present, considering conflicting results, there is no consensus as to whether the figure-of-eight method provides any benefit when compared to the single wire technique for unselected patients. Some modifications of the figure-of-eight technique, such as the interlocking sutures variation (Supplementary Fig. 3), have been recently shown to be a promising alternative for sternal closure in case of fragile sternum [15, 16], yet requiring an adequate validation.

Weave

The "Robicsek's weave" technique (Supplementary Fig. 4) was introduced in 1977 to prevent rupturing of the sternal bone by anchoring of the wires. A continuous wire suture is passed anteriorly and posteriorly to the costal cartilage alternatively, providing lateral support. Parasternal sutures are then utilized as described above in the single wire technique [17]. This method was developed for use in patients with a fragile sternum. However, the constrictive weaving of the wires has the potential to disrupt the collateral blood supply to the sternum. Simplified adaptations of this method have allowed to avoid the risk of this complication by removing the wires encircling the costal cartilages [18]. Further disadvantages of the weave method are an increased surgical time and the fact that the cranial and caudal ends of the sternum might be not adequately approximated [10].

A prospective study suggested that for high-risk patients (with more than two risk factors such as chronic obstructive pulmonary disease, osteoporosis, obesity, off-midline sternotomy, or NYHA class ≥ 3) the weave technique should be utilized to minimize postoperative complications and morbidity [19]. A recent meta-analysis evaluated seven studies including both the Robicsek method and adapted versions. It was concluded that there was no significant difference between the techniques in patients with risk factors such as osteoporosis and diabetes [17].

Sternal bands

An alternative to parasternal wiring is the use of interrupted steel bands (Supplementary Fig. 5). The concept of a band is to decrease the stress placed upon the sternum allowing for the load to be distributed over a larger surface area. There are, however, drawbacks to the technique: the rigidity of the band means that they cannot conform to the shape of individual sternums; also, if re-operation for postoperative bleeding is required the bands are potentially difficult to cut and, apart from the tightening device, there is no locking apparatus [20]. A retrospective study compared the use of sternal bands in high-risk patients with the conventional single wire method. The incidence of sternal dehiscence and mediastinitis in the steel band group was lower compared to the single wire group [21]. Therefore, steel bands might be a valid method to decrease sternal closure complications in high-risk patients [22].

The increased cost of steel bands has been discussed in the literature as a disadvantage to the technique. However, the increased incidence of infection and prolonged hospital stays associated with steel wiring is greater than the cost of steel bands, or indeed the cost of a possible reoperation to remove a band. This suggests that the use of steel bands in high-risk patients might be an effective way to control medical costs. The combination of steel wires and bands has been demonstrated as a lower-cost alternative to steel bands in isolation whilst still showing a statistically significant decrease in the incidence of sternal dehiscence [23].

Polymer cable ties

Polymer cable ties, called "Zipfix cable ties"(De Puy Synthes, West Chester, PA, USA), are made of poly-ethyl-etherketone(PEEK), a surgically implantable plastic (Supplementary Fig. 6). Premarket biomechanical studies have shown that Zipfix have superior strength and fatigue resistance to stainless steel wire. Benchtop studies have shown that Zipfix are less likely to cut through bone than wires as they are 5 mm wide, making them particularly useful for osteoporotic bone [24].

A recent study compared the use of sternal bands with the conventional single wire method. Authors enrolled 120 patients and randomized the day prior to surgery to either standard wire closure with six to eight single wires(dependent on patient size), or Zipfix closure using a single wire high in the manubrium then five Zipfix cables [24]. Although there appeared to be more movement in the manubrium and body of the sternum in the Zipfix group at four weeks follow-up, this was not associated with any increased pain or analgesic requirements in that group either in hospital or at four weeks [24].

Sternal plates

Other possible methods to reduce the incidence of the complications of standard sternal closure techniques relies in rigid fixation techniques, which aim to decrease movements after sternotomy, reduce postoperative pain and improve primary bone healing rates [25].

A cadaveric biomechanical study emphasized rigid fixation superiority to wire fixation in allowing good bone healing. The experimental fixation method utilized 'H'-shaped titanium plates that not only provided superior rigidity and decreased lower-lateral displacement, but also preserved sternal blood supply [25] (Supplementary Fig. 7). However, the cost associated with the technique remains a drawback despite rigid fixation techniques operative times are shorter than with standard wiring techniques. The potential damage caused by the drill to nearby structures and emergency reopening of the sternum were major concerns.

More recently the development of self-tapping screws has made drilling into the sternum easier and safer. Plate designs, such as the Sternalock, have been developed specifically to allow re-entry, allowing for a midline cut using standard wire cutters [26].

The advantages of sternal plates over wire fixation have been illustrated previously in animal studies [27]. A retrospective analysis with matched perioperative risk factors demonstrated that wire fixation had a significantly higher frequency of mediastinitis than plate fixation, particularly in high-risk patients [28-30].

The first randomized control trial that associated rigid plate fixation with improved clinical outcomes and sternal healing was published in 2017. 236 patients were randomized into either a wire fixation or rigid plate fixation, resulting in significantly superior sternal healing and a lower complication rate at 6 months in the rigid fixation group. Additionally, it was illustrated that there was no difference in cost between the groups [31].

A meta-analysis including three randomized control trials and five observational studies found that at 6 months follow-up there was no significant difference between rigid fixation and wire groups in terms of sternal complications. However,

when analyzing the subset of patients deemed at high risk, a decrease in these complications was demonstrated [32]. This meta-analysis, driven by the results of unmatched observational studies, suggested that rigid plate fixation may lead to reduced sternal complications in high-risk patients, improved perioperative survival, and decreased hospital length of stay. Additionally, plate fracture and delayed sternal dehiscence have been reported in the extreme obesity population (BMI > 40), and studies with longer follow up periods are required to investigate the longevity of this technique [30, 33].

Adjunct strategies

The importance of an adequate sternum approximation has been pointed out in the literature, despite the ideal closure technique is still debated. Considering the specific risk factors and differences related to patient-specific situations, a tailored approach seems reasonable, reserving weave technique or device-assisted closures in patients deemed at high risk for mediastinitis or mechanical failure of the sternum. However, besides mechanical closure, it is important to describe the role of internal or external supports in sternal fixation. In addition, recent advances in tissue engineering have been described even in the field of sternal fixation. Future researches will help in clarifying whether tissue engineering approaches might be an effective adjunctive therapy to reduce post-sternotomy complications.

Internal aids: gentamicin-containing collagen sponges

Intravascular antibiotic prophylaxis given prior to surgery has consistently demonstrated a reduction in rates of infections post-operatively [34]. Collagen sponges containing gentamicin (Supplementary Fig. 8) were developed aiming to deliver high doses of gentamycin locally, and minimizing surgical wound infections whilst avoiding systemic concentrations associated with nephrotoxicity [35]. A randomized control study, the LOGIP trial, evaluated 2000 patients concluding that the treatment group had a significantly reduced risk for post-operative sternal wound infections, the incidence being 4.3% compared with 9.0% in the control group [36]. There was a concern that the use of local gentamycin could result in microbial resistance. However, this study found that after 7 years of use there was no trend suggesting decreased effect over time. Additionally, there was no change in the type of causative bacteria [37]. These results suggest that the prophylactic effect demonstrated in the LOGIP trial is maintained over time, without the feared complication of resistance.

A meta-analysis of 21 randomized control studies illustrated that the use of gentamicin-collagen sponges was associated with a significant reduction in sternal wound infections. It was, however, stated that many of these trials were not of high quality and to determine the effect of gentamycin-collagen sponges on mortality rates further high-quality randomized control studies are required [38].

External aids: support vests

To reduce mechanical stress after median sternotomy, patients could use a post-operative thoracic support device. These corsets could be useful to provide antero-posterior stabilization while holding the two halves of the sternum in place. Beyond the specific models on the market, most of the support vests share similar biomechanical principles.

Two cushions are placed longitudinally on the left and right sides of the sternum and serve as shock absorbers when the patient coughs or breathes deeply, as well as supporting the sternum when the patient is turned in his/her bed. The use of support vests is known to reduce the mechanical complications of sternal healing and, therefore, the sternal dehiscence. Caimmi et al. [39] performed a prospective, randomized study analyzing 310 patients with predisposing factors for sternal dehiscence after sternotomy for cardiac surgery. Patients using vest demonstrated a lower incidence of mechanical sternal complications, a better anatomical sternum healing, lower hospital stay, no re-operations for sternal dehiscence before discharge and lower re-admissions for mechanical sternal complication. In addition, patients using a vest reported a better quality of life with better freedom from limitations in mobility, self-care, and pain. Vos et al. [15] also described similar result in their study. They performed an extensive literature search to assess interventions in the prevention of deep sternal wound infection. Out of 743 unique studies, a significant reduction in deep sternal wound infections was noted in the support vest group.

Tissue engineering constructs

Bone tissue engineering is becoming of interest clinically to repair and regenerate bony defects. Tissue-engineered constructs (TEC) have been developed via the implantation of autologous osteogenic cells in biodegradable scaffolds which mimics the extracellular matrix(ECM) (Supplementary Fig. 9) [40]. The implantation of biologically active signals within the scaffold ECM has been suggested to augment, induce or support progenitor cell growth and differentiation towards a desired lineage [41]. Poly (L-lactic acid) (PLLA) has been greatly investigated in the literature due to its biocompatibility and its ability to be modified with inorganic materials, improving its biological properties for tissue engineering purposes [42]. Calcium phosphates, such as hydroxyapatite(HA) and tricalcium phosphate(β-TCP), have a similar mineral component to natural bone, and their

properties allow for the formation of new bone and have resulted in their use clinically as bone substitutes [43]. A study used PLLA/HA scaffold across the sternal fracture during closure of a rabbit model of median sternotomy, directly exposing the scaffold to the bone marrow. The scaffold-treated group achieved complete healing a week before the control group. Additionally, in comparison to the control group, the neo-formed bone within the scaffold had histologically a higher degree of maturity, due to the presence of trabeculae. The study concluded that, compared to conventional closure techniques, this tissue engineering approach allows for improved healing and tissue remodeling [44]. Because these approaches do not involve the use of autologous cell culture, many of the limitations of previous studies such as cost, time and logistics might be overcome [44, 45].

Bioabsorbable sternal pin have been recently adopted as an adjunct to various closure technique, being placed within the sternum before sternal closure [46, 47] and thus preventing the antero-posterior and cranial-caudal displacement of the sternum [48, 49]. Recently, a mixture of PLLA and uncalcined hydroxyapatite showed higher mechanical strength and proved to be completely resorbable, and its clinical application resulted in reduced antero-posterior sternal displacement with earlier sternal fusion, thus promoting osteogenesis [50]. This beneficial effect was recently confirmed in the pediatric scenario, with reduced incidence and severity of sternal protrusion [51].

The clinical application of bone tissue engineering is a rapidly growing field. Despite this, numerous limitations have been identified. Fundamentally, the most effective scaffold/cell type/growth factor combination has yet to be found. Additionally, achieving adequate vascularization and host integration could prove to be a challenge and should be carefully evaluated in tailored long-term studies. This is especially important in median sternotomies post CABG, in which the use of one or both internal thoracic arteries could affect sternum vascularization. The cost of tissue engineering is also another main limitation. As an attempt to reduce costs, biologic bone adhesives (such as Kryptonite bone cement) have been shown to provide an adequate sternal fixation and reducing the sternal displacement under physiologic loading conditions, with feasible sternal re-entry if required; however, long-term studies are required [52–54].

Autologous platelet gel

Application of growth factors within platelets stimulates the body's natural healing. Autologous platelet gel (APG), the combination of these growth factors and a mixture of calcium and thrombin, can be applied to surgical wounds to aid healing. The use of APG in cardiac procedures has been investigated in the literature. It has been observed that the incidence of both superficial and deep sternal wound infections were reduced in groups treated with APG compared to a control group [55]. These findings have been reproduced in further studies which additionally suggested that APG could decrease the rates of pain, bruising and blood loss post-surgery [56]. A pilot study found that both leg and chest pain post-surgery was decreased in the group treated with APG [57]. Further, larger, studies are required to see if these promising results can be reproduced reliably.

Discussion

The critical scenario: patients undergoing CABG

CABG can be considered a special cardiac procedure in terms of sternal closure, as it implies mammary artery harvesting and patients at higher risk for cardiovascular disease; those risk factors, such as diabetes or obesity, might affect sternal closure [58, 59]. The recent guidelines and results arising from the largest randomized clinical trials on coronary artery bypass surgery (CABG) have opened an intense debate on the widespread use of total arterial techniques in myocardial revascularization [58, 59]. Apart from the technical challenge, the main criticism towards total arterial revascularization (TAR) using bilateral internal mammary artery regards the risk of sternal wound infection and dehiscence requiring reoperation [60, 61].

The evidence in favor of right internal thoracic artery has been acknowledged since the initial report by Lytle and colleagues, heralds of the bilateral internal thoracic artery

(BITA) "era" [62]. Subsequent studies have been systematically analyzed in meta-analyses over the last decade which showed a survival advantage provided by the addition of a second ITA at the expense of an increase in the risk of sternal wound complications, as deep sternal wound infections (DSWI) [63–68]. Despite being remarked as one of the Achilles' heels of BITA grafting in the ART Trial [60], the actual importance of DSWI has been underrated when balanced against the benefit in morbidity and survival provided by BITA [63].

However, the association between BITA and DSWI remains a concern for short-term outcomes in the real-life scenario [3, 5, 15, 69–74], and several risk factors have been reported in the literature (Table 1). Also, DSWI is associated with a significant mortality rate, ranging from 14 to 50% [18], and increased costs for subsequent hospitalization and treatment [75]. The relationship between sternal wound infections and sternal dehiscence has suggested that infection can be secondary to instability of the sternal wound postoperatively [76]. Achieving an adequate bony union is dependent on a dynamic fixation and approximation of the two sternum halves, which allows for repair of the wound via

Table 1 Overview of the risk factors for deep sternal wound infection after CABG [3, 5, 15, 71, 72]

Preoperative factors	Operative factors	Postoperative factors
Diabetes	Paramedian sternotomy	Blood transfusions
Corticosteroid use	Sterility breaks	Re-exploration
Obesity	Prolonged operative time	Longer hospital stay
Chronic pulmonary disease	Bilateral internal mammary artery	
Osteoporosis	Poor closure technique	

the formation of blood vessels and the subsequent supply of nutrients. Patient-specific risk factors and operative strategy for sternal closure play a pivotal role in the prevention of DSWI and, potentially, in improving outcomes of multiple arterial grafting.

Sternal closure in the everyday practice: current state and decisional approach

The limitations of the literature on the topic of sternal closure regard the absence of a clear, consistent definition of the outcomes to be measured. Notably, one of the main outcomes, mediastinitis, is not only related to ineffective sternal closure. This makes the comparison of studies difficult (with some focusing on sternal instability and others dehiscence and infection) and determines variability between findings. There are numerous inconsistencies between studies and the lack of randomized control trials, as well as heterogeneities in retrospective studies, further harness the reliability of the results. Randomized control studies are more challenging in a surgical environment and blinding cannot be achieved due to the visible nature of the method and the variations in the skill level of surgeons conducting the trials. Despite the use of various sternal fixation techniques, there is high variability (and mostly no definition nor a protocol) for the entire procedure of sternal wound closure. This is of major importance, as there is variability between single surgeons and their techniques, although they may use the same technique of bone fixation. Thus, all the reviewed results are highly influenced by a variety of biasing variables despite the ones of the patients. Many studies do not analyze operative and ventilation times, with different protocols for each technical step.

As a result, and considering the advantages and disadvantages of each closure technique (Table 2), no clear directions or recommendations in sternal closure have been defined leaving this part of the operation to the discretion of surgeons and their experience.

In the single wire technique, the use of seven or more wires and the addition of sutures caudally on the sternum strengthens the fixation and results in a reduction in the incidence of sternal wound infections [6]. However, it has been demonstrated that the presence of risk factors such as osteoporosis could result in the wire sutures cutting through the sternum [7], and despite the low cost and many advancements to the single wire fixation method, no adaptation has been shown to overcome the complications found in high-risk patients. Despite conflicting results, figure-of-eight closure seemed to be superior to interrupted steel wire closure in case of fragile sternum [14]. Steel bands have been shown to be a method of decreasing sternal closure complications and medical costs in high-risk patients compared to standard wiring methods [21, 23]. Similarly, rigid fixation methods using sternal plates may lead to reduced sternal complications in patients at high risk, improving perioperative survival [32]. However, steel bands and sternal plates are not available in many cardiac surgery centers for routine procedures.

Large clinical practices from individual surgeons have generated suggestions to reduce the incidence of DSWI after CABG, such as the avoidance of bone wax, the use of harmonic scalpel harvest of ITAs, vancomycin paste on sternal marrow, iodine-impregnated skin drapes, chlorhexidine-alcohol skin preparation, and marrow irrigation before sternal approximation [3, 77, 78]. However, these and other recommendations remain at the level of "expert opinion" and greatly differ with the practice and experience of the different units and surgeons. The beneficial effect of these maneuvers should be validated in larger tailored studies.

From the current data on the comparative performance of one or the other method including efficacy, durability and cost-effectiveness it seems that the choice among the sternal closure techniques should be mainly inspired and tailored on the patient's characteristics. A decisional algorithm (Fig. 1) has been proposed as an attempt to overcome the absence of specific guidelines and to guide the operative approach.

Conclusion

Post-sternotomy wound complications pose a significant problem in high-risk patients, and patients undergoing CABG are at highest risk of complications. The absence of consensus in the literature and the severe lack of randomized control studies regarding the optimal sternal closure method has resulted in the inability to numerically compare previous

Table 2 Advantages and disadvangages of current sternal closure techniques

Technique	Advantages	Disadvantages
Single wire	Easy to use	Requires seven or more wires
	Allows a good bony union in most patients	Potentially harmful in case of fragile sternum(bone cutting)
Figure-of-eight	Potential benefit in osteoporotic sternum	Conflicting results in literature
	Biomechanical benefit(larger surface area)	
Weave	Potential benefit in osteoporotic sternum and in high-risk patients[a]	Conflicting results in literature
		Disrupted collateral blood supply to the sternum
		Increased surgical time
		Inadequate approximation of cranial and caudal ends
Sternal bands	Potential benefit in osteoporotic sternum and in high-risk patients[a]	Unable to adapt to the shape of the sternum
	Biomechanical benefit(larger surface area)	Difficult to cut in case of urgent re-exploration(such as re-exploration for postoperative bleeding)
		No locking apparatus
		Increased costs
		Not available in any center
Polymer cable ties	Potential benefit in osteoporotic sternum and in high-risk patients[a]	Prolonged sternal instability
		Needs tailored studies
	Easy to use	Not available in any center
Sternal plates	Potential benefit in osteoporotic sternum and in high-risk patients[a]	Not available in any center
	Decreased lower-lateral displacement	Difficult to cut in case of urgent re-exploration(such as re-exploration for postoperative bleeding)
		Potential delayed sternal dehiscence
	Preserved sternal blood supply	Potentially ineffective in extremely obese patients
	Shorter operative time	Increased costs(?)
	Shorter postoperative length of stay	

[a]High-risk patients: chronic pulmonary disease, obesity, bilateral internal mammary artery harvesting, diabetes, off-midline sternotomy

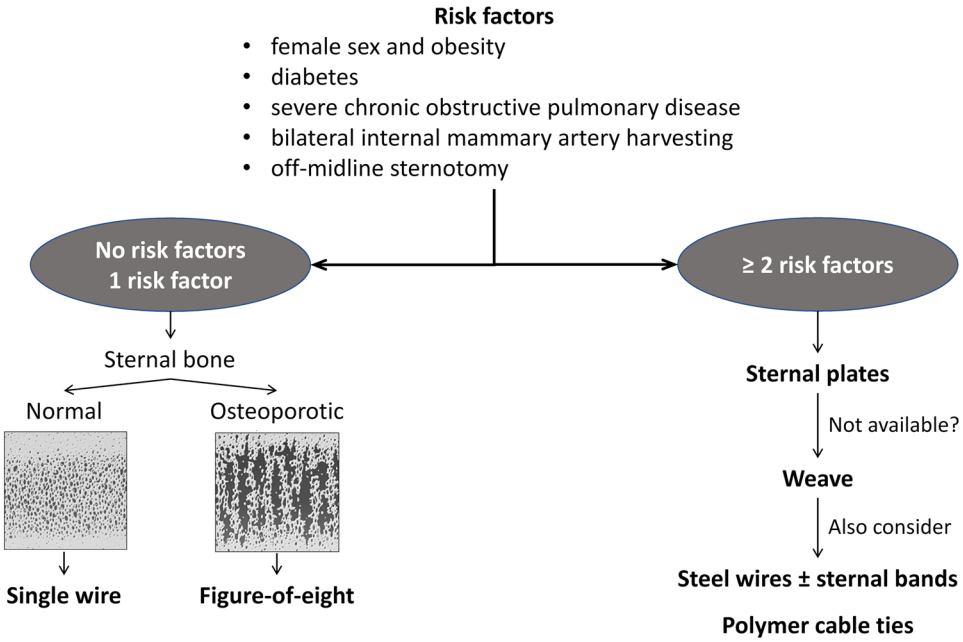

Fig. 1 Tailored sternal closure: proposed decisional algorithm

studies and a definitive answer regarding the optimal fixation method requires further investigation.

Correct judgement and experience remain the most important factors for a proper sternal closure. Single wire fixation methods, at present, seems the most useful method to perform sternal closure in routine patients, although patients with a fragile sternum might benefit more from a figure-of-eight technique. In high-risk patients, however, rigid plate fixation is currently the most effective method, but further randomized control studies are required to confirm the reliability of this observation. In everyday clinical practice, the use of sternal plates depends mainly on the availability in each center. If not possible, sternal plates should be replaced by weave techniques. The correct use of a postoperative support vest should be encouraged in all patients and this appears to be extremely important in rehabilitation settings.

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Compliance with ethical standards

Conflict of interest All authors state no conflicts of interest.

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