ORIGINAL RESEARCH

Removal of Wires for Sternal Internal Fixation After Cardiac Surgery in Adolescents

Yanbo Dong, Mmed; Li Tian, Mmed; Xiaobo Li, Mmed; Yukun Cui, MD

ABSTRACT

Objective • The objective of this study was to assess the safety and patient satisfaction of sternal wire removal surgery, rendering reference for clinical practice in the future.

Methods • A total of 70 adolescent patients with completely healed sternum and no other diseases or able to receive surgery were randomly selected and subjected to sternal wire removal surgery. Besides, relevant data including patient age, gender, wire rupture, reason for wire removal, postoperative wire residuals, patient satisfaction, age at cardiac surgery, waiting time after cardiac surgery, and removal duration were recorded.

Results • Raptured wire group exhibited higher proportions of males and chest pain cases and longer operative time than unruptured wire group. The demand for wire removal had no relation to gender, but patients receiving surgery due to chest pain were mainly aged 12-15 years old, those undergoing surgery due to employment and further education were mainly aged 9-12 years old, and those subjected to surgery sue to ruptures found in physical examinations were mainly aged 6-9 years old. According to statistics of wire rupture position, the rupture of the 4th wire accounted for the largest proportion, and rupture of multiple wires was found in some patients. No statistically significant differences were found in gender, age, age at cardiac surgery, and waiting time after cardiac surgery between patients with only one wire ruptured and those with multiple wires ruptured. Patients were grouped based on the absence and presence of chest pain, and it was found that chest pain group had a longer removal duration, but comparable age at cardiac surgery and waiting time after cardiac surgery, and the waiting time after cardiac surgery was a risk factor for chest pain. The waiting time after cardiac surgery was positively correlated with operative time, so we recommend that if there were symptoms of chest discomfort, it should be removed as soon as possible. However, due to the needs of the patients, no control group was set up, which is the limitation of this study. In the next step, we will conduct more long-term observation of the patients to confirm whether the chest pain can be relieved by itself without removing the wire.

Conclusion • This study found that for adolescent patients with chest pain or other life troubles after cardiac surgery, removing the sternal internal fixation wire can quickly and effectively relieve the troubles, and is a safe and reliable treatment means. Therefore, if it is necessary to remove the wire, it should be removed as soon as possible to avoid wire breakage and increase the difficulty of surgery. (*Altern Ther Health Med.* 2024;30(1):351-357).

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INTRODUCTION

Thoracotomy through a longitudinal midsternal incision is one of the main approaches to cardiac surgery.[1,2] In recent years, the fixation of the sternum mainly involves sternal wires in this era despite the emerge of many methods for sternal fixation.[3-5] Wires have good compatibility with the human body, and are generally not removed since they have no effect on health.[6,7] except for allergies in very few cases. However, in our clinical work, we found that with the growth of adolescents, chest wire can lead to uncomfortable side effects, including pain, infection, wire displacement, wire slip, arrhythmia, and even chest tightness and shortness of breath, which will bring certain damage to the body and directly affect the learning and mental state of adolescent patients. In addition, some patients were found to have broken fixed wires during physical examination, which has no practical effect, and whether to remove these wires is still controversial in the academic field. Therefore, we conducted this study to evaluate the safety and patient satisfaction of sternal wire removal in adolescent patients who had previously received heart surgery.

First of all, this study was approved by the Ethics Committee of the First Hospital of Hebei Medical University. The main purpose of this study is to evaluate the safety and patient satisfaction of sternal wire removal in adolescent patients who have received heart surgery in the past. Since children and adolescents are in a growing stage and their minds are not sound, it is particularly important to quickly and effectively relieve or even cure patients' discomfort. The results of this research have important social value. However, at present, there are few studies on wire fixation and fracture after thoracic surgery in adolescents,[8,9] so the results of this study have important guiding significance and therapeutic basis for the treatment of wire in the growth stage of adolescent patients with intrasternal lesions. For example, in 2018, one patient undergoing aortic dissection had obvious postoperative sternal pain and right arm pain, as well as poor incision healing. During debridement and suture, it was found that the muscle around one of the wires had poor healing. For this reason, wires for sternal fixation were removed during debridement operation. Following the removal of wires, anterior chest pain and right arm pain of the patient disappeared. Inspired by this, the removal of sternal fixation wires was performed on a total of 70 adolescent patients in 2020 and 2021 after obtaining the informed consent. Before this operation, we had predicted and assumed that the removal of the steel wire would not adversely affect the sternal development of the adolescent patients and would not aggravate the symptoms of the patients, and the statistical results we obtained also confirmed this hypothesis. Based on the findings of this study, we recommend patients remove the steel wire as soon as possible in actual clinical treatment to alleviate clinical symptoms. At present, no significant and dominant adverse consequences and symptoms have been found after removing the steel wire, which provides certain guidance for clinical and nursing work.

There is no systematic statistical literature on sternal wire removal for adolescents, and the feasibility of sternal wire removal for adolescents is unknown. Therefore, this study aims to evaluate the safety and patient satisfaction of sternal wire removal surgery for adolescents, offering reference for clinical practice in the future. However, due to the fact that the population for observation in this study was mainly those with chest discomfort or steel wire fracture found by physical examination, there was no control group after steel wire installation, and the time for case statistics was limited, this study could only prove that steel wire removal was beneficial to symptomatic patients, but could not prove whether chest pain could be alleviated by itself. Therefore, it is necessary to accumulate more clinical cases in the future for a longer period to summarize the trend of the disease and provide more effective treatment.

DATA AND METHODS

Case data

First of all, this study has been approved by the Ethics Committee of the First Hospital of Hebei Medical University, and all patients and their guardians have obtained informed consent. Ethical approval number: 20210382. A total of 70 adolescent patients were selected from June 2020 to September 2021 and subjected to cardiac surgery through a longitudinal midsternal incision. The preoperative study data of the above patients were obtained by verifying medical records, admission, and physical examination imaging data such as X-ray, MRI, etc. After surgery, the study data were obtained by combining imaging data with test results and physical status data of the patients.

Table 1. Case data

Item	Total
n	70
Gender	
Male	34 (48.57%)
Female	36 (51.43%)
Postoperative wire residuals	
Yes	3 (4.29%)
No	67 (95.71%)
Satisfaction	
With regrets	3 (4.29%)
Satisfied	67 (95.71%)
Reason for surgery	
Chest pain	36 (51.43%)
Ruptures found in physical examinations	6 (8.57%)
Employment and further education	23 (32.86%)
A requirement of magnetic resonance imaging (MRI)	5 (7.14%)
Age	13±7
Age at cardiac surgery	2(1,5)
Waiting time after cardiac surgery	8.37±3.84
Removal duration	35(30,50)

During surgery, four wires were employed for sternal fixation, with the first three wires placed in the 1st, 2nd, and 3rd intercostal spaces, respectively. The 4th wire was placed in the 5th or 6th intercostal space (based on the shape of the sternum) of the sternum to fix the end of the sternum. After obtaining approvals from the Ethics Committee of the hospital and informed consent from patients, sternal wire removal was performed.

The inclusion criteria were set as follows: 1) patients receiving cardiac surgery through a longitudinal midsternal incision, 2) those whose sternum had been completely healed after over 6 months after cardiac surgery and wires retented in the body had exerted no effect, and 3) those who or whose guardian requested the removal of sternal wires.

The exclusion criteria involved: 1) patients with suspected incomplete sternal healing, 2) those with infection foci at the incision, or 3) those with other circumstances that would lead to the failure of surgery.The basic data of all patients were recorded, including gender, age, reason for removal surgery, age at cardiac surgery, waiting time after cardiac surgery, removal duration, patient satisfaction, and postoperative wire residuals (Table 1).

Surgical procedures

All the data on blood routine examination, coagulation function examination, biochemical item examination, electrocardiography, and chest antero-posterior and lateral X-ray radiography were collected before surgery. The intercostal spaces where wires were located were preliminarily identified through chest X-ray radiography. At 10 min before surgery, an appropriate amount of hemocoagulase injection was given to reduce the bleeding of the wound surface.

During surgery, the skin was cut open to the periosteum along 1 cm of the upper or lower end of the original surgical incision, with no need to distinguish subcutaneous layers. During cutting, unabsorbed sutures found were removed. Next, the periosteum was cut longitudinally along the median of the sternum to the anterior bone lamella using an electric knife in the electrocoagulation mode at low power. Usually, slight sparks would be generated after touching by the electric knife in case of obviously exposed wires, based on which the position of wires could be determined.

In addition, unobvious slight sparks were observed in some patients since winding wires were embedded by sclerotin. Under this circumstance, the position of wires was shown in chest radiographs with the sternum angle as a marker, and slight bulges would be discovered through careful discrimination after cleaning up blood and tissue debris, in which winding wires were usually located. The winding position of wires was identified from the left and right sides, and the then winding wires were loosened using pliers. If winding wires were identified but could not be clamped, the anterior bone lamella could be cut open from a point, and then wires were pried from the place below wires (Figure 1).

Next, loosened wires were straightened towards the left and right, respectively, parallel to the bone surface, and one side was cut off. After that, the remaining wires were fully clamped with pliers and pulled up with one hand, with the other hand pressing down on the sternum, so as to pull out wires. As to ruptured wires which were often buried in the soft tissue around the sternum, but were not too far from the original position, they were usually found in nearby soft tissues such as cartilages and muscles instead of the bone lamella. In case of slight bleeding of the sternum, gauzes could be used to slightly compress the bleeding point. Thereafter, the incision and the surrounding skin were disinfected again, subcutaneous layers were sutured in 1-2 layers according to the layer and thickness of the incision, and the epidermis was sutured intradermally. Lastly, the incision was covered with sterile dressings and subjected to slight pressure bandaging with elastic bandages for 24 h.

The position of wires could be found by virtue of intraoperative X-ray scanning if necessary. In brief, during surgery, a metal marker was placed vertically to the torso, and anterio-posterior X-ray radiography was conducted to identify the upper and lower positions of wires. Next, another metal marker was placed inside the incision, and lateral (either right or left) X-ray radiography was carried out to measure the depth of wires (Figure 2). If ruptured wires were found behind the sternum, the surgery should be terminated in time to avoid the damage of the integrity of the stern. Note:

1. An appropriate amount of snake venom hemthrombin injection can be given 10 minutes before surgery to reduce wound bleeding.
2. Because of the history of surgery, the subcutaneous layer can not be distinguished, the skin should be cut directly to the periosteum after incision, there is no need to

Figure 1. Methods for wire removal in sternal

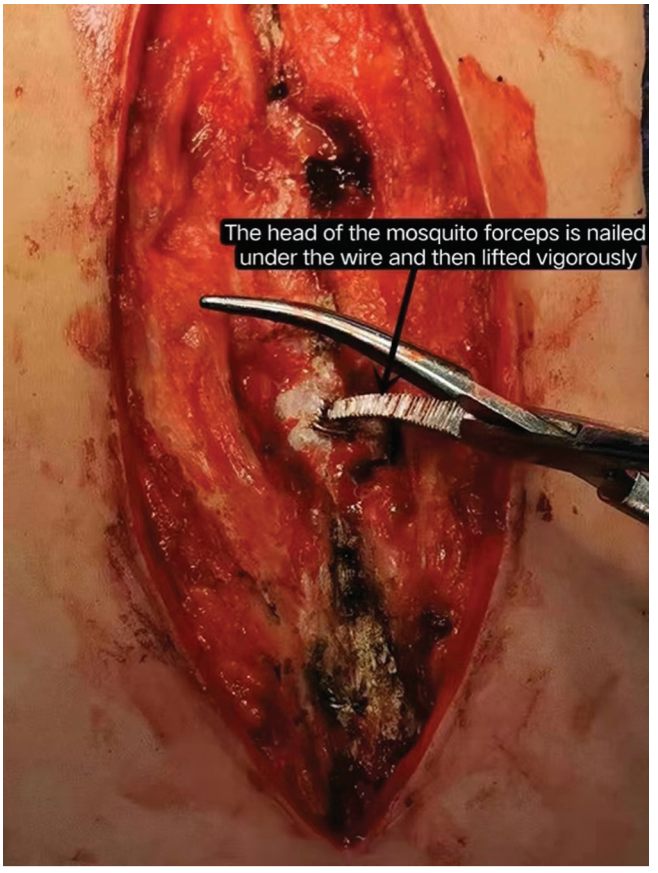

Figure 2. Intraoperative X-ray scan

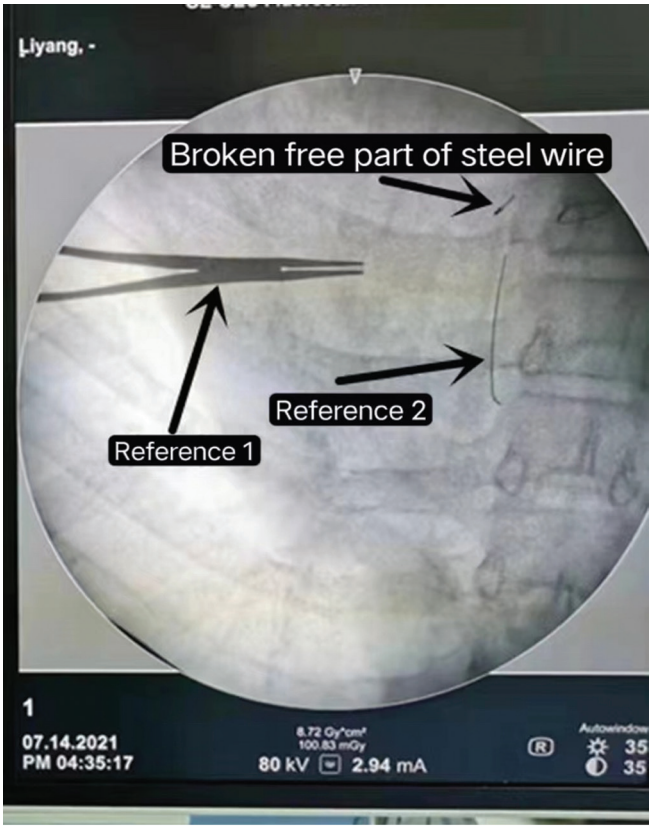

Table 2. Comparison of data related to sternal wire removal between ruptured wire group and unruptured wire group

Item	Unruptured wire group	Ruptured wire group	χ^2/Z/*t*	*P* value
n	37	33		
Gender[a]			8.184	.004
Male	12 (32.43)	22 (66.67)		
Female	25 (67.57)	11 (33.33)		
Postoperative residuals			0.01	.919
Yes	1 (2.70)	2 (6.06)		
No	36 (97.30)	31 (93.94)		
Satisfaction				
With regrets	1 (2.70)	2 (6.06)	0.01	.919
Satisfied	36 (97.30)	31 (93.94)		
Reason for surgery[a]			33.171	.000
Chest pain	12 (32.43)	24 (72.73)		
Ruptures found in physical examination	0 (0.00)	6 (18.18)		
Employment and further education	20 (54.05)	3 (9.09)		
A requirement of MRI	5 (13.51)	0 (0.00)		
Age (Year)	12 (10, 17)	13 (9, 15)	-0.213	.832
Age at cardiac surgery (Year)	3 (2,6)	2 (0.8, 4.7)	-1.860	.063
Waiting time after cardiac surgery (Year)	7.55±4.35	9.28±2.98	-1.564	.118
Removal duration (min)[a]	30 (22, 39)	42 (35, 52)	-3.575	.000

[a]indicates that two-sample rank-sum test was used, indicates that two independent samples *t* test was used. When $P < .05$, the results were statistically significant, and when $P > .05$, the results were not statistically significant.

Note: The data showed that compared with the unruptured wire group, the incidence rate of male was higher than that of female in the ruptured wire group, and the removal time of ruptured wire group was significantly longer than that of the unruptured wire group. The purpose of operation also has obvious difference between the two groups. There were no significant differences in postoperative residual, satisfaction, age, age of operation, and postoperative waiting time between the two groups.

Table 3. Correlations of gender and age with the demand for sternal wire removal

	Chest pain	Employment and further education	Ruptures found in physical examination	A requirement for MRI	χ^2	*P* value
n	36	23	6	5		
Gender					4.091	.252
Male	20 (55.56)	9 (39.13)	4 (66.67)	1 (20.00)		
Female	16 (44.44)	14 (60.87)	2 (33.33)	4 (80.00)		
Age[a]					10.483	.015
1-3 years old	0 (0.00)	1 (4.35)	1 (16.67)	1 (25.00)		
3-6 years old	1 (2.78)	2 (8.69)	0 (0.00)	0 (0.00)		
6-9 years old	5 (13.89)	4 (17.39)	3 (50.00)	0 (0.00)		
9-12 years old	10 (27.78)	6 (26.09)	1 (16.67)	1 (25.00)		
12-15 years old	12 (33.33)	4 (17.39)	1 (16.67)	1 (25.00)		
15-18 years old	5 (13.89)	5 (21.74)	0 (0.00)	1 (25.00)		
>18 years old	3 (8.33)	1 (4.35)	0 (0.00)	1 (25.00)		

[a]represents statistical significant differences.When $P < .05$, the results were statistically significant.

Note: All items are subjected to chi-square test between the two groups.

distinguish the subcutaneous layers.

3. In some patients, the steel wire entanglement will be encased in bone, and the slight spark is not obvious. At this time, we can use the sternal Angle as a symbol and combine the location of the steel wire shown in the chest radiograph, clean up the blood and tissue debris, and carefully analyze, and often find a small slight bump, which is often the steel wire entanglement.
4. When the position of the wire is determined but clamping is not possible, the front bone plate can be broken in points and the wire can be pried from below.
5. The broken wire is often buried in the soft tissue around the sternum, but will not deviate too far from the original position. At this time, it should not be found in the bone plate, but in the nearby soft tissue such as cartilage and muscle.
6. If necessary, the position of the wire can be determined by intraoperative X-ray scanning.

Statistical methods

Data were statistically analysed using SPSS 21.0 software. Enumeration data were expressed as [n (%)], and the composition ratio was compared between groups *via* chi-square test. Measurement data were tested for normality first, those in line with normal distribution were expressed as ($\bar{x} \pm s$), while those not conforming to normal distribution were expressed as the median (P25, P75). The mean and median were separately compared between groups through two-sample *t* test and two-sample rank-sum test. The risk factors of chest pain were determined using Logistic regression analysis. Spearman analysis was performed on the correlation between waiting time after cardiac surgery and removal duration. A correlation coefficient not equal to 0 meant that there was a correlation between them, and a correlation coefficient closer to ±1 suggested a stronger correlation. The two-sided test was employed for all statistics, and the significance level was $\alpha = 0.05$.

RESULTS

Comparison of data related to sternal wire removal between ruptured wire group and unraptured wire group

Patiens were grouped by wire rupture. It was found that ruptured wire group exhibited higher proportions of males and chest pain cases and longer operative time, indicating that removal is harder (Table 2). Among the results, it is noteworthy that in the adolescent population, the difference in the development level of males and females will lead to the difference in the speed of chest and sternum growth, so the incidence of broken steel wire showed the difference between genders. In this result, age is the most related factor to the fracture of the steel wire. The reason for this result is that adolescent patients develop faster and the bones are thickened, and the original fixed steel wire cannot withstand the current tension, resulting in fracture.

Correlations of gender and age with the demand for sternal wire removal

The demand for sternal wire removal was recorded by gender and age. The results showed that the demand for wire removal had no relation to gender, but patients receiving surgery due to chest pain were mainly aged 12-15 years old, those undergoing surgery due to employment and further education were mainly aged 9-12 years old, and those subjected to surgery due to wire ruptures found in physical examination were mainly aged 6-9 years old (Table 3). The reason for this difference is that the bones of adolescent males are stronger than those of females and that the bones of males develop faster with age.

Associations of sternal wire removal with position and quantity of ruptured wires

According to statistics of wire ruptures, the rupture of the 4th wire accounted for the largest proportion (56.41%). The main reason for this result is that the distance between the bones in this segment is large, so with breathing movement, the intercostal muscles contract and the adjacent bones have greater motion than the rest of the bones, and some patients had two or more ruptured wires . The analysis results revealed that no statistically significant differences were found in gender, age, age at cardiac surgery, and waiting time after cardiac surgery between patients with only one ruptured wire and those with multiple ruptured wires (Table 4 and Table 5).

Table 4. Statistical results of position of ruptured sternal wires

Item	Quantity of ruptured wires	Percentage
Rupture of the 1st wire	7	17.95%
Rupture of the 2nd wire	3	7.69%
Rupture of the 3rd wire	7	17.95%
Rupture of the 4th wire	22	56.41%

Table 5. Comparison of data related to sternal wire removal between ruptures of one wire and multiple wires

	Rupture of one wire	Rupture of two or more wires	χ^2/Z/t	*P* value
n	30	3		
Gender			6.63	.412
Male	20 (66.66)	2 (66.66)		
Female	10 (33.33)	1 (33.33)		
Age (Year)	12±4	14±2	-0.786	.438
Age at cardiac surgery (Year)	2 (1, 5)	1 (1, 4)	-0.126	.900
Waiting time after cardiac surgery (Year)	9±3	11±2	-0.841	.407

Note: The data showed that there were no significant differences in gender, age, operation time, and postoperative waiting time between rupture of one wire and rupture of two or more wires, and the results were statistically significant.

Relationship between chest pain and time

After grouping by chest pain, statistics uncovered that the removal duration was longer in chest pain group than that in non-chest pain group, showing a statistically significant difference. The age at cardiac surgery and waiting time after cardiac surgery displayed no statistically significant differences between the two groups. According to Logistic regression analysis with chest pain as the dependent variable, the waiting time after cardiac surgery was a risk factor for chest pain, with an OR of 1.173 and a 95% CI of 1.024-1.345, whereas the age at cardiac surgery and removal duration had no relation to chest pain. Moreover, it was discovered in Spearman analysis on the correlation between the waiting time after cardiac surgery and the removal duration that the waiting time after cardiac surgery was strongly and positively correlated with the removal duration, with a correlation coefficient of 0.638 (Table 6).

Table 6. Correlation analysis of chest pain with time

	Chest pain group	Non-chest pain group	Z/t	*P* value
n	36	34		
Age at cardiac surgery (Year)	2.25 (1.58, 4.78)	2.5 (1, 5)	-0.159	.873
Removal duration (Year)	39.50 (31.50, 52.25)	32.50 (22.75, 40.25)	-2.604	.009
Waiting time after cardiac surgery (Year)	9.42±2.93	7.25±4.39	-2.449	.017

Note: The results showed that there were significant differences in removal duration between the chest pain group and the non-chest pain group, while there were no significant differences in surgical age and postoperative waiting time.

DISCUSSION

In this study, 70 cases of removal of sternal internal fixation wire after cardiac surgery in adolescents were collected, and it was found that the age of operation due to chest pain was mainly 12-15 years old, among which the proportion of fracture of the fourth sternal wire was the highest (56.41%). The proportion of steel wire fracture and sternal pain in male patients was higher than that in female patients. The main reason for this phenomenon was that the bones of adolescent males were stronger and developed faster than those of females. And with the increase of age, the thickening of the bone will make the original fixed wire can not withstand the pressure and break, which will induce symptoms such as infection and chest discomfort, so the operation time was longer. The correlation between chest pain, cardiac surgery time, waiting time after cardiac surgery, and time spent on removal surgery was analyzed, and it was found that longer waiting time was strongly correlated with removal surgery time, indicating that waiting time after cardiac surgery is a risk factor for chest pain. One month after the surgery, 95.71% of the patients said that the surgery relieved their troubles and no adverse reactions occurred. Therefore, we believe that for adolescent patients with chest pain and other life troubles after cardiac surgery, removing the sternal fixed steel wire is the safest and most reliable treatment for relieving chest pain in the short term.

In 33 patients with wire ruptures, the rupture of the 4th wire, namely the wire bundled between the 5th and 6th ribs, accounted for the largest propotion (56.41%). The possible reason is that the connection between the 5th-7th ribs with the sternum is more concentrated, and the costal arch also exerts near this area. As a result, this area is subject to greater tension. Besides, this area is greatly affected by shear stress during motion since the lower part of the thorax has a greater range of motion.[10] Hence, ruptures occur easily.

A study uncovered that sternal wire ruptures occur after thoracotomy, and long-term ruptures will lead to the dissociation of sternal wires.[11] In previous studies, sternal wires are positioned by X-ray scanning in most cases,[12,13] and their ruptures can easily lead to many complications.[14-16] During surgery, it was found that in case of wire ruptures, the ruptured part often cruised into surrounding soft tissues, so it was hard to find the ruptured part. For this reason, anterio-posterior and lateral (ethier right or left) X-ray radiographies were carried out during surgery, and a reference object was placed in the incision. In this way, wires could be found based on the relative position of wires and the reference object on X-ray images to improve the removal rate, thereby prolonging the removal duration.

Moreover, patients were divided into 2 groups according to the occurrence of rupture. The two groups exhibited no

statistically significant differences in the age, age at cardiac surgery, and patient satisfaction. Ruptured wire group had larger proportions of males and chest pain cases and longer removal duration than unruptured wire group. It is because boys have sturdy skeleton, with a greatly increased bone diameter.[17] This further demonstrates that wires will locally restrict the bone growth, resulting in the rupture of wires. Additionally, boys exercise more than girls,[18] to more pulling of the sternum in boys. It further denotes that compressive stress on the periosteum may be a contributor to pain. Patients with such ruptures are more prone to chest pain, which is consistent with the previous finding that sternal wire rupture may be a contributor to chest pain.[19]

Sternal fixation with wires following open cardiac surgery has been widely applied since it is economical, effective, and reliable.[20] As an internal fixator, wires are optimally removed at 1-1.5 years after surgery under normal conditions. However, in traditional view, it is unnecessary to remove wires for sternal fixation.[16] According to the case collection and previous experimental results, however, many problems will be caused if wires are not removed.[21,22] In this study, the results revealed that the main reasons for wire removal in adolescents mainly included: 1) chest pain, manifested as prickling pain, soreness when pressing, or pain in case of weather variations, 2) the need for employment and further education, mainly due to conerns about the fact that the discovery of metals in the body by physical examination for further education, physical examination for entry, and aircraft security inspection will cause unwanted troubles (1 patient lost his job opportunity because of the discovery of metals in the body, and he/she needed to apply for another job), 3) rupture of wires found during treatment of other diseases, and 4) a requirement of MRI (MRI of some patients was refused due to potential risks of wires). Among the 70 patients enrolled in this study, 36 (51.4%) patients received the surgery because of discomfort in the precordial area, mainly aged 12-15 years old (33.33%), 23 (32.8%) patients received the surgery because of concerns about the presence of foreign bodies, mainly aged 9-12 years old (26.09%), and 11 (15.7%) patients were diagnosed with and treated for other diseases, mainly aged 6-9 years old. There was no statistically significant difference in gender among groups, further proving that the demand for sternal wire removal is related to the age of patients.

According to analysis of chest pain cases, the median age at cardiac surgery was 2.25 years old, and patients underwent wire removal were mainly aged 12-15 years old. For these patients, the binding of wires to the chest was performed before the rapid growth of the sternum, and chest pain occurred during adolescence when the skeleton experiences the fastest development.[23] Therefore, it was speculated that wires imprisoned the growth of the sternum and placed a stress on the sternum, resulting in a feeling of pain. A previous study reported that chest pain often occurs after thoracotomy for sternal fixation with wires.[24] Except for the pain caused by the cruising of ruptured wires to other tissues,[25] chest pain often disappears after sternal wires are removed.[26] Hence, further experiments are required to confirm whether there is a specific relationship between chest pain and growth and development in adolescents after thoracotomy. In this study, correlation analysis was conducted on chest pain, age at cardiac surgery, waiting time after cardiac surgery, and removal duration, and the results uncovered that the waiting time after cardiac surgery was a risk factor for chest pain, and it was strongly correlated with removal duration, with a correlation coefficient of 0.638. In this study, it was found that after cardiac surgery, as patients grew older to puberty, due to the rapid growth and development of the sternum and surrounding connective tissue, a longer waiting time often resulted in more severe bone encrust steel wire, which also made patients more prone to chest pain. When removing the steel wire in such patients, the anterior bone plate even had to be destroyed during the operation, which greatly increases the difficulty of removal and the operation time.

Patients were followed up at 1 month after the removal surgery, and the results revealed that 67 patients believed that their troubles were addressed by the surgery, with a satisfaction rate of 95.71%, and no adverse reactions were observed. The remaining 3 patients with postoperative residuals had regrets. The results are basically in line the results of previous studies, especially in patients whose chest pain disappears after sternal wire removal.[19]

CONCLUSION

In conclusion, it is believed that for adolescent patients with chest pain or other life distractions after cardiac surgery, the removal of sternal fixation wires is able to eliminate distractions in a short time, which is safe and reliable. If needed, the removal of sternal fixation wires should be conducted as soon as possible, so as to avoid the rupture of wires and the increase in surgery difficulty. In addition, removing the steel wire as soon as possible can help to quickly relieve the symptoms of patients, and prevent or stop the occurrence of complications such as infection and chest pain as soon as possible, to improve the overall happiness and satisfaction of adolescent patients after heart surgery. However, due to the demand of patients, no negative control group was set up in this study, which is the weakness of this experiment. In the later stage, we will carry out a long-term evaluation of steel wire removal on patients. Therefore, this study suggests that if the indications are combined, the chest wire should be removed as soon as possible for adolescent patients, which can quickly alleviate the symptoms of patients, reduce later complications, and improve the happiness and satisfaction of patients.

DATA AVAILABILITY

All data generated or analyzed during this study are included in this article. Further enquiries can be directed to the corresponding author.

ETHICAL APPROVAL

The study was approved by the Ethics Committee of the First Hospital of Hebei Medical University.

CONFLICTS OF INTEREST

The authors declare no competing interests exist.

AUTHORS' CONTRIBUTIONS

Yanbo Dong and Li Tian contributed equally to this work.

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