THE NUSS PROCEDURE FOR THE CORRECTION OF PECTUS EXCAVATUM

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Pectus excavatum is one of the most common chest malformation. It occurs 4-5 times more often in boys. Familiar occurrence of the malformation has been observed. Two surgical techniques have been performed predominantly: the Ravitch method (1949) with further modifications and the Nuss minimally invasive method (1998).

The aim of the study was presentation of our own, slightly modified surgical technique, its results and original analgesia method in early postoperative period.

Material and methods. 190 Nuss procedures have been performed in years 1998-2008. 140 children operated on for the period of 8 years have been analyzed. A slightly modified surgical method and original postoperation intrapleural analgesia method have been presented. No thoracoscopy and no lateral stabilizations have been used. The Haller index of operated children was 2.2-5.8. The children’s age was 4-18 years, av. 14 years. An average operation time was 40 min and 80 min together with anesthesia.

Results. Very good result was achieved in 72%, good in 22% and bad in 5%. No mortality and inner organ injuries were noticed. Minor complications occurred in 12% of children.

Conclusions. The Nuss procedure for the correction of pectus excavatum gives good and very good results in 94% of children. The minimal invasiveness of this method allows to use this method for minor defects. The limitation of this technique is asymmetric defect in which the Ravitch procedure is still the method of choice.

Key words: pectus excavatum, Nuss procedure, intrapleural analgesia, children

Pectus excavatum is one of the most common chest deformation. Its incidence rate is estimated as 1 per 400 births (1), 1 per 1000 (2,3), 8 per 1000 births (4, 5, 6). Boys are affected three (6) or four (3) times more often. Familiar occurrence has been observed (7).

In 1998 Donald Nuss presented a new technique for the correction of pectus excavatum. Its principle is an insertion of an adequately shaped bar into the thorax and turning it resulting in elevation of the sternum. Nuss assumed that because chronic pulmonary emphysema causes “barrel chest” formation in adults thereby in children chest deformation is more possible. Based on the orthopedists’ experiences in the treatment of equinovarus or spinal deformities as well as orthodontists’ experiences in correction of the occlusal abnormalities, he concluded that lasting fixation of the sternum in the proper position will rebuild costal cartilages and preserve normal chest shape (8). One of the authors (Bohosiewicz) had an opportunity to observe the operation and to learn the photographic documentation and original paper before publishing. Fascinated by the new method we started to perform Nuss procedures in 1998 (9, 10).
The aim of our study was presentation of our own, slightly modified surgical technique, its results and original analgesia method in early postoperative period.

MATERIAL AND METHODS

190 operations were performed from July 1998 to June 2008. 140 operations performed from May 2000 to April 2008 (8 years) in the Department of Paediatric Surgery, Upper Silesian Centre for Child Health in Katowice were analyzed. The other children were operated before 2000 in the Department of Paediatric Surgery in Bytom, later in a few other hospitals in Poland and in Lviv, Ukraine and after April 2008 in Katowice.

The age of the operated children was 4-18 years, av. 14 years. 109 boys and 31 girls were operated. The indication for surgery, apart from the Haller index, was unaccepted by the child and his parents chest appearance. In every child computed tomography (CT), cardiology and pulmonology consultations with pulmonary function tests were performed before the operation.

The stages of the operation with our modification:

1. Intratracheal anesthesia, supine position, upper limbs on the brackets. One dose of antibiotic.
2. Marking on the skin the deepest excavations of the sternum and the same level points in intercostal spaces.
3. Choosing the bar of the proper size and modeling adequately to the chest shape. Marking on the skin the incision places between anterior and middle axillary lines (fig. 1).
4. Bilateral 2-3 cm skin and subcutaneous tissue incision in axillary lines.
5. Creating a free space between subcutaneous tissue and fascia surpassing the formerly marked places in paracostal lines.
6. Introduction of the bar through the created space into the thoracic cavity (fig. 2).
7. Carefull pushing of the bar toward the other side, all the time filling the inner thoracic cavity wall and sternum in contact with the bar and extraction of the bar from the thoracic cavity on the other side in the marked paracostal place.
8. Final modeling of the bar endings for to fit the bar to the external costal surface.
9. Slow turning of the bar.
10. Suturing of the both bar endings to the intercostal muscles using three absorbable sutures (through the holes in the bar).
11. Subcutaneous and intracutaneous sutures (fig. 3).
12. Bilateral insertion of intrapleural catheters for postoperative analgesia; bolus and subsequent continuous injection of the analgesic controlled by injection pomp.
13. Postanaesthetic recovery.

The patient stays in the postanaesthesia ward till the next day, when he is transferred to the surgical department. The A-P chest X-ray is done during this transfer.

Intrapleural analgesia by means of continuous injection is used till the fours postoperative day. The patient is allowed to walk on the fourth or fifth postoperative day and is discharged to home on the 5th-8th postoperative day. Two or three months after operation, the
A child is allowed to return to full sport activity.

Two pectus bars were inserted in one child. We do not use thoracoscopy and lateral stabilizations in any case. The bar displacement was observed in one child several days after operation. The bar placement was corrected and final result was very good.

RESULTS

The Haller index was calculated based on CT images; its values were 2.2-5.8. Pulmonary function test were abnormal in 67% of children; predominantly vital capacity was lower. Displacing and rotation of the heart, valve malformations or conduction disturbances were found in 45%.

The operation time from marking points to skin suturing was 20 to 140 min, av. 40 min. The time from beginning of the anesthesia till leaving the operating room was 40 to 210 min, av. 80 min.

The evaluation of the results is very subjective; it is based on chest appearance assessed by the surgeon, patient and his parents. We used the author’s classification of the results: very good, good and poor results. Very good result means excellent chest appearance with no complaints. Good result means persisted minimal excavation of the sternum or other deformations of the ribs. Poor result is a recurrence of the defect (11). In the analyzed series very good results were obtained in 101 (72%) of children, good in 32 (23%) and bad in 7 (5%) children.

In almost all children in whom very good results were not achieved, the chest deformation was more or less asymmetric. In the group of 7 children with poor result: three had displaced pectus bar after several months. Two were re-operated. The parents of one child did not agree for re-operation; they claimed that cosmetic result is sufficient. In one child the pectus carinatum deformation emerged after removal of the bar; conservative treatment was introduced. Deformed chest persisted in three children, although excavation was smaller. These children had severe asymmetry of the chest.

No mortality and inner organ injuries were noted. Minor complications were found in 19 children (12%), (tab. 1). No complication necessitated bar removal.

The bar was removed after 2-3 years in 108 children. Wound abscess was noted in two children after bar removal. Usually the child is discharged to home on the first postoperative day.

DISCUSSION

The operations for correction of pectus excavatum have been performed worldwide utilizing Ravitch method since 1950s. Introducing of the Nuss technique in 1998 was a breakthrough in the treatment of this deformation. Because of its simplicity the procedure has been introduced also for only cosmetic indications. The operation has been also performed in adults (12, 13).

Many papers presenting both methods and comparing their results have been published in recent 10 years (1, 4, 14, 15, 16). Both methods have been modified many times (11, 16, 17, 18). Besides these two techniques, other ones have been proposed in recent years: non-surgical method by means of suction (19, 20), chest correction utilizing implants (5, 21), sternal retraction (22) and sternal stabilization.

<table>
<thead>
<tr>
<th>Complications</th>
<th>No.</th>
</tr>
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<tbody>
<tr>
<td>Wound abscess</td>
<td>5</td>
</tr>
<tr>
<td>Prolonged pain</td>
<td>4</td>
</tr>
<tr>
<td>Allergic reaction against bar</td>
<td>3</td>
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<tr>
<td>Haemothorax requiring no drainage</td>
<td>2</td>
</tr>
<tr>
<td>Subcutaneous haematoma</td>
<td>2</td>
</tr>
<tr>
<td>Pneumothorax requiring drainage</td>
<td>1</td>
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<tr>
<td>Pericarditis</td>
<td>1</td>
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<tr>
<td>Pneumonia</td>
<td>1</td>
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by unabsorbable net (23). We did not do these methods. Using implants in children is not justified.

The first operations were done utilizing orthopaedic plates, modeled by locksmith’s tools similar to the first Nuss publication scheme (8). It had no impact on the results but removal of the plate was troublesome. Fortunately all first 10 plates have been removed. Original American pectus bars (Walter Lorenz Surgical, Jacksonville FL) were too expensive and were not registered in Poland. The production of both pectus bars and special tools for the bar introduction started in BHH Micromed in Dąbrowa Górnicza (fig. 4). Costs of the bars and tools are much lower and their quality is good. The standard bar size is 12 to 36 cm and can be also ordered in other size. Bioabsorbable and tytan bars which are more elastic then steel ones are also used (24).

The original Nuss procedure starts with pushing the introducer into the thorax, then a tape is dragged out, and a bar which is fixed to the tape is extracted. This procedure has been modified and the bar is introduced directly. The end of “our” bar is more oval then the end of the introducer. Therefore the blunt introduction of the bar to the thoracic cavity through the intercostals muscles is more difficult (it takes more time and needs more strength) but later pushing the bar through the thorax is in our opinion safer. Nuss has modified the introducer to the oval shape (11). Hernandez et al. (25) postulated extrapleural introduction of the bar with a control of intrapleurally introduced thoracoscope. They believe that this modification makes the insertion and removal of the bar safer.

Described in the literature complications, among them three cases of heart injuries (26) caused that Nuss and others insert pectus bar with thoracoscopic control with trocars introduced to one or ever both pleural cavities (27, 28). However there are surgeons who still introduce the pectus bar without thoracoscopy (29, 30) or use thoracoscope in selected cases (31).

In our opinion, based on the experience of 190 operations with no inner organs injuries, thoracoscopy is unnecessary on condition that the directly inserted bar has oval endings, the introduction of the bar is careful with constant contact with ribs and sternum an the operator has proper surgical experience.

During the operation in the Department of Paediatric Surgery in Katowice, the thoracoscopy equipment is ready to use on the operation room and the surgeon can open the thorax immediately. Neither thoracoscopy nor thoracotomy was necessary in the presented material. In one 11-year-old boy with Marfan syndrome operated in Lviv, bilateral haemothorax and haemopericardium was noticed in the first postoperative day. The source of the bleeding has remained unknown because it was cured by means of the triple drainage and blood transfusion. It was our only severe complication after the Nuss procedure.

There are also described severe complications in the literature as bilateral pleural empyema with bacterial pericarditis or numbness and ischemia of the upper limbs (Thoracic Outletlike Syndrome) (32) and hemorrhage from internal thoracic artery 4 months after operation (33). We observed also a few cases of transient pain and numbness of upper limbs. We thought it was rather connected with neural plexuses compression during child’s position changing then compression by pectus bar. The referred authors had these complications during surgeon’s first ten operation or when the surgeon performed the operation based on the method description he had read or video

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Fig. 4. Pectus bar, bender and measure (BHH Micromed Dąbrowa Górnicza)
The nuss procedure for the correction of pectus excavatum

image (32). The authors from Korea emphasize the role of the experience. They performed 335 operations. The complication rate was 29.4% in the early group, and it was cut down to 12% (35). Next described complication is an exudate to the pericardium in the tenth postoperative day (36).

Minor complications, which are not life threatening: would abscess, adverse reaction against the bar, pneumonia, minor pneumothorax are described in similar rate by many authors (32, 34).

In one of the largest analyzed group of 461 operated children the general number of intra- and postoperative complications was 13.4% (13). The allergy on the bar is in 1% of cases (35). Infectious complications or adverse reaction against the bar, which is very often indistinguishable, were noted in 8 children (5.7%). There was no need to remove the bar. The infectious complication rate in the study from Graz and Utrecht was 6.8%. The bar had to be removed only in one case (37).

Bar displacements several days or even months after the operations are described by many authors. Accessory metal crossbars are used for pectus bar stabilization or the bar is fixed uni- or bilaterally by means of steel wire (28, 29, 34). The cardiac tamponade caused by the wire migration two years after the operation was described (38). In the presented material the bar displacement was noted in one case a few days after surgery and it needed reoperation. In one case the bar displacement was found several months after operation; the chest became again excavated but less then before and the patient did not agree for repairation. In a few other cases the bar endings were displaced but it caused no secondary excavation of the sternum. We have fixed the bar by means of three bilateral absorbable sutures. But the most important is proper bar length and adjusting to the shape of the chest. Many times we turned the bar again once or even more times to readjust its shape. Such modeling of the bar has also disadvantages. The complaints for discomfort during deep breathing caused by excessive bar pressure were noted; as well as minor deformations of the ribs were found during bar removal. The tight fitting of the bar can theoretically limit lateral growth of the chest. We did not find clinical sights of such limitations. The connective tissue grows around the bar endings during two years, sometimes it has a character of peristium and a chisel was necessary during its removal. One can conclude that tight adjustment of bar will prevent its displacement but, for above mentioned arguments, it has also some disadvantages. Very many surgeons use lateral crossbars which prevent bar displacement (11, 27, 34). It is however an accessory foreign material near the skin surface. The authors from Japan (39) showed that lateral crossbars are responsible for adverse reactions in the wound. Besides the stabilizing crossbars the bar can be fixed by means of a wire around a rib in one or more points (13, 30, 40).

Till now the bar was removed in 101 children. A wound abscess was noted in one case. A need to do a second operation to remove the bar is a disadvantage of the Nuss procedure. The endings of the bar are usually surrounded by the connective tissue, so bar removal is troublesome sometimes. There is a description of a case of massive hemorrhage from the right lower pulmonary segmental artery that happened during bar removal and it needed transfusion of 13 blood units and emergency thoracotomy (26).

The time of the operation presented by different authors is inexplicably long: 80.4 ± 27.4 min (42) 67.2±33.1 (7, 43), 90 min (28) and even 3.3 hours together with insertion of the epidural catheter (4). In the presented material, the mean operation time from marking points to skin suturing was. 40 min and the mean time from beginning of the anesthesia together with insertion of bilateral intrapleural catheters was 80 min. Many times the time of bar introduction was shorter then its removal, however we did not analyze it. Thoracoscopy, lateral crossbars and wire stabilizations probably influence the extension of the operation time.

The age range of the patients who were qualified to the operation is wide in the literature, from 2 to 18 years (4, 43). Adults are also operated (13, 44). In our children’s hospital the age limitation is 18 years. In our opinion the best age for this operation is 12-16 year. Fonkalsrud (1) is of a similar opinion. The chest construction is still pretty elastic and compliant for the shape changes. During two years the costal cartilages gradually ossify and the chest shape is permanently stable. The tendency to operate children in the age 6-10 years
is in our opinion a result of parents’ pressure and it can cause secondary deformation after the bar removal which can need next operation. The authors from Japan, based on small material of 23 operated children concluded that better cosmetic results and lower complication rate are achieved in children operated before 10\textsuperscript{th} year of life (45). No age is a contraindication for operation. We have operated on a two-month-child with severe deformation of the chest who was mechanically ventilated since the birth. A few days after the operation the child became respiratory stable. In the next child operated on in the second year of life because of extreme deformation (a child with cerebral paralysis) the cosmetic result couldn’t be assessed as good but a great improvement was achieved and recurrent pneumonias and bronchitis ceased. The operation is easier in younger children. The children with chest deformations are observed in the surgical clinic. Major worsening of the deformation and mostly emerging of the asymmetry is an indication for earlier operation.

The results of the operation justify its wide application. The authors who compare Nuss and classic Ravitch procedure omit a very important aspect: a very exposed scar on the from wall of the chest versus two 2-3 cm scars in the axillary region (41, 43) (fig. 5, 6). And the operation is performed in many cases for psychological reasons. A growing up child is ashamed of his chest appearance and it is disadvantageous for his psychophysical development. The indication for the operation in our material was first of all unaccepted by a child and his parents body appearance. Many times child, consulted in the age of 7, 10 or 12 years, accepted his appearance however in the age of 15, 16 years asked us for even immediate operation.

There are many papers assessing the influence of the chest deformation on the cardiovascularily and respiratorily efficiency. The opi-

Fig. 5. Before operation  
Fig. 6. After operation
nions are ambiguous. It seems however that the chest deformations (excluding extreme cases) have no impact on average physical efficiency but limit maximal physical efficiency. Postoperative studies showed small but significant improvement of respiratory efficiency (46). The survey study of the children and their parents after the operation showed significant improvement of their physical efficiency and psycho-social behavior (3, 47). The results assessed by the physician as good were many times assessed by patients and parents as very good. Every child before the operation had pulmonology consultation with pulmonary function test, cardiology consultation and computed tomography. The results are similar to other authors’ ones. Haller index was assessed based on CT image. Its value above 3.25 is a common indication for operation (47). Haller index does not only depend on the depth of deformation but also on the chest width. The Haller index in our series was 2.2 to 5.8 (Normal = 2.52). In our material the qualification to the operation was done based on chest appearance and not Haller index. A mean value of CT index in the literature was: 4.2, 4.8 (1), 4.96 (34).

Bad results are caused predominantly by improperly introduced bar, its displacement or asymmetry of the deformation. Therefore, in the case of asymmetric deformation modified Ravitch procedure seems to be more advantageous (1, 18). Asymmetric pectus bar has been proposed as a modification of the Nuss procedure (48). We used asymmetric bar in two recent cases and the early postoperative result was very good. A precise morphologic analysis of the defect, presented by Cartoski et al. (49) can be useful in the accurate qualification for Nuss or modified Ravitch methods what will undoubtedly improve the results of pectus excavatum repair.

The pain after the operation of the chest is caused by its shape changes and it is intensified by the respiratory movements. A fear about a painful deep breathing and difficult expectoration endangers in the postoperative period such complications as atelectasis, hypoxia and pneumonia. Sever postoperative pain affects adversely on the child’s psyche and delays physiotherapy. Traditional administration of the calculated doses of opiates can be disadvantageous because of the risk of breath depression and chest rigidity. Regional analgesia is free of these disadvantages and can be used after such operations. Introducing at the end of the operation, the regional analgesia enables smooth reviving. Epidural thoracic analgesia, intercostal nerve blockade, paravertebral analgesia or bilateral intrapleural analgesia can be used after the operation of pectus excavatum (50). The latter method is used in our institution. In all children the postoperative analgesia is applied by inserted bilaterally intrapleural catheters. A 0.375% solution of bupivacaine with epinephrine 1:200 000 used to be injected every four hours, a and nowadays is applied in form of infusion (50).

CONCLUSIONS

The results of the Nuss procedure for the correction of pectus excavatum are good in most cases. The minimal invasiveness of this method allows that this procedure can be performed in cases where the defects are even minimal. The limitations of this method are asymmetric defects in that modified Ravitch procedure remains a method of choice.

REFERENCES

8. Nuss D, Kelly RE, Croitoru DP et al.: A 10-Year Review of a Minimalny Invasive Technique For the
40. Uemura S, Nakagawa Y, Yoshida A et al.: Experience In 100 cases with the Nuss procedure

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COMMENTARY

The commentary to the paper is very difficult. Undoubtedly so called Nuss procedure is one of the methods that recently have significantly influenced surgical treatment of chest deformity of pectus excavatum type. It is important to include this procedure in the routine management of patients. Although this procedure is mainly used in pediatric patients, it is also widely used by thoracic surgeons taking care of adult patients. In my opinion it is underscored by a very interesting session on this subject, during 4th Congress of Cardiac and Thoracic Surgeons that took place in Warsaw in June 2008.

Thus we can understand the “fascination” of the Authors with this method. However, introduction of a new method must be done according to certain conditions and even rigors. Preferably an original management protocol should be used in its introduction, if only this is possible. Thus I have doubts whether this fascination justifies use by the Authors of plates intended for different purposes in their first 10 cases. Plates for bone fusion have numerous holes for nails and it was obvious that they would grow inside the chest cavity. I hope that the Authors had obtained approval of an appropriate bioethics committee for such deviation. Otherwise one could timidly ask whether it was a “medical experiment”, acute one in fact. In fact, an expensive but original equipment could have been imported and on its basis cheap plates and equipment, adjusted to Polish conditions, could have been made in cooperation with technical scientific institutions (1, 2, 3). In this way such method could have been popularized in Poland.

The “own modification” method, presented by the Authors, does not differ from the original protocol used by D. Nuss. The modifications apply only to three out of 13 steps of the procedure described in the methods (steps 6, 7 and 12), i.e. “blind” introduction of the plate without previous use of appropriate guide, positioning band and videothoracoscopic guidance and analgesic management. Such management could be questioned. It is being used less and less commonly and even D. Nuss treated thoracoscopy as a standard management for several recent years. However, direct insertion of the plate is more risky than its insertion using a clamp and directional band used in the original protocol of the procedure performed by D. Nuss.

However, the statement “In our opinion ... thoracoscopy is not required” raises serious
doubts in a surgeon who is familiar with mediastinal anatomy, the size of deformity and possible adhesions in the pleural cavity. Without videothoracoscopic guidance the procedure is extremely risky and could be associated with complications that are difficult to foresee. Furthermore, the statement "equipment for thoracoscopy is ready for use in the operating room along with tools for thoracotomy and a surgeon that is able to immediately open the chest cavity" seems not only surprising but also terrifying for a thoracic surgeon who knows how difficult is to help a patient when thoracotomy must be performed "immediately". 

These facts made it difficult for me to comment on this paper. Because how we are to convince a surgeon who has the impression that "his own modification" is optimal and is associated with no more complications than a safe method under thoracoscopic guidance. Let me present an example: the author of this commentary, during first years of using the Nuss procedure, mad a slight tear of pericardial sac in three children despite careful preparation of the mediastinum. If it were not for the fact that the procedures were performed under optical guidance I would have also be convinced that these procedures were uncomplicated due to "sensed friction between the plate and the inner surface of the sternum". The Authors describe bleeding into both pleural cavities and pericardium in a boy who underwent surgery in Lvov; in this case such major bleeding was controlled with a triple drainage (!) and blood transfusion (!). Because it was a "blind" procedure, no one can tell what complications occurred. It is a pity, too, that once the complications were detected, no thoracoscopy was performed to determine the intraoperative injuries.

The results obtained by the Authors support the opinion, already presented and established in the literature, that so called Nuss procedure was a minimally invasive procedure that allowed expansion of therapeutic indications to encompass cosmetic deformations.

My comments that are based on experience of 700 patients that were operated using this method and over 35 years of experience in the surgical treatment of chest deformations, should be treated only as a contribution to the search of optimal and safe solutions. I believe it is an obvious precondition in view of more and more common "cosmetic" indications for the surgical treatment. I hope to build such standard just as I succeeded in creating a cheap and safe set of tools enabling popularization of this method in Poland, in cooperation with employees of Silesian University of Technology and BHH Micromed in Dąbrowa Górnicza.

REFERENCES


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