

Minimally invasive repair of *pectus excavatum* (the Nuss procedure) in Poland and worldwide – a summary of 25 years of history

Adam J. Białas, Bogumiła Kempieńska-Mirostawska

Department of History of Medicine and Pharmacy, Medical University of Lodz

Kardiochirurgia i Torakochirurgia Polska 2013; 10 (1): 42–47



*“Progress is the opus of the unsatisfied”
Jean-Paul Sartre*

Abstract

In 1987, Donald Nuss performed the first minimally invasive repair of *pectus excavatum* (MIRPE).

The aim of the study was to summarize the 25 years of performing this technique and analyze its modifications.

The study was prepared using methods commonly used in historical research: descriptive, comparative, inductive and deductive methods.

The history of the earliest Nuss operations and updated Nuss procedure was described. The most important modifications of the Nuss procedure were summarized: Miller, Hebra, Schaar-schmidt, Hendrickson and Al-Assiri modifications. Polish input to Nuss procedure surgery was described as well.

Key words: Nuss procedure, history of thoracic surgery.

Streszczenie

W 1987 r. Donald Nuss przeprowadził pierwszą minimalnie inwazyjną korekcję lejkowatej klatki piersiowej.

Celem pracy było podsumowanie 25 lat stosowania metody Nussa i analiza jej modyfikacji.

Badania zostały przeprowadzone z użyciem metod powszechnie stosowanych w badaniach historyczno-medycznych: metoda opisowa, porównawcza, indukcyjna oraz dedukcyjna.

W pracy zanalizowano historię najwcześniejszych operacji metodą Nussa oraz jej pierwsze uaktualnienie. Podsumowano także najważniejsze jej modyfikacje: Millera, Hebry, Schaarschmidta, Hendricksona oraz Al-Assiriego. Opisano polski wkład w historię korekcji lejkowatej klatki piersiowej metodą Nussa.

Słowa kluczowe: metoda Nussa, historia torakochirurgii.

Introduction

Pectus excavatum is one of the most common congenital deformities of the anterior chest wall. It is characterized by a depression of the sternum, mainly in its lower part (Fig. 1, 2). The deformation can be symmetrical or asymmetrical, appearing commonly with costal arch deformity and scoliosis. The prevalence of the deformity is estimated at approximately 1 in 1000 live births, significantly more common among males. The etiology is not known [1, 2].

The history of surgical methods used for correction of *pectus excavatum* began about 100 years ago. It was Meyer who performed the first operation of this deformation, in 1911. Although his operation did not improve the deformity, from that time until the present day, *pectus excavatum* surgery has evolved constantly.

In 1913, Ferdinand Ernst Sauerbruch performed the first successful correction of *pectus excavatum*: he resected

a 2-cm fragment of the left 5th rib cartilage and the whole left 6th to 9th rib cartilages with a fragment of the adjacent sternum. This procedure was described in the first handbook to thoracic surgery, written by Sauerbruch – *Chirurgie der Brustorgane*, published in 1920 by Springer in Berlin.

However, he invented the technique which is presently known as “the Sauerbruch procedure” in the 1920s. The method was based on wide, bilateral resection of 3-5 rib cartilages and sternal osteotomy. External traction to hold the sternum in the correct position for 6 weeks after the operation was used [3-6].

The natural evolution of the Sauerbruch method was the attempt to eliminate the external traction, which was the cause of some severe postoperative complications. The well-known method from this period, used in many various modifications until the present day, was the Ravitch procedure. Described in 1949, it comprised bilateral resection of deformed rib cartilages, complete detachment of

Address for correspondence: Adam J. Białas, Department of History of Medicine and Pharmacy, Medical University of Lodz, Muszyńskiego 2, 90-151 Łódź, tel. +48 609 541 521, e-mail: radius425@gmail.com

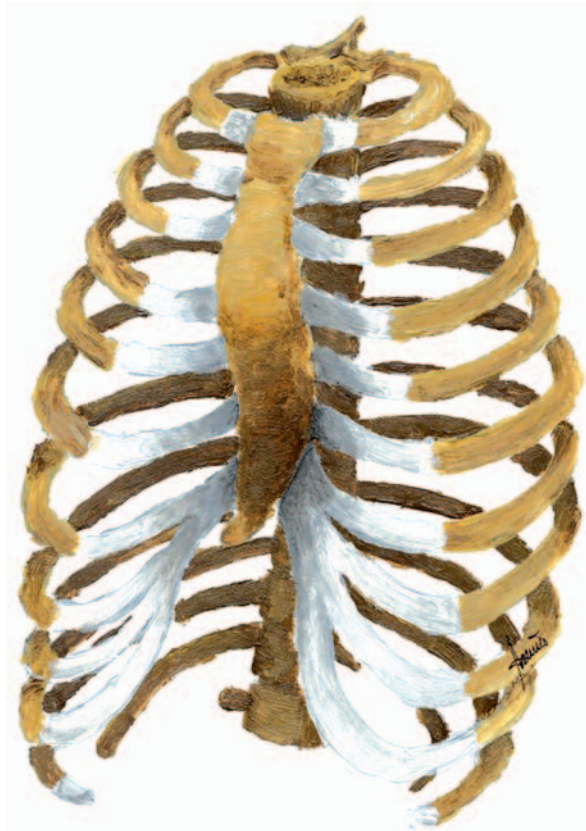


Fig. 1. The chest walls in pectus excavatum

the sternum from all of its attachments, sternal osteotomy and resection of the xiphoid process [7] (Fig. 3).

Ravitch did not use additional support of the sternum, which was the cause of the high recurrence rate of the deformity. Due to that, the authors of later modifications developed a variety of methods of supporting the sternum.

A natural step in the evolution was to invent a means of internal traction to hold the sternum in the correct position for long enough to minimize the risk of deformation recurrence. The multiplicity and variety of modifications of the Ravitch procedure was an image of imperfections of open surgical procedures used in pectus excavatum surgery and strong confirmation that none of them was satisfactory enough.

At the beginning of our review, we quoted the thought of Jean-Paul Sartre – “Progress is the opus of the unsatisfied”. It is due to this dissatisfaction that the Nuss procedure was invented and developed. We can see that this method was an effect of the consistent evolution process of pectus excavatum surgery. However, the lack of rib cartilages resection and sternal osteotomy made this method revolutionary. Analyzing previous publications in this field, describing the results of the operation, as well as long-term follow-up studies, we can say that the Nuss procedure opened a completely new chapter in the history of pectus excavatum surgery.

The primary procedure – 1987

The first MIRPE was performed in Norfolk in 1987. The technique was officially presented at the conference of the Ameri-



Fig. 2. The anatomical cross-section in pectus excavatum



Fig. 3. The Ravitch procedure

can Pediatric Surgery Association in May, 1997. The next year, it was published in the *Journal of Pediatric Surgery* [5, 8].

The novelty of the Nuss procedure is the lack of rib cartilages resection and sternal osteotomy. The sternum is lifted and stabilized by a steel bar (or bars) placed substernally (Fig. 4).

The idea of developing the new operating procedure was based, among others, on the assumption that if chronic emphysema can lead to changes in the shape of the thorax in adults, in children the plasticity of the ribs and sternum should be even greater. The treatment using the Nuss bars was compared to braces used by dentists.

From 1987 to 1990, the bar was inserted through an incision on the anterior chest wall. Later (1991) wounds were limited to short, lateral thoracic incisions. To dissect the substernal tunnel in the primary method, a Kelly clamp was used.

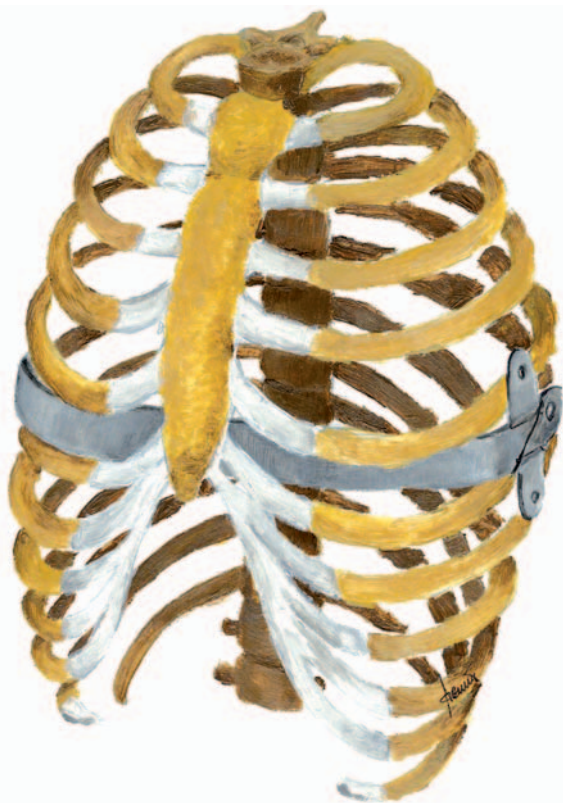


Fig. 4. The chest walls with the Nuss bar placed subinternally

Early procedures were performed under general anesthesia, which was later gradually replaced by using epidural anesthesia [9].

First update to the Nuss procedure

The first update to the Nuss procedure was published by the authors of the primary procedure in the *Journal of Pediatric Surgery*, in 2002.

Up to the year 2002, operations were conducted without thoracoscopy. In the updated procedure, thoracoscopy was an important part of the operation. The thoracoscope was inserted from the right side, two intercostal spaces below the lateral skin incision. Thoracoscopy increases the safety of the procedure.

To dissect the substernal tunnel in the primary method, a Kelly clamp was used. In the updated procedure, special introducers were developed.

The correction bar was modified to improve fixation of the bar as well. The ends of the Nuss bar were serrated to promote scar tissue formation and became rounded to ease passage through the substernal tunnel. The shape of stabilizers was modified as well (Fig. 5).

The bar removal procedure is usually conducted after 2-4 years.

The use of epidural catheter placement in all patients undergoing the Nuss procedure was maintained as the best pain management strategy [10].

Most reported complications did not pose a threat to the life of the patients. Therefore the Nuss method enables

a good esthetic effect to be obtained, with low risk of serious complications [11]. That is why, nowadays, it is becoming a “gold standard” in surgical repair of pectus excavatum [1, 3, 5, 8, 12-15].

The risk of postoperative complications is, among others, associated with the age of patients. The early postoperative complications include pneumothorax, pleural effusion and pericarditis. Possible, but very rarely described is heart perforation and erosion of the Nuss bar into the internal mammary artery. In the later postoperative period there may occur: displacement of the bar, allergy to the Nuss bar (chrome and nickel), overcorrection (reactive pectus carinatum is possible) and wound infection [11, 16-20].

Low risk or recurrence of the deformity clearly distinguishes the Nuss method from previously used techniques.

Miller modification

Miller *et al.* described in 1999 a method whose idea was to increase the safety of passage of the Nuss bar through the mediastinum. The method is based on performing an additional subxiphoid incision for mediastinal dissection [21].

Hebra modification – the third point of fixation

The aim of this modification of the Nuss method was to reduce one of the most frequent postoperative complications – dislocation of the Nuss bar.

The method of a third point of fixation described by Hebra *et al.* was probably the first modification in this field. It was published in August of 2001 in the *Journal of Pediatric Surgery* [22]. The procedure is easy to perform: an additional suture was placed in the parasternal line to fixate the bar into the rib cartilage. To place that suture, a small skin incision in the parasternal line, in the place where the bar overlaps with the cartilage, has to be made. Through the incision, a lumbar puncture needle was inserted, which was necessary to put the prolene suture inside the thorax. The suture

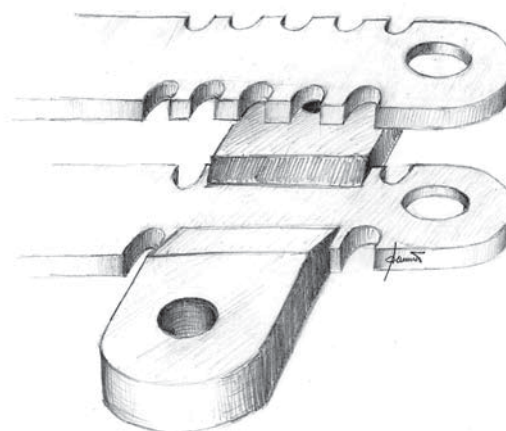


Fig. 5. The modification of the Nuss bar in the first update to the procedure (the ends of the bar were serrated to promote scar tissue formation and became rounded to ease passage through the substernal tunnel) and the bar with stabilizer

was captured by a 3-mm grasper which was inserted through the same incision (after the needle had been removed), but on the opposite site of the rib cartilage (Fig. 6).

According to Hebra's publication, the method reduced dislocations of the Nuss bars to one in a group of twenty operated patients [22]. The authors recommended their technique in all patients operated on using the Nuss method.

The Schaarschmidt modification – the eight points of fixation method

The Schaarschmidt modification was introduced in 2000, and published in 2002 in the *Journal of Pediatric Surgery*. The aim of the method was to reduce dislocations of the pectus bars. The author invented a new system of bar fixation: The muscles were dissected from the ribs to prepare the muscle pockets. In these pockets the ends of the Nuss bars and the stabilizers were placed directly on the ribs. The bars were fixed to the ribs using 8 sutures under thoracoscopy visualization (Fig. 7). The authors maintained that even if we use additional sutures, although we fix the bar into the muscle, full stabilization is not provided [23]. On the other hand, fixation of the bar into the rib without dissecting the muscles bears the risk of its necrosis.

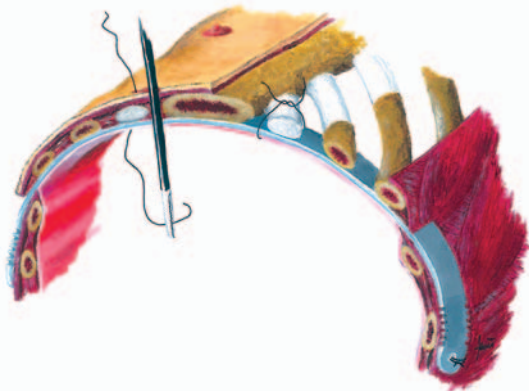


Fig. 6. The Hebra modification – the third point of fixation placed in the parasternal line



Fig. 7. The Schaarschmidt modification – eight points of fixation

Stabilizers are placed on the Nuss bar using a bone hammer, without wires.

In cases of severe deformations, a second Nuss bar is inserted through the same skin incisions as the first bar. The second bar was shorter by 2 inches and was not secured by stabilizers.

In prospective analysis, dislocations of the Nuss bar did not occur in this modification [23].

Hendrickson modification

The Hendrickson modification was invented to reduce the risk of cardiac perforation. In this procedure, instead of standard right thoracoscopy the authors used left thoracoscopy. Use of an Endo-kittner dissector which enables precise substernal space dissection was described as well. The left thoracoscopy enables direct visualization of the heart during the whole time of the procedure. The authors maintained that by using left thoracoscopy and Endo-kittner dissectors, the risk of cardiothoracic injury can be eliminated [24].

Al-Assiri modification

The Al-Assiri modification was published in 2009. It is based on performing relaxation incisions of the rib cartilage in the area of maximal depression of the sternum (Fig. 8). The aim of the modification was to decrease the tension which occurred between the sternum and rib cartilages, and facilitate the dissection of the retrosternal space [25].

The authors compared their modification with the standard Nuss procedure. No differences in blood loss, days of epidural requirements or days to reach functional independence were reported between the groups. Nor were there differences in the improvement in subjective appearance, complications, or pulmonary and cardiac function. The advantage of the modification was subjective facilitation of bar positioning and better intraoperative visualization. Median number of relaxing incisions was 4 (3-8 incisions). To evaluate the place of this method in pectus excavatum surgery further clinical studies are necessary.



Fig. 8. The relaxation incisions in Al-Assiri modification

The Nuss method in Poland

Probably, the first to use the Nuss procedure for correction of pectus excavatum was the team led by Professor Janusz Bohosiewicz from the Department of Pediatric Surgery of the Silesian Medical University of Katowice. They operated using the Nuss method from 1998 – the year when the procedure was published in the *Journal of Pediatric Surgery*. Due to the high costs and lack of registration in Poland, the original surgical equipment dedicated for the Nuss method, especially the Nuss bars, were not available. Instead of pectus bars, orthopedic plates were inserted. The use of different bars did not have a negative impact on the final result of the operations. Soon after, production of the Nuss bars was begun by the Micromed company. By the year 2008, 190 patients had been operated on with a good overall result. As a limitation in use of the Nuss method, the authors recognized asymmetrical deformations [26-28].

Significant clinical material was published by Professor Jozef Dzielicki from the Department of Pediatric Surgery of the Silesian Medical University of Zabrze, first in 2000 – the material comprised 14 patients. The operating team used the original surgical equipment dedicated for the Nuss procedure. No significant postoperative complications were reported. By 2005, 461 patients had been operated on. Postoperative complications were as high as 9.3% of patients, and the frequency of dislocations of the Nuss bar requiring intervention was 2.8%. The authors used the following modifications of the original procedure: transverse sternotomy in teenagers with rigid thorax, limited rib cartilage resection in asymmetrical deformations, and parasternal point of fixation of the Nuss bar to prevent bar dislocation. The authors performed the operations under thoracoscopy. The authors agree that the Nuss procedure can be the method of choice for correction of pectus excavatum [29, 30].

In 2004, early results of the minimally invasive pectus excavatum repair were published by Jaroslaw Adamczak from the Wielkopolskie Center of Pulmonology and Thoracic Surgery in Poznan. 54 patients were analyzed in that publication. It is important to note that dislocation occurred only in one patient and did not require an intervention. The cause of such a good effect is probably in the method of stabilization of the Nuss bar: it was fixed by braiding nonabsorbable Amifil sutures to the rib. Each bar and stabilizer was covered by serratus anterior muscle.

It is worth mentioning that the analyzed group was homogenous: all patients were operated on using the same procedure [31].

Summary

The Nuss procedure is the modern method for correction of pectus excavatum. High effectiveness of this method and low risk of significant complications are the reasons why the Nuss procedure is becoming the “gold standard” in correction of pectus excavatum. It has been 25 years since the first minimally invasive pectus excavatum repairs. This

period has seen modifications of the previous method to make the operation easier and safer, and to improve its final result.

In Poland, the Nuss method has been used since 1998. Those 14 years have resulted in important publications and enriched Polish pectus excavatum surgery with new experiences. Due to this, the Nuss procedure is the main correction method in Poland.

It can be expected that the Nuss procedure will continue to evolve, further consolidating its already stable role in surgery of pectus excavatum, both worldwide and in Poland.

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