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Application of Wenlin procedure combined with Wung procedure in operation of severe pectus carinatum

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Abstract
The treatment of pectus carinatum has a history of many years, and the early operations were mainly open operations. In recent years, minimally invasive surgery has gradually become the mainstream technology for the treatment of pectus carinatum. The first minimally invasive surgery used was Abramson procedure. This kind of operation has certain effect, but its defect is obvious. To eliminate the defects of this procedure, we designed Wenlin procedure. Compared with Abramson procedure, this procedure has obvious advantages. However, for severe pectus carinatums, Wenlin procedure alone cannot achieve satisfactory results. For this reason, we added Wung procedure during the operation. This combined operation method can obtain the effect of template plastic surgery, so it is a very ideal surgical method. This paper introduces the use of Wenlin procedure and Wung procedure in a patient with severe pectus carinatum.

Keywords: Wenlin procedure, Wung procedure, pectus carinatum, template plastic surgrey

Introduction
Pectus carinatum is a common thoracic deformity, and its treatment has a history of many years [1-3]. In the early years, the treatment was mainly open surgery. The deformed bones were exposed through a large incision, and then the whole skeleton was shaped. This kind of operation has certain advantages, but its disadvantages are also very clear [1-3]. In order to eliminate the disadvantages, minimally invasive surgery has been highly praised in recent years. The earliest minimally invasive surgery is Abramson procedure [4, 5], which is inspired by the classic Nuss procedure [6] and is sometimes even called anti-Nuss operation [7]. The shape of pectus carinatum is completely opposite to that of pectus excavatum, and the principle of Abramson procedure is generally opposite to that of Nuss procedure. However, if the details of the two operations are studied carefully, it can be found that they are not completely opposite. In this case, it is obviously inappropriate to regard Abramson procedure as anti-Nuss operation. Our department is the only independent chest wall surgery department in China, and it is also the largest chest wall deformity correction center in China [8, 9]. Our main work is to complete all kinds of chest wall deformity surgery. In the past work, we have completed a large number of surgical treatments for pectus carinatum. After Abramson procedure was reported, we also used this technique, but in the process of using it, we found many defects in this operation, so we improved it and finally designed Wenlin procedure for deformities of protrusion [10-15], and specially for pectus carinatum [10]. This operation is similar to Abramson procedure, but the basic principle and operation details are different. We took this procedure as the basic operation for the treatment of pectus carinatum and achieved satisfactory results. However, for some severe patients with pectus carinatum, especially those with depression, the use of Wenlin procedure alone cannot achieve the most satisfactory results. At this time, other additional operations need to be completed at the same time. This paper reports the use of Wenlin procedure combined with Wung procedure in a patient with severe pectus carinatum.

Case Report
The patient was a 20-year-old male, with no obvious abnormality of chest wall in early childhood. After the age of 8 years, his anterior chest wall was found to be protrusion, and the

appearance was barrel-shaped. The protrusion of his upper half of the chest wall was more obvious. He had received calcium supplement treatment, but the effect was not good. After puberty, the deformity was aggravated, and the anterior chest wall protrusion was severe. The upper half of the chest wall is obvious, and the appearance is hemispherical. The patient has no discomfort, but is not satisfied with the appearance, and anxious for correction. The patient was admitted to our hospital for surgical treatment. Preoperative physical examination showed that the anterior chest wall is protrusive, the middle part is the most obvious, the total appearance of the chest wall is hemispherical, the lower part is slightly depressed, and the bone structures is abnormally hard (Fig 1). The imaging examination showed that the anterior chest wall was convex and the rib arch was depressed (Fig 2, 3, 4). The patient was diagnosed as severe pectus carinatum before operation. After adequate preoperative preparation, we performed surgical treatment for the patient (Fig 5, 6). The operation was performed under general anesthesia with supine position and abduction of both upper limbs. A longitudinal incision was made between the axillary frontline and the axillary midline on both sides slightly below the highest plane of the protrusion. The incision was 4cm long. The muscles of the chest wall were dissected and the ribs of the side chest wall were exposed. Three horizontal lines were made on the body surface. The upper two lines were located at the highest plane of the protrusion, with an interval of 3cm. The intersections of the two horizontal lines and the ribs on both sides were the fixed points of the steel bars. Several steel wire traction lines were placed around the ribs at the fixed points. The third horizontal line was located at the bottom of the depression. The intersection of the third horizontal line and the rib outside the costal arch is determined as the fulcrum of the third steel bar. An incision is made between the ribs above the fulcrum by cutting the intercostal muscle, which serves as the channel for the steel bar to enter the thoracic cavity. A steel wire traction line is placed around the rib at this fulcrum. The introducer was put into the thoracic cavity through intercostal incision, reaching the contralateral thoracic cavity through the mediastinum, and then pass through the contralateral intercostal incision and skin incision. The introducer was connected to the steel bar guiding tube. The third steel bar guiding tube was pulled to the target position at first, and then two tunnels were made between the muscle of the anterior chest wall and the bony structures. The tunnels were located in front of the sternum and parallel to the two horizontal lines on the both sides. The introducer was put into the tunnels, connect with the guiding tubes, and put them into the tunnels. Two steel bars were connected with the guiding tubes and pulled into the superior two tunnels respectively, and fixed to two different ribs with steel wires. After the steel wires were tightened, the protrusion of the front chest wall was basically flattened, but there was an obvious depression below. The third steel bar was connected with the guiding tube and pulled into the chest. After turning the bar over, the depression was supported, and the overall shape of the chest wall was basically restored to normal (Fig 7). The total operative time was 55 minutes, and the intraoperative bleeding was 20ml. The operation was stable and there were no complications. Postoperative X-ray examination showed that the position of the plate was normal and the thoracic shape was satisfactory (Fig 8). The patient was discharged 6 days after surgery.

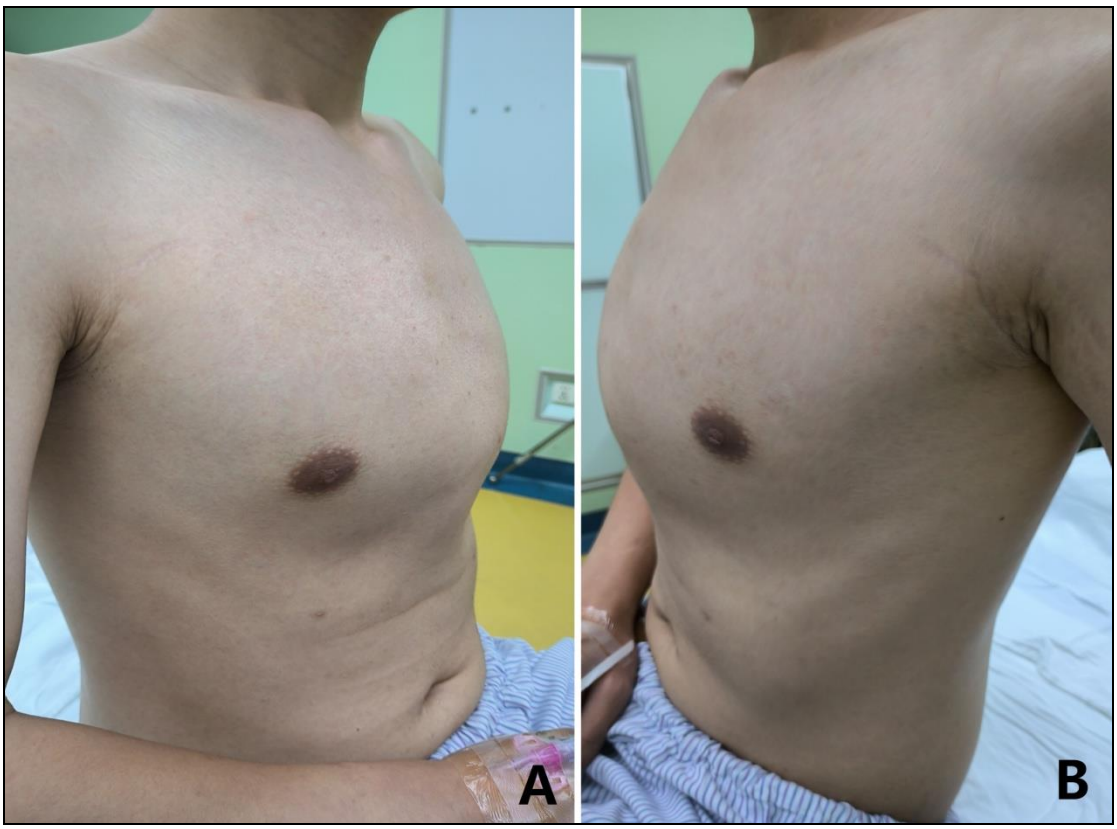

Fig 1: Appearance of chest wall before operation. A, Right side view; B, Left side view.

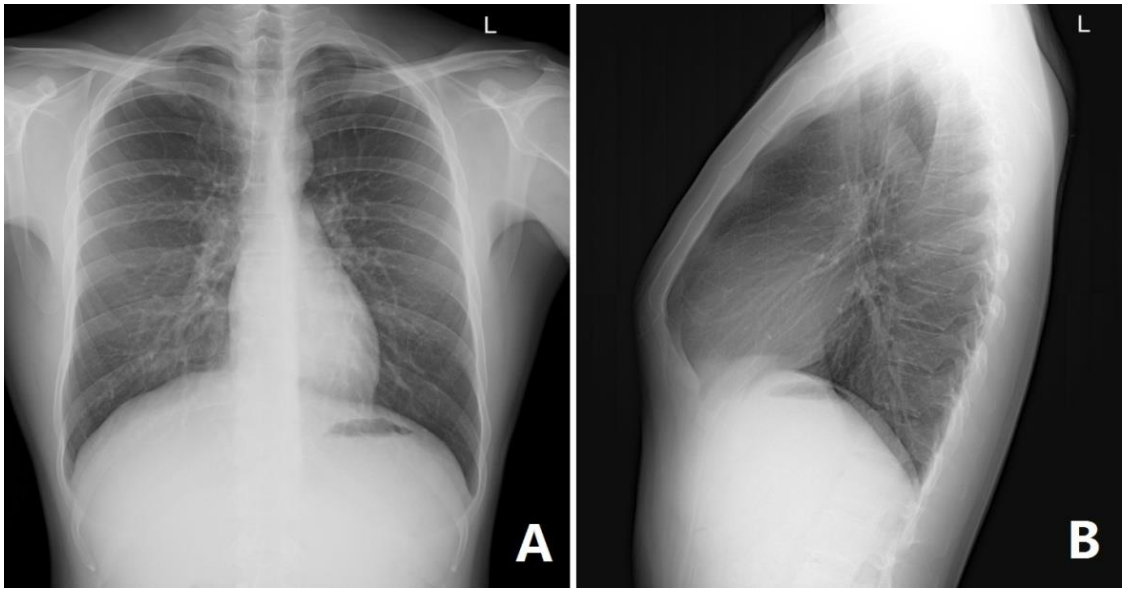

Fig 2: X-ray examination films of chest wall before operation. A, Posteroanterior film; B, Lateral film.

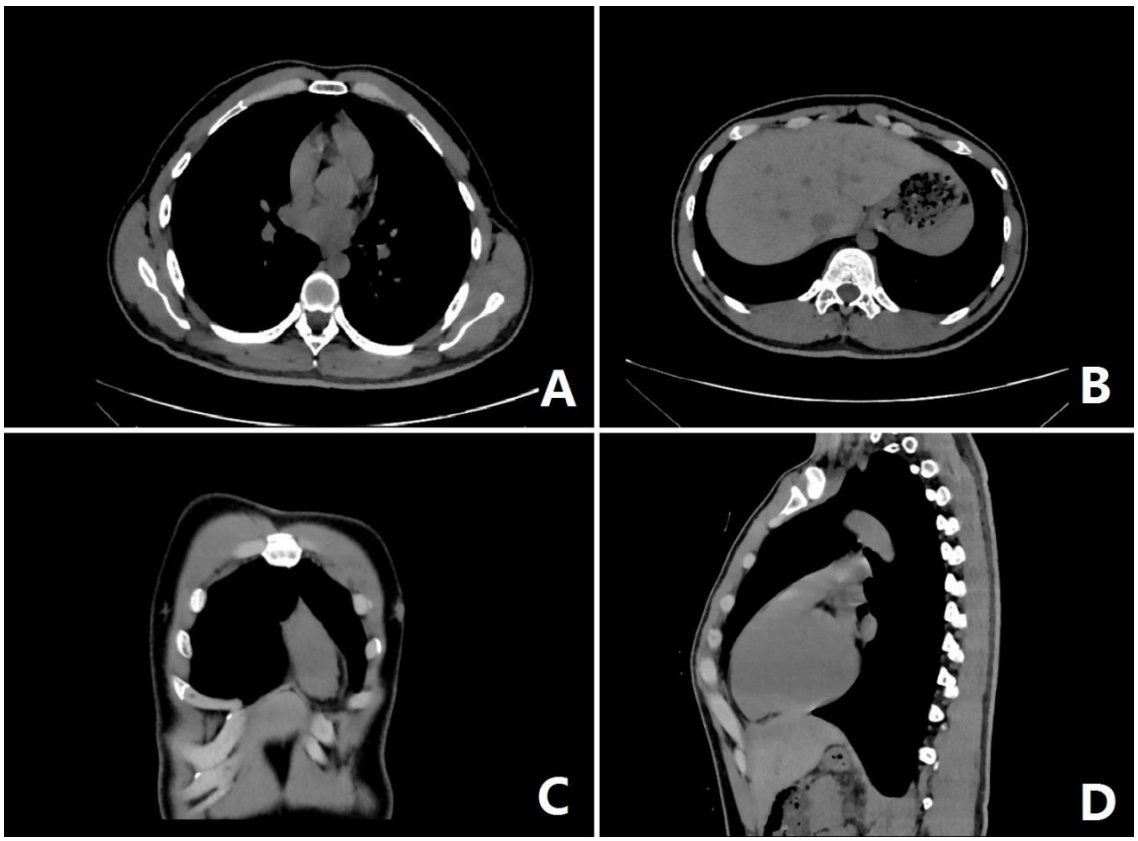

Fig 3: Preoperative chest wall CT images. A, Sectional image of the middle part of the chest wall; B, Sectional image of the lower part of the chest wall; C, Coronal image of chest wall; D, Sagittal image of chest wall.

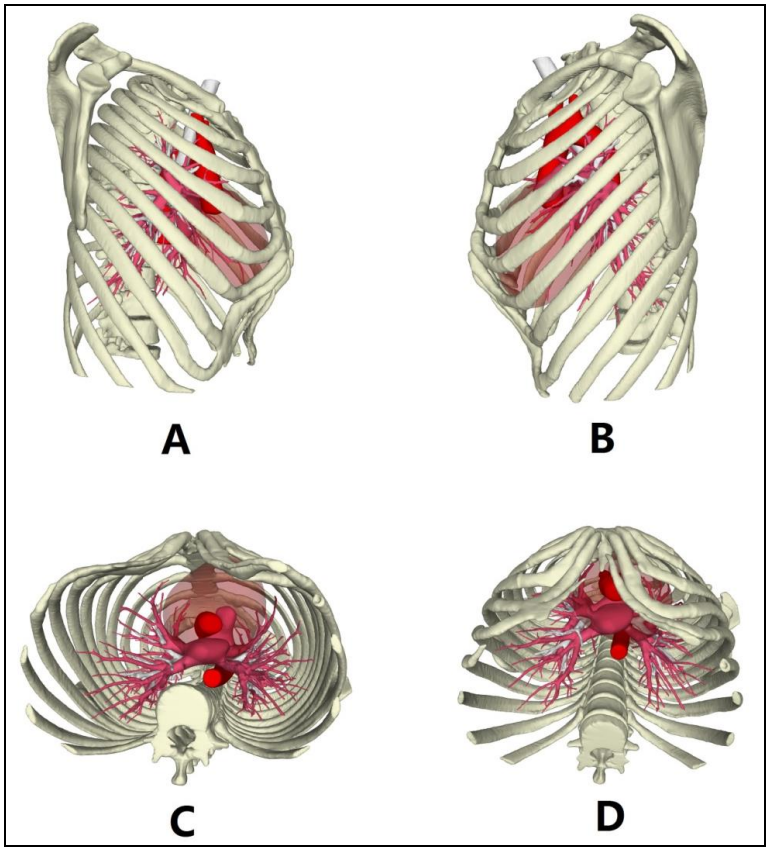

Fig 4: Three dimensional image of chest wall. A, B, side view; C, D, bottom view.

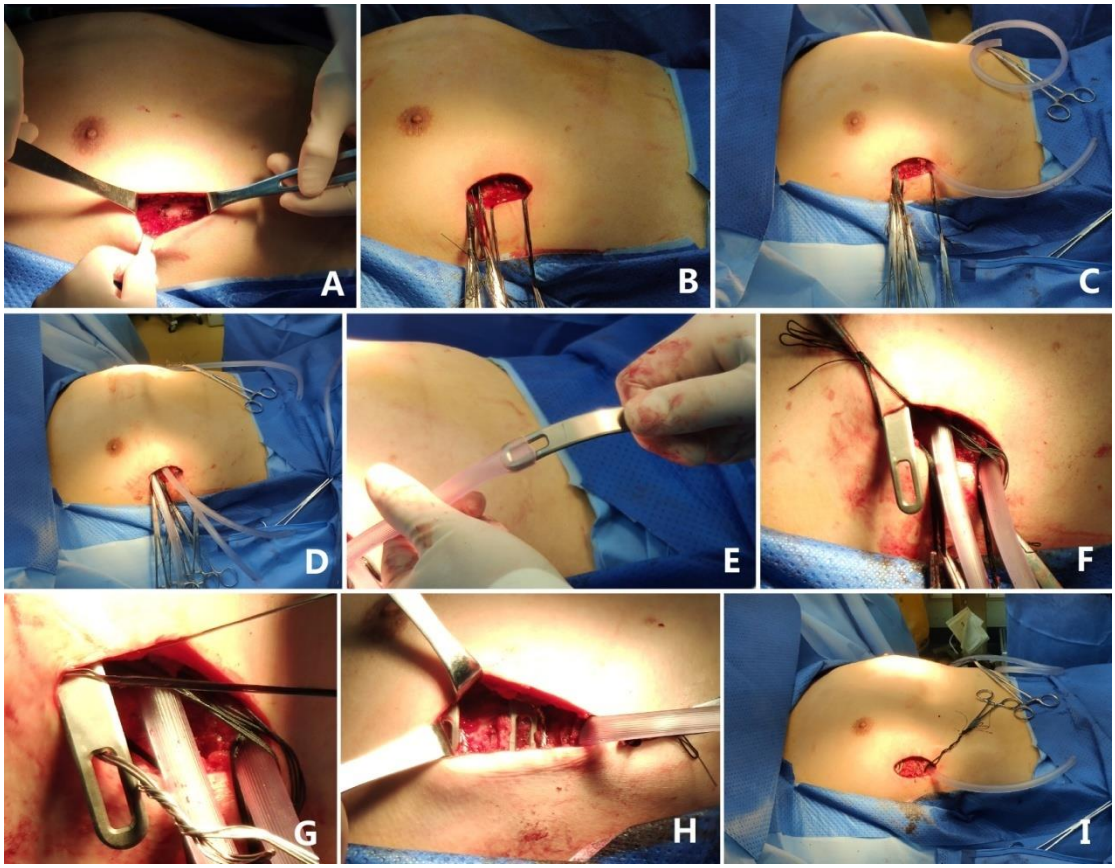

Fig 5: Operation pictures (1). A, The ribs in the incision are exposed; B, The steel wire guiding lines are placed; C, The steel bar guiding tube for Wung operation is placed; D, Two steel bar guiding tubes for Wenlin operation are placed; E, The steel bar guiding tube is connected with one end of the steel bar; F, The steel bar is pulled into the tunnel; G, The steel bar is fixed with steel wires; H, The placement and fixation of two steel bars in Wenlin procedure were completed by the same method; I, The upper protrusion of the anterior chest wall was flattened, but the lower part was depressed.

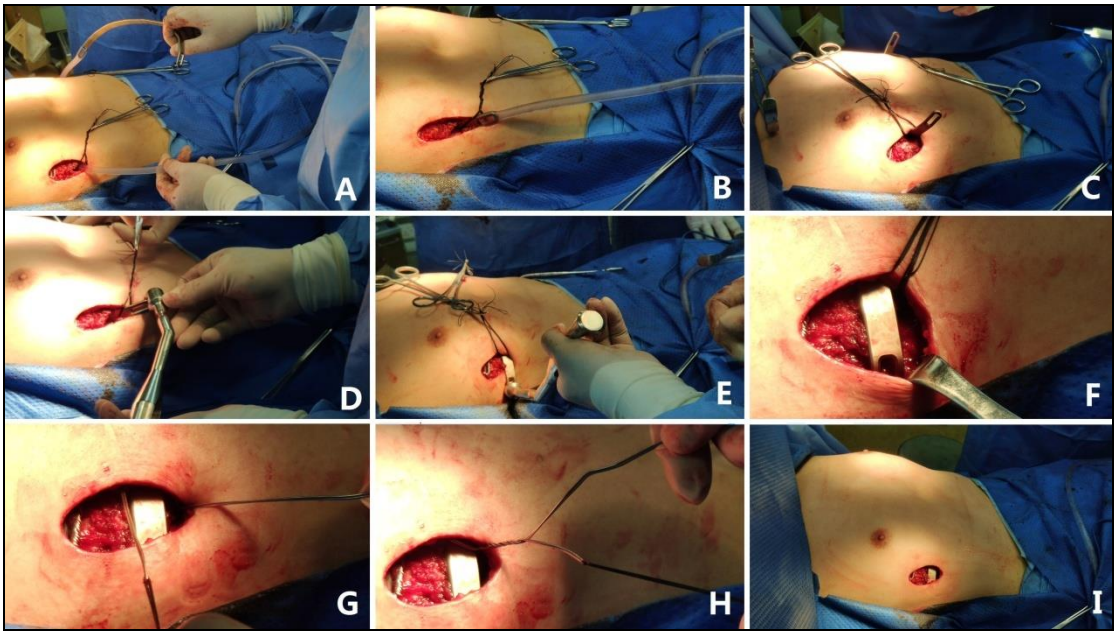

Fig 6: Operation pictures (2). The placement and fixation of the third steel bar. A, The steel bar is connected with the steel bar guiding tube; B, The steel bar is dragged into the chest and passed through the incision on the opposite chest wall; C, The two ends of the steel bar are located outside the incision of the chest wall on both sides, and the middle is located in the chest; D, The steel bar is turned over; E, The steel bar is placed at the target position; F, The position of the end of the steel bar; G, The steel wires are placed; H. The steel bar and rib are fixed with steel wires; I, The steel bar is placed, and the deformity was completely eliminated.

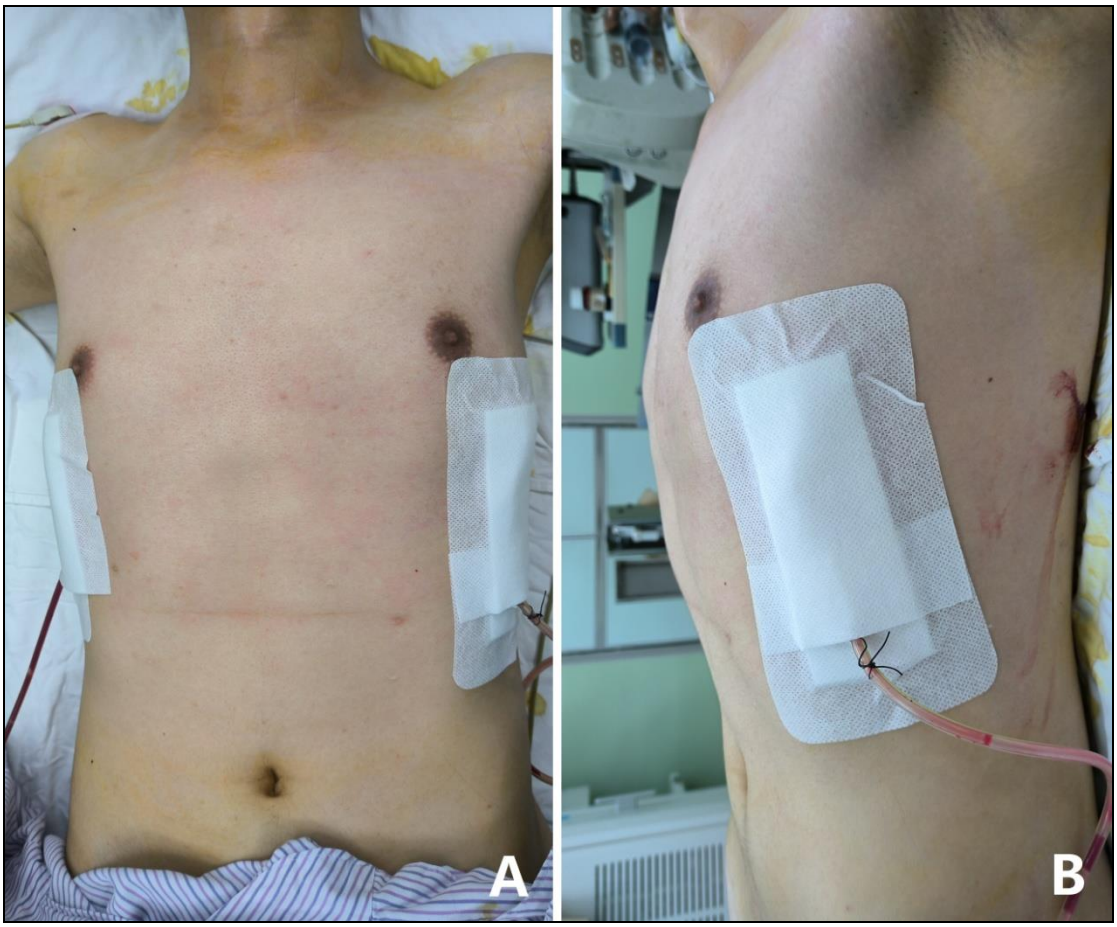

Fig 7: Appearance of chest wall after operation. A. Front view; B. Side view.

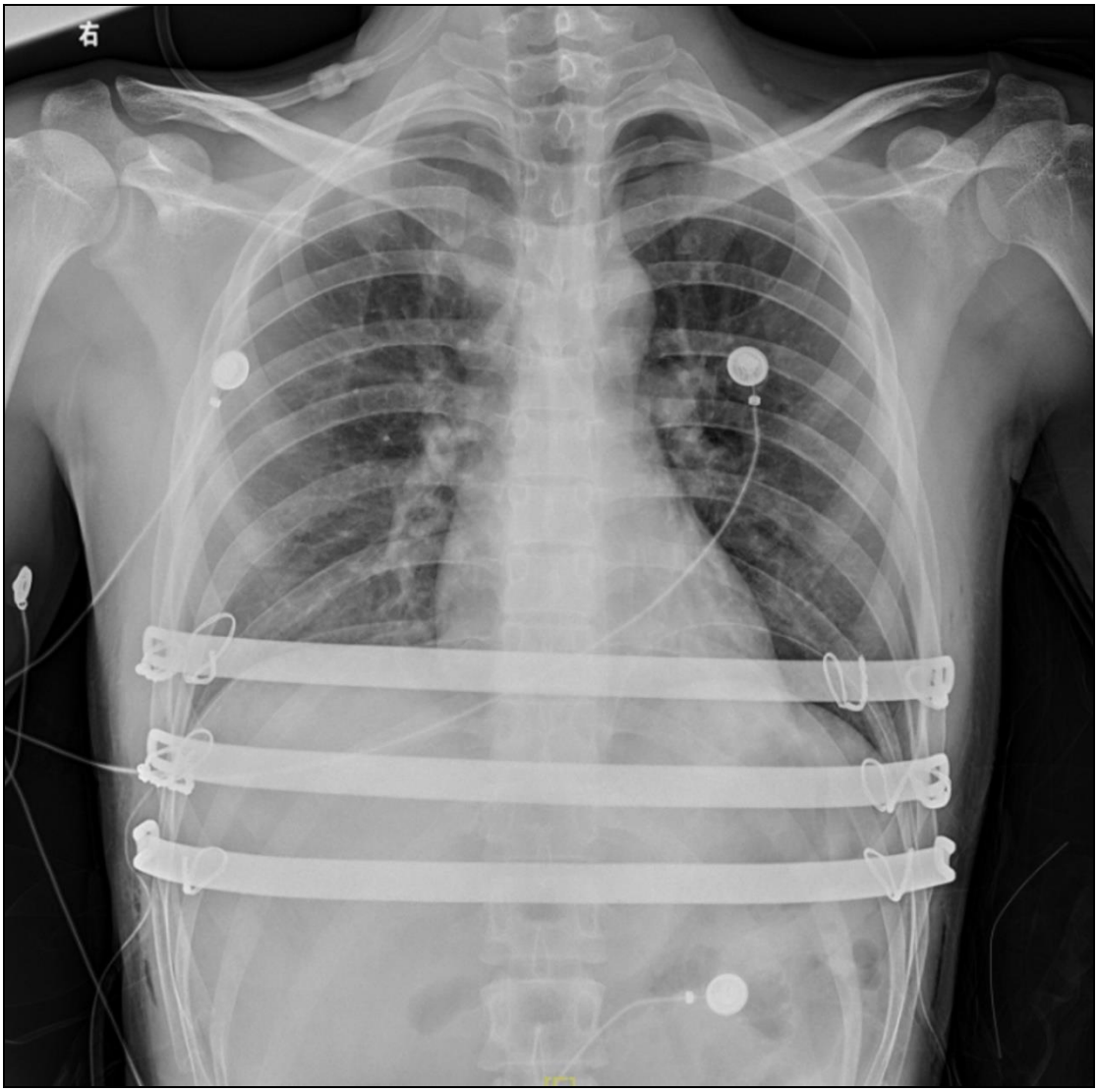

Fig 8: Postoperative chest X-ray examination films.

Discussion

Minimally invasive surgery of pectus carinatum has appeared in clinic for many years, but the treatment situation is not ideal [4, 5]. Besides the technical factors of the operation itself, the operation effect should be an important factor affecting the promotion of the operation. Because the previous technology has not been mature or has defects, even if there are some methods, it has not been popular on a large scale.

The main pathological feature of pectus carinatum is protrusion of anterior chest wall [1, 2, 10]. Theoretically, after the anterior chest wall is directly pressed, the deformity can disappear. However, since the protrusion structure of the anterior chest wall itself is often not a planar structure, but mostly arc-shaped or other irregular structures, when the most protrusive part is pressed, the degree of compression will certainly not be the same at different positions, and the chest wall after compression cannot be completely flat. The most common result is local depression, which is mostly located at the lower part of the anterior chest wall, or located in other parts. The older the patient is, the harder the bone is, the greater the possibility of depression.

Wenlin procedure is a surgery for compression of the protrusion of the anterior chest wall [10-15]. This kind of operation can have a better effect on patients whose bones are not too hard. However, if the bone is very hard, it will inevitably lead to some local depressions. Such a depression will not only affect the surgical effect, but also may cause various complications. In order to make the Wenlin procedure more perfect, it is necessary to correct the depression deformity additionally.

There are many kinds of surgical methods for depression deformity. The early choice is Nuss procedure [6]. Because this operation has many disadvantages, we improved it to be the Wung procedure at first [16], and then, we designed a new operation, namely Wang procedure [17,18]. In the process of pectus carinatum treatment, we use Wung procedure to correct the concave deformity after Wenlin procedure in most cases [19]. If the depression is located near the xiphoid process and is limited and deep, we also use Wang procedure. After the completion of Wenlin procedure, since the depression area is always large and wide, it is not suitable for Wang procedure. Therefore, we adopted Wung procedure for correction, and finally achieved satisfactory results.

Wenlin procedure combined with Wung procedure is similar to that of sandwich operation reported by some authors [20]. However, it is clear that our operating principles and details are significantly different from those of other authors. These differences are reflected in the following aspects: (1) the surgical principle we adopted is completely different from that of other authors. The principle we use is generalized template plastic surgery, which is the most advanced plastic technology; (2) The Wenlin procedure and Wung procedure we adopted are our original technologies, which are different from the methods used

by other authors; (3) All the details and techniques of our operation are different from those of other authors. For example, the steel bar fixation technology we use is Wang technique designed by us, which is different from the fixation techniques used by all other authors.

Our method involves two original surgical techniques. When each operation is completed independently, the operation is relatively simple. However, if it is implemented in one operation at the same time, it will be a huge system engineering. To obtain satisfactory results, the following surgical essentials must be strictly mastered.

1. Determination of incision position. The two operations involve the placement of three steel bars. Due to the large operation range, all details need to be considered. Generally, the incision is selected at the position of the middle steel bar. Since all operations in the incision are carefully designed and will not occupy too much space, the incision length does not need to be too long, generally not more than 5cm.
2. Determination of fixed position. Both procedures require bar fixation. Since the fixed steel wire guiding wires should be placed before the steel bar is placed, it needs to be determined in advance. Wenlin procedure requires two fixations, one at the end of the bar and the other at the inner side of the end. The two positions are located in the two ribs respectively. The position needs to be determined according to the length of the steel bar. Wung procedure needs to be fixed at one place, which is basically located at the fulcrum of the steel bar. It is the lower rib where the steel bar enters the thoracic cavity. This position is the best position to play the role of steel bar support.
3. Preparation of steel bar. Both kinds of operations are completed with the help of steel bar. If the bar is to function, it must have a proper length first. The length of the bar is determined according to the force. Generally, the position of the end of the bar should reach the axillary frontline. Since the working principle of the two operations is different, the requirements for the radian of the steel bar are different. The radian of Wenlin procedure steel bar should not be too large, otherwise it is difficult to exert force on the protrusion. Wung procedure is to support the depression with arc-shaped steel bar, so the radian can be slightly larger, but the shape should be determined according to the degree of depression. In addition to the length and radian of steel bars, another important issue is the number of steel bars. Wung procedure generally requires one steel bar. If the protrusion is not very serious, a steel bar is enough to complete the Wenlin procedure. However, if the protrusion is severe or the bone is abnormally hard, two or even three steel bars are required to meet the needs. In general, the number of steel bars needs to be determined according to the structural characteristics of the deformity.
4. Position of steel bar. The purpose of steel bar placement is to correct the deformity of protrusion and depression, so the position must be arranged according to the needs of surgery. The steel bar of Wenlin procedure is generally located at the position where the protrusion is most serious, and the stress dispersion needs to be considered. Wung procedure has only one steel bar, and its position is particularly important. Generally, it needs to be placed on the lowest plane of the depression. This is the basic requirement for eliminating depression deformity.
5. Steel bar fixation technology. We designed a technique specially used for steel bar fixation, namely Wang technique [21, 22]. This technique was used for the fixation of all bars in both procedures. This technique does not require short fixing plates but directly fixes the bar on the rib. This design is simple and convenient, and can greatly save operating space, so it is a very satisfactory technique. In these two operations, the fixation technique similar to that of Abramson procedure cannot be used, otherwise the operation effects will not be guaranteed.
6. Sequence of steel bar fixing. Due to the severe deformity and hard bone of the patient, if the stress is not noticed during the implementation, the operation may fail. The most common failure is the fracture of the steel wires or the ribs, which is mainly related to excessive local stress. Therefore, in the process of fixing, it is necessary to understand the stress condition, and fix the steel bars in a gradual manner, so that the stress of each part of the steel bar increases evenly, to avoid failure.
7. The general order and organization of the operation. Since all operations are completed in a very small incision, there will be a large amount of materials in the incision. If there is no good organization, the surgical field will be very messy and it is difficult to ensure the success of the operation. Therefore, it is necessary to make a clear plan for steps and sequence before the operation, which is the basic guarantee for the success of the operation.

Wenlin procedure combined with Wung procedure is an ideal surgical mode for the treatment of severe pectus carinatum. So far, we have completed the treatment of a large number of severe pectus carinatums with this method [19]. The operation of this patient is discussed separately because the deformity is severe and typical, which is more conducive to introducing our method. Our experience shows that this method is a safe, simple and effective minimally invasive method. This special combination has the advantages that simple pectus carinatum surgery does not have.

Conclusion

Mild pectus carinatums can be treated by a single minimally invasive operation. However, if the deformity is serious or combined with visible depression or secondary depression, any single operation cannot achieve satisfactory results. At this time, combined operation is required for treatment. Wenlin procedure is used for the operation of protrusion deformity, while Wung procedure is used for the operation of depression deformity. Since there are many similar or even identical operations in the process of the two procedures, the combined use of these two surgical methods will be more convenient, so it is an ideal choice.

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