Journal of Physical Education and Sport ®(JPES),Vol 21 (Suppl. issue 2), Art 151 pp 1191 – 1196, Apr. 2021
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Assessment of the effectiveness of using physical exercises in patients after surgical intervention by the „pectus excavatum" owing to the Nuss procedure

IAKIV FISHCHENKO[1], IRINA ROY[2], LYUDMILA KRAVCHUK[3], VOLODYMYR KORMILTSEV[4]
[1,2] State Institution «Institute of Traumatology and Orthopedics National Academy of Medical Science of Ukraine», UKRAINE
[3,4]National University of Ukraine of Physical Education and Sport of Ukraine, UKRAINE

Published online: April 30, 2021
(Accepted for publication April 15, 2021)
DOI:10.7752/jpes.2021.s2151

Abstract.
To date, more than 80 different options for surgical interventions and their modifications have been described for the treatment of «pectus excavatum». The problem of rehabilitation of patients after reconstructive operations on the chest is relatively new in orthopedic rehabilitation; many aspects of this complex process have not been sufficiently studied yet. *The research aims* to evaluate the effectiveness of using a therapeutic exercise for patients after surgical intervention in case of the "pectus excavatum" according to the Nuss procedure. *Materials and methods.* The study was performed at the Spine Surgery clinic of the Institute of Traumatology and Orthopedics of the National Academy of Medical Sciences of Ukraine. Studied population: 145 patients with the diagnosis "pectus excavatum" underwent the minimally invasive correction using the Nuss procedure. After corrective surgery according to the Nuss method, the patients were divided into two study groups: the control group, or the observation group (CG, n = 96), which did not resort to physical rehabilitation and was observed throughout the study period, and OG (n = 49), whose patients have undergone a physical rehabilitation program. *Results*. The 14 days after the operation, according to the scale "Physical activity", "The role of physical problems in limitation of vital functions", the main group indices were significantly higher: in main group (61,1±4,5), ($\bar{x}$±S)) against control group (42,5±3,88), ($\bar{x}$±S)),(p<0,05) accordingly. A similar trend continued at the remote stage of the survey after 12 months (in the main group 99,3±1,12(($\bar{x}$±S)) and the control group 85,3±5,54($\bar{x}$±S)), (p<0,05), respectively. During the comparing indicators on the scale "Physical activity" at the remote stage of the examination, it was found that the results of the patients of the main group significantly exceeded the results of the control group (in the main group 94,3±5,32 ($\bar{x}$±S)) against 80,3±4,21 ($\bar{x}$±S)) in the control group), the differences were statistically significant (p<0,05). *Conclusions.* The program developed a postoperative rehabilitation program for patients after surgical correction of pectus deformity using the Nuss procedure significantly improved quality of life according to the SF-36 questionnaire, especially in physical and vital activity in the early stages after the operation. These indicators were also significantly higher after 12 months. after surgical intervention.
Key words: **funnel chest deformity, Nuss procedure, therapeutic exercise**

Introduction.

Among all congenital chest defects, funnel chest deformity (as the «pectus excavatum») is the most common defect (Nuss D., 2008; Kotzot, D., Schwabegger, A. 2009; Biniwale R., 2009). The most likely reasons for forming the «pectus excavatum» scientists distinguish a decrease in the strength of the costal cartilage and chondrodysplasia of the costal cartilage, bringing to the advanced growth of the ribs. The exact cause of costal cartilage overgrowth remains unknown, and research results are conflicting (Kotzot, D., Schwabegger A., 2009., Nuss D., 2008).

Today, more than 80 different options for surgical interventions and their modifications have been described to treat pectus deformity (Croitoru, D., Kelly R., 1998). Since 1998, the Nuss procedure has been introduced into the practice of surgical correction in children; it implies remodeling of the anterior chest wall using a retrosternal metal fixator without costal cartilage resection (Croitoru, D., Kelly, R., Goretsky, M., Lawson, M., Nuss, D., 2002). The procedure has several advantages, and there are followed: small skin incisions, shorter surgery time, minimal blood loss, and early return to full activity. This method quickly established itself in the practice of various clinics around the world due to the relative ease of learning and low trauma (Nuss D., 2008, Hebra, A., 2000; Watanabe, A., Obama, T. 2004).

According to the scientific data, approximately 75-80% of patients rank a cosmetic defect and a low level of self-esteem among the reasons for resorting to surgical correction. Nuss, D. (2008), Kotzot, D.,

Corresponding Author: IAKIV FISHCHENKO, E-mail: fishchenko@gmail.com

Schwabegger, A. (2009) additionally to a cosmetic defect, the disease entails pathological changes in the cardiovascular and respiratory systems. Thus, the question of the feasibility and need for physical rehabilitation after such surgical interventions remains open. Postoperative recovery of such patients requires bringing the specifics of the disease. In addition to deformity, patients with "pectus excavatum" have varying degrees of severity of pulmonary ventilation disorders, cause hypoxia and metabolic disorders in the tissues. This leads to the appearance of several vasoactive substances that contribute to the development of microvascular diseases, maintaining and aggravating disorders of tissue metabolism. Dysfunctions of external respiration and microcirculation decrease myocardial contractility, leading to a decreasing in the cardiorespiratory system's reserve capabilities, which are clinically manifested by respiratory and heart failure and a decrease in exercise tolerance (Hebra A., 2000). The rehabilitation of the patients after reconstructive surgery on the chest is relatively new in orthopedic rehabilitation; many aspects of this complex process have not yet been sufficiently studied. (Quigley P., Haller J., Jelus K., Loughlin G., Marcus C., (1996). There are no randomized studies that would justify and describe rehabilitation features after surgical intervention by the "pectus excavatum" deformity by the Nuss procedure. The followed aspects led us to initiate this study and defined its aim.

The research aims to evaluate the effectiveness of using a therapeutic exercise in patients after surgical intervention by the "pectus excavatum" according to the Nuss procedure.

Materials and methods.

The study was performed at the Spine Surgery clinic of the Institute of Traumatology and Orthopedics of the National Academy of Medical Sciences of Ukraine from the 2015 to 2020 years. Studied population: 145 patients with the diagnosis "pectus excavatum" underwent the minimally invasive correction using the Nuss procedure. The average age of patients was 16.8 ± 8.5 years (from 11 to 42), 121 (83.5%) were males, 24 (16.5%) were females. Indications for surgical intervention were the cosmetic defect of the chest's anterior surface and the depth of the sternum's retraction of more than 2 cm. All patients examined clinically and radiographically before the operation using the Gizhytska index. Subsequently, after the corrective surgery according to the Nuss procedure, the patients were divided into two study groups: the control group or the observation group (CG, n = 96), that did not resort to physical rehabilitation and was observed throughout the study period, and MG (n = 49), patients with using the rehabilitation intervention after surgery. Postoperative complications and quality of life after surgery were assessed in patients of both groups.

Patients of both groups filled out the SF-36 questionnaire (Medical Outcomes Study Short Form (SF-36), to assess the quality of life before and after surgery (Croitoru, D.P., Kelly, R.E., Goretsky, M.J., Lawson, M.L., Nuss, D. 2002) . Follow-up research was 12 months. The questioning was carried out before surgery, after 14 days, and after 12 months, after the surgical intervention. The obtained data were subjected to statistical processing with the calculation of the reliability of differences. The level of statistical significance was recorded at $p < 0,05$. Statistical calculations were performed using Microsoft Excel and a statistical data analysis package Statistica 5.1 for Windows (Stat. Inc., USA).

Physical rehabilitation program

Features of interventions after surgical correction of the "pectus excavatum."

The program of rehabilitation for MG was developed for the following phases.

1 – early postoperative phase (5-7 days after surgery).

On the 1st day after the surgical treatment, we recommended bed rest, the maximum restriction of physical activity; in the next 4-6 days, they were allowed to get up and move but try to limit physical activity to a minimum. Despite the rather pronounced pain syndrome after the first three days, patients need to get up and walk around since prolonged bed rest leads to complications from the lungs.

Permitted exercises:

- ⇒ For a performing household elementary self-service manipulations;
- ⇒ Easy breathing exercises (for the chest type of breathing), without involving the diaphragm;
- ⇒ Exercises of low intensity in the starting position of sitting and lying;
- ⇒ Dynamic hand movements (with limitation of abduction up to 40-50 degrees);
- ⇒ Various exercises for the lower limbs;
- ⇒ Walking (10-15 min.).

Prohibited exercises:

- ⇒ Exercises with torso bending;
- ⇒ Exercises with torso rotation (up to 3 months after surgery);
- ⇒ Any exercises for the abdominal muscles;
- ⇒ Exercises with an immediate change in starting position (as the from lying on back to sitting transfer);
- ⇒ Jumping exercises;
- ⇒ Exercises in the starting position, lying supine and prone.

Physical therapy was contraindicated in the presence of any complications (pneumonia, pleural effusion, seroma, empyema).

A specific feature of the postoperative course after chest reconstruction was the presence of severe pain syndrome. We recommended that patients of both MG and CG use narcotic analgesics for four days after the operation to resolve pain syndrome, followed by switching to non-narcotic. After discharge from the hospital, the patients took painkillers for 2-6 weeks with a gradual dose reduction. *2nd phase - late postoperative (from the 7th day after the operation and up to 3 months*). Patients were transferred to the rehabilitation department (patients from the MG) or were discharged home (patients from the CG). During this period, the use of physiotherapeutic exercises aims to solve the main problem - the prevention of postoperative complications. During the first eight weeks, patients were advised to limit their usual physical activity, perform movements of the upper limbs without burdening. Breathing exercises were recommended to patients by the physical therapists.

These exercises aim to teach the patient to breathe correctly to strengthen the respiratory muscles. During the activities performing, the patients should consider followed recommendations:

⇒ correct breathing during exercise; inhalation is performing through the nose, and exhalation is two times longer than inhalation, acting by the mouth (lips with a "tube");

⇒ all exercises must be performed slowly; vigorous movements are contraindicated;

⇒ the load during exercises increases gradually, due to the number of repetitions of each exercise, but not the intensity;

⇒ if painful sensations appear, the session must be stopped.

⇒ It is categorically not recommended to perform exercises at elevated temperature, with exacerbated pain syndrome or "through the pain."

⇒ Breathing exercises are performed in lying and standing; the range of motion in the chest is limiting as much as possible.

In the first month after the operation, deep bending forward-backward - to the sides was excluded. Lifting weights, including school bags or backpacks, was limited for one month. Excluded completely contact sports performances, any exercises for the abdominal, deep diaphragmatic breathing exercises. It was recommended to return to everyday household activity as pain syndrome decreased. Walking was unlimited activity.

3 - training phase (from 3 months and later).

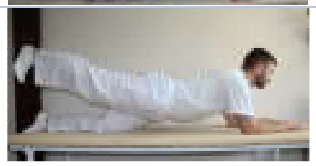
Since the capsule around the metal retainer is formed within 3-4 months, the retainer displacement probability enormously decreases after this period. From 3 months onwards, patients were allowed to perform active exercises in various starting positions. In patients with "pectus excavatum," postural disorders in the sagittal projection were quite often observed. Therefore, the complexes were supplemented with exercises aimed at strengthening the dorsal muscles (trapezius, rhomboid, latissimus dorsi), preventing the formation of thoracic hyperkyphosis. Since during the period of restriction of physical exertion, the muscle corset weakened, it was recommended to start with minimum amplitude exercises and isometric exercises.

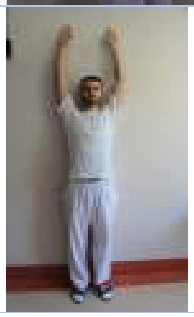
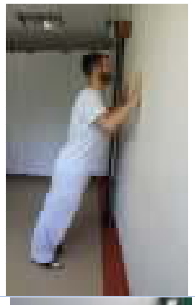
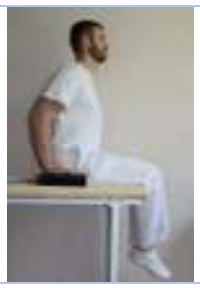
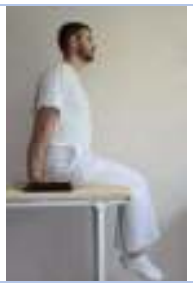
The main tasks during this phase of rehabilitation:

1. To eliminate muscle wasting and strengthen the muscle corset.
2. To develop a stereotype of correct posture.

The exercises were aimed at increasing mobility in the shoulder joints and strengthening the strength endurance of the back muscles, abdominal muscles (in isometric contraction mode), and other postural muscles. From the active sports, cycling, swimming was allowed to the physical therapist patients (with restrictions, as the water exercises or aqua aerobics, without the upper shoulder girdle's active involvement).

The presented set of exercises was recommended for MG patients to be performed three months after surgery.

Content	Picture
1. Starting position – lying prone, hands at chest level. Lift the body, unbending your arms at the elbow joints; knees are on the couch. Keep the back straight. Return to starting position. Do two sets (15 reps)	
2. Starting position - lying prone, arms bent at the elbow joints, support on the forearm. Tighten abdominal muscles and lift the torso and right leg. Hold this position for 5-6 seconds, then return to the starting position. After 5 seconds of rest, repeat the exercise with your left leg. Do 1 set (10 reps)	
3. Starting position - lying supine. The right hand is on the stomach; the left is located on the chest. Breathe in through the nose and inflating the abdomen while keeping the chest relaxed and motionless. Exhale slowly through the mouth. Complete 1 set (20 reps)	

4. Starting position - standing, hands rest against the wall at chest level. Take a step forward, slowly resting both hands on the wall, keep your back straight (30 sec.). Return to starting position. Follow 1 set, (2-3 reps)	
5. Starting position - standing against the wall, arms bent at the elbow joints, along the body. Gradually raise the arms through the sides, keeping them straightened over the head, tighten the abdominal muscles and press the lower back against the wall (hold for 5-8 seconds). Return to starting position. Complete 1 set (10 reps)	 
6. Starting position - standing facing the wall at a distance of 2-3 steps. Place both hands against the wall at shoulder level. Slowly bending the elbow joints' arms, approach face to the wall, keep the back straight. Return to starting position. Follow two sets (15 reps)	 
7. Starting position - standing at the Swedish stairs, holding the elastic band with both hands. The arms are straightened and brought to the torso at waist level. Bring the arms back, keeping them straightened. Return to starting position. Perform two sets (15 reps) * *Do not bend the lower back during the exercise*	
8. Starting position - sitting on a chair, arms along the body. Pressing on the support with the hands, lift the buttocks off the couch. Hold the position for 5-7 seconds, keep back straight, return to the starting position. Do two sets (10 reps)	 

* - After completing a set of exercises, patients need to rest 5-10 minutes to recover.

Results

According to the research results, there are no lethal outcomes in the postoperative period. In 129 (88.9%) patients, we managed to achieve an ideal cosmetic result. 128 patients (88.2%) used one retainer, 16 patients (11.8%) used 2 retainers. The number of required fixators determined on the operating table depends on the results of correction after the first installation. The average length of hospital stay after surgery was 7-8 days (range was 5-11 days). Pleural drainage was left for one day only after repeated operations on the background of recurrent deformity. The next day after the operation, all patients underwent an X-ray of the lungs in frontal projection in the standing position. In 12 patients (8.3%) determined the pneumothorax presence, only the second (1.4%) required pleural puncture with drainage installation according to Bulau protocol. In 3 patients (2.06%), hemothorax was determined with a subsequent pleural puncture.

Other postoperative complications included:

– pneumonia was in 3 (2.06%) patients,
– pleural effusion was in 2 (1.4%),
– empyema was in 1 (0.68%),
– deep infection was in 1 (0.68%).

One patient (1.1%) underwent reoperation due to displacement of the retainer.

Evaluation of the results according to the SF-36 questionnaire showed that the patients of both groups at the time of the initial examination before the operation showed reduced physical activity as followed: in the MG (before the operation was 59.5 ± 3.67), ($\bar{x}$±S)) and in the CG (before the operation was 60,2±3,46), ($\bar{x}$±S)), the difference between the indicators of the groups was not statistically significant (p > 0,05). The RP indicator (the role of physical problems in limitation of life activity) was quite high, indicating an insignificant role of physical problems in limitation of life activity in children with deformity "pectus excavatum," the indicators are followed: in the MG (81,3±3,35), ($\bar{x}$±S)) and in the CG (83,6±4,01), ($\bar{x}$±S)) (p > 0,05). A similar trend observed during the assessing of the indicators on the pain intensity scale (BP), emotional ability to engage in habitual activities (RE), social activity SF: before surgery, both in children with MG and in the CG, the indicators were slightly reduced but did not differ significantly between the groups. (p >0,05). But according to the results of the scale of the general perception of health (GH), vitality (VT), and mental health (MH), both groups showed an unsatisfactory result, there are followed: according to the scale of the indicator of the general perception of health (GH) in MG (52,3±6,17), ($\bar{x}$±S)) and in the CG (55,21±4,32), ($\bar{x}$±S)), (p > 0,05) respectively; and on the mental health scale (MH) indicator was in MG (43,2±4,21), ($\bar{x}$±S)), and in the CG (40,9±4,65), ($\bar{x}$±S)), (p > 0,05) respectively.

Table 2

Assessment of the quality of life according to the SF-36 questionnaire in patients before and after surgical correction according to the Nuss procedure at the examination stages

Scale	Results before surgery		Results after surgery (14 days)		Long-term effects (after 12 months)	
	MG	CG	MG	CG	MG	CG
PF – Physical activity	59,5±3,67	60,2±3,46	*59,2±4,73*	*37,3±3,66**	*94,3±5,32*	*80,3±4,21**
RP – The Role of Physical Problems in Disability	81,3±3,35	83,6±4,01	*61,1±4,54*	*42,5±3,88**	*99,3±1,12*	*85,3±5,54**
BP – Pain intensity	88,5±3,54	89,5±4,12	23,3±4,22	25,5±5,12	90,5±4,32	89,7±4,16
GH – General perception of the health	52,3±6,17	55,2±4,32	54,4±6,33	54,2±5,23	97,7±5,05	95,6±4,55
VT – Vital activity	54,8±4,32	47,3±5,21	*69,5±5,43*	*50,4±4,34**	97,7±5,56	93,9±5,23
SF – Social activity	73,6±5,21	77,3±3,87	50,3±4,23	52,2±4,23	90,8±5,51	92,3±6,73
RE – Emotional Role Functioning	79,5±3,76	81,12±4,43	60,1±4,12	62,3±5,21	96,5±3,23	95,3±6,01
MH – Mental health	43,2±4,21	40,9±4,65	73,2±4,44	74,9±5,01	98,4±2,09	98,3±3,03

*Notes: * - the difference between the results of the MG and the CG is statistically significant when p <0,05;*

Thus, according to the results of the SF-36 questionnaire, children in MG and CG with deformity "pectus excavatum" showed a high level of social activity, i.e., sufficient emotional and physical ability to communicate with other people and the ability to domestic self-care; however, indicators of the general perception of health (GH) and mental health (MH) in children before surgery fluctuated within a reasonably low range. After the surgical intervention and evaluating early postoperative and long-term treatment results, it was found that statistically significant differences were observed between MG and CG in some indicators. So, 14 days after the operation, according to the scale "Physical activity" (PF), "The role of physical problems in limitation of vital functions" (RP), the MG indices were significantly higher: in MG (61,1±4,5), ($\bar{x}$±S)) against CG (42,5±3,88), ($\bar{x}$±S)),(p<0,05) accordingly. A similar trend continued at the remote stage of the survey after 12 months (in the MG 99,3±1,12(($\bar{x}$±S)) and the CG 85,3±5,54($\bar{x}$±S)), (p<0,05), respectively. During the comparing indicators on the scale "Physical activity" (PF) at the remote stage of the examination, it was found that the results of the patients of the main group significantly exceeded the results of the control group (in the MG 94,3±5,32 ($\bar{x}$±S)) against 80,3±4,21 ($\bar{x}$±S)) in the CG), the differences were statistically significant (p<0,05).

Thus, the assessment of the long-term treatment results according to the questionnaire (SF-36) showed that the quality of life in children after surgical treatment of deformity "pectus excavatum" significantly improves. However, such indicators as physical activity and the ability to return to an active household and physical activity are higher in people with physical rehabilitation, both in the early postoperative and long-term training phases. Therefore, the use of rehabilitation exercises reduced the risk of complications associated with treating patients with "pectus excavatum" after surgical intervention. Contrary, non-adherence to instructions for

postoperative treatment and exercise settings increased the risk of complications, the most common of which were fixator displacement, pneumothorax, and inflammation in the surgical wound area.

The physical rehabilitation program should include analgesic pharmacotherapy and take bringing the individual condition and physical condition of the patient. The physician should draw up a personal plan for each patient following his physical condition and personal characteristics.

Conclusions

The program developed a postoperative rehabilitation program for patients after surgical correction of pectus deformity using the Nuss procedure significantly improved quality of life according to the SF-36 questionnaire, especially in physical and vital activity in the early stages after the operation. These indicators were also significantly higher after 12 months. after surgical intervention.

References

Nuss, D. (2008), "Minimally invasive surgical repair of pectus excavatum", *Semin Pediatr Surg.,* Vol. 17(3), pp. 209–217. doi: 10.1053/j.sempedsurg.2008.03.003. [PubMed] [CrossRef] [Google Scholar]

Kotzot, D., Schwabegger, A.H. (2009), "Etiology of chest wall deformities- a genetic review for the treating physician", *J Pediatr Surg.,* Vol. 44(10), pp. 2004 – 2011. doi: 10.1016/j.jpedsurg.2009.07.029. [PubMed] [CrossRef] [Google Scholar]

Biniwale, R.M., Weinstein, S., Boulauger, S.C. (2009), "Chest wall deformities", *E-medicine. Medscape's continually updated clinical reference.* https://emedicine.medscape.com/article/906078-overview

Nuss, D. *(*2008), "Minimally invasive surgical repair of pectus excavatum", *Semin Pediatr Surg*, Vol. 17(3), pp. 209 – 217. doi: 10.1053/j.sempedsurg.2008.03.003. [PubMed] [CrossRef] [Google Scholar]

Nuss, D., Kelly, R., Croitoru, D.P., M.E. Katz. (1998), "A 10-year review of a minimally invasive technique for the Croitoru, D.P., Kelly, R.E., Goretsky, M.J., Lawson, M.L., Nuss, D. (2002correction of pectus excavatum", *J Pediatr Surg*, Vol. 33, pp. 545 – 52.

Цветкова, Т.А., Козлов, Е.А., Рудаков, С.С., Дельвиг, А.А. (1988), "Экстрагируемость коллагена реберного хряща и кожи при воронкообразной деформации грудной клетки у детей. *Вопросы мед. хим*. 1988; 34(1): 71.

), "Experience and modification update for the minimally invasive Nuss technique for pectus excavatum repair in 303 patients", *J Pediatr Surg*, Vol. 37, pp. 437 – 45. http://dx.doi.org/10.1053/jpsu.2002.30851

Hebra, A. (2000), "Minimally invasive pectus surgery", *Chest Surg Clin N Am*., Vol.10, pp. 329 – 39.

Кулик, И.О., Саруханян, О.О., Игнатьева, Н.Ю., Полюдов, С.А. (2013), "Этиология и патогенез воронкообразной деформации грудной клетки у детей", *Травматология и ортопедия России, Т.* 2 (68), с. 136-141.

Watanabe, A., Obama, T. (2004), "The use of a lateral stabilizer increases the incidence of wound trouble following the Nuss procedure", *Ann Thorac Surg.*, Vol.77., pp. 296 – 300. http://dx.doi.org/10.1016/S0003-4975(03)01335-3

Ravitch, M.M. (1956), "The operative treatment of pectus excavatum", *J Pediatr.*, Vol. 48, pp. 65 – 72. http://dx.doi.org/10.1016/S0022-3476(56)80075-9

Dzielicki, J., Korlacki, W., Janicka, I., Dzielicka, E. (2006), "Difficulties and limitations in minimally invasive repair of pectus excavatum – 6 years experiences with Nuss technique", *Eur J Cardiothorac Surg*., Vol. 2006. 30, pp. 801–804.

Quigley, P.M., Haller, J.A., Jelus, K.L., Loughlin, G.M., Marcus, C.L. (1996), "Cardiorespiratory function before and after corrective surgery in pectus excavatum", *J Pediatrics*, Vol.128, pp. 638 – 643

Fonkalsrud, E.W. (2004), "Open repair of pectus excavatum with minimal cartilage resection", *Ann Surg.,* Vol. 240, pp. 231– 235. http://dx.doi.org/10.1097/01.sla.0000133116.16484.bb

Jaroszewski, D., Fonkalsrud E. (2007), "Repair of pectus chest deformities in 320 adult patients: 21year experience", *Ann Thorac Surg,* Vol. 84, pp. 429 – 433. http://dx.doi.org/10.1016/j.athoracsur.2007.03.077

Wang L.S., Kuo K.T., Wang H.W., Yang C.H., Chin T. (2005), "A novel surgical correction through a small transverse incision for pectus excavatum", *Ann Thorac Surg*., Vol. 80, pp. 1951–1954. http://dx.doi.org/10.1016/j.athoracsur.2004.05.029

Krasopoulos, G., Dusmet, M., Ladas, G. (2006), "Nuss procedure improves the quality of life in young male adults with pectus excavatum deformity", *Eur J Cardiothorac Surg*., Vol. 29, pp. 1-5. http://dx.doi.org/10.1016/j.ejcts.2005.09.018