Complications after Nuss bar removal procedure for pectus excavatum. Analysis and proposal of a safety protocol

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ABSTRACT

Objective. The Nuss bar removal procedure may bring about different complications. Some are mild while others can be life-threatening. An adequate surgery setup and the fulfilment of some security steps may reduce their incidence. This study aims to analyze our experience with the complications that occurred during bar removal and our safety protocol for the prevention and management of these complications.

Materials and methods. Observational cohort study from a retrospective chart review of all patients who underwent Nuss bar removal from November 2013 to March 2022 at a University hospital. Variables analyzed include patients' demographics; presence of comorbidities; time elapsed from bar placement to removal, and the occurrence of operative and postoperative complications. Study written under the 'PROCESS Guideline'.

Results. Fourty (40) patients were included in the study; 37 were male. One bar was removed in 17 patients and two in 22 patients. Median age at surgery: 17.5 years (Percentile 25-75%: 16.75-19.25). Time elapsed from placement to removal: 26 months (Percentile 25-75%: 23.75-30.25). Complications: 10 in 9 patients (22.5%); 6 Clavien-Dindo class I (67%); 2 class II (22%); 1 class IIIb, 1 class IV. The hemorrhagic complication motivated the development of a safety protocol to reduce incidence of complications.

Conclusion. Nuss bar removal is a safe procedure with usually scant complications. Nonetheless, these may be serious sometimes. To prevent them, a protocol for a safe procedure is important.

KEY WORDS: Pectus excavatum; Hemothorax; Angiography; Intraoperative complications.

COMPLICACIONES TRAS RETIRADA DE BARRA DE NUSS EN *PECTUS EXCAVATUM*. ANÁLISIS Y PROPUESTA DE UN PROTOCOLO DE SEGURIDAD

RESUMEN

Objetivo. La retirada de la barra de Nuss puede provocar diversas complicaciones, algunas leves y otras potencialmente mortales. Su incidencia puede verse reducida con una preparación quirúrgica adecuada y siguiendo ciertos pasos de seguridad. El presente estudio tiene por objeto analizar nuestra experiencia con las complicaciones acontecidas durante la retirada de la barra, así como nuestro protocolo de seguridad para la prevención y el manejo de dichas complicaciones.

Material y métodos. Estudio de cohortes observacional llevado a cabo a partir del análisis retrospectivo de todos los pacientes sometidos a cirugía de retirada de barra de Nuss entre noviembre de 2013 y marzo de 2022 en un hospital universitario. Se analizaron las siguientes variables: demografía de los pacientes, presencia de comorbilidades, tiempo desde la colocación de la barra hasta su retirada, y complicaciones operatorias y postoperatorias. El estudio se realizó conforme a las directrices de la *PROCESS Guideline*.

Resultados. Se incluyó a 40 pacientes, 37 de ellos varones. En 17 pacientes se retiró una barra, y en 22, dos. La edad media en el momento de la cirugía fue de 17,5 años (percentil 25-75%: 16,75 - 19,25). El tiempo transcurrido desde la colocación hasta la retirada fue de 26 meses (percentil 25-75%: 23,75 - 30,25). Se registraron 10 complicaciones en 9 pacientes (22,5%), 6 de clase I según la clasificación de Clavien-Dindo (67%), 2 de clase II (22%), 1 de clase IIIb y 1 de clase IV. La complicación hemorrágica motivó la creación de un protocolo de seguridad para disminuir la incidencia de las complicaciones.

Conclusión. La retirada de la barra de Nuss es un procedimiento seguro, habitualmente con escasas complicaciones, aunque en ocasiones pueden ser graves. Para evitarlas, es importante contar con un protocolo que garantice la seguridad.

PALABRAS CLAVE: *Pectus excavatum*; Hemotórax; Angiografía; Complicaciones intraoperatorias.

INTRODUCTION

Removing surgical implants after a successful Nuss procedure for correcting pectus excavatum is usually a safe

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Table 1. Patients' surgical information.

Patient	*Age (at extraction)*	*Previous disease*	*N° of bars extracted*	*Implant stay (months)*	*POP complication*	*Complication treatment*
1	15	NO	1	18	Keloid scar	Plastic surgery
2	17		2	25	Keloid scar	Expectant management
3	17	Moderate ventilatory insufficience	2	26	Mild pleural effusion	Expectant management
4	15	NO	1	21	Pneumothorax I - wound dehiscence	Expectant management
5	17	NO	1	28	Pneumothorax I	Expectant management
6	17	NO	1	24	Severe hemorrhage	VATS –Thoracotomy– Angiography
7	18	Ravitch surgery, Gilles de la Tourette	2	26	Surgical wound dehiscence	Expectant management
8	20	NO	2	25	Wound infection	ATB
9	20	Inflammatory bowel disease	1	50	Wound infection	ATB

POP: Postoperative.

operation. However, different complications may occur. According to published reports, about 4% of bar removals result in complications, the most common being seroma, surgical site infection, and wound dehiscence[1]. Minor complications are relatively easy to manage with simple maneuvers such as incision and drainage, antibiotics, and pressure dressings. Major ones, including vascular injuries and life-threatening hemorrhage, require much more aggressive interventions, such as reoperation or endovascular procedures[2]. To the best of our knowledge, there is no standardized protocol to reduce their incidence following bar removal.

This report aims to describe the complications related to the removal of the chest bars and their management. Additionally, we propose a protocol to minimize the incidence of these complications.

MATERIALS AND METHOD

The following study is a case series of patients treated at a single institution. We conducted a retrospective chart review of all patients who underwent Nuss bar removal from November 2013 to March 2022. Information was collected from the department's surgical records keeping patients' identities confidential.

The analyzed variables included: patients' demographics (sex, age, presence of comorbidities), the time elapsed from bar placement to removal, the number of bars extracted, and the occurrence of operative and postoperative complications.

A summary of patients who experienced a postoperative complication, as well as their management, and previous comorbidities are described in Table 1.

This case series has been reported in line with the PROCESS Guideline (PROCESS Checklist at references)

RESULTS

Forty patients were included in the study, 37 of which were male. One bar was removed in 17 patients (42.5%), and two bars in the remaining 23 patients (57.5%). Mean age at removal was 17.5 years (Percentile 25-75%: 16.75-19.25). After placement, the bars were removed after a median time of 26 months (Percentile 25-75%: 23.75-30.25).

There were ten complications in nine patients (22.5%). One bar was removed in 5 of them and 2 bars in the remaining 4. Complications, which are described in Table 1, included two wound dehiscences that resolved with no surgical intervention; two keloid scars, one of which required plastic surgery; two surgical site infections, both managed with antibiotics; two grade 1 pneumothoraces which together with one mild pleural effusion cured spontaneously and one severe hemorrhage (Fig. 1) which were finally controlled with angiography and endovascular embolization (Fig. 2).

In this last patient, a Video-assisted Thoracoscopic Surgery (VATS) was initially performed after confirming hemodynamic decompensation (measured by a decrease in blood pressure, tachycardia, and desaturation) 1 hour

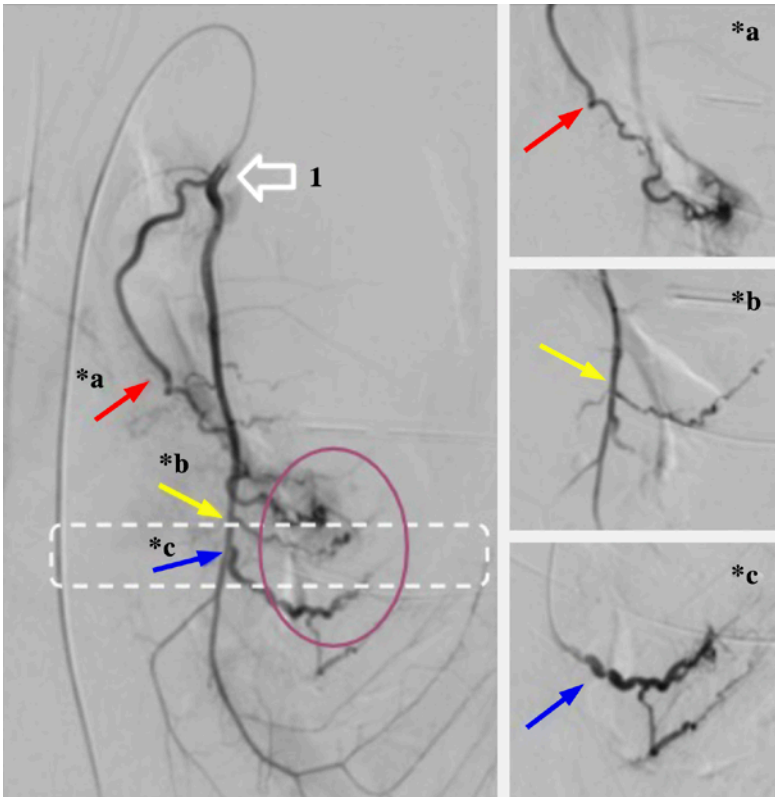

Figure 1. Pre-embolization: Anomalous left mammary artery angiography *(1: big white arrow)* showing pericardiophrenic artery *(arrow a*)* which showed active bleeding and tortuous intercostal branches with marked hyperemia *(arrows b*, c*)* which were embolized. The white dashed line rectangle marks the site of the bar extraction, and the violet circle indicates the bleeding area with the compromised vessels.

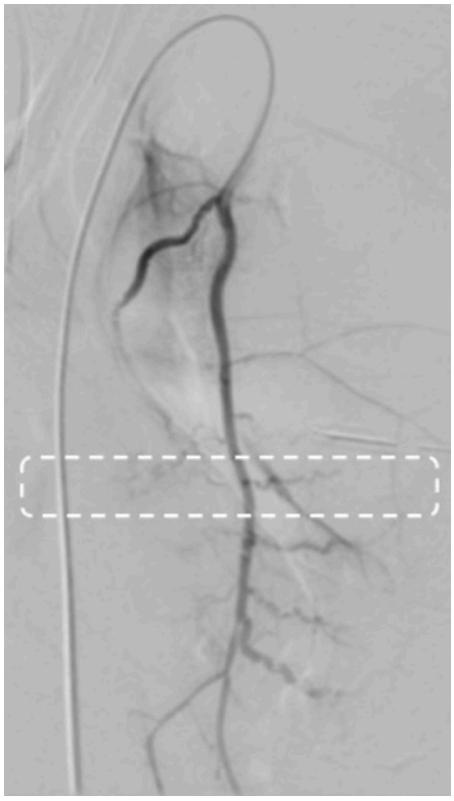

Figure 2. Post-embolization: Anomalous branches without flow after embolization. Selective catheterization of these branches was done with a 4 Fr vertebral catheter and a 2.8 Fr microcatheter. All vessels were embolized with N-butyl-2-cyanoacrylate mixed with ultra-fluid lipiodol. The white dashed line rectangle marks the site of the bar extraction.

post-surgery at the recovery room with a chest X-ray showing complete opacification of the right hemithorax. This procedure was unable to control the bleeding with an approximate blood loss of 1,500 ml of blood during this procedure. Therefore, a thoracotomy was executed. The bleeding site was identified over the area where the bar was removed. The area was cauterized, hemostatic sutures were performed and a pleural drainage was placed. The patient was transferred to the Pediatric Intensive Care Unit (PICU). Due to persistent bleeding despite multiple blood transfusions, a diagnostic and therapeutic angiography was performed 12 hours later which identified the bleeding coming from three branches of the left internal mammary artery: the pericardiophrenic artery (Fig. 1*a) and two anterior intercostal arteries (Fig. 1*b/1*c). These three vessels were successfully embolized, ultimately achieving control over the active bleeding.

According to the Clavien-Dindo (C-D) classification, there were six complications class I (67%), two class II (22%), one class IIIb and one class IV.

The severe hemorrhagic complication motivated us to develop a bar-removal safety protocol to reduce the incidence of complications (Table 2). The components of the protocol and their rationale are explained in the Discussion.

DISCUSSION

The final stage of the Nuss procedure is removing the bars 2 to 3 years after placement[1,3,4]. Throughout the years, various modifications to the original technique have been made in an attempt to achieve a safer procedure. Some authors report the use of two operating tables placed perpendicularly in a T-shape configuration to remove implants in 1 movement without bending them[5]. Others prefer straightening the bar on both ends to decrease the risk of a mediastinal injury during the removal[1,6]. The placement of a single bar stabilizer during bar insertion, eventually allowing for a single incision during removal, has been

Table 2. Safety protocol critical aspects.

Pre operative work-up	*Surgery*	*Post operative follow-up*
• Verification of blood type compatibility for the patient and laboratory analysis of the coagulation profile. • Control chest X-ray. **Considerations for implant surgery:** • Utilization of smooth-ended bars. • Placement of bilateral stabilizers to prevent dislodgment. • Planning for bar removal 24 months post-initial surgery.	• Constant monitoring of vital signs. • Bilateral alignin of implants for smooth extraction. **Required supplies:** • Row tape. • Thoracotomy kit. • Sengstaken-Blakemore tube. • Blood supply available.	• Control chest X-ray. • 24-hour admission in the PICU. • Use of a thoracic support belt for 10 days

described to reduce potential complications[7]. The "safety string maneuver" to maintain hemostatic control of the area left by the bar after removal is another strategy to mitigate the potential problem before it occurs[8]. Some authors even describe systematic thoracoscopic control during removal to detect potential bleeding sites[9], and postoperative control X-rays are usually indicated to identify unsuspected bleeding or air leak[10].

In our series of patients (n=40), the removal procedure consisted of bilateral incisions and straightening of the bars before removal. During immediate follow-up, a chest X-ray was performed to detect potential complications following the procedure, along with monitoring vital signs.

When complications arise following bar removal, they are typically mild and easily resolved. Wound seroma, infection, and dehiscence (2.36%) are the most frequently reported in the literature, followed by hematoma (0.22%)[1,5,11,12].

We detected ten complications in 9 of our patients (22.5%), noting that the majority were benign (67%). The C-D classification was used to define the severity of the complication and the therapy required to repair it[13]. Two patients seen at the outpatient clinic had a surgical wound dehiscence. Both of them healed with medical treatment (mineral ointments), being a C-D "class I" complication. Two patients developed keloid scars. One of them required plastic surgery (C-D class IIIb), while the other one had medical treatment with good results (C-D class I). Surgical site infections were seen in two patients, which were solved with oral antibiotic therapy (C-D class II). Two patients suffered from grade 1 pneumothorax (one also suffered wound dehiscence), and one had a mild pleural effusion. All three patients resolved spontaneously (C-D class I).

Despite the described above, serious complications following surgery may still occur, and bleeding is probably the most life-threatening one[2,10]. As regards the source of bleeding, some authors describe potential cardiac or great vessel injury resulting from treacherous maneuvers during bar removal[14]. Others blame an excessive inflammatory response to the implant material or previous history of cardiac surgery, which may generate surgical adhesions that could trigger bleeding when removed[9,15]. In our series, one patient experienced a severe bleeding complication originating from the internal mammary artery. This patient required initial re-operation and subsequent angiography (C-D class IV). When analyzing potential causes of the bleeding, we found that the patient had no medical history except for a slight alteration in coagulation factor VII (which was detected during the preoperative workup, and received the appropriate dose for surgery) and that the removed bar had serrated endings. We hypothesize that these two factors could have contributed to the unfavorable outcome following the procedure.

To control major postoperative bleeding, emergency surgery through thoracoscopy, thoracotomy or an anterior approach may be required to have rapid exposure and be able to control vascular injuries[2]. When bleeding persists after these first-line therapeutic options, angiography could be another alternative to be considered. In any case, we believe that if there is a well-prepared angiography service, along with suitable transportation logistics that meet the urgency, angiographic resolution could also be considered as a first-line treatment. Angiographic embolization was useful to finally constrain the bleeding in our patient.

This severe complication led to a detailed analysis of what happened and stimulated the design of a safety protocol to prevent complications following bar removal in the future. Our safety protocol includes preoperative, operative, and postoperative measures (Table 2).

As regards the material, we believe that dentated bars should be avoided, if possible, during bar placement. Smooth-ended bars are available nowadays. This would help reduce the risk of vascular lesions during removal.

Regarding the pre-work-up, routine lab analysis should include blood type compatibility of the patient to reduce waiting time if blood is required in an emergency. An initial chest X-ray is useful to depict the correct position of bars without any unnoticed displacement or dislodged screw.

During surgery, we maintain that employing bilateral incisions over the bar stabilizers to ensure the correct alignment of implants enhances safety during smooth extraction. This practice helps prevent vascular tears caused by unbent ends. Additionally, as part of our standard procedure, we secure a row tape to one end of the bar prior to extraction. The tape is passed laterally along the cavity left by the bar and apply pressure either upward or downward to control any active bleeding that may arise ("safety string maneuver"[8]). A thoracotomy emergency kit and a Sengstaken-Blakemore (SB) tube are consistently accessible for immediate use if required. The thoracotomy kit is essential for promptly addressing any emergent thoracic complications that may arise during the procedure. Additionally, we believe that having an insufflated SB tube available can aid in achieving hemostasis by effectively tamponading bleeding sites.

Post-operative follow-up, now adopted as the standard of care, includes immediate admission to the Pediatric Intensive Care Unit (PICU) for the first 24 hours to monitor the patient's hemodynamics and manage pain. A chest X-ray is performed on the same day after surgery and repeated as necessary in response to any clinical changes or vital signs alterations. This practice aids in detecting and ruling out complications related to bleeding, pneumothorax, or pleural effusions[10]. Subsequent to discharge, albeit lacking scientific substantiation, we recommend the utilization of a compressive thoracic belt for a duration of 10 days to mitigate the risk of seroma and hematoma. Moreover, it has been observed that the patient demonstrates enhanced mobility assurance when employing the thoracic support belt.

Upon analysis of the data, a decreasing trend in complications following the hemorrhagic event was observed within the described patient series. Only 3 complications occurred in the last 26 patients (11.5%), in contrast to 7 complications in the initial 14 patients (50%) prior to the event. Various explanations may account for this observation; however, the adoption of the safety protocol subsequent to this severe complication, along with a more experienced surgical team, are two pertinent factors. We believe it would be relevant to prospectively evaluate the outcomes of patients operated under the implementation of the safety guidelines to assess its efficacy. This study is currently ongoing.

The primary limitations of this study include the limited sample size and its retrospective chart review design. Conducting a prospective study comparing patients subjected to these safety measures versus those receiving "standard care" to assess the efficacy of the safety protocol may pose ethical considerations, as patient safety is paramount in procedures of this nature.

In conclusion, Nuss bar removal is generally considered a safe procedure with minor and benign complications being the norm. Nevertheless, it is imperative not to underestimate potential risks, as in certain instances, complications may escalate to serious and life-threatening situations. Based on our experience, we advocate for the implementation of a comprehensive safety protocol, a well-prepared surgical team, and sufficient resources to ensure the successful and safe execution of the procedure.

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