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Application of Wenlin procedure in the treatment of thoracic deformity

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Abstract
Wenlin procedure is a minimally invasive surgery designed for pectus carinatum, which is similar to Abramson procedure to a certain extent, but their natures are completely different. Wenlin procedure is a typical template plastic surgery. This nature makes it possible to be used not only in protrusion deformities such as pectus carinatum, but also in a variety of complex deformities including depression deformities. With the progress of the concept of deformity treatment, the role of Wenlin procedure will become more and more significant.

Keywords: Wenlin procedure, thoracic deformity

Introduction

Thoracic deformity refers to the abnormal shape of the bony structures of the chest wall, which is the most common disease in chest wall surgery [1, 2]. According to the different structures, all deformities can be divided into two categories, one is protrusion deformity and the other is depression deformity [3]. The representative of protrusion deformity is pectus carinatum, while the representative of depression deformity is pectus excavatum. These two deformities account for the majority of all thoracic deformities. In addition to simple protrusion and depression deformities, there are also some special deformities clinically, which include both protrusion and depression simultaneously. These deformities are called complex deformities [4]. The diagnosis and treatment of complex deformities are complicated. In order to simplify the clinical work, it can be regarded as a combination of protrusion and depression deformities, which can not only facilitate the understanding of deformities, but also facilitate the treatment of them. The deformity operations in the early years were all open surgeries, and the typical representative was Ravitch procedure [5]. This kind of operation has large trauma and long incision, and the effect is often not ideal. Since the appearance of Nuss procedure in clinic, the treatment of deformities has entered the era of minimally invasive surgery, and the treatment of deformities has undergone tremendous changes. With the continuous progress of concepts and technologies, a variety of minimally invasive operations for different deformities have gradually appeared in the clinic [6]. In general, there are roughly three kinds of operations for depression deformities, namely Nuss procedure [6], Wang procedure [7, 8] and Wung procedure [9]. There are two kinds of surgery for protrusion deformities: one is Abramson procedure [10], and the other is Wenlin procedure [11, 12]. In addition to all these procedures, there are other operations in the clinic. Although these operations have different names, they are almost all modified operations of the above procedures. Abramson procedure and Wenlin procedure are designed for protrusion deformities. Generally speaking, although the two procedures have some similarities, their natures are completely different. This makes Wenlin procedure have a unique application in the treatment of various thoracic deformities.

Wenlin procedure first appeared in 2016. It is a minimally invasive surgery designed by us for pectus carinatum. Its advantages are mainly reflected in the comparison with Abramson procedure. These advantages include the following aspects [10-13]: (1) Direct fixation of steel bar. In Abramson procedure, the steel bars are fixed to the ribs with fixation plates. Since the steel bars are indirectly fixed to the ribs, the fixation is not firm. Meanwhile, the operation of fixation plate is very complex, which will increase the difficulty of the whole operation.

In addition, because the fixation plates take up a lot of space, the incision must be long enough to complete the operation. Finally, the presence of fixation plates often affects the healing of the incision, which is another obvious disadvantage of it. In general, the application of fixation plates is almost the biggest defect in Abramson procedure. In contrast, Wenlin procedure does not use the fixation plate, so all the disadvantages of Abramson procedure can be eliminated. Wenlin procedure directly fixed the steel bar on the ribs, making the fixation very firm. Especially, due to the use of Wang technique to fix the steel bar, the whole operation is extremely simple [14]. Since there is no need to worry about the space occupied by the fixation plates, the incision can be made very small, thus making the operation more minimally invasive; (2) Advanced surgical principles. Judging from the nature of surgery, the surgery of thoracic deformity can be divided into three types, namely destructive plastic surgery, mechanical external force plastic surgery and template plastic surgery [1, 2]. In the three types, template plastic surgery is the highest form [1, 2, 15, 16]. Wenlin procedure is a typical template plastic surgery, while Abramson procedure is a mechanical external force plastic surgery. From the perspective of surgical principle, Wenlin procedure is a more ideal operation; (3) Diversity of uses. Wenlin procedure can be used not only to compress protrusion, but also to lift the depression, so that more deformities can be corrected. Abramson procedure can only be used to compress the protrusion, and it is impossible to treat the depression at the same time, which not only limits the scope of its use, but also may lead to additional complications; (4) Reasonable fixed position. In Wenlin procedure, the position of fixation is located in various planes of different ribs, which can effectively disperse the stress and avoid complications such as rib fracture. In Abramson procedure, fixation position is located at the end of the steel bar and is only fixed at one point. Because the stress is too concentrated, it is easy to lead to local fracture and other complications.

In general, compared with Abramson procedure, Wenlin procedure has significant advantages, which makes it more useful. So far, Wenlin procedure has been used in the operation of the following deformities.

(1) Pectus carinatum surgery. Wenlin procedure was first designed for pectus carinatum [11, 12]. The basic operation is to place the steel bar between the muscles and bone structures of the anterior chest wall, press the protrusion of the chest wall with the steel bar in the middle, and then fix both ends of the bar to the corresponding ribs on both sides of the chest wall. This operation is safe and simple, with a good effect on protrusion. For mild protrusion, one bar can be used to complete the correction. If the deformity is serious, it can be corrected by increasing the number of steel bars. Wenlin procedure is the most basic choice to treat pectus carinatum, and all pectus carinatum can be treated with this operation. However, some special situations need to be noted during use. For pectus carinatum with limited protrusion and extremely hard bone structures, secondary depression may occur when Wenlin procedure is used alone. At this time, the combination of Wenlin procedure and Wung procedure can eliminate the secondary depression [4, 17]. Pectus carinatum is the most suitable treatment object for Wenlin procedure. However, some technical details need to be reasonably designed during the operation, such as the number, length, radian, placement position, fixation mode and operation sequence of steel bars, which are all crucial technical details. If these details are not handled properly, the surgical effect will be affected. Pectus carinatum is a common deformity next to pectus excavatum. Since most doctors only perform Abramson procedure instead of Wenlin procedure, the treatment of pectus carinatum has been unsatisfactory. In recent years, we have assisted in carrying out Wenlin procedure in hundreds of hospitals in China, and more and more doctors have mastered the technology, which will undoubtedly promote the progress of pectus carinatum treatment [1, 2].

(2) Barrel chest surgery. Barrel chest is a common deformity, which is often seen in the elderly and secondary to chronic lung disease. This kind of deformity belongs to secondary deformity and generally does not need treatment. What needs to be treated clinically is barrel chest that occurs in young and middle-aged people. From the overall classification, barrel chest is also a kind of protrusion, which can be regarded as the overall protrusion of the anterior chest wall [3]. Because of the presence of protrusion, it is also possible to use Wenlin procedure. After long-term observation, we have designed the specific method of surgery and applied it to clinical practice, and achieved good results. Our design method is to use three or more steel bars for correction. The steel bars are located on the surface of the bony structures of the anterior chest wall, and both ends are fixed to the ribs of the lateral chest wall, so as to achieve the purpose of orthopedics [18-20]. Compared with pectus carinatum surgery, barrel chest surgery is more complex, so it requires higher level of technology. However, the basic operating essentials have not changed. If the essentials of surgery are strictly mastered, good results can be obtained. So far, no other doctor in the world has done minimally invasive surgery on barrel chest except us. Our number of operations has been nearly 100 cases, and good results have been achieved.

(3) Wenlin chest surgery. This deformity was regarded as a kind of pectus carinatum in the early years [21]. Because of its distinctive characteristics, it is clearly different from the typical pectus carinatum. In order to better understand and treat this deformity, we named it Wenlin chest [22, 23]. In addition to our name, some authors have also noticed the particularity of this deformity, and made other names, such as arcuatum chest [24-26] or pigeon chest [27], which describe the particularity of this deformity. No matter how it is named, it shows that this deformity is a special deformity different from pectus carinatum and needs to be treated with special methods. The main feature of Wenlin chest is that the upper part of the anterior chest wall is protrusive and the lower part is depressive. Its sternum is thickened and "S" shaped [22, 23]. Because of both protrusion and depression, some people even regard it as a combination of pectus carinatum and pectus excavatum. Although this view is inappropriate, it reflects the essential attribute of Wenlin chest, that is, it is a complex deformity. Since it is not a single deformity, it cannot be treated with a single surgical method. After a long-term study of this deformity, we designed a special surgical method, that is, combined Wenlin procedure with Wung procedure or Wang procedure for treatment [22, 23]. Wenlin procedure was used to eliminate protrusion, and Wung procedure or Wang procedure was used to eliminate depression. Satisfactory results can be obtained when two procedures of different uses are simultaneously applied to the complex deformities of Wenlin chest. Of course, the combination of the two procedures is not a simple addition. There must be a premise that is, preshaping [28]. The purpose of preshaping is to change the shape of the sternum in advance. Only when the sternum itself is plastic can subsequent surgery be possible. Wenlin chest itself is an extremely rare deformity, and the surgical reports of this deformity in the literature are mostly case reports. We have carried out a lot of work for this deformity, and our number of surgical cases exceeds 40, which is the largest in

the world, and we have achieved good results.

(4) Asphyxiating thoracic dystrophy (ATD) (Jeune syndrome) surgery. ATD is an extremely rare and dangerous deformity with a very low incidence rate, and the vast majority of children will die soon after birth [29-36]. Therefore, there are few reports about this deformity in the literature, almost all of them are case reports. However, our department has received a large number of ATD patients. By July 2022, we had completed 34 ATD operations, which was the largest number in the world. In the process of treating these patients, we found that ATD can be divided into two types [29-36]: type I has a columnar thoracic appearance and mild depression in the lateral chest wall; Type II thoracic appearance is irregular, with protrusion of anterior chest wall and depression of lateral chest wall. Type I ATD can be treated with median and lateral thoracic expansion. The lateral chest wall of type II has obvious depression, so it can be treated with surgery for depression. However, because there was protrusion at the same time, we found Wenlin procedure could be considered for treatment [33-36]. Since Wenlin procedure can correct both protrusion and depression at the same time, it is a very ideal operation. In our 34 operations, we used Wenlin procedure in the vast majority of patients and obtained satisfactory results [36].

(5) Complex deformity surgery. There are many patients with complex deformities in clinic. These patients have both protrusion and depression, which objectively requires two different types of surgery at the same time [4]. Some authors combined Nuss procedure and Abramson procedure to perform surgery, and named this surgery sandwich technique [37]. Since both Nuss procedure and Abramson procedure have obvious defects, this sandwich technique is not an ideal choice. We combined Wenlin procedure with Wang procedure or Wung procedure. Because each procedure has special advantages, the effect of operation is very ideal [4]. So far, this combined operation has become our routine technique. We have completed the treatment of a large number of complex deformities, and the clinical effect is satisfactory.

(6) Costal arch deformity surgery. Costal arch deformity can exist independently or in combination with other deformities. It can be manifested as simple flared or local depressed [38]. On the whole, flared costal arch can be regarded as a kind of protrusion, so Wenlin procedure can be considered for treatment [38]. Since this procedure can also correct the depression, it can be used for all types of costal arch deformity operations. So far, few people around the world have treated costal arch deformities, but this kind of surgery has long been our routine surgery. We have completed a large number of such surgeries and obtained very satisfactory results.

(7) Saddle chest surgery. Saddle chest is a special deformity named by us [39]. Its structural feature is that there are depressions below the chest walls on both sides, and the middle of the depressions is separated by the chest wall of normal height. Because it looks like a saddle, we named it saddle chest. Saddle chest is composed of two depressions on both sides of chest wall. Although the median separation is not higher than the body surface, it can be seen as a relative protrusion. Therefore, Wenlin procedure can also be used. In practice, the steel bar is centered on the surface of the bony structure of the anterior chest wall, and both sides of the bar are located in front of the depressions. The median bone structure acts as a fulcrum, ensuring the steel bar on both sides lifting the depression, so that a good therapeutic effect can be obtained. Clinically, most saddle chest is primary deformity, and Wenlin procedure is the first choice to treat this deformity. In addition to the primary deformity, there is a kind of saddle chest that occurs after Nuss procedure, which is called secondary saddle chest. This deformity is caused by the compression of the steel bar. Because this compression cannot be avoided in Nuss procedure, it is considered to be an inevitable cost of this procedure, and no one has ever tried to eliminate this deformity. After long time observation, we found that this secondary deformity was not uncorrectable. We used Wenlin procedure to correct it and obtained very satisfactory results.

(8) Flat pectus carinatum operation. Flat pectus carinatum is also a special deformity named by us. The main feature of this deformity is that the anterior chest wall is protusive totally, but there are longitudinal depressions in the anterior median part. This kind of deformity is also a complex deformity. Because of the presence of protrusion, Wenlin procedure can be considered. However, due to the combination of localized depression in the middle, other methods need to be used to correct this depression. Our method is to use Wang procedure on the basis of Wenlin procedure. Wang procedure can eliminate the depression, so it can have a good effect [7, 8]. Flat pectus carinatum is an uncommon deformity. We have received cases of surgical failure from other hospitals. The reason for the failure is that they did not recognize the nature of its complex deformity, which directly led to the failure of the operation.

In conclusion, Wenlin procedure can be used in the treatment of a variety of deformities. This advantage is mainly related to its basic properties, which are the characteristics of its template plastic surgery [1, 2, 15, 16]. The template plastic surgery can not only be used for the correction of protrusion, but also for the treatment of combined depression deformities, which makes it almost a universal operation.

Recently, we proposed Wenlin principle for the treatment of pectus excavatum [15], which is also the basic principle for the treatment of other deformities. We believe that the treatment of any deformity cannot be limited to a specific surgical method, and the treatment of deformity cannot be regarded as the completion of a certain surgical method [15, 16]. Only when the treatment of deformities gets rid of the limitations of specific surgical methods can the goal of personalized treatment be truly realized and the appropriate surgery be reasonably selected according to the needs of deformity correction. This will significantly improve the quality and effect of surgery. Among the available surgical procedures, Wenlin procedure is one of the most basic options. As long as the essentials of Wenlin procedure can be strictly mastered, satisfactory results will be obtained.

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