Research Article

Pediatric Appendectomy Outcomes: A Prospective Cohort Study for Comparison of Laparoscopic and Open Techniques

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Abstract: Background: Acute appendicitis (AA) is a universal surgical emergency. The established standard of care for appendicitis is surgical removal of the infected appendix with two approaches; laparoscopic and open procedure. The variation in reported outcomes creates clinical uncertainty regarding the optimal surgical approach for appendicitis in children.

Objective: To compare postoperative outcomes between laparoscopic and open appendectomy in children with acute appendicitis.

Materials and Method: This prospective cohort study was conducted in Pediatric Surgery Department, at institute of maternal and child health, Nawabshah, from 1st January 2025 to 30th June 2025. Children were allocated to laparoscopic (LA) or open appendectomy (OA) group based on surgeon's decision.

Result: A total of 140 patients were studied with 1:1 group ratio. Operative time was longer (65±23 vs 49.5±22 minutes). On postoperative day 2 (4.2 ± 1.1 versus 5.5 ± 1.8, p < 0.001) and day 7 (2.7 ± 1.4 versus 4.6 ± 2.1) mean pain score for LA was significantly lower than OA (4.2 ± 1.1 versus 5.5 ± 1.8, p < 0.001). Hospital stay was shorter in the LA group (3.0±2.0 vs 5.0±2.0 median days), p values for both were <0.001). Wound infection rates were lower in the LA group compared to OA group (1.4% vs 11.4%, p=0.039). Other postoperative complications were infrequent and comparable between the groups.

Conclusion: LA demonstrates postoperative advantages over OA in terms of early pain control, a lower surgical site infection and a shorter hospital stay. However, its successful implementation in low-resource settings depends on the availability of adequately trained surgical personnel and infrastructures.

Keywords: Pediatric, Acute appendicitis, Open appendectomy, Laparoscopic appendectomy, Postoperative outcomes.

INTRODUCTION

Acute Appendicitis (AA) is a universal surgical emergency in pediatrics population and can lead to serious complications, such as ileus, peritonitis, abscess, and even death [1]. A rapid diagnostic evaluation and timely treatment, is essential to prevent life-threatening complications. The estimated life time risk ranges between 7-9% [2] with an incidence of 1/1000 persons per year in the general population [3]. Pakistan reports an estimated over 110,000 appendicitis cases annually, highlighting the heavy national burden of this emergency and need for timely, efficient, cost-effective and sustainable management strategies [4] to avoid related morbidity and mortality.

The established standard of care for appendicitis is surgical removal of the infected appendix [5]. Currently, there are two primary surgical approaches, open appendectomy (OA) and laparoscopic appendectomy (LA) [6]. The first successful open appendectomy was performed in early 18th century by Claudius Amyand, later Charles McBurney advanced the open technique by introducing the McBurney incision, which improved the access and reduce postoperative complications. A major milestone occurred in 1980 when German gynaecologist Kurt Semm performed the world's first laparoscopic appendectomy at the University of Kiel, that demonstrated the feasibil-

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ity and safety of minimally invasive surgery, paving the way for laparoscopic appendectomy to become a global standard with added advantages over open approach [7].

LA has gained popularity within the last several decades and has recently been performed more frequently than OA even in complicated appendicitis cases. The increased use of LA is due to several benefits of this approach, such as decreased postoperative complications, less incidence of ileus, shorter length of hospital stay, lower reoperation rates, and faster return to daily routine.

There are ongoing discussions about laparoscopic appendectomy (LA) versus open appendectomy (OA). Even though there are some well-designed randomized controlled trials showing that LA has the potential to be better than OA [8, 9], there are still regional studies that have shown either non-significant differences between the two surgical techniques [10] or have pointed out possible limitations to LA, including longer operative times and greater cost of treatment. Other studies suggest LA offers significant advantages such as quicker recovery and decreased complications compared with OA [11].

This ongoing variation in reported outcomes creates clinical uncertainty regarding the optimal surgical approach for appendicitis in children. The lack of consensus is particularly notable in diverse healthcare settings where resource availability, surgeon experience, and patient characteristics vary widely particularly in low resource settings. Therefore, a well-designed comparative study is essential to clarify the true differences in patient outcomes, evaluate procedure-related risks and benefits in a standardized manner, and provide evidence-based guidance to inform surgical decision-making and healthcare policy to improve the outcomes.

We aimed to systematically collect reliable scientific evidence to guide clinical decision-making and optimize surgical techniques for the management of AA in children. The findings contribute to the ongoing debate on the most effective surgical approach that intended to support improved patient care and outcomes. A prospective study was designed to compare operative time, incidence of postoperative complications and hospital stay between laparoscopic and open appendectomy in pediatric population.

MATERIALS AND METHODS

This prospective cohort study was conducted in the pediatric surgery department at institute of maternal and child health, Nawabshah from 1st January 2025 to 30th June 2025 after obtaining approval from the Hospital Ethics Committee [ERC#: PUMHSW/SBA/PVC/ERC/103/2024], dated: 28-11-24. All children aged 5-12 years presenting with acute abdomen in the emergency room during study period were clinically diagnosed for appendicitis were enrolled. Patients with prior history of abdominal surgery or require emergent surgery were excluded. Written informed consent was obtained from the parents/guardians after explaining pros and cons of each technique prior to children's enrolment.

The sample size was calculated using Open Epi software version 2. The sampling parameters were derived from a systematic review and meta-analysis by Neogi S, *et al.* [12] who reported an overall complication rate in open appendectomy (OA) group was 30.3% and in laparoscopic appendectomy (LA) group, 18.6% with a power ($1-\beta$) of 80% and level of significance $\alpha = 0.05$. Assuming an expected absolute difference in complication rate of about 12%, the estimated sample size at 1:1 ratio was at least 63 in each group yielding a total sample size of 126 children in both the groups. To account for potential conversion, dropouts, incomplete data, or loss to follow-up, the sample size was increased by approximately 10%, resulting in a final target sample size of 140 participants. Non-probability consecutive sampling technique was used to enroll patients. Allocation to the study groups was based on surgeon preference, availability of laparoscopic facilities and the clinical suitability of the child.

Both of the surgical procedures were performed under general anesthesia and standard hospital protocols were adhered, including administration of prophylactic and perioperative antibiotics. In both open and laparoscopic appendectomy, suction and irrigation were performed using warm normal saline and metronidazole solution until the aspirated fluid appeared clear.

The patient was positioned supine to perform OA. Then a standard McBurney's incision was made to access the appendix. After identification, the appendix was exteriorized through the incision. The mesoappendix was ligated in an antegrade manner from the tip toward the base using absorbable sutures (Vicryl 3/0, Ethicon, Cincinnati, Ohio, USA). The base of the appendix was securely ligated, followed by transection. The mucosa of the appendiceal stump was then cauterized, and stump inversion was achieved using a purse-string suture.

The patient was placed supine with a Trendelenburg tilt and slight left-lateral rotation for performing LA. A 5-mm supraumbilical incision was created for Veress needle insertion, and pneumoperitoneum was established using carbon dioxide to an intra-abdominal pressure of 6-10 mmHg and adjusted according to the patient's age and body weight. A 5-mm trocar was introduced at the same site for camera insertion. A three-port technique was used (5 mm and 10 mm trocars). The mesoappendix was dissected using either monopolar electrocautery or an ultrasonic dissector. The appendix was ligated at its base and excised distal to the ligature. All trocar sites were inspected for bleeding, and port incisions were closed following standard institutional protocols.

Data was recorded for patients' demographic features such as their age, gender, height, weight and BMI, Clinical history was also recorded in terms of presenting symptoms. Postoperative outcomes included operative time, pain score, and wound complications including surgical site infection (SSI), wound dehiscence and intra-abdominal abscess. Patients were followed at postoperatively day 2, one week, one month and at third month. Patients were given prior booked appointment and reminder calls for timely follow-up. Moreover, patients were advised to visit emergency department prior to the planned follow-up time in case of any adverse event.

Diagnosis of AA was based on Alvardo scoring system which has 10-point scoring system incorporating right lower quadrant tenderness, elevated temperature (>99.10F), rebound tenderness, anorexia, nausea/vomiting, leukocytosis (>10,000 WBC), and shift of leukocytes to the left (>75% neutrophils). A threshold of ≥7 score [10] was used for screening of appendicitis [13]. The duration of surgery was defined as the time taken from making of skin incision till the application of last skin stitch in minutes [14]. Pain was assessed using visual analog scale (VAS). VAS scores pain severity on a scale of 0-10; 0: No pain, 1-3 mild, 4-6 moderate, and 7-10 severe pain [15] measured at 2nd day, one week, one and third month post operatively. Surgical site infection (SSI) was defined as per CDC criteria and categorized as superficial, deep and organ/space SSI. Superficial Incisional SSI involves skin and subcutaneous tissue at the incision site. Deep incisional SSI involves deeper soft tissues, such as muscle and fascia, and Organ/Space SSI involves organs or body spaces opened or manipulated during surgery (e.g., abdominal cavity) [16]. Wound dehiscence was considered as the partial or complete separation of a surgical wound after it has been closed in OR. It occurs when the layers of a surgical incision fail to stay approximated, leading to the wound reopening [17]. Port site infection (PSI) was defined as an infection that occurred at one or more of the incision sites where trocars or access ports inserted during minimally invasive procedures such as laparoscopic surgery and exhibited signs of erythema, swelling, pain, or purulent discharge at the incision site. PSIs ranged from superficial infections limited to the skin and subcutaneous tissue to deeper infections involving fascia or muscle [18]. Intra-abdominal abscess (IAA) defined as an intra-abdominal collection of pus or infected material, resulting from a localized infection [19]. A port site hernia was defined as hernia that occured at the site of an incision made for the insertion of a surgical instrument during laparoscopic surgery [19]. A bowel obstruction was defined as a partial or complete blockage of the small intestine or large intestine, preventing the normal passage of food, fluids, gas, and stool through the bowel [20]. Length of Stay (LOS): It was calculated from date of admission to date of discharge in days.

STATISTICAL ANALYSIS

Data was collected in a pre-designed questionnaire. All collected data was entered in excel sheet and imported and analyzed in statistical software SPSS (IBM Statistics for Windows, version 23.0). Normality of continuous variables were assessed by Shapiro Wilks test and histogram. Means and standard deviations were reported for normally distributed data and median with IQR was computed for non-normal data. Group comparison done by independent sample t test or Mann-Whitney-U test where appropriate. Categorical data were described using counts and percentages. Differences between groups were assessed with either the Chi-square test or Fisher's exact test, depending on the data characteristics. Statistical significance was established at $p < 0.05$.

RESULT

A total of 140 children were studied with equal allocation in both of the groups. The average age of patients was 8.3±2.5 and 7.9±2.6 years in LA and OA groups respectively which was not different statistically (p=0.355). Gender distribution (p=0.237), average BMI (p=0.275), disease duration (p=0.594) and fever (p=0.999), vomiting (p=0.612), pain (p=0.999) and diarrhea (p=0.275) at presentation were comparable between groups (Table **1**).

Table 1. Comparison of Demographic and Clinical Characteristics of the Patients by LA and OA groups, n=140.

Variables	LA Group n=70	OA Group n=70	P-value
Age (Years)*	8.3±2.5	7.9±2.6	0.355
Weight (kg)	30.1±9.3	30.41±8.8	0.816
Height (cm)	121.6±18.0	127.1±18.3	0.073
BMI (kg/m^2)	21.9±10.2	20.2±8.9	0.275
Gender			
Male n (%)†	32 (45.7%)	39 (55.7%)	0.237
Female	38 (54.3%)	31 (44.3%)	
Symptoms			
Duration of symptoms (days)	3.0 ± 1.4	2.9 ± 1.4	0.594
Fever	68 (97.1%)	67 (95.7%)	0.999
Vomiting	37 (52.9%)	34 (48.6%)	0.612
Pain	70 (100%)	70 (100%)	0.999
Diarrhea	19 (27.1%)	25 (35.7%)	0.275

*±(SD) standard deviation; †(n%); P value computed using independent t-test or Mann Whitney U test, or Chi-square or Fisher exact test where appropriate.

The operative time was significantly longer for the laparoscopic approach (LA) as compared to the open approach (OA) with 66.2 minutes mean operative time was in LA group versus 49.7 minutes in OA group; (p<0.001). The postoperative length of stay (LOS) was substantially less for patients undergoing LA as compared to OA i.e. around 2.9 days in LA group than almost 4.8 days in OA group (p<0.001). Time to oral intake was lower in LA group than OA group (p<0.001) (Table **2**).

Table 2. Comparison of Operative Time, Hospital Stay and Time to Oral intake between Two Groups.

Variables	LA Group n=70	OA Group n=70	P-value
Operative Time (Minutes), mean±SD	66.2±13.5	49.7±12.7	<0.001
Hospital Stay (days), mean±SD	2.9±0.8	4.8±1.1	<0.001
Time to oral intake (days), mean±SD	2.1±0.6	3.1±1.7	<0.001

Across all time points during the study, there was a steady decline in pain scores for each group (LA and OA). On postoperative day 2, mean pain score for LA was significantly lower than OA (4.2 ± 1.1 versus 5.5 ± 1.8, p < 0.001). One week later on Day 7, mean pain score continued on their downward trend to 2.7 ± 1.4 for LA versus 4.6 ± 2.1 for OA, (p < 0.001). At 1 month postoperatively, mean pain scores dropped to 0.9 ± 0.7 and 1.4 ± 0.8 for LA and OA respectively but did not reach statistical significance (p=0.748). At the end of 3 months, mean pain scores for LA (0.5 ± 0.1) and OA (0.6 ± 0.2) were comparable, and both were considered to be at very low levels (p=0.913) (Fig. **1**).

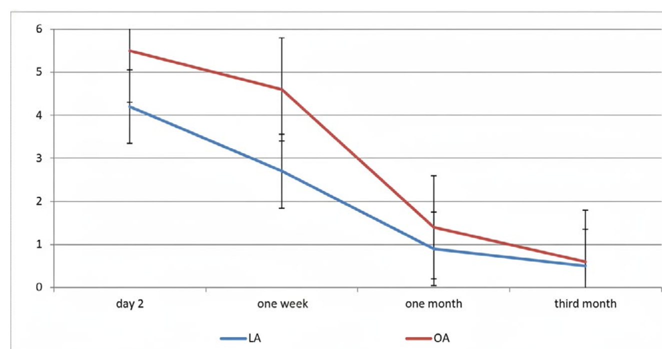

Fig. (1). Trends of Mean Pain Score by LA and OA Group over follow up Time Points

SSI was observed in less number of patients among patients who had laparoscopic-assisted surgery (LA) compared to patients who underwent open surgery (p = 0.043) though when exploring dehiscence, the results from LA and OA were not significant (p = 0.512) nor for intra-abdominal abscesses (p = 0.441). At the one-week follow-up, the incidence rates for these complications revealed no significant difference, with 1.5% of the LA patients and 6.4% of the OA patients developed SSI (p = 0.154), None of the LA patients and 2.1% of the OA patients had dehiscence (p = 0.233), and no intra-abdominal abscesses reported in either cohort. In addition, none of the patients from either group had any of these complications at their one-and-three month follow-ups (Table **3**).

Table 3. Comparison of complication rates among the two groups over the study time period

In hospital Complications	LA Group	OA Group	p-value
SSI	1 (1.4%)	8 (11.4%)	0.039
Dehiscence	4 (5.7%)	6 (8.6%)	0.512
Intra-Abdominal Abscess	2 (2.9%)	5 (7.1%)	0.441

Continue

Continue

Complications at one week			
SSI	3 (4.3%)	1 (1.4%)	0.154
Dehiscence	0(0)	1 (1.4%)	0.233
Intra-Abdominal Abscess	0(0)	0(0)	-

DISCUSSION

This study aimed to produce evidence to the continuing controversy over the superiority of LA versus OA in uncomplicated appendicitis among pediatric population. In our study, both groups were demographically and clinically comparable at baseline recruitment with no significant differences in age, BMI, presentation of typical symptoms such as fever, vomiting, abdominal pain, diarrhea, and its duration. The equivalence suggesting that the observed differences in the surgical outcomes are unlikely to be attributable to baseline variations, thereby strengthens the validity of outcome comparisons between the two surgical approaches [12, 21,22]. The distribution of gender was comparable in the sampled population; although, some epidemiological studies have reported a higher incidence of appendicitis in males [23, 24]. The possible explanations include hormonal influences on inflammatory response, immune function and regional environmental factors.

Our results showed a significant difference in perioperative recovery parameters such as a prolonged duration of operating time was evident in OA group compared to LA group that allows direct access to the appendix through a long incision, thereby increasing operative duration [25] while LA procedural requires port placement, pneumoperitoneum creation, and the technical complexity of laparoscopic dissection. In line to our finding, longer operative times for open appendectomy (OA also reported by Sreekantamurthy *et al.* [21].

In our study other results for other recovery parameters indicates that the patients in the LA group had shorter hospital stays and were able to start eating orally sooner than patients in the LA group [26, 27]. This finding is consistent with prior literature available on this scope. The reasons for this difference include less surgical trauma, smaller incisions, and very little tissue handling involved with laparoscopic surgical techniques; thus resulting in decreased inflammatory response, less post-operative pain, and earlier return of bowel function. These factors combine to promote the earlier resumption of oral intake and improved mobility; therefore enhancing recovery overall. On the contrary, the performance of open surgical procedures leads to: 1) greater disruption of body tissues; 2) increased post-operative pain; and 3) increased inflammatory burden to the body. The combination of these three factors will result in a delay in gastrointestinal recovery, a prolonged ileus after surgery, reduced mobility, and will ultimately cause delayed resumption of oral intake and an increased length of hospital stay following surgery.

The LA group had significantly less pain after surgery than the OA group in the first two days after having surgery, then again at 1 week and 1 month after surgery, but after 3 months, the groups are comparable in terms of pain score. This finding suggests that early recovery benefits in LA group than OA group. The reduced pain at early phases is possible as minimally invasive technique utilizes smaller incisions with less handling of the underlying muscles and facilities and reduces inflammation and the amount of nociceptive stimulation during laparoscopic appendectomy, promoting early functional recoveries. Contrarily, open appendectomies result in much greater trauma directly to the abdominal, delayed mobility contributing to higher pain levels compared to LA during the early phases. Our findings support and are consistent with the evidence provided by other studies. For instance, the majority of previously published research has reported lower pain scores following laparoscopic surgery when comparing the laparoscopic cohort to an open cohort [28, 29], as well as having less need for analgesic medications in the laparoscopic cohort compared to the open cohort [26, 29]. Thus, they have concluded that postoperative comfort is improved after laparoscopic surgical procedures. Most studies assessing pain levels following laparoscopic surgery have evaluated pain on a single occasion [27-29]; however, Y Liu *et al.* at [30] followed patients from the second day postoperatively until the twenty-sixth postoperative day and demonstrated that, as compared with the open group, patients in the laparoscopic cohort had persistent decreases in pain levels up to 26 days postoperatively, which is supported by our current study's findings. The lack of a statistically significant difference in pain levels in our cohort at three month postoperatively can be explained due to healing naturally occurring. At the end of 90 days of postoperative recovery, tissue healing has largely occurred within both study groups, the inflammatory process has significantly resolved in both cohorts and, therefore, there would be minimal difference in pain levels regardless of whether a patient underwent laparoscopic or open surgical proce-

dures. Therefore, although LA provides patients with less postoperative pain in the early postoperative period, this benefit diminishes as the recovery process progresses, and the two groups will eventually reach similar baseline pain levels.

This study demonstrates that patients undergoing open appendicectomy (OA group) showed significantly higher rates of surgical site infection (SSI) both in-hospital and in total post-operative period than patients undergoing laparoscopic appendicectomy (LA group). This indicates that there is a substantial decrease in SSI among patients undergoing laparoscopic appendicectomy. This conclusion is supported by the literature reporting significantly reduced rates of SSI for laparoscopic appendicectomy including a systematic review conducted by Alganabi *et al.* reported significant reductions in SSI among patients undergoing laparoscopic appendicectomy (Odds Ratio: 2.22, 95% CI: 1.19-4.15, p=0.01) [31] as well as Ullah *et al.* who have reported significantly fewer SSIs in patients undergoing laparoscopic appendicectomy during the early post-operative period [32]. The primary reason for these differences are thought to be due to the minimally invasive technique of laparoscopic appendicectomy which is performed via smaller incisions and allows for less disruption of tissue than open appendicectomy; thus, there will be a considerably lower exposure to intra-abdominal contamination and greater tissue perfusion than that experienced by the patient receiving open appendicectomy, resulting in significantly less bacterial colonisation and wound infection. On the contrary to the laparoscopic method, open appendicectomy employs larger incisions and greater handling of tissue which results in greater exposure to intra-abdominal contamination than laparoscopic appendicectomy resulting in the higher incidence rate of SSI in open appendicectomy.

While there were higher rates of open abdominal wound dehiscence and intra-abdominal abscesses in the open abdomen (OA) group when compared to the laparoscopic approach (LA) group, there were no statistically significant differences in the overall number of patients with these outcomes in this study. This is consistent with existing literature which also fails to show significant differences in these complications between laparoscopic and open appendectomy procedures [33-35]. The lack of statistically significant differences in these two approaches may be due to the relatively low incidence rate of wound dehiscence and intra-abdominal abscesses in both groups of patients. Additionally, the use of standard perioperative antibiotics and improvements in surgical techniques have resulted in fewer deep and superficial infectious complications associated with either laparoscopic or open appendectomy procedures. Furthermore, while laparoscopic surgery may offer some theoretical advantages over open surgery with regards to reducing contamination and reducing the potential for tissue trauma, patient specific risk factors (e.g. severity of appendicitis, perforation status and comorbidities) often have a greater impact on the rates of developing wound dehiscence and intra-abdominal abscess than the choice of surgical technique (laparoscopic or OA). Therefore, laparoscopy (LA) vs. open (OA) will likely not show noticeable differences between them with certainty in the above-mentioned situations due to this observed trend. Other postoperative complications, such as bowel obstruction and bowel obstruction were infrequent and similar in both groups, suggesting that laparoscopic procedures are safe and non-inferior to open surgery in terms of severity of complications [21, 22].

The present study conducted prospectively, allowing systematic collection of perioperative outcomes in a well-matched pediatric cohort. To limit procedural variability and reduce potential operator related bias, the same experienced surgical team conducted all surgeries. Follow-up was performed at 3 months, enabling the assessment of early and intermediate postoperative outcomes, including SSI, dehiscence, and intra-abdominal abscess, which are critical for evaluating the safety and efficacy of OA in children. By focusing specifically on children under the age of 12, the study addresses a population in which smaller intra-abdominal cavity size presents unique technical challenges for minimally invasive surgery, providing practical insights for surgeons managing younger pediatric patients.

LIMITATIONS

Despite these strengths, several limitations should be viewed while evaluating the findings. The study was carried out at a single center and involved a relatively modest sample size, which may reduce of external validity of the results. Although the laparoscopic and open appendectomy cohorts were well-matched for most baseline characteristics, the LA group tended to be slightly older and heavier, potentially offering marginally more favorable conditions for minimally invasive surgery; however, these differences dis not attain statistically significance. Additionally, while the three-month follow-up captures early and intermediate outcomes effectively, longer-term complications beyond this period late

cosmetic concerns, could not be assessed. Furthermore, we did not assess cost-related outcomes; however, LA is generally more costly than open surgery, representing a limitation in understanding overall cost-effectiveness [30], particularly from health system and policy perspectives. Subsequent studies should be performed on multiple centers, long-term outcomes such as postoperative adhesions, cosmetic results, cost-effectiveness and quality of life. Particularly in resource-limited environments, decision-making regarding laparoscopic appendectomy must account risk and benefit ratio.

CONCLUSION

Laparoscopic appendectomy is a safe, effective, and feasible alternative to open appendectomy in children. Despite slightly longer operative times, laparoscopic procedures are consistently associated with shorter hospital stays and lower rates of early wound complications and related postoperative morbidity. The evidence collected systematically with up to three months of follow-up, this study supports the broader adoption of laparoscopic appendectomy in routine pediatric practice.

AUTHORS' CONTRIBUTION

Farhan Ali Qureshi and **Ali Raza Brohi**: Conceptualized, Study design, Methodology, Data analysis and interpretation, Writing Draft, Critical review and revision of the manuscript and Final approval, final proof to be published.

Sadia Sarwar: Study design, Methodology, Data analysis and interpretation, Writing Draft, Critical review and revision of the manuscript and Final approval, final proof to be published.

Habibullah Maitlo: Methodology, Data analysis and interpretation, Critical review and revision of the manuscript and Final approval, final proof to be published.

Masoom Ali Shah and **Ishaque Cader**: Methodology, Data analysis and interpretation, Writing Draft, Critical review and revision of the manuscript and Final approval, final proof to be published.

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Declared none.

ETHICAL DECLARATIONS

Data Availability Statement

Data will be available from the corresponding author upon a reasonable request.

Ethical Approval

This study was approved by the Ethical Review Committee of Institute OF Maternal And Child Health, Nawabshah, ERC#: PUMHSW/SBA/PVC/ERC/103/2024], dated: 28-11-24.

Consent to Participate

Written voluntary informed consent was obtained from all individual participants.

Consent for Publication

Participants provided consent for the publication. No personal or any sensitive information is disclosed in this publication.

Conflict of Interest

Declared none.

Competing Interest/Funding

Declared none.

Use of AI-Assisted Technologies

The authors used Claude AI to assist with language editing and proof reading. All intellectual work has been done by the authors.

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