Characteristics of Fibroblasts in Pediatric Indirect Inguinal Hernia

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Abstract- Inguinal hernia is one of the most common congenital abdominal wall defects in children, predominantly presenting as lateral (indirect) hernias. Fibroblasts play a crucial role in maintaining the structural integrity of connective tissue by synthesizing and remodeling extracellular matrix components, including collagen. Altered fibroblast activity has been suggested to contribute to abdominal wall weakness and the development of hernia. This study aimed to describe the fibroblast characteristics in pediatric lateral inguinal hernia cases. A descriptive observational case-series design was conducted at Haji Adam Malik General Hospital and the Anatomical Pathology Laboratory, Faculty of Medicine Universitas Sumatera Utara between July–September 2024. Sixteen pediatric patients diagnosed with lateral inguinal hernia were enrolled through total sampling. Data on age and sex were obtained from medical records, and fibroblast counts were evaluated from excised hernia sac tissue using hematoxylin-eosin staining under light microscopy. Most subjects were aged 1–4 years (37.5%), followed by 5–9 years (25%), and the majority were male (75%). The mean number of fibroblasts was 99.25 ± 21.60 cells per high power field (range 54–119). The elevated fibroblast count may indicate an active tissue response associated with structural weakness or ongoing remodeling processes at the inguinal region. These findings provide foundational data regarding fibroblast involvement in the pathophysiology of pediatric lateral inguinal hernia. Further studies incorporating immunohistochemical markers and comparison with normal tissue controls are recommended to better characterize fibroblast function and collagen metabolism in hernia development.

Index Terms- Children, Fibroblast, Indirect Inguinal Hernia, Pediatric Surgery

I. Introduction

Inguinal hernia is a condition in which visceral organs protrude through a defect in the abdominal wall, particularly within the inguinal canal. A hernia consists of the hernia ring, sac, and contents, which commonly include abdominal organs such as the small intestine, colon, adipose tissue, and omentum. Inguinal hernias account for approximately three-quarters of all hernia cases. The condition is reported to occur five to ten times more frequently in males than in females. A family history of inguinal hernia is noted in about 11.5% of affected individuals. Additionally, studies have shown an increased incidence among twins, with rates of around 10.6% in boys and 4.1% in girls.[1]

Previous research on pediatric inguinal hernia at Haji Adam Malik General Hospital, Medan, reported that 58.3% of cases occurred in male patients, with the majority presenting between 1–5 years of age. The right side was the most commonly affected (71.6%). Globally, more than 20 million inguinal hernia repairs are performed annually, with incidence varying among countries from 100 to 300 cases per 100,000 population each year. In the United Kingdom, approximately 100,000 repairs are performed annually, whereas the United States reports up to 500,000 repairs per year.[2]

Several conditions and risk factors are associated with hernia development, including intrauterine growth restriction, which predisposes to preterm birth and low-birth-weight infants—both of which contribute to neonatal complications, including inguinal hernia. Patent processus vaginalis (PPV) maintains communication between the peritoneum and scrotum, allowing bowel or peritoneal fluid to descend into the scrotal sac. Approximately 80–95% of male newborns have PPV, which decreases to 60% by age 1, 40% by age 2, and 15–37% beyond age 2. In children, congenital factors are the primary cause of inguinal hernia.[3]

Recent studies have focused on understanding structural weaknesses of the inguinal canal, particularly in the anterior and posterior walls. Excessive mechanical stress or impaired metabolism of extracellular matrix (ECM) components has been proposed to contribute to this weakening. Specifically, ECM plays a key role in providing strength and integrity to the aponeurosis and fascia of the inguinal canal.[4]

Fibroblasts are the predominant cells within connective tissue and are responsible for ECM synthesis and remodeling, including collagen production. Under normal physiological conditions, fibroblasts synthesize type I collagen, which provides tensile strength, and type III collagen, which contributes to tissue elasticity and structural support. In cases of inguinal hernia, however, studies have shown dysregulation in the synthesis of collagen types I and III due to aberrant fibroblast function. This imbalance weakens connective tissue in the inguinal region, thereby increasing the risk of hernia formation. Previous study found that children with inguinal hernia exhibit a markedly elevated type III to type I collagen ratio, indicating tissue that is more elastic but biomechanically fragile.[5]

Fibroblasts also play a critical role in wound healing and tissue

regeneration. In lateral inguinal hernia, fibroblast activity contributes to the tissue response against mechanical pressure and to reparative processes following surgical correction. Recent studies have shown that fibroblast behavior influences postoperative outcomes and the likelihood of hernia recurrence.[6]

Given their essential role in ECM maintenance, fibroblasts are central in the pathophysiology of pediatric lateral inguinal hernia. Improved understanding of fibroblast characteristics in hernia tissue may identify contributing factors to abdominal wall weakness and support optimization of surgical interventions. Additionally, greater insight into fibroblast dynamics may aid in the development of preventive strategies and targeted therapeutic approaches.[7]

Histopathological studies have demonstrated that fibroblasts in hernia patients differ phenotypically from those in healthy controls, including reduced collagen-producing capability and altered responsiveness to normal wound-healing signals.[8,9]

In the setting of hernia, fibroblasts are subjected to chronic mechanical distortion, which may further modulate their phenotype and function.[10,11] Inflammation also exerts profound effects on fibroblast activation, primarily mediated through signaling molecules such as Transforming Growth Factor-beta (TGF-β). TGF-β plays a critical role in shifting acute inflammatory responses toward fibrogenesis. During tissue injury, cytokines including TNF-α, IL-1, and IL-6 stimulate TGF-β expression, promoting fibroblast recruitment and differentiation into myofibroblasts—cells with increased contractility and ECM-producing capacity.[12]

Persistent TGF-β activation may lead to pathological fibrosis through excessive ECM deposition. This regulatory balance is influenced by multiple microenvironmental elements including cytokines, ECM modifiers, oxidative stress, cell-cell interactions, and mechanical tension which modulate fibroblast proliferation and collagen turnover.[13]

Understanding the molecular interactions governing fibroblast dysregulation is therefore crucial for advancing regenerative and anti-fibrotic therapies. Gene-based interventions, nutritional optimization, MMP inhibitors, and bioactive scaffolds represent potential therapeutic pathways currently under development. Based on these scientific considerations, investigating fibroblast morphology and distribution in pediatric lateral inguinal hernia is essential to elucidate cellular mechanisms that contribute to inguinal wall weakness and to identify potential targets for improvement of clinical management.

II. Methodology

This study employed an observational descriptive case-series design to characterize the fibroblast profile in children diagnosed with lateral inguinal hernia. The case-series approach was selected to document the frequency distribution and histopathological patterns observed in the targeted pediatric population. The research was conducted at Haji Adam Malik General Hospital, Medan, Indonesia, with histopathological examinations performed at the Anatomical Pathology Laboratory of the Faculty of Medicine, Universitas Sumatera Utara. Data collection was carried out from July to September 2024 following ethical approval from the institutional review board and after obtaining informed consent from parents or legal guardians.

The study population consisted of all pediatric patients clinically diagnosed with inguinal hernia. A total sampling technique was utilized, in which all eligible patients undergoing surgical herniotomy during the research period were included. Based on hospital patient flow estimates, approximately 12–16 subjects were expected for inclusion. Eligible subjects were children aged 0–18 years diagnosed specifically with lateral (indirect) inguinal hernia. Exclusion criteria included patients with other types of hernia and those with additional congenital disorders that might influence connective tissue properties.

During the operation, the hernia sac tissue was excised as part of the standard surgical procedure. The tissue specimens were then fixed and subjected to routine histopathological processing. Hematoxylin-Eosin (H&E) staining was performed to evaluate fibroblast density and morphology, as fibroblasts are the principal cells responsible for extracellular matrix production within connective tissue. Fibroblasts were quantified microscopically by counting the number of cells per high-power field (HPF) across multiple visual fields to reduce sampling bias. Photomicrographs of selected areas were obtained to document morphological characteristics.

In addition to fibroblast analysis, demographic variables including age and sex were collected through review of medical records. Age was measured on a ratio scale and categorized into pediatric developmental groups for distribution description, while sex was recorded as a nominal variable. The primary variable, fibroblast count, was assessed as a continuous numerical measure based on microscopic quantification.

All collected data were analyzed using descriptive statistical methods. Categorical variables such as age group and sex were summarized as frequencies and percentages, whereas numerical data such as fibroblast count were presented as mean ± standard deviation (SD). Findings were interpreted and discussed by comparing them with established literature to provide a broader scientific context regarding the role of fibroblasts in the pathogenesis of pediatric lateral inguinal hernia

III. Results

This is a descriptive, observational study to determine the fibroblast profile in pediatric lateral inguinal hernias. The study used a case series design, with 16 pediatric inguinal hernia patients as the subjects. Based on the sample data collected, the frequency distribution of study subjects by age is shown below. According to Table 1, the largest sample size was found in children aged 1-4 years (37.5%), followed by those aged 5-9 years (25%). The smallest sample size was found in patients aged <4 weeks, with one (6.25%).

Table 1. Frequency Distribution of Research Subjects by Age

Age	Frequency (n)	Percentage (%)
<4 weeks	1	6.25
1-12 months	3	18.75
1-4 months	6	37.5
5-9 years	4	25
10-14 years old	2	12.5

Based on gender, the frequency distribution of study subjects by gender is shown in Table 2 below. The results showed that the frequency distribution of children with inguinal hernias was highest among male, with 12 (75%). Conversely, fewer female suffered from inguinal hernias, with four (25%).

Table 2. Frequency Distribution of Research Subjects by Gender

Gender	Frequency (n)	Percentage (%)
Male	12	75
Female	4	25

Based on fibroblast imaging, the results of microscopic examination of fibroblasts using Hematoxylin-Eosin staining are as follows with an average mean ± SD of 99.25 ± 21.60 (min-max: 54-119) shown in figure 1.

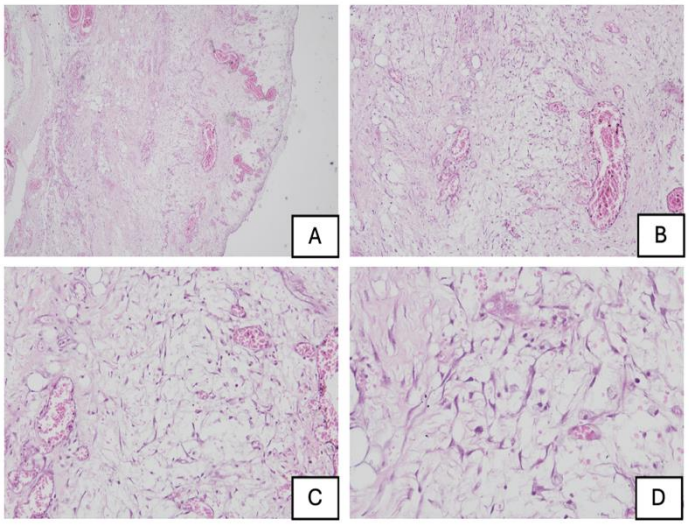

Figure 1. Histological description of tissue staining using Hematoxylin Eosin to assess fibroblasts A. 40x B. 100x C. 200x D. 400x

IV. Discussion

Lateral inguinal hernia in children is one of the most common pediatric surgical conditions, with a particularly high incidence among premature infants and male children.[14] Its primary pathophysiological mechanism is related to the failure of obliteration of the processus vaginalis, resulting in weakness of the inguinal canal and predisposing intra-abdominal organs to protrusion. In addition to anatomical factors, disturbances in the connective tissue of the inguinal region—especially those mediated by fibroblasts play an important role in compromising wall integrity.[15]

Fibroblasts are the principal cells responsible for synthesizing extracellular matrix (ECM) components such as type I and III collagen and elastin, which contribute to tissue tensile strength and elasticity.[16] In pathological states such as hernia, fibroblast dysfunction may lead to reduced collagen production, alterations in the type I/III collagen ratio, and increased matrix degradation, all of which contribute to structural weakness.[17]

Under normal physiological conditions, fibroblast numbers remain relatively constant in accordance with tissue maintenance requirements. However, in response to injury or mechanical stress, fibroblast proliferation may occur. Prior study reported that normal fibroblast counts vary and are significantly lower than those observed in pathological conditions. Histopathological studies demonstrate that fibroblasts in hernia tissue often display altered structure and activity compared with normal controls. In pediatric lateral inguinal hernia, a reduction in active fibroblasts and disrupted signaling pathways involving fibroblast growth factor (FGF) and transforming growth factor-β (TGF-β) have been reported.[18] Additionally, fibroblasts in hernia tissue may undergo phenotypic remodeling resembling cells involved in chronic wound repair, with increased expression of matrix metalloproteinases (MMPs), particularly MMP-2 and MMP-9, which enhance ECM degradation.[19,20]

Understanding fibroblast dysregulation in hernia pathogenesis may support the development of innovative therapeutic strategies. Promising approaches include the use of growth factor-based therapies, MMP inhibitors, genetically modified fibroblast therapies, and biologically active mesh materials that enhance ECM production and tissue strength.[21-23]

In the present study, the mean fibroblast count was found to be 99.25 ± 21.60 cells/HPF with a range of 54–119 cells. This relatively high value suggests an active reparative or compensatory response within the hernia tissue, as fibroblasts are central to healing and connective tissue regeneration.[24] Previous studies in pediatric healthy tissues reported fibroblast counts ranging from 30 to 60 cells/HPF, consistent with lower metabolic demands in the absence of injury. Thus, the increased fibroblast count observed in this study likely reflects chronic inflammation, increased growth factor signaling, or heightened mesenchymal stem cell activity.[25,26]

Beyond cell number, fibroblast morphology also offers insight into their functional state. Normal fibroblasts typically exhibit a spindle-shaped form with elongated nuclei and minimal cytoplasm. Activated fibroblasts involved in regeneration or fibrosis show increased cytoplasmic volume and prominent nuclei, indicative of high biosynthetic activity. Future studies should therefore incorporate morphological and molecular characterization for stronger interpretation of fibroblast behavior.[25,27]

Although this study provides valuable preliminary data, several limitations should be acknowledged. First, immunohistochemistry was not performed, limiting detailed evaluation of fibroblast phenotype and protein expression profiles. Second, this study did not differentiate fibroblast subtypes or assess collagen type I/III ratios, which could further elucidate connective tissue dysregulation. Third, only lateral inguinal hernias were examined, limiting generalizability to other hernia types. Additional comparative studies are needed to broaden pathophysiological understanding across hernia variants.

Future research employing advanced molecular assays, immunolabeling, and quantitative collagen analysis is recommended to confirm whether elevated fibroblast numbers represent normal remodeling or pathological fibrosis. Such investigations may provide a foundation for precision therapy and improved clinical outcomes in pediatric hernia repair.

V. Conclusion

Pediatric indirect inguinal hernia predominantly affects younger children and is more commonly observed in males. Histopathological evaluation revealed an increased number of fibroblasts within the hernia sac tissue, indicating active cellular involvement that may reflect a response to tissue weakness or ongoing connective tissue remodeling. These findings support the concept that both demographic predisposition and alterations in fibroblast activity contribute to the pathophysiology of indirect inguinal hernia in children.

Further studies are recommended to deepen the understanding of fibroblast characteristics and their role in pediatric hernia development.

Future research should include more advanced analytical methods, such as immunohistochemistry, to assess fibroblast phenotypes and collagen regulation more precisely. Comparative studies involving other types of hernias may also help to determine whether similar tissue

changes occur across different clinical presentations. Enhanced knowledge in this area may lead to more targeted therapeutic strategies and improved clinical outcomes for affected children.

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