Advancing pectus deformity care: evaluation of current treatments, complications and future innovations

Braak, H. van

Chapter 9

Nuss bar infections: risk factors and management strategies

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Submitted for publication

ABSTRACT

Background

This study aims to evaluate the incidence and characteristics of Nuss bar infections, identify surgical risk factors, and proposes an optimized management strategy.

Methods

We conducted a retrospective cohort study of all patients who underwent the Nuss procedure between 1999 and 2024 at the Amsterdam Pectus Center. Primary outcomes included the incidence and management of Nuss bar infections. Secondary outcomes included infection characteristics (early- versus late-onset, superficial versus deep), diagnostics, cultured bacteria, prognostic factors (sex, age, type of anesthesia, number of bars, bar dislocation, stabilizer position, use of sutures), impact on bar removal, and incidence of allergies and terra firma-forme dermatosis.

Results

Of 695 patients, 4.0% (28/695) developed Nuss bar infections, on average six months postoperative, presenting with erythema, pain and exudate. Over time, infections shifted from early- to late-onset (P=.03). Deep infections (71.4%, 20/28) more often required surgery (P=.007) whereas superficial infections were managed with antibiotics, involving a wide range of regimens. Bar dislocations (5.6%, 39/695) and stabilizer plate loosening (1.0%, 7/695) required reoperation and were associated with infections (P=.001). Operative time for bar removal was longer in infected patients (52.0 (32.0–68.0) versus 35.0 (26.0–49.0) minutes, P=.03). One case of cobalt allergy was identified. Terra firma-forme dermatosis (0.4%, 3/695) was successfully treated using alcohol wipes.

Conclusions

The incidence of Nuss bar infections remains low but requires structured, multidisciplinary management. Bar dislocation and plate loosening are key risk factors. Our protocol emphasizes precise diagnostics, consistent and tailored antibiotic therapy, and awareness of alternative diagnoses in atypical presentations.

INTRODUCTION

Pectus excavatum (PE) is a chest wall anomaly for which minimally invasive repair (MIRPE), first described by Nuss et al.,[1] is the most common treatment.[2] Despite favorable outcomes, postoperative infections remain a concern, with an incidence of 1.5%-9.4%.[3-15] For clean surgical wounds, a 1-5% infection rate is considered acceptable.[16] Affected patients often require extended antibiotic therapy and occasionally, additional surgical interventions, although the Nuss bar is typically retained.[4, 13, 17] The most comprehensive study on postoperative infections following MIRPE, including a protocol, was published in 2018.[4]

Since then, the surgical technique of the Nuss procedure has advanced significantly. In particular, the introduction of intercostal nerve cryoablation in 2019 has altered care.[18] We observed an increase in low-grade surgical postoperative infections alongside these advancements. We therefore reevaluated current protocols for prevention, diagnosis, and management of Nuss bar infections.

This study aims to evaluate the incidence and characteristics of Nuss bar infections, identify surgical risk factors, and propose a management strategy for postoperative infections.

PATIENTS AND METHODS

Study population and design

We performed a retrospective cohort study of patients undergoing MIRPE in the Amsterdam Pectus Center, Amsterdam University Medical Center, between March 1999 and April 2024. The Medical Ethics Review Committee of the Amsterdam Medical Center waived ethical approval. Informed consent was obtained from all patients (or their parents).

Data extraction

Data were retrospectively obtained from patient records. Infections were defined as cellulitis that required antibiotics, superficial infection with active drainage, or deep infections involving hardware, regardless of onset.[4] An infection was considered deep if ultrasound confirmed bar involvement, the bar or stabilizer plate became exposed, or imaging or surgery revealed direct connection between the infection and the bar (fistula/abscess). A 30-day threshold differentiated between early-onset and late-onset infections. Operative time for Nuss bar removal was defined as time between incision and wound closure. Rotation, lateral shift, flipping, or intrathoracic displacement are

all defined as Nuss bar dislocation. Stabilizer plate loosening is defined as fixation loss, allowing plate migration along the bar. Nuss bar allergy had to be confirmed by a dermatologist, through standardized patch testing.

Treatment protocol

Figure 1 shows our treatment protocol. Routine allergy testing is not part of our protocol. Until 2019, patients undergoing the Nuss procedure received continuous epidural analgesia combined with patient-controlled analgesia. Since then, the procedure has been performed using intercostal nerve cryoablation combined with patient-controlled analgesia for the first 24 hours after surgery.[18]

All patients receive intravenous cefazolin for 24 hours, starting 30 minutes before first incision (adolescents: 3x1000mg/day, children: 3x100–150mg/kg, maximum of 6gr/day). We follow the Dutch and international guidelines regarding surgical site infection prevention.[19, 20] Scrubbing is done twice with chlorhexidine/alcohol skin antiseptic solution.

We perform MIRPE using a modified version[21] of the original technique.[1] Typically one Nuss bar is used; although sometimes two bars are required. A single stabilizer plate on the left side of the bar, as medially as possible on the chest wall, secures the bar(s). In the early years, the bar (Biomet) was sutured to the stabilizer plate on the one side, and secured with a thoracoscopic placed pericostal, absorbable suture on the other side. We later adopted bars (MedXpert) that featured a stabilizer plate with screws, making sutures abundant. We recommend leaving the bar in situ for three years.

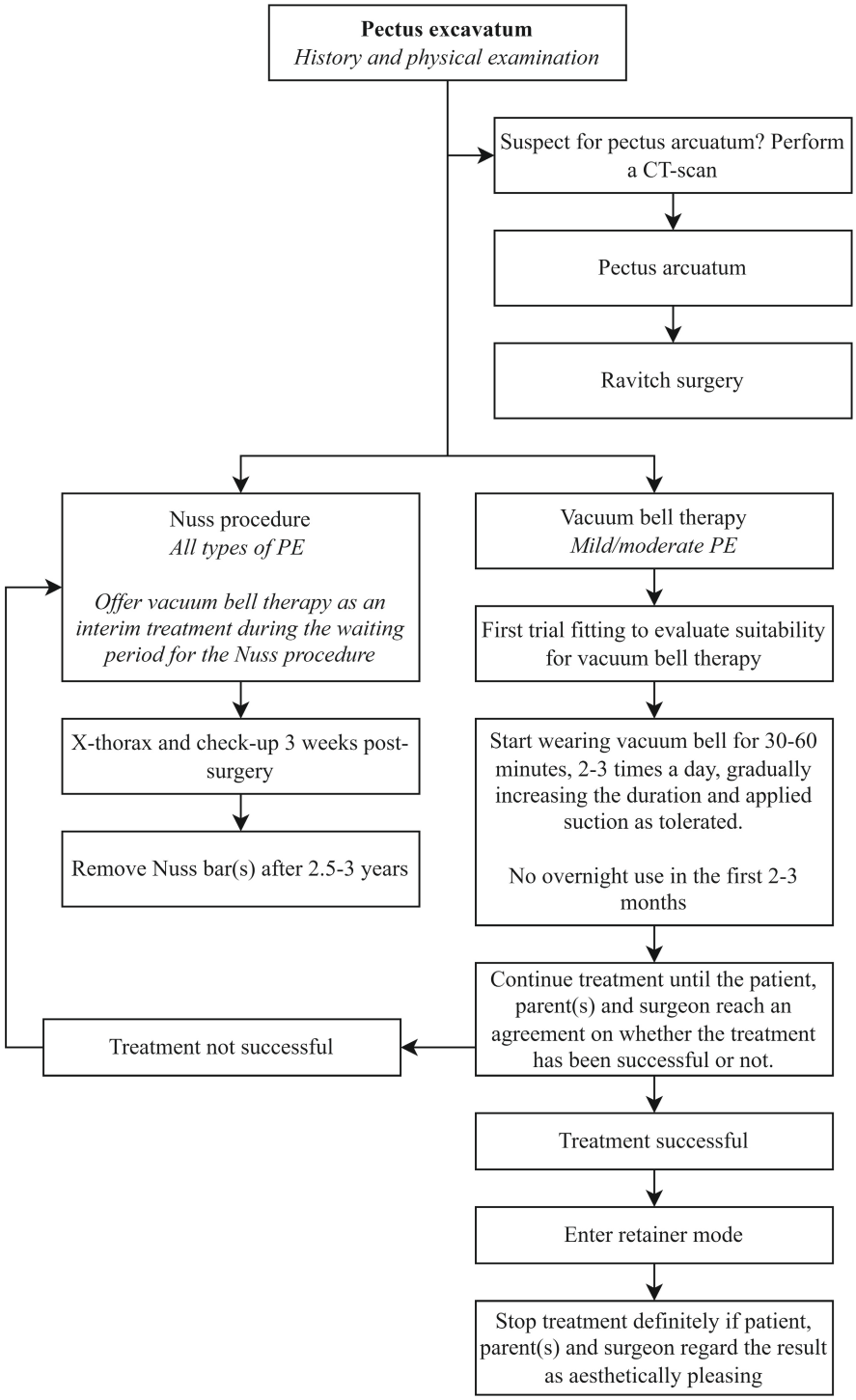

Figure 1 Treatment protocol for pectus excavatum (PE=Pectus Excavatum)

Outcomes

Primary outcomes were incidence and management of Nuss bar infections. Secondary, the early- and late onset infections were compared based on annual incidence, C-reactive protein (CRP), leukocyte count and type of bacteria. Also, the superficial and deep infections were compared based on the need for surgical intervention, hospital admission, wound drainage, type of cultured bacteria, timing of infection, annual incidence, and type and duration of antibiotic treatment. Other secondary outcomes were infection symptoms, used diagnostics, type of cultured bacteria, analysis of prognostic factors for Nuss bar infections (sex, age, type of anesthesia, number of Nuss bars, Nuss bar dislocation, place of stabilizer plates, suture use), Nuss bar removal time after infection and incidence of allergies and terra firma-forme dermatosis.

Statistical analysis

Descriptive measurements were utilized for baseline characteristics. A P-value <0.05 was considered significant. Data were analyzed using IBM SPSS Statistics 28.0. Distribution of continuous variables was assessed using the Shapiro-Wilk test. Normally distributed variables are reported as mean ± standard deviation (SD) and non-normally distributed variables are reported as median with interquartile range (IQR).

RESULTS

All (N=695) patients who underwent the Nuss procedure were included. Median age at surgery was 15.0 (14.0-17.0) years, 82.4% of patients were male (573/695). Most patients received one bar (89.8%, 624/695), 10.1% received two bars (70/695) and 0.1% received three bars (1/695). All patients had a minimal follow-up of six months after Nuss bar placement. Nuss bar removal has occurred in 82.2% of the included patients (571/695), with an median interval of 32.0 (29.0–37.0) months.

Incidence of Nuss bar infections

Of all patients, 4.0% (28/695) developed a Nuss bar infection. Figure 2 shows infections per year and cultured bacteria. There was no relationship between the year of surgery and the incidence of infections (P=.29).

Early versus late-onset infections

The mean time between Nuss bar placement and infection was 27.6±38.7 weeks (6.0±9.0 months). A significant association was found between the year of surgery and infection timing, with early-onset infections predominating in earlier years and a gradual shift toward late-onset infections in recent years (P=.03). Compared to late-onset infections, early-onset infections had higher CRP (mg/L) and leukocyte levels

(10^9L) (CRP 408.0, 240.0, 223.0, 61.8, leukocytes 25.8, 23.0, 15.9, 11.9) (CRP 11.1 (6.2-40.2), leukocytes 9.3 (6.7-10.4)).

Cutibacterium acnes (CA), formerly Propionibacterium acnes, was isolated more frequently in late-onset infections (one versus four), although this difference was not significant (P=.62). Although more early-onset infections occurred in patients with sutures, this difference was not significant (P=.24).

Deep versus superficial infections

Twenty patients (71.4%) developed deep infections. None of the superficial infections required surgery, whereas 55.0% (11/22) of deep infections did (P=.007). No significant differences were seen between deep and superficial infections in hospital admissions (P=.07), wound drainages (P=.14), or bacteria cultured (P=1.0). No correlation was found between deep or superficial infections and the year they occurred (P=.75), early and late-onset infections (P=.62) or antibiotic treatment duration (P=.57).

Symptoms and diagnostics

Table 1 shows an overview of symptoms and diagnostic tests. Most patients presented with erythema (67.9%, 19/28) and pain (71.4%, 20/28), while fever (32.1%, 9/28) and exudate (39.3%, 11/28) were less common. Of patients, 21.4% (6/28) had one symptom, 46.4% (13/28) had two symptoms, and 32.1% (9/28) had three symptoms. Thoracic X-rays and Nuss bar ultrasounds were made in respectively 85.7% (24/28) and 53.4% (15/28) of patients. Allergy tests were conducted in 14.3% (4/28), revealing a cobalt allergy in one patient.

Shift in bacterial species

Figure 2 shows a shift in bacteria over time. CA has replaced Staphylococcus aureus (SA) as the most commonly cultured bacterium since 2018.

Treatment

Table 2 provided an overview of treatment for Nuss bar infections. Of all patients, 53.6% (15/28) was hospitalized one (14/15) or two (1/15) times and 39.3% (11/28) underwent one (8/11) or two (3/11) surgeries. Patients received antibiotics for a mean duration of 51.3±75.0 days. In 14.3% (4/28) the Nuss bar was removed early.

Table 1 Overview of symptoms and (results of) diagnostic tests

	Year	Time after Nuss placement		Early onset	After surgery for dislocation	Symptoms			L	CRP	E	Ultrasound Nuss bar	Deep infection	Thoracic X-ray	Allergy test [a]
						Erythema	Pain	Fever	Exudate							
		Weeks	*Months*												
1	2000	11	2				X						X	X	
2	2001	14	3						X				X	X	
3	2003	3	0	X					X				X	X	
4	2004	1	0	X		X	X		X				X	X	
5	2005	6	1			X	X		X				X	X	
6	2005	11	2		X	X	X	X					X	X	
7	2007	2	0	X		X	X	X		25.8	408.0		X	X	X	
8	2007	11	2		X	X		X	X						X	
9	2008	0	0	X			X	X						X	X	
10	2008	1	0	X			X	X					X	X	X	
11	2009	1	0	X			X	X					X		X	
12	2010	10	2			X				14.0	64.0					
13	2013	130	30			X			X	6.8	6.0	0.13	X	X	X	0
14	2015	2	0	X		X	X		X				X			
15	2016	89	20		X	X	X			5.8	9.5	0.07	X	X		
16	2017	3	0	X		X	X	X		23.0	240.0	0.00	X	X	X	
17	2017	3	0	X	X		X	X		15.9	223.5	0.07		X	X	
18	2018	107	24			X				6.6	8.0		X	X	X	
19	2019	105	24			X	X			10.3	3.0		X		X	0
20	2019	6	1		X		X	X		9.7	47.0		X	X	X	

Table 1 Overview of symptoms and (results of) diagnostic tests *Continued.*

	Year	Time after Nuss placement		Early onset	After surgery for dislocation	Symptoms				L	CRP	E	Ultrasound Nuss bar	Deep infection	Thoracic X-ray	Allergy test [a]
						Erythema	Pain	Fever	Exudate							
		Weeks	*Months*													
21	2019	71	16		X	X	X			8.0	15.0	0.12	X		X	
22	2019	66	15			X	X		X	9.2	0.8		X	X	X	
23	2020	3	0	X		X			X	11.9	61.8	0.57			X	
* 24	2021	24	5		X	X	X			12.9	64.9	0.16	X	X	X	1
25	2021	5	1			X	X			5.5	6.7	0.32			X	0
26	2022	54	12			X	X			10.4	19.6	0.36	X	X	X	
27	2023	28	6						X					X	X	
28	2024	5	1			X	X		X	9.3	12.7		X	X		
N (%)				10 (35.7)	7 (25.0)	19 (67.9)	20 (71.4)	9 (32.1)	11 (39.3)				15 (53.4)	20 (81.4)	15 (85.7)	4 (14.3)
Mean (SD)		27.6 (38.7)	6.0 (9.0)													

CRP=C-Reactive Protein (mg/L), E=eosinophils (10^9/L), L=leukocytes (10^9/L)
[a] 0=negative, 1=positive, * cobalt allergy

Table 2 Overview of treatment

	Year	N of hospital admissions	LOS	N of surgery	Drainage	Tissue culture	Bacterium	Total duration of antibiotics	Intervals of antibiotics (administered sequentially, unless in the same column)				Bar removed early (months)
			Days						*Antibiotic (days of treatment)*				
1	2000	1	1	1		X	-	10	Au (10)				
2	2001	1	2	1		X	-	10	Au (10) Fl (10)				
3	2003				X	X	-	5	Am (5)				
4	2004	1	10	1				10	Au (2)	Fl (8)			1 (replaced)
5	2005	1	4	2		X	SA	>365	Fl (>365)				
6	2005	1	15	1	X	X	SA	26	Au (5)	Fl (7) Ri (7)	Cl (14) Ri (14)		
7	2007	1	23		X	X	SA	35	Au (2) Ge (2)	Fl (21)	Cl (12)		
8	2007	1	21			X	SA	42	Fl (21)	Fl (21)			
9	2008				X			42	Au (13)	Fl (9)	Fl (20)		
10	2008	1	14	1	X	X	SA	49	Fl (7)	Fl (14)	Fl (28)		
11	2009	1	14					14	Au (3)	Va (11) Cefta (11)			
12	2010							14	Au (14)				
13	2013					X	-	14	Au (14)				
14	2015							10	Fl (10)				
15	2016	2	7	2		X	MM	54	Fl (21)	Ci (14)	Co (5)	Co (14)	
16	2017	1	10	1	X	X	SA	42	Fl (14)	Cl (28)			

Table 2 Overview of treatment *Continued*.

	Year	N of hospital admissions	LOS	N of surgery	Drainage	Tissue culture	Bacterium	Total duration of antibiotics	Intervals of antibiotics (administered sequentially, unless in the same column)					Bar removed early (months)
			Days						*Antibiotic (days of treatment)*					
17	2017	1	14	1		X	SA	42	Fl (14)	Cl (28) Ri (28)				
18	2018					X	CA	7	Au (7)					
19	2019							7	Au (7)					24
20	2019	1	5					49	Fl (5)	Fl (42)				12-22[a]
21	2019					X	-	21	Cl (21)					
22	2019	1	6	2		X	CA	220	Au (6)	Au (8)	Cl (10)	Cl (196)		
23	2020					X	CA	56	Fl (56) Cl (56)					
* 24	2021	1	2	1		X	CA	114	Cl (28)	Cl (53)	Au (14)	Cl (5)	Ph (14)	24
25	2021					X	SA	73	Au (7)	Cl (36)	Cl (30)			
26	2022							14	Fl (14)					
27	2023							49	Am (49)					
28	2024					X	CA	42	Fl (7)	Am (28)				

Am=Amoxicillin, Au= Augmentin, CA=Cutibacterium Acnes, Cefta=Ceftazidime, Ceftr=Ceftriaxone, Ci=Ciprofloxacin, Co=Cotrimoxazole, Fl=Flucloxacillin, Ge=Gentamycin, LOS=Length of Stay, MM=Morganelli Morganii, N=number, Ri=Rifampicin, SA=Staphylococcus Aureus, Va=Vancomycin

Grey shaded=intravenous antibiotics, * cobalt allergy, [a] one bar removed at 12, other at 22 months

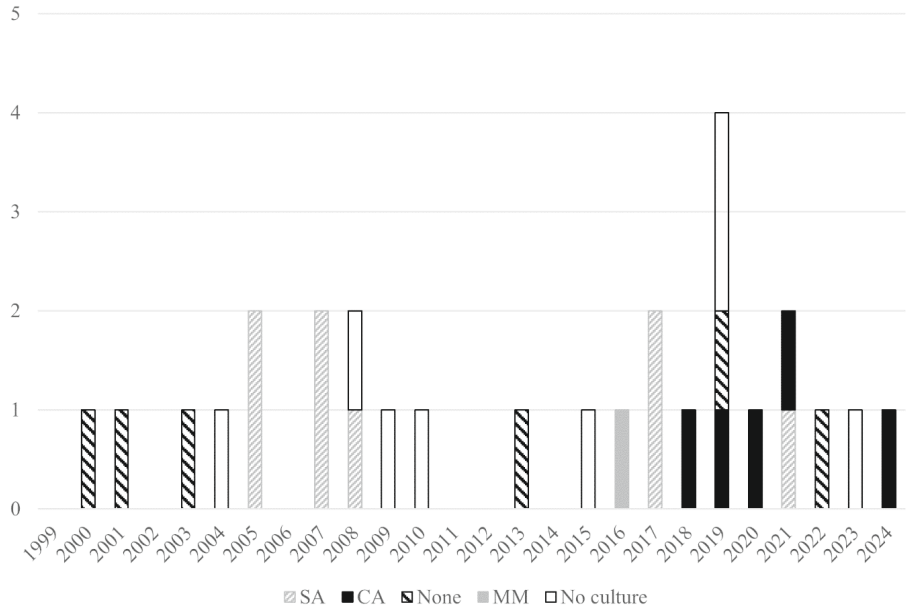

Figure 2 Number of Nuss bar infections per year and cultured bacterial species (CA= Cutibacterium Acnes, MM=Morganelli Morganii, SA=Staphylococcus Aureus)

Figure 3 Terra firma-forme dermatosis. Early erythematous lesions (A). Late, brownish, dirt-like patches (B).

Prognostic factors and impact of infection on Nuss bar removal time

Bar dislocation (5.6%, 39/695) and stabilizer plate loosening (1.0%, 7/695), caused reoperations in all affected patients and were more prevalent in Nuss bar infections (P=.001). Reoperations for bar dislocation, plate loosening, and pain have declined over time (P=.02), with an annual rate of 0–3.1% in the past five years.

Stabilizer plates were placed on the left in 60.7% of patients (17/28), on the right in 25.0%, and on both sides in 10.7% (3/28). Infection site and stabilizer plate position were significantly related (P=.007).

Operative time for Nuss bar removal was longer in patients with infections (52.0 (32.0–68.0)), compared to those without (35.0 (26.0–49.0), P=.03). Infection rate was not related to age (P=.06), sex (P=.14), number of bars (P=.15), or type of analgesia (P=.71).

Skin reactions

Aside from bar infections, three patients were suspected allergic. Two experienced allergy-like symptoms, although no allergy was found. One patient's allergy was misdiagnosed as infection. Multiple antibiotics failed to treat his erythema and pain. A cobalt allergy was diagnosed, however prednisolone provided only mild relief. After two years, the patient chose bar removal over methotrexate treatment.

Terra firma-forme dermatosis, presenting as erythematous lesions that subsequently develop into brownish, dirt-like patches resistant to soap and water (Figure 3), occurred in 0.4% of patients (3/695) and was effectively treated with alcohol wipes.

DISCUSSION

Postoperative infections were found in 4.0% of the patients, with a shift from early- to late-onset infections over time. Most common infection symptoms were erythema and pain. CA became increasingly prevalent in the past decade. Infection occurred more often on the stabilizer plate side, and after bar dislocation and bar loosening. Bar removal operation times were longer with bar infections. Allergies can mimic infections. Terra firma-forme dermatosis is effectively treated with alcohol wipes.

Incidence of bar infections

Our infection rate of 4.0%, aligns with current literature (1.5%-9.4%).[3-15] No consensus exists on acceptable infection rates in Nuss bar surgery. Even if the 1-5% threshold for clean wounds excluding prosthetic material is considered, our rate is still within this range, which is acceptable considering prosthetic operations have a higher threshold.

Infection management

Studies describe a wide range of antibiotics, mostly based on the surgeon's preference,[11, 12] with SA being the most commonly cultured bacterium. The latter study suggested oral clindamycin and cotrimoxazole for one to two months as long-term suppressive treatment. Rifampicin was also described in literature.[4] Since SA is common, we recommend oral flucloxacillin plus biofilm-active rifampicin as first-line treatment for acute infections for six weeks. If a pathogen other than SA is found, cultures should be taken and antibiotics changed. Until bar removal, treat low-grade infections with oral amoxicillin or clindamycin. Shared decision-making and bar removal should be considered throughout this phase of treatment due to the risks of long-term antibiotic use. Use intravenous treatment only for clinically unstable individuals.

We recommend the following infection protocol (Figure 4) based on our findings and experience.

Preoperative measures

We recommend cefazolin preoperatively and for 24 hours postoperatively.[4, 22] To minimize infection risk, we recommend following the international guidelines on prevention of surgical site infections.[19, 20] The international guidelines for surgical site infections do not recommend adhesive drapes or double gloves,[20] and recent evidence on the effects of adhesive drapes, including antimicrobial ones, on prosthetic surgery infection rates is inconclusive.[23]

Symptoms, imaging and culturing

Erythema, pain, and exudate indicate infection, but fever is rare. A thoracic X-ray and if inconclusive, a CT scan should be performed in all suspected cases to rule out bar dislocation, pneumonia, and pleural effusion. If these causes are excluded, ultrasound should be used to detect fistulas or fluid collections around the bar. When fluid is present, drainage and culture are essential for guiding antibiotics. Fistulas require surgical treatment.

In all suspected infections, cultures should be obtained before administering antibiotics, preferably fluid aspiration or intraoperative biopsies (at least five).

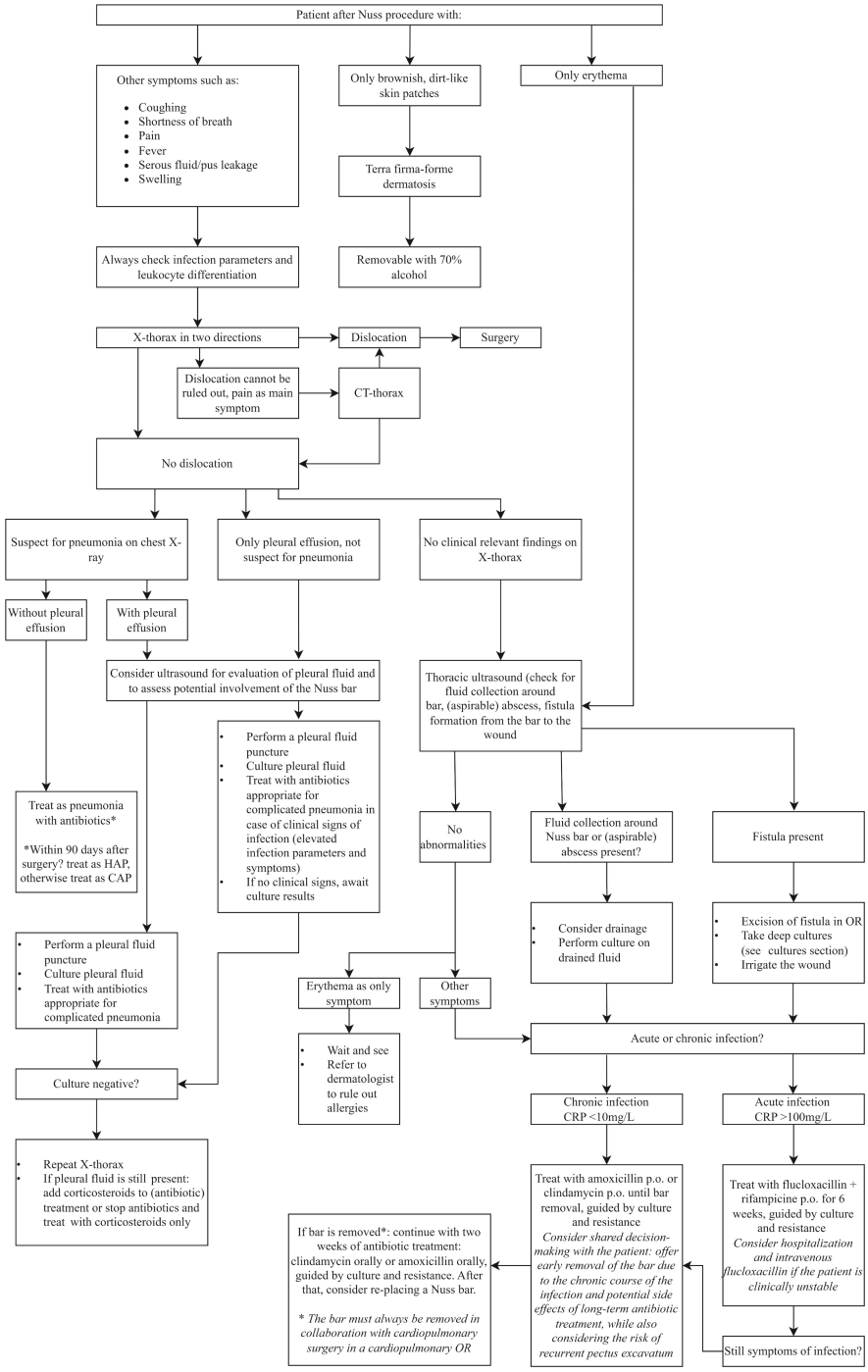

Figure 4 Protocol for managing postoperative Nuss bar infections (CAP = Community Acquired Pneumonia, CRP = C-Reactive Protein, HAP = Hospital Acquired Pneumonia)

Shift in time of infections and type of bacteria

SA was the most commonly cultured pathogen in early-onset Nuss bar infections. Late-onset CA infections, a slow-growing bacterium linked to indolent implant infections, have increased over the past decade. This may be due to improved surgical procedures lowering acute infections and increasing chronic, low-grade infections. Frequent and targeted testing may also increase CA detection. Since CA is a common cutaneous bacterium, it is commonly neglected unless implanted material is present. Surface swabs may detect CA even when it is not clinically relevant, leading to needless antibiotic therapy and delayed allergy diagnosis. Future investigations should focus on culturing explanted bars to identify if CA is a pathogen or a contaminant in chronic infections.

Prognostic factors

Bar dislocation and stabilizer plate loosening were correlated to higher infection rates with 5.6% and 1.0% prevalence, respectively. These findings support previous publications linking mechanical instability to postoperative infection risk.[24] Infections were more frequent on the side with a stabilizer, confirming the idea that enhanced tissue manipulation or injury in these locations may enable bacterial colonization and increase infection risk. Such manipulation may potentially change the local tissue milieu, making latent or low-virulence bacteria like CA clinically relevant.

According to the literature, only the bridge technique has created a zero percent dislocation rate.[25,26] We mostly employ a single bar, making bridging impractical. Despite this, we have lowered our dislocation rate to 0–3.1% during the past five years. This improvement may be attributed to the expanding experience of our surgical team,[27] and the use of screw-fixed stabilizers and their medial placement, which reduces leverage and limits bar movement.

Influence of Nuss bar infection on bar removal

Infections complicate the bar removal procedure, resulting in prolonged operative times. Bar removal and reimplantation after infection require multidisciplinary collaboration, particularly involving cardiac surgeons. The risks of infection and recurrent pectus excavatum should be considered before reimplantation. A second surgery increases the risks due to scar tissue, which increases the risk of pericardial injury. Culture-based two-week targeted antibiotic therapy with oral amoxicillin or clindamycin is recommended prior to bar replacement.

Skin reactions

If prolonged erythema without systemic infection markers, diagnostic imaging abnormalities, or unexplained postoperative inflammation occurs, allergies to implant materials (e.g., cobalt) should be investigated.

A recent article describes delayed-onset postoperative grayish-brown hyperpigmentation,[28] which we believe is terra firma-forme dermatosis. A review noted it occurs more often near surgical sites, possibly triggered by surgery or cryoablation.[29] Though the cause is unclear, the pigmentation resists soap and water but is removed with 70% isopropyl alcohol.

Future directions and limitations

The retrospective nature of our study introduces inherent biases, and may lead to missing data due to non-digitized medical records. The findings of this study can be validated by using standardized follow-up protocols in order to improve techniques.

Additionally, the impact of sutures on infection development requires more research considering the use of hammocks. When sutures were utilized, early infections were more likely, suggesting they fostered bacterial colonization. Fixation methods should be optimized to reduce infection risk as surgical techniques advance.

Conclusion

Postoperative infections had an incidence of 4.0%, with a shift from early- to late-onset infections over time. Bar dislocation and stabilizer plate loosening are correlated with infection, emphasizing the need to optimize surgical procedures. Our infection protocol emphasizes a structured diagnostic approach, tailored antibiotic therapy, and multidisciplinary management. In cases with mild symptoms and negative cultures, or when CA is detected, alternative diagnoses such as implant allergy should be considered. Terra firma-forme dermatosis is easily treated with alcohol wipes.

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