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MODIFICATION OF THE NUSS PROCEDURE-PREVENTION OF INJURIES OF THE HEART AND MAJOR BLOOD VESSELS

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Objective: The Nuss procedure is a widely accepted technique for correcting pectus excavatum. Unfortunately, fatal complications such as cardiac perforation and injury of the great blood vessels have been noticed in a few patients.We modified original Nuss technique to be simpler and less dangerous. **Methods**: We modified Nuss procedure with the sternal elevation to improve sternal depression. Modified Nuss procedure was carried out by applying metal lifter raise sterum until the patient starts to raise from the operating table. The space behind sternum is now wider, and surgery has become safer with less probability of injuries intrathoracic organs. We compared 46 patients operated by the original Nuss method (taking into account the data from the literature on complications of the original method on a large series of patients) with 54 patients operated by a modified Nuss method. **Results**: Before lifting the sternum depth of the deformity was between 2.9 and 6.2 cm (mean 5.4 cm), and the increase were between 1.5 and 4.0 cm (mean 2.8 cm). The difference of 2.6 cm is large enough, and the width of introducer and bars are about 3 mm for securely passed along the chest. **Conclusions**: A modified method of treating pectus excavatum is safer, better and with fewer complications than the original method of Nuss.

Key words: ***pectus excavatum, modification, Nuss technique, lifting the sternum***

INTRODUCTION

Pectus excavatum is the most common chest deformity, which consequently leads to changes in the health of patients. Surgery for reconstruction of the chest may be indicated because of the very pronounced symptoms of cardiovascular and respiratory systems. Similarly, in children and adolescents as well as cosmetic, psychological and social factors could be the leading reason for setting indications for surgical correction. Some patients may be present either as a reason to change cardiorespiratory system with a strong psychological problem.[1,2] Surgery is recommended for symptoms that worsen the deformity. Usually expressed are obstructive symptoms and/or restrictive changes in the lungs, the heart shift with pressure of the lungs and changes in the heart in terms of prolaps mitral valve or conduction block branches.[3-6] In all patients with pronounced symptoms of cardiovascular and respiratory system on CT findings is evident compression of the heart and lungs. In all patients Haller index was greater than 3.25. In patients with psychological symptoms surgery is indicated if the psychological and psychiatric treatment did not lead to results, although Haller index is not greater than 3.25.[7-10]

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Surgery in the treatment of pectus excavatum is necessary:

- in patients with pronounced symptoms of cardiovascular and respiratory systems
- in patients whose Haller index greater than 3.25 and
- in patients with mental problems, if psychological and psychiatric treatment is not given satisfactory results.

The Nuss procedure is a minimally-invasive procedure, invented by Dr. Donald Nuss for treating pectus excavatum.

Through two small incisions in the side of the chest, an introducer is pushed along posterior to the sternum and ribs, anterior to the heart and lungs. Then a concave stainless steel bar is slipped under the sternum, through the incisions in the side of the chest. Thoracoscope is used to help guide the introducer and the bar under sternum. We set thoracoscope in the area of the incision and thus obtain better cosmetic results. With thoracoscope introduce CO2 in chest cavity and thus reduce the volume of the lungs and get better visibility. With thoracoscopic assisted Nuss procedure we can see the space behind the sternum and possible anatomic anomalies. Top of the introducer and bar must always be in contact with the sternum, and so we try to avoid contact with the pericardium and heart. The bar is then flipped, and the sternum pops out. To support the bar and keep it in place a metal plate called a stabilizer may be inserted with the bar on one side or both sides of the torso. The stabilizer fits around the bar and into the ribcage. The bar and

stabilizer are secured with sutures that dissolve in about six months. The only drawback of Nuss method is a narrow space behind the sternum and can get to injury of the heart and large blood vessels.[11-14]

With modification of the Nuss method we wanted to expand the space between the sternum and heart, and thus get a safer procedure for the treatment of funnel chest. In the area of greatest depression of the sternum, ribs, and the vertex of the sternum, we set the lifter which we raise the sternum. Raising the sternum deformity is smaller and raising stops when the patient begins to raise the operating table. Reducing deepest depression gets a wider space between the breastbone and heart and mediastinal tunnel could be created safely with our technique.

METHOD

Improving the original method was conceived as increasing retrosternal space. Set metal tendril of sternum in the strongest depression, and then raise the sternum. Lifting the sternum is only necessary in times of wiring introducer and bar. Breastbone raise with metal tendril until began to lift patients from the operating table. Immediately after pull through introducer and bar under sternum, we take off metal holder and further surgery is performed by the method already described.

This research was approved by the Regional Ethical Review Board in Croatia by the Zagreb Hospital, Zagreb Croatia. All patients included gave their informed consent signed by their parents. We compared 46 patients operated by the original Nuss method (taking into account the data from the literature on complications of the original method on a large series of patients) with 54 patients operated by a modified Nuss method. Throughout the comparison, there were statistically significant differences in several parameters between the original and modified Nuss methods.
Increasing the space behind the sternum, we get a wider area, which until now could not see. Thus increasing the space behind the sternum can be set with greater security introducer and bar. Safety of surgery was significantly higher. Thoracoscopic view until now has seen the area below the sternum completely, but after raising the sternum retrosternal space is wider and has set up introducer and bar more easily. To prove the value of improvements we have measured the depth of the deformity before surgery and after lifting the sternum. Before surgery the average depth of the deformity was between 2.9 and 6.2 cm, which is an average of 5.4 cm. Lifting the sternum deformity was reduced from 1.5 to 4.0 cm, which is an average of 2.8 cm. The difference in measurements before and after lifting the sternum is 2.6 cm (p = 0.0000, according to Wilcox test for dependent samples). Through such expanded space with greater certainty can be implemented first introducer, and then bar. Retrosternal space is significantly expands and provides greater safety operating procedures. The difference of 2.6 cm is large enough, and the width of introducer and bar are about 3 mm for securely passed along the chest.

RESULTS

In the original and a modified method of the indications for surgery do not differ. Indications for surgery in patients with psychological problems were not significantly different in both methods, as well as in patients with clinical problems. The difference between these two methods is the duration of surgery. Duration of the modified surgery was 65 to 98 minutes (average 77 minutes), duration of the original surgery between 65 and 98 minutes (average 72 minutes) (p = 0.0004). The average difference of 5 minutes duration of the operation relates to the time required for mounting and dismounting metal tendril for lifting the sternum. Also there was no statistically significant difference in the need for blood transfusion, duration of hospitalization, duration of pain and return to normal life. Statistically significant difference was not observed in the postoperative appearance of satisfaction. Statistically significant difference was the width of space between the sternum and intrathoracic organs (heart, pericardium, lungs and large blood vessels) before and after lifting the sternum. Before lifting the sternum depth of the deformity was between 2.9 and 6.2 cm (mean 5.4 cm), after lifting the sternum deformity is reduced between 1.5 and 4.0 cm (mean 2.8 cm). The difference of 2.6 cm is large enough, because the width of the introducer and bar are about 3 mm, for safe passage below the sternum. Statistical analysis provides a statistically significant difference in the width retrosternal space before and after lifting the sternum. What is a child younger and have more cartilage a result of lifting the sternum is better. In children over 16 years raising the sternum is possible, but with less success. Statistically significant differences in ECG findings we noticed during the operation of the original and modified Nuss methods. In all patients who have operated the original method of Nuss without raising the sternum and Hallerov index was greater than 3.25, 8 patients (17.4%) had extrasystoles before correction of the deformity. In all patients who had operated with Nuss modified method of raising the sternum 11 patients (20.4%) had extrasystoles before operative treatment. Comparing the number of extrasystoles before surgery was not observed statistically significant differences between patients (p = 0.9023). During surgery, we noticed an increased number of disturbances in the work of the heart in the form of extrasystoles, whose cause was contact with the heart and introducer or bar. This phenomenon is

particularly pronounced in patients operated with Nuss original method. During the operation with the original Nuss method extrasystoles had 38 patients (82.6%), and during the operation with Nuss modified method 12 patients (22.6%). The difference in the number of extrasystoles was created due to contact introducer and bar with a heart. Statistical analysis (p = 0.001) showed statistical difference between the number of extrasystoles occurred in patients operated on both methods. With the modified method reduced the number of extrasystoles because there are no contact introducer and bar with a heart. Duration of hospitalization was not statistically different, because the original method is calculated between 8 and 20 days, an average of 12 days, a modified method of between 8 and 17 days, an average of 12 days (p = 0.7794). Duration and intensity of pain after surgery than the original and modified methods do not differ statistically (Table 1, Figure 2). The border of statistical significance is considered p = 0.05.

Table 1
Comparison of Original and Modified Nuss Methods

Parameter	Original N = 46	Modified N = 54	Diff**
Age (years)	14 (7 – 17)	14 (8 – 20)	p = 0.494
Haller index	5.2 (2.9 – 6.4)	5.2 (3.0 – 6.1)	p = 0.995
The depth of the deformity (cm)	5.2 (3.5 – 6.1)	5.4 (2.9 – 6.2)	p = 0.090
The depth of the deformity after lifting (cm)	–	2.8 (1.5 – 4.0)	p = 0.001*
Extrasystoles	8 (17.4%)	11 (20.4%)	p = 0.902
Extrasystoles during the operation	38 (82.6%)	12 (22.2%)	p = 0.001
Duration of surgery (min)	71 (65 – 95)	77 (65 – 98)	p = 0.001
Duration of hospitalization (days)	12 (8 – 20)	12 (8 – 17)	p = 0.779

* The difference between increase the depth before and after surgery with Nuss modified method, tested with Wilcoxon test for dependent samples
**The border of statistical significance is considered p = 0.05

According to statistics from the literature pericardial and heart lesions occur in 0.4 to 1.5% operated patients.[15-19] In our 100 patients who were operated by Nuss method or a modified Nuss method, we can expect one patient with an injury of the heart or major blood vessels.

Operated with original Nuss method in some patients with pronounced deformities, we were in direct contact with the heart. In all patients we had thoracoscopic monitoring of the operation and thanks to that there has been no injury to the heart. Changing the methods and the introduction of modifications in 54 of our patients, even with the greatest deformity, there was no contact with the heart or pericardium. Retrosternal larger space was sufficient for safe wiring introducer and bar. Analyzing the results we come to the conclusion that increased retrosternal space and thoracoscopic visualizations are a great combination for the safe operation

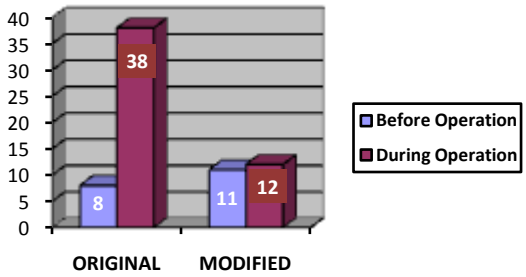

Figure 2
Extrasystoles in patients operated with original and modified Nuss method

DISCUSSION

According to statistics from the literature pericardial injuries and heart occur in 0.4 -1.5% operated patients. Of the 100 patients who were operated with the original and modification of the Nuss method, we can expect to have one patient with lesion of pericard and heart during surgery. The first step in preventing these complications is introduce of the thoracoscope and visualization of the heart, pericardium and space below the sternum.[20,21] Another step that helps in preventing life-threatening complications is to raise the sternum. The difference in the depth of deformation prior to lifting the sternum is an average of 5.4 cm and an average increase of 2.8 cm was a statistically significant difference of 2.6 cm (p = 0.000, according to Wilocox test for dependent samples). When we consider that the mounting plate and the thickness of about 3 mm, we can conclude that the obtained retrosternal much wider area. The possibility of lifting the sternum depends on the age of the patient. Raising the sternum is easier and more successful in children with more cartilage at the junction of ribs and sternum. The ideal age for surgery is 10 to 14 years, when lifting the sternum is easily and successfully. Lifting the sternum like operative modification of the original Nuss method ensure a safer operation. When the width of retrosternal space is bigger, the better the visibility and therefore reduces the possibility of complications that have already been described. Evidence that the

guidelines and contact plates with the heart and pericardium is the increase in the number of extrasystoles during the operation. At the original Nuss operating techniques before surgery 8 patients (17.4%) had cardiac arrhythmias. In the course of the original operation by Nuss method a heart rhythm disorder had 38 patients (82.6%). Before surgery 11 patients (20.4%) had cardiac arrhythmias, and during operations by a modified method in 12 patients (22.6%) there was a disruption in the work of the heart. Statistically increased number of extrasystoles in the original Nuss method shows that the ongoing operations in close contact bar and heart, and with a modified method to that contact does not come.

CONCLUSION

We have not encountered cardiac perforation, aortic laceration or lung injury during the modified procedure. The number of patients who were operated with modified procedure was too small but we prove validity of our modification.

Analyzing the results of original and modified Nuss methods we have detected a number of advantages which has a modified method. In our study we have identified the following advantages: lifting the sternum significantly increased retrosternal space.

Large retrosternal space for the passage of the introducer and bar reduces the incidence of complications. During the operation was statistically significantly lower number of reported disturbances in heart rate and number of extrasystoles. Less contact of the heart and guides present a small number of extrasystoles.

All the advantages of the original Nuss method is also present with the modified method.

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