



## Research Article

## Ravitch versus Nuss for Adolescent Pectus Carinatum: Multicenter Evidence to Guide Deformity-Specific Surgical Decision-Making

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## Abstract

**Background:** Pectus carinatum (PC) is a congenital malformation of the chest wall, affecting adolescent males predominantly and associated with psychosocial effects. In the Middle East, many studies address the same topic. **Objective:** To evaluate outcomes of modified Ravitch and Nuss procedures in Iraqi adolescents. **Methods:** A multicenter retrospective cohort study (2020–2025) involved 102 adolescents (12–18 years) who underwent PC correction using Ravitch (n=52) or Nuss (n=50) techniques. Procedure selection was based on the severity of deformity, rigidity of the chest wall, and expertise of the surgeon. Outcomes included operative time, hospital stay, complications, aesthetic results, and patient satisfaction (5-point Likert scale). A severity-stratified subgroup analysis was performed. **Results:** Baseline characteristics were comparable, although severe deformities were more frequent in the Ravitch group (65.4% vs. 16.0%,  $p<0.001$ ). The Nuss procedure had a shorter operation time ( $65\pm 15$  vs.  $85\pm 20$  minutes,  $p<0.001$ ) and less hospitalization ( $1.5\pm 0.4$  vs.  $2.1\pm 0.6$  days,  $p<0.001$ ). The rates of complications were identical (13.5% vs. 14%;  $p=0.93$ ). Severity-stratified analysis showed higher Nuss operation efficiency in moderate levels of deformities with comparable rates of complication and satisfaction at severity levels. Favorable aesthetic outcomes were obtained in 82.7% of Ravitch and 88% of Nuss, and more than 90% of patients were satisfied after two years of follow-up. **Conclusions:** The two techniques are safe and effective in PC correction, supporting the Nuss procedure for moderate deformities, and the Ravitch technique is preferred for severe or rigid cases.

**Keywords:** Deformity-specific surgery; Nuss procedure; Pectus carinatum; Ravitch procedure; Surgical outcomes.

مقارنة رافيتش ونوس في تصحيح البيكتس كاريناتوم عند المراهقين : أدلة متعددة المراكز لتوجيه القرارات الجراحية الخاصة بالتشوهات

الخلاصة

**الخلفية:** يعد البيكتسكاريناتوم (PC) تشوهاً خلقياً في جدار الصدر، يصيب الذكور المراهقين بشكل رئيسي ويرتبط بآثار نفسية واجتماعية ملحوظة. في الشرق الأوسط، تناولت العديد من الدراسات هذا الموضوع. **الهدف:** مقارنة نتائج عمليتي رافيتش المعدلة ونوس المعدلة لدى المراهقين العراقيين، مع التركيز على شدة التشوه ورضا المرضى. **الطرائق:** دراسة استيعادية متعددة المراكز (2020–2025) شملت 102 مراهقاً بعمر 12–18 سنة خضعوا لتصحيح PC باستخدام تقنية رافيتش (n=52) أو نوس (n=50) تم اختيار الإجراء وفقاً لشدة التشوه، صلابة جدار الصدر، وخبرة الجراح. شملت النتائج وقت العملية، مدة البقاء في المستشفى، المضاعفات، النتائج التجميلية، ورضا المرضى (مقياس ليكرت من 5 نقاط). أُجري تحليل فرعي مصنف حسب شدة التشوه. **النتائج:** كانت الخصائص الأساسية متقاربة بين المجموعتين، مع انتشار أكبر للتشوهات الشديدة في مجموعة رافيتش (65.4% مقابل 16.0%،  $p=0.001$ )، أظهرت عملية نوس وقتاً جراحياً أقصر (65 مقابل 85 دقيقة،  $p<0.001$ )، وإقامة أقصر في المستشفى (1.5 مقابل 2.1 يوم،  $p<0.001$ ) وكانت معدلات المضاعفات متشابهة (13.5% مقابل 14%،  $p=0.93$ ) وأظهر التحليل الطبقي كفاءة أعلى لعملية نوس في التشوهات المتوسطة، مع معدلات مماثلة من المضاعفات والرضا عبر مستويات الشدة. النتائج التجميلية كانت إيجابية في 82.7% من رافيتش و 88% من نوس، وأكثر من 90% من المرضى أبدوا رضاهم بعد سنتين من المتابعة. **الاستنتاجات:** كلتا الطريقتين آمنتان وفعالتان في تصحيح PC وتُعد عملية نوس الخيار الأمثل للتشوهات المتوسطة، بينما تبقى تقنية رافيتش مفضلة للحالات الشديدة أو الصلبة.

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## INTRODUCTION

Among congenital chest wall deformities, pectus carinatum (PC) ranks as the second most prevalent, defined as the protrusion of the sternum and the costal cartilages that surround it. Its prevalence is estimated to be 1/1000 people with a marked male predominance of around 4:1 [1,2]. The deformity is usually aggravated during the adolescent period when body image formation

is critical; thus, the attendant psychosocial effects such as lowered self-esteem and quality of life constitute principal motivators for correction [3,4]. PC management includes conservative and surgical approaches. In case of flexible deformity, dynamic compression bracing is the first choice of treatment, with success rates of 60–90% [5]. Surgical treatment is the standard of care for rigid deformities that have not responded to conservative management or when there is significant psychosocial distress associated with

the deformity [6,7]. Two major surgical options exist: the modified Ravitch procedure, an open technique involving subperichondral costal cartilage resection, transverse sternal osteotomy, and internal fixation [7,8] and the modified Nuss technique, a minimally invasive technique involving retrosternal bar insertion and rotation to remodel the anterior chest wall [9,10]. Available evidence is inconsistent in its recommendations of the best surgical approach for PC. Advocates of Nuss have cited its minimal invasiveness, shorter operative duration, and excellent cosmesis [6,11], while Ravitch is favored in situations of severe or asymmetric deformity requiring extensive structural reconstruction [12]. Limited comparative data from Middle Eastern regions is obtained, which is constraining the international recommendations' applicability and underscoring region-specific needs and deformity-tailored surgical guidance. PC management in Iraq operates within a healthcare system with limited resources, such as insufficient healthcare facilities, which limited the availability of hospital beds and elective operating rooms, and affected the scheduling of surgical procedures. Additionally, treatment decisions were affected by the lack of advanced imaging technology, which inhibited correct diagnosis and preoperative assessments. Surgeons also had to adjust their methods depending on the tools and staff that were available, which made allocating resources difficult. Also, the opportunity to obtain new medical equipment that could have improved patient care was limited due to financial constraints. Even though Ravitch and Nuss techniques have been extensively investigated for pectus excavatum, there is limited evidence related to PC in Middle Eastern adolescents [13]. To our knowledge, this is the first Iraqi study, multicentric in nature, that compares the results of these techniques for PC, focusing on outcomes, complications, and patient satisfaction, ultimately aiming to nurture specific deformity evidence to guide surgical decision-making in environments with limited resources.

## METHODS

### Study design and setting

The study was a retrospective comparative cohort study conducted in four centers in Baghdad and Al-Anbar provinces, Iraq. Medical records of adolescent patients who underwent surgical correction for PC during the period of five years between January 2020 and January 2025 were reviewed. All centers work in a state-funded healthcare system with similar limitations on availability of elective operating rooms, capacity of hospital beds, implant supply, and advanced imaging access. Experienced thoracic and cardiovascular surgeons performed surgical operations. The distribution of patients across selected centers (24 patients from Al-Ramadi Teaching Hospital, 28 from Ibn Al-Bitar Teaching Hospital, 25 from Ibn Al-Nafees Teaching Hospital, and 25 from Al-Yarmouk Teaching Hospital).

### Inclusion criteria

Inclusion was considered when patients are 1) aged 12–18 years; 2) have moderate-to-severe PC confirmed by clinical and radiologic assessment; 3) undergo surgical correction with either the Ravitch or Nuss procedure; and 4) complete perioperative data with a minimum of 6 months of follow-up.

### Exclusion criteria

Prior chest surgery, concomitant developmental anomalies, or incomplete medical records.

### Participants

Of 124 patients initially reviewed, 22 were excluded: 8 for prior chest surgery, 7 for concomitant developmental anomalies, and 7 for incomplete records or follow-up <6 months (Figure 1). The final cohort of 102 consecutive patients represents all eligible cases at the four centers during the study period.

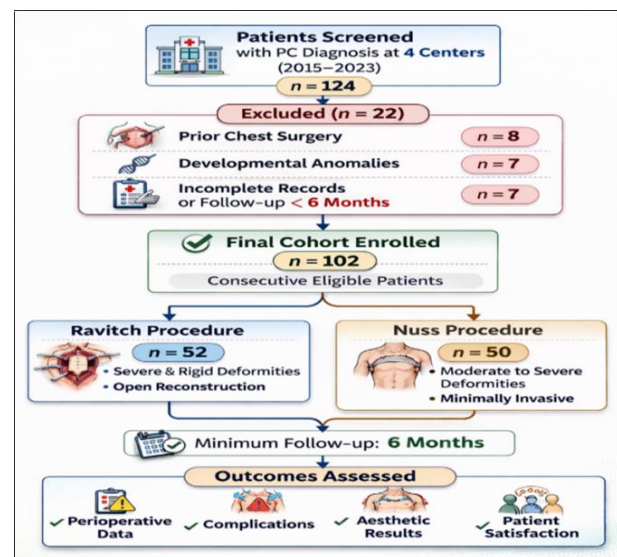


Figure 1: Patient selection flow chart.

### Surgical technique selection

Since this study was a non-randomized real-world study design, surgical technique was chosen based on a multidisciplinary evaluation including surgeons, anesthesiologists, and radiologists who took into consideration the following: 1) severity and rigidity of the deformity; 2) patient age and skeletal maturity; 3) surgeon preference and expertise; and 4) resource availability. In general, the Nuss technique was preferentially used in moderate deformities that were flexible, and the Ravitch procedure was reserved for severe, rigid, or asymmetric deformities that required osteotomy and extensive reconstruction. In some cases, patients with moderate abnormalities were treated by the Ravitch procedure. This

was done based on the surgeon's assessment of the best choice for obtaining ideal cosmetic and functional outcomes, considering specific anatomical concerns. On the other side, the Nuss method may have been used to treat certain severely deformed individuals because of its little invasiveness and faster recovery duration. Crucial factors in these cases include surgical judgment and particular patient characteristics.

### *Preoperative evaluation and severity assessment*

All patients underwent standard preoperative assessments, including physical examination, chest radiograph, and ECG. CT, echocardiography, and pulmonary function tests were performed only when clinically indicated. ECG findings were categorized as normal or abnormal (including minor non-specific changes such as incomplete right bundle branch block and sinus tachycardia). Deformity severity was classified according to the Haller index (HI), which is based on degree of sternal protrusion, chest wall rigidity, asymmetry, and functional impact, as determined by clinical examination and selective imaging. HI measures PC severity by dividing the internal transverse diameter of the chest by the anterior-posterior (AP) diameter, with lower values indicating more severe protrusion (mild:  $HI \geq 1.29$ ; moderate: HI between 1.18 and 1.28; severe: HI between 1.07 and 1.17; and extreme:  $HI < 1.07$ ).

### *Surgical techniques and perioperative care*

The modified Ravitch technique involved a transverse or submammary incision that included bilateral resection of deformed costal cartilages (typically ribs 3-7) but preserved the perichondrium. When indicated, a transverse sternal osteotomy was performed, and then the sternal fixation was done with steel wires. The routine insertion of pleural and subcutaneous drains was used. The modified Nuss technique involved bilateral 3–4 cm mid-axillary incisions to insert retrosternal bars. The use of thoracoscopic guidance was applied when available. A pre-shaped pectus bar was advanced and rotated 180° to correct the deformity, secured with lateral stabilizers, and combined with subcutaneous drainage. All procedures were performed under general anesthesia with endotracheal intubation and preoperative cephalosporin prophylaxis. Multimodal analgesia, incentive spirometry, respiratory physiotherapy, and early mobilization were applied as postoperative management. Drains were removed when output was less than 50 mL/24 h (pleural) or less than 30 mL/24 h (subcutaneous).

### *Follow-up protocol*

Patients were evaluated at 1 month, 6 months, 1 year, and 2 years. Follow-up consisted of clinical examinations, evaluation for complications, standardized photographic documentation, and structured satisfaction surveys.

### *Outcome measures*

Primary outcomes include operative time, length of hospital stay, and intraoperative and postoperative complications. The secondary outcomes include aesthetic results, which are evaluated by two independent surgeons who are blinded to the study, using standardized photographs to assess sternal symmetry, chest wall contour, absence of residual protrusion, and scar acceptability at 2 years; these outcomes are categorized as good (indicating optimal chest symmetry, where the chest appears normal and closely conforms to anatomical norms, resulting in high patient satisfaction) or regular (indicating some noticeable imperfections, such as minor asymmetry or shape abnormalities). The patient may be dissatisfied because of these, even if they have only a minor impact on the overall appearance, and unsatisfactory (severe abnormalities that cause an obvious cosmetic deficiency such as extreme asymmetry or protrusions). Unhappy patients typically mention that their emotional health and self-esteem have been affected by the way their chest looks. By using photographs, the aesthetic outcomes of chest surgery can be evaluated in a consistent and objective manner, reducing the inherent heterogeneity in clinical assessments. This technique allows for the consistent recording of data under varying illumination and viewing angles, offering a transparent visual reference for future comparisons. Images also help impartial reviewers conduct complete reviews, which can lessen the impact of subjective clinical assessments and their inherent biases. Moreover, this method improves the accuracy of outcome measurements, which benefits the surgical team and the patients. Patient satisfaction was assessed using a 5-point Likert scale at 6 months, 1 year, and 2 years (scores  $\geq 4$  were considered satisfied), and outcomes related to Nuss bar removal were not evaluated due to insufficient long-term follow-up.

### *Ethical considerations*

The Declaration of Helsinki lays forth the ground rules for ethical conduct. The study protocol was approved by the institutional review boards of the University of Anbar, with informed consent waived due to the retrospective design.

### *Statistical analysis*

Continuous variables were expressed by mean  $\pm$  standard deviation, and an independent t-test was used to compare these variables. Categorical variables were expressed as frequencies and percentages and analyzed using a chi-square test or Fisher exact test as appropriate. To address baseline severity imbalance, a pre-specified severity-stratified subgroup analysis was performed. Separately comparing Ravitch vs. Nuss within the moderate-deformity subset and the severe-deformity subset. Outcomes assessed within each subgroup were operative

time, hospital stay, total complications, excellent aesthetic results, and 2-year patient satisfaction. The significance level was  $p < 0.05$ ; statistical analysis was conducted with the Statistical Package for the Social Sciences (SPSS) version 28.

## RESULTS

Of 124 patients who were initially screened, 22 were excluded (prior chest surgery  $n = 8$ , developmental anomalies  $n = 7$ , incomplete records  $< 6$  months follow-up  $n = 7$ ), resulting in a final cohort of 102 patients (Figure 1). Male patients constituted 93.1% of the cohort ( $n = 95$ ),

with a mean age of  $15.2 \pm 1.8$  years (range 12–18). The cohort was divided into Ravitch ( $n = 52$ , 51%) and Nuss ( $n = 50$ , 49%) groups. No statistically significant differences were observed in mean age (Ravitch:  $15.4 \pm 1.7$  vs. Nuss:  $14.9 \pm 1.9$  years;  $p = 0.16$ ) or sex distribution (Ravitch: 92.3% male vs. Nuss: 94.0%;  $p = 0.72$ ). Severe deformities predominated in the Ravitch group (65.4% vs. 16.0%,  $p < 0.001$ ). ECG was normal in 88.2% of the total cohort (Ravitch 88.5% vs. Nuss 88.0%;  $p = 0.94$ ); the remaining 11.8% had minor non-specific findings (e.g., incomplete right bundle branch block, sinus tachycardia) of no perioperative consequence. No patient had ECG findings precluding surgery (Table 1).

**Table 1:** Baseline demographic and clinical characteristics of patients with pectus carinatum

Characteristic	Ravitch (n=52)	Nuss (n=50)	Total (n=102)	p-value
Age (year)	15.4±1.7	14.9±1.9	15.2±1.8	0.16
Male sex	48(92.3)	47(94)	95(93.1)	
Female sex	4(7.7)	3(6.0)	7(6.9)	0.72
Severity category				
Moderate	18(34.6)	42(84)	60(58.8)	
Severe	34(65.4)	8(16)	42(41.2)	<0.001
ECG findings				
Normal	46(88.5)	44(88)	90(88.2)	
Abnormal (minor non-specific changes)	6(11.5)	6(12)	12(11.8)	0.94

Values are presented as frequency, percentage and mean±SD.

Significant differences were observed in operative characteristics, reflecting the non-randomized selection design. Nuss was associated with shorter operative time ( $65 \pm 15$  vs.  $85 \pm 20$  min;  $p < 0.001$ ) and hospital stay ( $1.5 \pm 0.4$  vs.  $2.1 \pm 0.6$  days;  $p < 0.001$ ). Sternal osteotomy was performed exclusively in the Ravitch group (67.3%;  $p < 0.001$ ). Internal fixation methods and drainage patterns differed significantly between groups (all  $p < 0.001$ ) (Table 2).

**Table 2:** Surgical operation-related characteristics of patients with pectus carinatum

Variable	Ravitch (n=52)	Nuss (n=50)	p-value
Operative time (min)	85±20	65±15	<0.001
Hospital stay (day)	2.1±0.6	1.5±0.4	<0.001
Sternal osteotomy	35(67.3)	0(0.0)	<0.001
Internal fixation			
Steel wire	52(100)	0(0.0)	<0.001
Pectus bar	0(0.0)	50(100)	
Drainage			
Plural + subcutaneous	48(92.3)	8(16)	<0.001
Subcutaneous only	4(7.7)	42(84)	

Values are presented as frequency, percentage and mean±SD.

Total complication rates were low and comparable (Ravitch 13.5% vs. Nuss 14.0%;  $p = 0.93$ ). No significant between-group differences were observed for individual complications, including seroma, chronic pain, superficial infection, or suture dehiscence. No major complications (cardiac injury, vascular trauma, pneumothorax requiring intervention, deep infection, and mortality) occurred in either group. Thirty-day readmission rates were similarly low (Table 3).

**Table 3:** Postoperative complications of patients with pectus carinatum

Complication	Ravitch (n=52)	Nuss (n=50)	p-value
Total complications	7(13.5)	7(14)	0.93
Subcutaneous seroma	3(5.8)	2(4.0)	0.68
Chronic thoracic pain	2(3.8)	3(6.0)	0.67
Superficial infection	1(1.9)	1(2.0)	0.99
Suture dehiscence	1(1.9)	0(0.0)	0.51
Readmissions (30-day)	2(3.8)	1(2.0)	0.62
Major complications	0(0.0)	0(0.0)	–

Values are presented as frequency and percentage.

At a 2-year follow-up, good aesthetic results were achieved in 82.7% (Ravitch) vs. 88.0% (Nuss) ( $p = 0.44$ ). Patient satisfaction (score  $\geq 4$ ) increased progressively in groups, reaching 90.4% and 92.0%, respectively, in 2 years ( $p = 0.77$ ) (Table 4).

**Table 4:** Aesthetic outcomes and patient satisfaction of patients with pectus carinatum

Outcome	Ravitch (n=52)	Nuss (n=50)	p-value
<i>Final aesthetic result (2-year)</i>			
Good	43(82.7)	44(88)	
Regular	7(13.5)	5(10)	0.44
Unsatisfactory	2(3.8)	1(2.0)	
<i>Patient satisfaction (score <math>\geq 4</math>)*</i>			
6 months	40(76.9)	41(82)	0.52
1 year	45(86.5)	45(90)	0.59
2 years	47(90.4)	46(92)	0.77

Values are presented as frequency and percentage. \* Includes satisfied and very satisfied patients.

Regarding severity-stratified subgroup analysis, within the moderate-deformity subset (Ravitch  $n = 18$ , Nuss  $n = 42$ ), the Nuss technique demonstrated significantly shorter operative time ( $63 \pm 12$  vs.  $78 \pm 14$  min;  $p < 0.001$ ) and hospital stay ( $1.4 \pm 0.3$  vs.  $1.9 \pm 0.5$  days;  $p = 0.001$ ), while

complication rates (14.3% vs. 11.1%;  $p= 0.74$ ), good aesthetic results (90.5% vs. 83.3%;  $p= 0.43$ ), and 2-year satisfaction (92.9% vs. 88.9%;  $p= 0.60$ ) were statistically equivalent. Within the severe-deformity subset (Ravitch  $n=34$ , Nuss  $n= 8$ ), operative time remained significantly shorter in the Nuss group ( $72 \pm 19$  vs.  $89 \pm 18$  min;  $p=$

0.03); however, no significant differences were observed in hospital stay ( $p=0.24$ ), complication rates ( $p= 0.87$ ), aesthetic outcomes ( $p= 0.62$ ), or 2-year satisfaction ( $p= 0.74$ ). Given the small size of the severe Nuss subgroup ( $n= 8$ ), these findings should be interpreted cautiously (Table 5).

**Table 5:** Severity-stratified subgroup analysis of outcomes by surgical technique

Outcome	Ravitch-Mod (n=18)	Nuss-Mod (n=42)	p-value
<b>Moderate deformity subgroup</b>			
Operative time (min)	78 ±14	63±12	<0.001
Hospital stays (days)	1.9±0.5	1.4±0.3	0.001
Total complications	2(11.1)	6(14.3)	0.74
Good aesthetic result (2-year)	15 (83.3)	38(90.5)	0.43
Satisfaction ≥ 4 at 2-year	16(88.9)	39(92.9)	0.6
<b>Severe deformity subgroup</b>			
Outcome	Ravitch-Sev (n=34)	Nuss-Sev (n=8)	p-value
Operative time (min)	89±18	72±19	0.03
Hospital stays (day)	2.2±0.6	1.9±0.5	0.24
Total complications	5(14.7)	1(12.5)	0.87
Good aesthetic result (2-year)	28(82.4)	6(75)	0.62
Satisfaction ≥4 at 2-year	31(91.2)	7(87.5)	0.74

Values are presented as frequency, percentage and mean±SD.

## DISCUSSION

To our knowledge, this report is the first study that compares modified Ravitch and Nuss techniques for PC repair among Iraqi adolescents, furnishing multicenter evidence to guide deformity-specific surgical decision-making in a resource-limited healthcare environment. Both techniques demonstrate high safety and effectiveness with different operative profiles, underscoring the need for context-specific planning in deformity-stratified surgery. Concerning operative efficiency and resource utilization, compared with the Ravitch procedure, higher operative efficiency is noticed in the Nuss technique with shorter operative time and reduced hospitalization, which agrees with prior evidence supporting minimally invasive approaches, such as studies conducted by Kaspiris *et al.* in 2025 [6], Viggiano *et al.* in 2022 [11], and Davari *et al.* in 2025 [14], which suggest that the Nuss procedure is preferable for concomitant pectus and cardiac surgery, except when infeasible. The Nuss procedure may be better than the Ravitch operation even though it is more effective. On the contrary, the expected results are usually better for patients with mild abnormalities, which is why Nuss surgery is usually reserved for them. This is largely responsible for its efficacy. The degree of abnormalities treated by each method should thus be considered when comparing the two procedures. Beyond technical benefits, these findings have significant system-level implications, particularly in contexts with limited resources, where maximizing bed turnover and decreasing indirect costs (costs aren't directly related to the procedure itself but arise as a result, such as lost productivity from patients taking time off work while they recover, the cost of transportation to and from medical facilities, and the overall financial burden on families dealing with the consequences of extended hospital stays) are crucial. The

Ravitch technique remains essential for the treatment of severe or rigid deformities that require structural reconstruction. Concerning safety and complication profiles, both methods showed low and approaching rates of complication in the current work, despite Ravitch having a greater proportion of severe cases, which is different from a study done by Huerta *et al.* in 2024 when it reported that the Ravitch cohort experienced higher rates of complications during index admission [15]. Even in settings with limited resources, when skilled surgeons do them, no serious complications are seen, which further supports the safety and reliability of both procedures [16,17]. In this study, a higher incidence of chronic pain in the Nuss group was detected, which might be attributed to patient-related factors and posture, and this finding is agreed with a previous study conducted by Media *et al.* in 2024 [12]. These side effects are typically ranging from mild to moderate and are treated conservatively. With respect to aesthetic and patient-reported outcomes, this study showed that by the end of the 2nd year of follow-up, more than 80% of patients achieved favorable cosmetic outcomes, and more than 90% of them were very satisfied with their results, which suggests that both techniques succeeded in structural correction and provision of psychosocial benefit. These findings agreed with those reported by studies done by Omanik *et al.* in 2024 [5], Orrick *et al.* in 2022 [18], and Elsayed *et al.* in 2016 [19]. Cosmetic results are critical when evaluating the procedures. Cosmeses remain the major indication for PC repair. It has important implications for patient counseling and expectation management since it shows that satisfaction improves gradually between 6 and 24 months, which may be due to continuous psychological adaptation and continued remodeling of the chest wall [20]. Minimal and nonspecific changes in the patients' ECG were noted in this study. The study group exhibited a wide range of

cardiac responses, despite the changes not reaching statistical significance. These changes must be carefully observed because they could shed light on the patient's physiology and potential underlying mechanisms. The relevance of these results in bigger cohorts or alternative clinical contexts might be the subject of future research. Therefore, although our study's ECG abnormalities aren't cause for alarm, they added to the picture of cardiac surveillance and response in that demographic. Contextualizing findings in the Iraqi healthcare landscape, the study's male preponderance (93.1% vs. the typically reported 4:1 ratio) [1,21] may shed light on cultural factors, healthcare-seeking habits, and referral patterns. Furthermore, patients primarily cited other reasons, not financial obstacles, for being unable to receive treatment, regardless of whether they were from urban areas with access to publicly supported surgical care [22,23]. In situations where sophisticated imaging and non-invasive alternatives aren't readily accessible, pragmatic clinical practice dictates the non-randomized allocation of procedures that favor Ravitch for more severe abnormalities. This finding lends credence to the deformity-tailored strategy since the results are comparable to those in high-income environments, particularly with regard to complication rates and patient satisfaction [15,24].

### Implications for Practice and Future Research

According to these results, there should be a hierarchy of surgical procedures based on severity; for non-severe, flexible abnormalities, the Nuss approach is better since it is efficient and the patient recovers faster, and for severe, inflexible, or asymmetric cases, the Ravitch procedure should be reserved because it requires osteotomy [15,19]. Each patient's surgical decision-making process should be unique, considering their surgeon's skill set, the available resources, and their personal preferences [25]. To enhance evidence-based practice in settings with limited resources, future larger studies should use prospective designs that incorporate validated patient-reported outcomes such as the Pectus Evaluation Questionnaire, markers of objective severity, and cost-effectiveness analyses [26].

### Strengths and Limitations

A high sample size for rare cases, standardized follow-up, blinded cosmetic evaluation, stratified analysis for severity, and a multicenter study design spanning four Iraqi teaching hospitals are all strengths of the study. The retrospective, non-randomized trial design carries the risk of selection bias; only 8 severe Nuss patients were included, severity was not assessed objectively, and long-term follow-up after bar removal was limited.

### Conclusion

With low rates of complications, great patient satisfaction, and outstanding cosmetic outcomes, this study demonstrates that both the modified Ravitch and Nuss methods are safe, effective, and clinically practical for the treatment of PC among Iraqi adolescents. Although the Nuss method offers benefits in operational efficiency for moderate-level abnormalities, the Ravitch procedure is still necessary for complicated cases needing structural repair. Healthcare systems should adopt a deformity-tailored approach more widely, prioritizing personalized, context-sensitive surgical planning based on these findings.

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### Conflict of interests

The authors declared no conflict of interest.

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### Data sharing statement

Supplementary data can be provided by the corresponding author based on a reasonable request.

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