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REVIEW

Subxiphoid incisional hernias after median sternotomy

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Abstract
Background Subxiphoid incisional hernias are notoriously difficult to repair and are prone to recurrence. The few reports on subxiphoid hernia published over the last two decades have not fully addressed the etiology, pathology, treatment, and outcome of this problem. This review was performed to analyze the published experience and increase the understanding of these difficult hernias.
Methods We reviewed the extensive literature, including the Medline and Current Contents computerized database searches, and searched the available bibliographies.
Results Seven retrospective studies of a total of 113 patients who had clinical subxiphoid hernias after median sternotomy were found. An additional surgical technique describing a modified median sternotomy preventing the hernia, and a single review article on selected technical considerations of subxiphoid ventral repair were also found.
Conclusions The incidence of subxiphoid hernia after median sternotomy can be possibly reduced by paraxiphoid extension of the sternotomy, reinforcement near the xiphoid end of the incision, or by optimizing closure of the distal sternotomy and the *linea alba*. Abdominal wall reinforcement by open-mesh closure or laparoscopic transperitoneal prosthetic repair can effectively deal with the defect. Long-term outcome analyses are not yet available.

Keywords Subxiphoid hernia · Median sternotomy · Hernia · Mesh repair · Tissue repair · Laparoscopic surgery

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Introduction

Subxiphoid incisional hernias after median sternotomy typically occur in the epigastrium, where the incision extends into the abdomen. They are notoriously difficult to repair and are prone to recurrence. Although their reported incidence is between 1% and 4.2% [1–9], their true incidence is difficult to estimate for at least two reasons. First, most subxiphoid hernias are small and asymptomatic. Thus, many patients do not seek medical attention. Second, long-term follow-up of a large group of patients with median sternotomies sufficient to make this assessment has not been described [8]. A recently published study from the Cleveland Clinic reported 117 repaired hernias among 24,000 patients who underwent median sternotomy (0.5%). However, the authors could not calculate the true incidence because of the significant number of national and international referrals in the patient population studied [9].

The few reports on subxiphoid hernia published over the last two decades have not fully addressed the etiology, pathology, treatment, and outcome of this problem. This review was performed to analyze the published experience and increase the understanding of these difficult hernias.

Review of the literature

The data reported herein are based on a literature review including the Medline and Current Contents computerized database searches. The following subject headings were searched and combined into search sets: sternum, hernia, anatomy, surgical wound dehiscence, and wound healing. Search sets of the following key words were used in addition to the subject heading terms: sternum, median sternotomy, hernia, subxiphoid hernia, subxiphoid space, anatomy, sternotomy closure, surgical wound dehiscence, xiphoid process, and wound closure. All variant combinations of subject headings and key words were checked. Finally, the existing bibliographies were explored for articles pertaining to the review.

The search of the literature and available bibliography revealed seven retrospective studies of a total of 113 patients who had clinical subxiphoid hernias after median sternotomy [1–3, 5–7, 9]. An additional surgical technique describing a modified median sternotomy in 2,500 patients very briefly reported a zero incidence of this hernia [4]. We were able to locate a single review article on the technical considerations of subxiphoid ventral repairs [8]. Of interest, the first of all xiphoid hernia series [1] was published 88 years after the first known description of median sternotomy [12], and 28 years after the incision was popularized as a contemporary approach to the heart and great vessels [13].

The clinical series of subxiphoid hernia are summarized in Table 1. Two articles focused on different aspects of the presentation and treatment of the same 20 patients [2, 3]. Overall, many of the demographic and technical details were not uniformly reported among the studies. Collectively, the majority of patients were male and their age ranged between 30 and 86 years. All patients had undergone median sternotomy extended to the midline epigastric area. The diameter of the defects identified varied from 2 cm to 15 cm. Between 35% and 100% of the hernias were symptomatic [1, 2]. Only one group provided details of their sternal closure method, which did not include suture of the xiphoid process [1]. Two studies reported that the *linea alba* was closed with absorbable material [1, 2]. Only two studies included patients with previously repaired hernias [1, 5]. Finally, only two studies reported on the postoperative time of detection, ranging from 3 days to 7 years [1], with a peak at 3–4 years [9].

Discussion

Surgical anatomy of the subxiphoid region

The borders of the subxiphoid space are created by the sternum and ribs superiorly, the rectus abdominis muscles and *linea alba* anteriorly, and the diaphragm posteriorly and inferiorly. The region's musculofascial structures are all anchored to the upper, osseous, or cartilaginous border, in

Table 1 Published studies of subxiphoid hernia (1985–2005)

Authors	Type of study	Patient number (n)	Recurrent	Incidence	Repair method	Follow-up	Recurrence rate
Cohen and Starling [1]	Retrospective	n = 14 (incarcerated n = 3)	n = 4[a]	NS	Marlex® onlay	4–36 months	0%
Davidson and Bailey [2][b]	Retrospective	n = 20	None	20/582 (4.2%)	Tissue approximation (n = 7, 35%)	NS	NS
Davidson and Bailey [3][b]	Retrospective	n = 20	None	20/582 (4.2%)	Tissue approximation (n = 8, 40%)	43 months	0%
Barner [4]	Technique (paraxiphoid incision)	n = 2,500 (sternotomies)	NA	0%	NA	NS	NA
Bouillot et al. [5]	Retrospective	n = 23	n = 3[a]	NS	Retromuscular Mersilene®	1–5 years	0%
Muscarella et al. [6]	Retrospective	n = 1	None	NS	Laparoscopic transperitoneal patch	6 months	None
Landau et al. [7]	Retrospective	n = 10 (incarcerated n = 1)	None	10/984 (1%)	Laparoscopic transperitoneal patch	20–42 months	1%
Mackey et al. [9]	Retrospective	n = 45	None		Primary repair (n = 14, 31%)* Mesh repair (69%)*: open n = 21 laparoscopic n = 10	27–69 months	Primary repair (n = 6, 43%) Mesh repair (32%): open n = 7 laparoscopic n = 3

NS = not stated, *NA* = not applicable; * no technical details

[a] Recurred after primary repair

[b] Duplicate publication with variation in the reported details

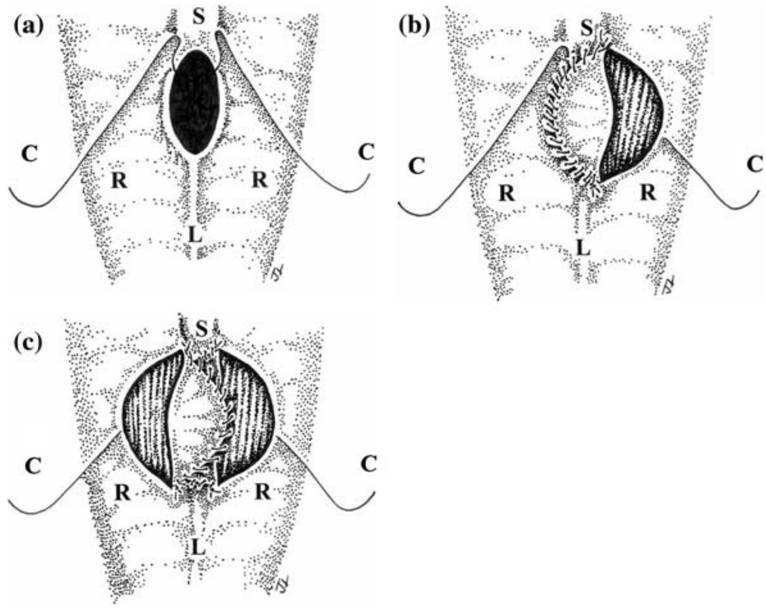

Fig. 1 Schematic drawing illustrating endogenous repair of the hernia (*black ellipse*) (**a**) using overlapping flaps of the left (**b**) and right (**c**) external oblique aponeuroses. *S* = sternum, *C* = costal arch, *R* = rectus abdominis, *L* = *linea alba*

the angle of which the xiphoid process emerges as a quite variable structure. Its multiple anatomic variants can be grouped into three main categories based upon the shape of the xiphoid. The xiphoid process may be categorized as small, long, or broad [8]. The rectus muscles and anterior rectus sheaths wrap up the front of the xiphoid region; the diaphragm, posterior rectus sheaths, and *linea alba* attach to the sternum and xiphoid process, thus, forming the boundary of the abdominal cavity.

The xiphoid process is incompletely ossified and is composed of cartilage in the majority of patients. It is firmly attached to four structures in the region: (1) the *linea alba* attaches to its anterior aspect; (2) the costoxiphoid ligament attaches its ventral and dorsal aspects to the 7th costal cartilages; (3) the transverse muscles of the thorax attach it to the 6th rib; and (4) the sternal portion of the diaphragm attaches to its posterior surface [1]. The arterial blood supply of the xiphoid process is limited when compared with that of the proximal sternum. In 61.3% of patients, blood is supplied by the so-called xiphoid artery, a terminal branch of the internal thoracic artery. This artery is found on the right side in 30.7%, on the left in 21%, and is bilateral in 9.7% of patients [14]. If the xiphoid artery is not present, the area is supplied by branches of the superior epigastric artery. Collateral blood supply to the area may be compromised if the internal thoracic or superior epigastric arteries are damaged or used as conduits in bypass procedures [14].

The preperitoneal space extends in a cranial direction behind the xiphoid process and forms the so-called retroxiphoid space, which is filled with fatty tissue. The sternal portion of the diaphragm, which is easily detachable by blunt-finger dissection, separates the retroxiphoid space and the lower anterior mediastinum, which also contains fatty tissue. The above-described relationship suggests how blunt-finger dissection behind the sternum can create a pocket which extends as far as the surgeon's index finger can reach. It must be noted that, in the majority of patients undergoing heart surgery, the myocardium is adherent to the posterior sternum. This limits the extent of blunt dissection because of a significant risk of myocardial injury.

Biomechanical considerations

The true etiology and pathogenesis of subxiphoid hernia after median sternotomy has not been fully elucidated. Both patient-related factors, such as impaired collagen metabolism, obesity, and older age, and technical factors, such as wound infection, absorbable suture material, and inadequate incisions and closures, may contribute to the genesis of this problem [15]. Recent studies of sternal biomechanics after median sternotomy suggest that the closure may start to fail at or near the xiphoid end of the incision in association with lateral traction forces caused by breathing or coughing [16, 10]. This suggests that separation of the lower sternum and xiphoid process may contribute to the hernia's etiology.

The *linea alba* is an area across which the tendinous aponeurotic fibers of the flat abdominal muscles (external, internal, and transverse) pass from one side to the other. This triple pattern crossing (also described using the term "decussation" [16]) is thought to specifically provide additional strength to the midline aponeurosis. Herniation has been described more frequently when only one layer (as opposed to three) of decussating fibers is present [11]. The aponeurotic fibers are oriented in oblique planes, forming a dynamic fabric that allows the fibers' configuration to change in response to movement of the trunk. This is exemplified by the absence of folds in the *linea alba* during flexion of the trunk while folds do occur in the skin, and the above-described adaptive function of the aponeurosis is lost as a result of post-surgical scarring [11].

During respiration and coughing, the abdominal muscles, fibers of the *linea alba*, costoxiphoid ligaments, transverse thoracic muscles, and the diaphragm all exert lateral distracting forces which, ultimately, result in increased fascial tension and possible fascial dehiscence [1, 11]. Biomechanical experiments using both human cadaveric and plastic surrogate sterna where most or all of the muscles were absent have demonstrated that lateral distracting forces transmitted through the ribs first cause sternal dehiscence at the xiphoid end of the incision [16, 10], suggesting that the distraction is mediated by the region's osseous geometry. One study found that the defects' distal border was formed by a bifid xiphoid process in all patients, supporting the theory of an early bony non-union [1].

Treatment of subxiphoid hernia

Subxiphoid hernia after median sternotomy is, in fact, a specific variety of incisional hernia. The contemporary treatment of the hernia follows a series of basic principles that are, or should be, common to all types of repair, whether open or laparoscopic, based upon extrapolation to this specific hernia of modern understanding of optimal hernia repair. These principles emphasize tension-free repair with permanent, well fixed, overlapping underlay prosthetic material, and are summarized in Table 2.

Table 2 General principles of ventral hernia repair [8, 9, 13]

Principle	Comment
Careful preoperative assessment	Multiple previous repairs operations may require open repair
Tension-free repair with permanent prosthesis	Monofilamented mesh (open repair); tissue-impervious composite on intestinal side (laparoscopic repair)
Mesh placement below rather than above the fascia	Retromuscular or preperitoneal in open repair; intraperitoneal (sublay) in laparoscopic repair
Requirement for healthy tissue at the edges	Mesh fixation away from the fibrotic defect margins
Adequate overlap between mesh and fascia	Ideally, 5 cm around all edges
Secure permanent fixation of the prosthesis	Multiple suture fixation; do not rely on tacks only if laparoscopic

Open repair

The retrospective nature of the reported series, small numbers, heterogeneous population, and the lack of detailed descriptions and statistical analysis all make it difficult for one to conclude how to best manage these hernias. Reinforcement of a subxiphoid defect through an anterior approach is technically challenging because of two reasons: (1) at the cranial aspect, the insertion of the posterior rectus sheath in front of and near the xiphoid process inhibits a sound overlap of the osseous border and (2) adhesion of the heart to the scar potentially increases the risk of myocardial injury as the dissection proceeds cranially.

Suture closure of the defect brings together the fibrotic, retracted fascial margins, and, thus, contradicts the principles of "tension-free" repair. Indeed, such closure has reportedly been associated with high recurrence rates, between 43% and 80% [1, 9]. Repair using permanent mesh has been reported to yield lower recurrence rates ranging from 0% to 32% [1, 3, 5, 9].

Open repair of subxiphoid hernia typically proceeds through the old incision and can be performed using various approaches, depending on the anatomy and the surgeon's preference. The hernia sac can be relatively easily dissected from the defect margins and reduced. A tension-free endogenous repair has used *linea alba*-based, overlapping flaps from the anterior rectus abdominis sheaths [3] (Fig. 1a–c). The literature provides no data on whether using a permanent prosthesis might be a better option [17].

Prosthetic repairs can proceed in one of several ways, including use of the preperitoneal space. The mesh can be anchored to the posterior rectus abdominis sheath and left either exposed in the subcutaneous space [1] (Fig. 2a) or covered with the external oblique aponeurosis, which has been relaxed by multiple incisions and approximated in the midline [5] (Fig. 2b), also known as the Clotteau method. The upper margin of the defect consists mainly of cartilage, which poses technical problems for reliable mesh fixation. Partial or complete resection of the scarred xiphoid process may be required to optimize exposure for the repair. Perichondral strips of mesh at the costal margin, although extremely painful, have provided very satisfactory attachment, with excellent long-term results in difficult hernias for which other repair methods were not available [18]. It must be noted that the costal perichondrium is very well innervated; encircling the ribs with foreign material can cause persistent pain and, therefore, should be avoided [8].

An effective sublay augmentation of the region requires an adequate cephalad overlap. The posterior rectus abdominis sheath must be transected at the costal margin in order to open the space between the peritoneum and the diaphragm. The maneuver helps to achieve a wide overlap cranial aspect of the defect, down to the hepatic veins and

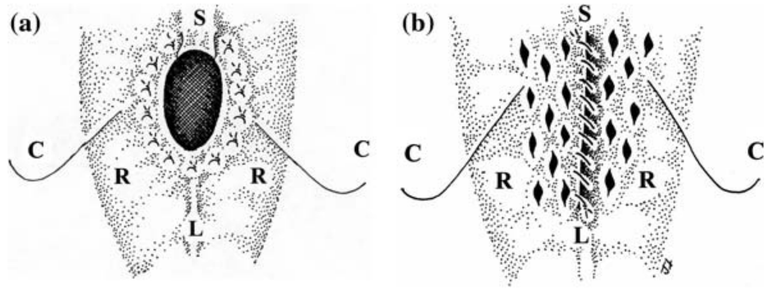

Fig. 2 Diagram showing a prosthetic screen in the preperitoneal space anchored with mattress sutures through the rectus abdominis sheaths (**a**), and the external oblique aponeurosis released by multiple relaxing incisions and closed on top of the mesh (**b**)

the esophagus (Fig. 3). Failure to achieve the overlap in the cephalad aspect approximates an *onlay* repair and carries a much higher recurrence risk.

The onlay method is, perhaps, the easiest and most reproducible technique for repair (Fig. 4). The ability to stay superficially in the subcutaneous plane, obtain good visibility, and achieve tissue overlap of 5 cm or more are among the claimed advantages of this technique. A 20% laxity has been recommended to compensate for shrinkage of the mesh [19, 20]. The literature suggests that using suprafascial mesh is associated with increased seroma formation and risk of infection, which cannot be fully eliminated by antibiotics and prophylactic drainage [21].

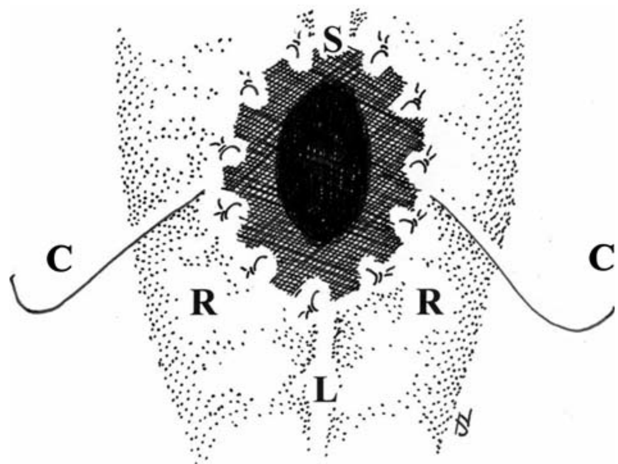

Fig. 4 Onlay of subxiphoid hernia overlapping the defect's margins

Laparoscopic repair

The laparoscopic treatment of subxiphoid hernia was pioneered in 2000 when a screen of bi-layer permanent composite (Composix™, C.R. Bard, Inc., Murray Hill, NJ) was brought up against the undersurface of the defect using four transmural corner stitches and tacked to the posterior rectus abdominis sheath all around the defect's margins [6]. An analogous method of fixation was used in two subsequently published laparoscopic series, with reported recurrence rates of 10% and 33%, respectively [7, 9]. The authors claimed improved visibility of the defect margins [9].

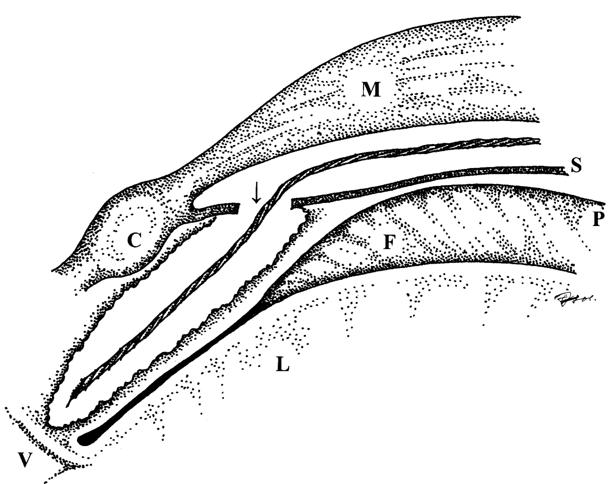

Fig. 3 Cross-sectional schematic diagram (sagittal right parasternal view) showing the topography of a sublay augmentation of the defect with adequate cephalad overlap. *C* = costal arch, *M* = rectus abdominis muscle, *S* = posterior rectus abdominis sheath, *V* = vena cava, *L* = liver, *F* = falciform ligament, *P* = peritoneal cavity, the *arrow* indicates the cut in the posterior rectus abdominis sheath through which the retromuscular prosthesis enters the preperitoneal space

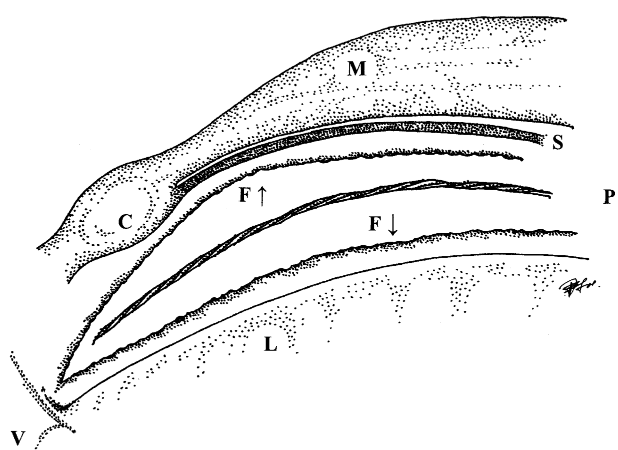

Fig. 5 Cross-sectional schematic diagram (sagittal right parasternal view) showing the topography of an intraperitoneal augmentation of the defect with adequate cephalad overlap. *C* = costal arch, *M* = rectus abdominis muscle, *S* = posterior rectus abdominis sheath (which was left intact), *V* = vena cava, *L* = liver, *F with arrows* = mobilized falciform ligament ventral and dorsal to the prosthesis, *P* = peritoneal cavity

Table 3 Fundamentals of laparoscopic and open repair of subxiphoid hernia after median sternotomy

Type of repair	Plane of dissection	Type of prosthesis	Placement of mesh	Tissue overlap	Anchorage (avoid diaphragm)
Open	Extraperitoneal (cranially between peritoneum and diaphragm)	Permanent mesh	Extraperitoneal	5 cm	Sutures
Laparoscopic	Totally intraperitoneal (dissect falciform ligament)	Tissue-impervious material on intestinal side (ePTFE)	Intraperitoneal	5 cm	Sutures, tacks

The laparoscopic repair of subxiphoid hernia after sternotomy is based on most of the principles described by the recently published major trials of minimally invasive vental hernia repair [22–25]. An important technical point concerning the laparoscopic repair is the necessity to dissect the falciform ligament up to the hepatic veins. By doing this, the mesh overlap can extend to the hepatic veins and the esophagus (Fig. 5). The tissue overlap around the prosthesis must be at least 4 cm and, ideally, close to 5 cm [23, 25]. A sheet of mesh with low adhesive potential (Dual Mesh, W. L. Gore & Associates, Flagstaff, AZ) is typically rolled into a cigar-shape, introduced intraabdominally, unfolded, and stretched to lie parallel to the abdominal wall by pulling previously placed anchoring sutures through all abdominal layers. Once the patch is firmly held in place, endoscopic tackers are used around the edges to fix the prosthesis. The placement of additional full-thickness abdominal wall stitches circumferentially every 3–6 cm is considered to be mandatory [22–25]. Mesh fixation only with spiral tacks is not recommended, since most tacks do not penetrate more than 2 mm beyond the mesh [23]. A recent porcine experimental study demonstrated that the tensile strength of sutures used to fix intraabdominal prostheses was up to 2.5 times greater than that produced by the tacks [26]. The cranial overlap of the prosthesis will be fixed by the liver and the stomach when desufflating the pneumoperitoneum. This technique is routinely used by laparoscopic surgeons when repairing hernias after midline incisions. The good exposure, tension-free placement of the prosthesis, and wide coverage beyond the defect's margin all contribute to a lower recurrence rate compared with open repairs [26].

It is considered sufficient to fix the mesh at or below the costal arch. Placement of endoscopic tacks right under the ribs and through the costochondral junction, along the edge of the sternum at the xiphoid, improves the closure, but creates chronic severe pain that often requires injection therapy in the office. Placing tackers beyond the costal chondral margin can cause life-threatening complications, such as pericarditis or even acute cardiac tamponade [27]. In addition, the limited accumulated experience with this method does not provide sufficient data regarding the influence of a prosthetic material anchored to the diaphragm on respiratory physiology [8].

Conclusions

The incidence of subxiphoid hernia after median sternotomy can be possibly reduced by paraxiphoid extension of the sternotomy [4], reinforcement near the xiphoid end of the incision, or by optimizing closure of the distal sternotomy and the *linea alba*. Non-absorbable aponeurotic suture of the epigastrium may further improve the closure's stability. The repair of an established subxiphoid hernia is technically demanding, with no procedural standardization. It must be based on sound scientific principles (Table 2). Abdominal wall reinforcement by open-mesh closure or laparoscopic transperitoneal prosthetic repair can effectively deal with the defect (Table 3). Long-term outcome analyses comparing laparoscopic and open repair are not yet available.

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