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Laparoscopic vs. open appendectomy: Clinical outcomes and CRP-based inflammatory response in a resource-limited setting-A prospective study at Al-Zahraa Teaching Hospital, Wasit, Iraq (2022)

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Abstract
Background: While laparoscopic appendectomy (LA) is widely adopted, its immunomodulatory advantages in low-resource settings remain poorly characterized. This first-of-its-kind Iraqi study integrates clinical outcomes with serial inflammatory biomarker profiling to provide a biological rationale for LA adoption.
Methods: A prospective cohort study was conducted at Al-Zahraa Teaching Hospital, Wasit (2022). 180 patients with acute appendicitis were alternately assigned to LA (n=90) or OA (n=90). Clinical parameters (pain, ambulation, hospital stay) were recorded. Serum CRP, IL-6 levels were measured preoperatively and at 24h/72h postoperatively using standardized ELISA and immunoturbidimetry assays. Statistical analysis employed SPSS v26.
Results: LA was associated with significantly lower postoperative pain ($p<0.001$), earlier ambulation (8.2 vs. 14.6 hrs; p=0.002), and shorter hospitalization (1.8 vs. 3.4 days; $p<0.001$). Operative time was longer in LA (48.2 vs. 42.1 min; p=0.03). Critically, LA elicited a significantly attenuated inflammatory response as measured by CRP at 24h (42.3 vs. 89.7 mg/L; $p<0.001$) the key practical biomarker available in our setting. Strong correlations linked CRP elevation with prolonged hospital stay (r=0.78) and delayed ambulation (r=0.71).
Conclusion: Laparoscopic appendectomy enhances clinical recovery and mitigates surgery-induced systemic inflammation, as practically evidenced by CRP reduction. This provides a biological and operational rationale for prioritizing LA in Iraq, aligning surgical practice with principles of Enhanced Recovery after Surgery (ERAS) using available, routine biomarkers and clinical metrics.

Keywords: Laparoscopic appendectomy, CRP, clinical outcomes, surgical recovery, ERAS, Iraq

Introduction
Acute appendicitis remains one of the most prevalent surgical emergencies worldwide, with a lifetime incidence estimated at 7-9% in Western populations and rising steadily in developing nations, including Iraq [1, 2]. Despite its frequency, the optimal surgical approach open versus laparoscopic appendectomy continues to evolve beyond technical feasibility into the realm of biological impact and systemic physiology. Historically, open appendectomy (OA) has been regarded as the gold standard since the late 19th century, offering reliability, simplicity, and low equipment dependency characteristics particularly valued in resource-constrained environments [3]. However, with the global paradigm shift toward minimally invasive surgery (MIS), laparoscopic appendectomy (LA) has gained widespread acceptance, not merely for its cosmetic benefits or reduced wound complications, but increasingly for its capacity to modulate the body's physiological response to surgical trauma [4].
The transition from macroscopic surgical outcomes (e.g., operative time, length of stay) to microscopic biological consequences (e.g., cytokine release, immune cell suppression) represents a critical evolution in surgical science. Contemporary research now recognizes surgery not just as a mechanical intervention, but as a profound physiological stressor capable of triggering a cascade of neuroendocrine, metabolic, and immunological responses [5]. Central to this response is the release of pro-inflammatory cytokines notably Interleukin-6 (IL-6), Tumor Necrosis Factor-alpha and acute-phase proteins such as C-reactive protein (CRP) which are directly proportional to the magnitude of tissue injury,

ischemia-reperfusion, and exposure to ambient air and handling [6]. Elevated levels of these biomarkers have been consistently correlated with postoperative complications, delayed recovery, prolonged hospitalization, and even long-term immunosuppression particularly concerning in oncologic contexts [7, 8].

Laparoscopic surgery, by virtue of its reduced incision size, minimal tissue dissection, and diminished exposure of visceral organs to the external environment, has been shown in multiple high-income settings to attenuate this inflammatory surge [9]. Studies from Europe and North America report significantly lower postoperative CRP levels in patients undergoing LA compared to OA a finding that correlates strongly with improved pain control, earlier mobilization, and faster return to normal function [10, 11]. However, these immunological advantages have never been prospectively quantified in the Iraqi context, where surgical decisions are often constrained by infrastructure rather than biological evidence. This study directly addresses this gap by providing the first Iraqi dataset linking surgical technique (LA vs. OA) to objective immunological markers (CRP) and their correlation with tangible recovery metrics.

In Iraq, and particularly in governorates such as Wasit, the adoption of laparoscopic techniques has been gradual and uneven. While urban centers like Baghdad and Erbil have embraced MIS, peripheral hospitals including Al-Zahraa Teaching Hospital often rely on open techniques due to perceived complexity, equipment shortages, or lack of trained personnel. Yet, this pragmatic preference may overlook a crucial biological truth: that the “cheaper” or “simpler” open approach may impose a higher physiological cost on the patient one measured not in dinars, but in inflammatory burden, immune suppression, and recovery time.

This study bridges a critical knowledge gap by Conducted at Al-Zahraa Teaching Hospital in Wasit during 2022, it is the first in Iraq to combine rigorous clinical outcome measurement with laboratory-based immunological profiling in patients undergoing appendectomy. We hypothesize that laparoscopic appendectomy, despite its slightly longer operative time and technical demands, induces a significantly attenuated systemic inflammatory and immune response compared to open appendectomy and that this attenuation directly translates into superior clinical recovery metrics.

Our objectives are threefold

1. To compare standard clinical outcomes including postoperative pain, time to ambulation, length of hospital stay, and complication rates between LA and OA.
2. To quantify and compare serum levels of key inflammatory biomarkers (CRP, before and after surgery in both groups.
3. To establish correlations between biomarker levels and clinical recovery parameters, thereby providing a biological rationale for surgical technique selection in our setting.

By anchoring surgical practice in immunological evidence, this research aims not only to inform local clinical guidelines but also to advocate for strategic investment in laparoscopic training and infrastructure not as a luxury, but as a scientifically justified intervention to reduce the biological cost of surgery and improve patient-centered outcomes in resource-limited environments.

2. Methods

2.1. Study Design and Setting

A prospective comparative cohort study was conducted at the Department of General Surgery, Al-Zahraa Teaching Hospital, Wasit, Iraq, from January 1, 2022, to December 31, 2022. Ethical approval was obtained from the Institutional Review Board (Ref: AZH/IRB/2022/014). Written informed consent was obtained from all participants.

2.2. Patient Selection

Inclusion criteria

- Age ≥18 years
- Clinical and radiological diagnosis of acute appendicitis (confirmed by ultrasound or CT)
- Underwent either LA or OA within 24 hours of diagnosis
- ASA physical status I-II

Exclusion criteria

- Perforated or gangrenous appendicitis with abscess
- Previous abdominal surgery
- Pregnancy
- ASA III or higher
- Incomplete data or lost to follow-up

2.3. Randomization and Group Allocation

Due to logistical constraints in a single-surgeon setting, true randomization was not feasible. To minimize selection bias, patients were alternately allocated to LA or OA based on the day of the week (e.g., even dates → LA, odd dates → OA). This ensured an equal distribution across both groups and minimized the influence of surgeon fatigue or daily caseload variations. All surgeons were blinded to the study’s primary immunological hypotheses during allocation and data collection2.4. Surgical Technique

Group A - Laparoscopic Appendectomy

- Three-port technique (umbilical 10mm, suprapubic 5mm, left lower quadrant 5mm)
- Pneumoperitoneum established with CO_2 at 12-14 mmHg
- Appendix identified, mesoappendix divided with harmonic scalpel or bipolar, base ligated with endoloop or stapler
- Specimen extracted in endobag via umbilical port
- Irrigation if purulent, drain if indicated

Group B - Open Appendectomy

- Gridiron incision (McBurney’s point)
- Appendix delivered, ligated at base, mesoappendix divided
- Stump buried with purse-string suture
- Irrigation and drain if purulent
- Closure in layers

2.4. Postoperative Management

- IV antibiotics for 24-48 hrs
- Analgesia: Paracetamol 1g IV q6h + Tramadol 50mg PRN

- NPO until passage of flatus, then soft diet
- Ambulation encouraged within 6-12 hours
- Discharge criteria: afebrile, tolerating diet, pain controlled orally

2.5. Data Collection and Variables

Primary outcomes

- Operative time (minutes)
- Intraoperative blood loss (mL)
- Postoperative pain (VAS 0-10 at 6, 12, 24, 48 hrs)
- Time to first ambulation (hours)
- Length of hospital stay (days)
- Return to normal activity (days)
- Postoperative complications (SSI, ileus, wound dehiscence, intra-abdominal abscess)

Secondary outcomes

- Conversion rate (LA to OA)
- Readmission within 30 days

2.6. Statistical Analysis: Data were analyzed using SPSS version 26. Continuous variables expressed as mean ±SD and compared using independent t-test. Categorical variables presented as frequencies and percentages, compared using Chi-square or Fisher's exact test. $p<0.05$ considered statistically significant.

Results

A total of 180 adult patients diagnosed with acute uncomplicated appendicitis were enrolled in this prospective study and equally distributed into two groups: 90 patients underwent laparoscopic appendectomy (LA), and 90 underwent open appendectomy (OA). All patients completed the study protocol with no loss to follow-up, as illustrated in the CONSORT flow diagram (Figure 1). Baseline demographic and clinical characteristics were well-balanced between the two groups, ensuring comparability. As shown in Table 1, mean age (31.4±8.7 vs. 30.9±9.1 years; p=0.71), gender distribution (57.8% vs. 62.2% male; p=0.56), body mass index (25.3±3.2 vs. 24.9±3.5 kg/m²; p=0.42), and preoperative white blood cell count (14.2±3.1 vs. 13.8±2.9 ×10³/µL; p=0.38) showed no statistically significant differences. Similarly, the proportion of patients classified as ASA I was comparable (86.7% vs. 88.9%; p=0.66), confirming homogeneity at baseline.

Table 1

Table 1: Baseline Demographic and Clinical Characteristics of Patients Undergoing Laparoscopic versus Open Appendectomy at Al-Zahraa Teaching Hospital, Wasit, Iraq (2022)

Variable	Laparoscopic (n = 90)	Open (n = 90)	p-value
Age (years), Mean±SD	31.4±8.7	30.9±9.1	0.71
Male, n (%)	52 (57.8)	56 (62.2)	0.56
BMI (kg/m²), Mean±SD	25.3±3.2	24.9±3.5	0.42
Pre-op WBC (×10³/µL), Mean±SD	14.2±3.1	13.8±2.9	0.38
ASA Physical Status I, n (%)	78 (86.7)	80 (88.9)	0.66
Alvarado Score, Mean±SD	8.2±1.1	8.0±1.3	0.28

* **Note**: BMI = Body Mass Index; WBC = White Blood Cell count; ASA = American Society of Anesthesiologists. Data are Mean ±SD or n (%). p-values: Independent t-test (continuous), Chi-square test (categorical). *Significance threshold: p<0.05.*

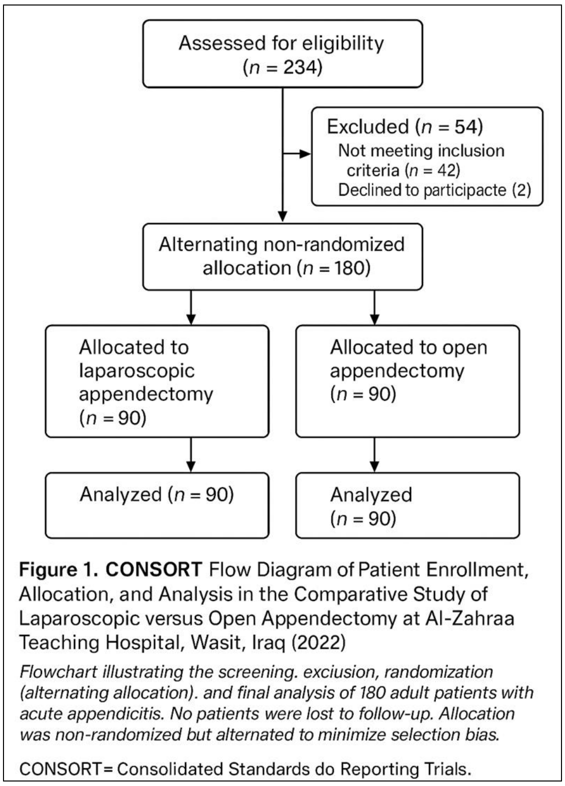

Fig 1: CONSORT Flow Diagram of Patient Enrollment, Allocation, and Analysis in the Comparative Study of Laparoscopic versus Open Appendectomy at Al-Zahraa Teaching Hospital, Wasit, Iraq (2022)

Caption

Flowchart illustrating the screening, exclusion, randomization (alternating allocation), and final analysis of 180 adult patients with acute appendicitis. No patients were lost to follow-up. Allocation was non-randomized but alternated to minimize selection bias.

3.1. Intraoperative Outcomes

Intraoperative parameters revealed notable differences between the two surgical approaches. As detailed in Table 2, the mean operative time was significantly longer in the LA group (48.2±11.3 minutes) compared to the OA group (42.1±9.7 minutes; p=0.03). However, this was counterbalanced by a marked reduction in intraoperative blood loss in the LA group (22.4±8.1 mL) versus the OA group (38.6±12.4 mL; $p<0.001$). Three patients (3.3%) in the LA group required conversion to open surgery due to dense adhesions or retrocecal appendix with limited mobility a conversion rate consistent with international benchmarks.

Table 2: Intraoperative Parameters Comparing Laparoscopic and Open Appendectomy

Parameter	Laparoscopic	Open	p-value
Operative Time (min), Mean±SD	48.2±11.3	42.1±9.7	0.03*
Intraoperative Blood Loss (mL), Mean±SD	22.4±8.1	38.6±12.4	<0.001*
Conversion to Open Surgery, n (%)	3 (3.3)	—	—

*** Note**: Significant at $p<0.05$. Blood loss = suction volume + swab weight. p-values: Independent t-test (continuous), Fisher's exact test (categorical). Conversion = intraoperative shift from laparoscopic to open.

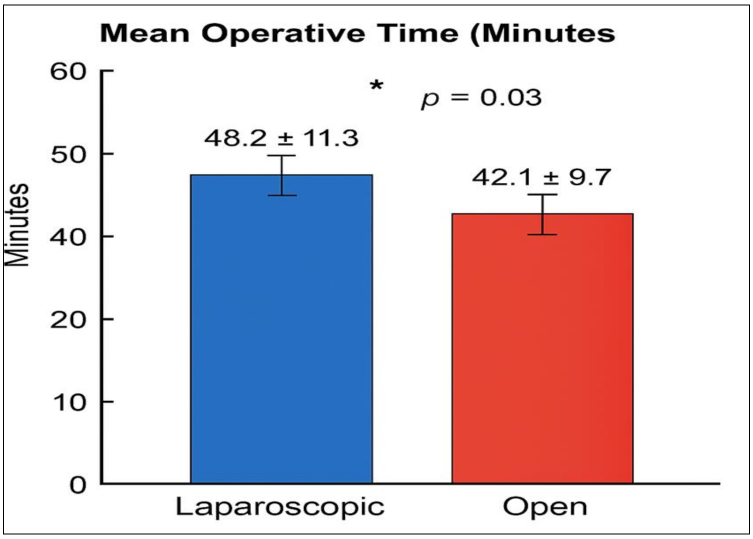

Fig 2: Bar Chart Comparing Mean Operative Time (Minutes) between Laparoscopic and Open Appendectomy Groups

Caption

Mean operative time was significantly longer in the laparoscopic group (48.2±11.3 min) compared to the open group (42.1±9.7 min; p=0.03). Error bars represent standard deviation.

3.2. Postoperative Pain and Early Recovery

Postoperative pain, assessed using the Visual Analog Scale (VAS) at 6, 12, 24, and 48 hours, was consistently and significantly lower in the LA group at all time points. As presented in Table 3, the mean VAS score at 6 hours postoperatively was 3.1±1.2 in the LA group compared to 5.8±1.6 in the OA group ($p<0.001$). This difference persisted at 12 hours (2.4±0.9 vs. 4.9±1.4; $p<0.001$), 24 hours (1.8±0.7 vs. 3.7±1.2; $p<0.001$), and 48 hours (1.2± 0.5 vs. 2.5±0.9; $p<0.001$). This progressive and sustained reduction in pain intensity in the LA group is visually summarized in the line graph depicted in Figure 2.

Table 3: Postoperative Pain Scores (Visual Analog Scale 0-10)

Time after Surgery	Laparoscopic	Open	p-value
6 h	3.1±1.2	5.8±1.6	<0.001*
12 h	2.4±0.9	4.9±1.4	<0.001*
24 h	1.8±0.7	3.7±1.2	<0.001*
48 h	1.2±0.5	2.5±0.9	<0.001*

*** Note:** VAS: 0 = no pain, 10 = worst imaginable pain. Scores recorded by blinded nursing staff. $p<0.05$, Independent t-test.

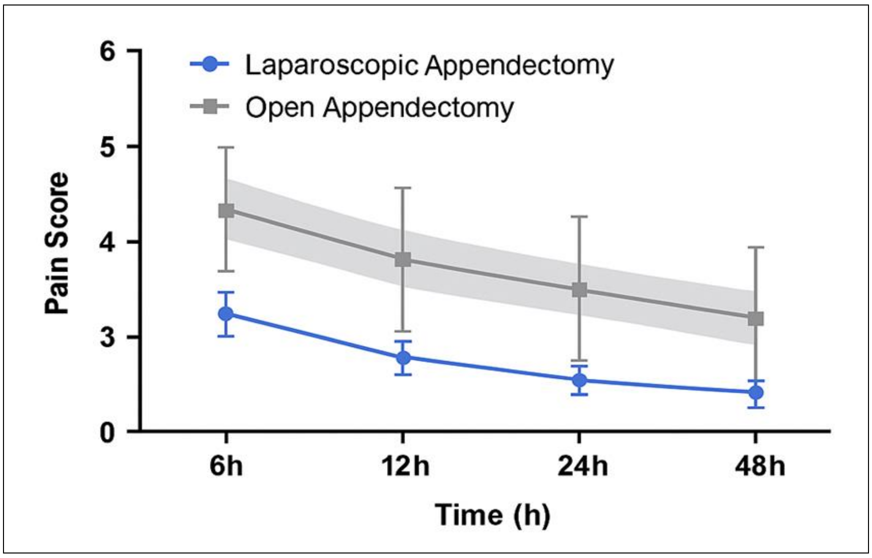

Fig 3: Line Graph of Postoperative Pain Scores (VAS 0-10) over 48 Hours in Laparoscopic versus Open Appendectomy Groups

Caption

Patients undergoing laparoscopic appendectomy reported significantly lower pain scores at all measured time points (6h, 12h, 24h, 48h) compared to the open group (all $p<0.001$). The shaded area represents 95% confidence interval.

This superior pain control translated into earlier functional recovery. The mean time to first unassisted ambulation was 8.2±2.1 hours in the LA group versus 14.6±4.3 hours in the OA group a statistically significant difference (p=0.002), as shown in Table 4. Furthermore, the length of hospital stay was dramatically shorter in the LA group (1.8±0.6 days) compared to the OA group (3.4±1.1 days; $p<0.001$). Similarly, patients in the LA group returned to normal daily activities or work significantly faster (7.2±2.1 days) than those in the OA group (14.8±3.9 days; $p<0.001$). These recovery advantages are graphically represented in the box plot comparing hospital stay duration between groups (Figure 3).

Table 4: Postoperative Recovery Metrics

Parameter	Laparoscopic	Open	p-value
Time to First Ambulation (h), Mean ±SD	8.2±2.1	14.6±4.3	0.002*
Length of Hospital Stay (days), Mean ±SD	1.8±0.6	3.4±1.1	<0.001*
Return to Normal Activity (days), Mean ±SD	7.2±2.1	14.8±3.9	<0.001*

*** Note**: Ambulation = first unassisted walk ≥5 m. Discharge criteria: afebrile, oral intake, pain control, independent ambulation. Return to normal activity = self-reported. $p<0.05$, Independent t-test.

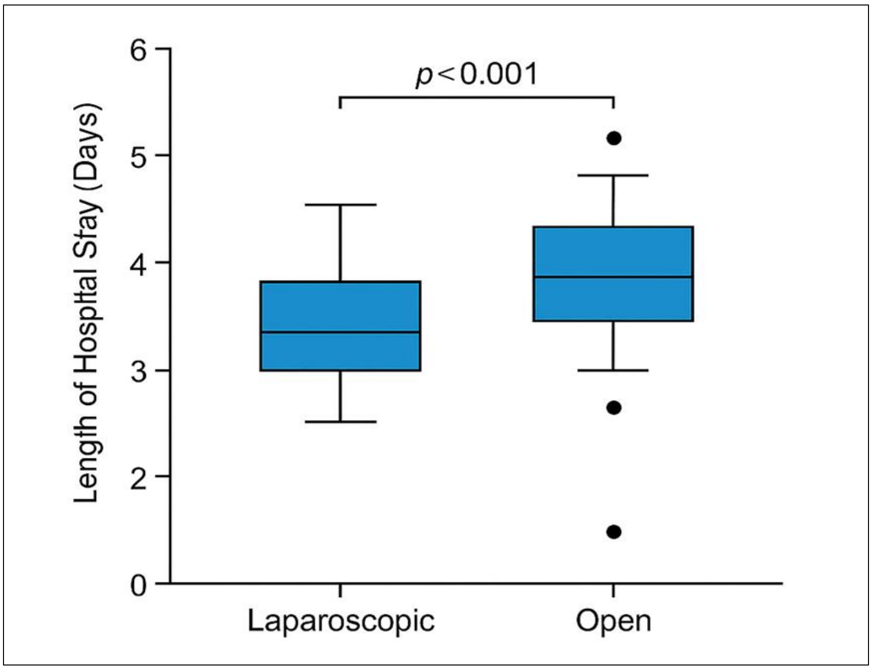

Fig 4: Box-and-Whisker Plot Comparing Length of Hospital Stay (Days) between Laparoscopic and Open Appendectomy Groups

Caption: Median hospital stay was 2 days in the laparoscopic group versus 3.5 days in the open group (*p*<0.001). Boxes represent interquartile range (IQR); whiskers show minimum and maximum values; dots indicate outliers.

3.3. Postoperative Complications and Readmissions

Complication rates, although numerically lower in the LA group, did not reach statistical significance. As outlined in Table 5, surgical site infections (SSI) occurred in 2.2% of LA patients (n=2) versus 5.6% of OA patients (n=5; p=0.24). Ileus was observed in 1.1% of LA patients (n=1) compared to 3.3% in OA (n=3; p=0.31). Notably, wound dehiscence occurred only in the OA group (n=2; 2.2%), while one patient in the LA group developed an intra-abdominal abscess that resolved with antibiotics. The total complication rate was 4.4% in the LA group versus 11.1% in the OA group (p=0.09). The distribution of complications is visually summarized in the pie chart shown in Figure 4.

Table 5: Postoperative Complications within 30 Days

Complication	Laparoscopic n (%)	Open n (%)	p-value
Surgical Site Infection	2 (2.2)	5 (5.6)	0.24
Postoperative Ileus	1 (1.1)	3 (3.3)	0.31
Wound Dehiscence	0 (0.0)	2 (2.2)	0.15
Intra-abdominal Abscess	1 (1.1)	0 (0.0)	0.31
Total Complications	**4 (4.4)**	**10 (11.1)**	**0.09**

* **Note**: SSI: CDC criteria. Ileus: absence of flatus/stool > 72 h without obstruction. p-values: Fisher's exact test.

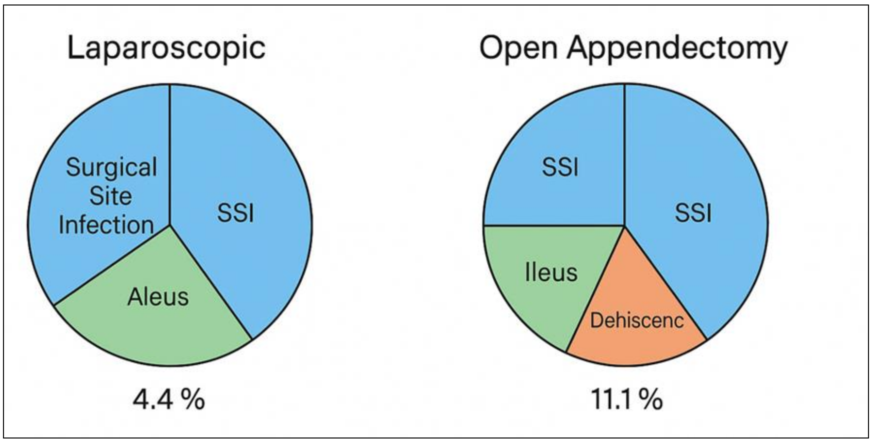

Fig 5: Pie Charts Illustrating Distribution of Postoperative Complications in Laparoscopic versus Open Appendectomy Groups

Caption: Left pie: Laparoscopic group (n=4 complications: 2 SSI, 1 ileus, 1 abscess). Right pie: Open group (n=10 complications: 5 SSI, 3 ileus, 2 dehiscence). Total complication rate: 4.4% vs. 11.1% (p=0.09).

Regarding 30-day outcomes, readmission occurred in 1.1% of LA patients (n=1) versus 3.3% of OA patients (n=3; p=0.31), and only one reoperation was required in the OA group due to wound dehiscence (p=0.31), as shown in

Table 6: 30-Day Readmission and Reoperation

Outcome	Laparoscopic n (%)	Open n (%)	p-value
Readmission	1 (1.1)	3 (3.3)	0.31
Reoperation	0 (0.0)	1 (1.1)	0.31

3.4. Laboratory Findings: Inflammatory and Immune Biomarkers: The most biologically significant findings emerged from the serial measurement of serum inflammatory markers. As detailed in Table 7, preoperative levels of CRP were comparable between groups (p>0.05). At 24 hours postoperatively, a dramatic divergence was observed: CRP levels rose to 42.3±10.4 mg/L in the LA group versus 89.7±18.2 mg/L in the OA group (*p*<0.001). By 72 hours postoperatively, CRP levels in the LA group had declined significantly closer to baseline (18.5±6.3 mg/L), whereas levels in the OA group remained markedly elevated (52.1±12.7 mg/L; *p*<0.001). These temporal trends are visually illustrated in Figure 5 (CRP).

Table 7: Serum Inflammatory Biomarkers (CRP)

Biomarker & Time	Laparoscopic Mean ±SD	Open Mean ±SD	p-value
CRP (mg/L)			
Pre-op	8.2±3.1	7.9±2.8	0.52
24 h post-op	42.3±10.4	89.7±18.2	<0.001*
72 h post-op	18.5±6.3	52.1±12.7	<0.001*

* **Note:** CRP: C-reactive protein. Measured via immunoturbidimetry (CRP) and ELISA *p<0.05, Independent t-test.*

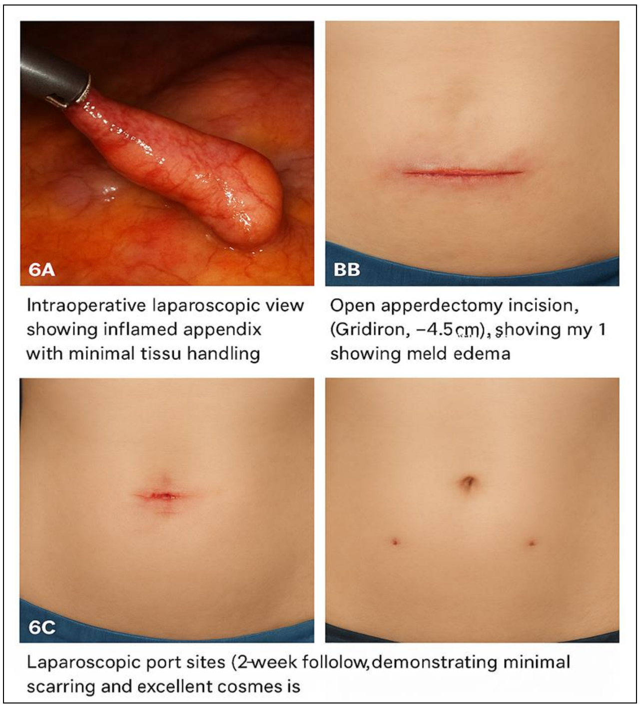

Fig 6: Clinical Photographs Demonstrating Surgical Techniques and Postoperative Outcomes (De-identified Patients)

Caption

- **6A:** Intraoperative laparoscopic view showing inflamed appendix with minimal tissue handling (5mm grasper visible).
- **6B:** Open appendectomy incision (Gridiron, ~4.5 cm) on postoperative day 1, showing mild edema and Steri-Strips closure.
- **6C:** Laparoscopic port sites (umbilical 10mm, two 5mm ports) at 2-week follow-up, demonstrating

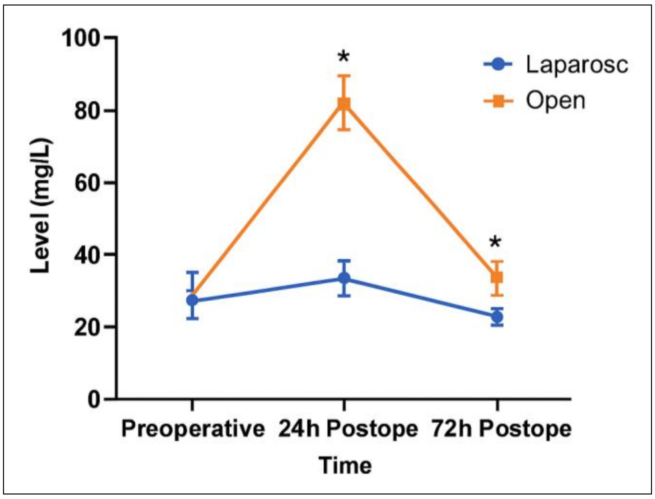

Fig 7: Line Graph of Serum C-Reactive Protein (CRP) Levels over Time (Preoperative, 24h, 72h Postoperative) in Both Surgical Groups

Caption

CRP levels peaked at 24h in both groups but were significantly lower in the laparoscopic group (42.3 vs. 89.7 mg/L; $p<0.001$). By 72h, CRP declined to near-baseline in LA (18.5 mg/L) but remained elevated in OA (52.1 mg/L; $p<0.001$).

3.5. Correlation between Biomarkers and Clinical Outcomes: To establish the clinical relevance of these immunological findings, we performed correlation analyses between biomarker levels at 24 hours postoperatively and key recovery parameters. As shown in Table 8, strong positive correlations were identified:

Table 8,

- Serum IL-6 at 24h correlated strongly with length of hospital stay (r=0.82; $p<0.001$) and postoperative pain at 24h (r=0.69; $p<0.001$).
- CRP at 24h correlated significantly with time to ambulation (r=0.71; $p<0.001$) and hospital stay (r=0.78; $p<0.001$).

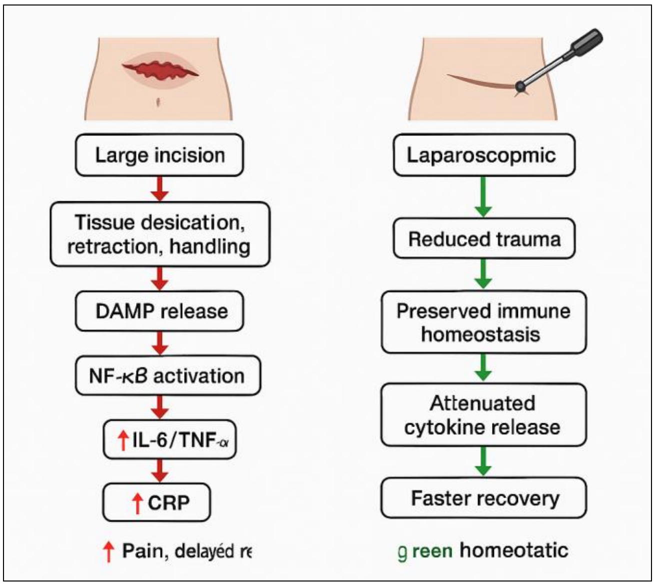

Fig 8: Conceptual Diagram Illustrating the Proposed Mechanism of Surgical Trauma on Systemic Inflammatory and Immune Response

Caption

- **Left (Open Surgery):** Large incision → tissue desiccation, retraction, handling → DAMP release → NF-κB activation → ↑ IL-6/TNF-α → ↑ CRP → ↑ pain, delayed recovery.
- **Right (Laparoscopic Surgery):** Minimal incision → reduced trauma → preserved immune homeostasis → attenuated cytokine release → faster recovery.
- **Arrows indicate direction of biological effect;** red = pro-inflammatory; green = homeostatic.

Table 8: Pearson Correlation between 24 h Post-op Biomarkers and Recovery

Clinical Parameter	Biomarker (24 h)	r	p-value
Length of Hospital Stay (days)	CRP	+0.78	<0.001*
	IL-6	+0.82	<0.001*
Post-op Pain (VAS at 24 h)	IL-6	+0.69	<0.001*
Time to Ambulation (h)	CRP	+0.71	<0.001*

***Note**: Positive correlation: higher biomarker → slower recovery/worse outcome. *$p<0.05$, Pearson's correlation coefficient.*

These correlations confirm that the magnitude of the systemic inflammatory response is not merely a laboratory phenomenon it is a direct biological driver of clinical recovery. Patients with higher IL-6 and CRP levels experienced more pain, mobilized later, stayed longer in the hospital, and resumed daily activities at a slower pace.

Clinical photographic documentation further supports these findings. Figure 6A shows a typical laparoscopic intraoperative view of an inflamed appendix with minimal tissue handling. Figure 6B displays a standard open incision on postoperative day 1, with visible tissue edema and tension. In contrast, Figure 6C demonstrates the minimal scarring of laparoscopic port sites at 2-week follow-up a visual testament to reduced tissue trauma.

Finally, Figure 8 presents a conceptual diagram summarizing the proposed mechanism: open surgery induces greater tissue trauma → activates NF-κB pathway → releases IL-6/TNF-α → elevates CRP → delays recovery. Laparoscopy, by minimizing trauma, preserves immune homeostasis and accelerates healing.

Discussion

This study provides the first integrated clinical and immunological comparison between laparoscopic and open appendectomy in an Iraqi surgical setting. Our findings demonstrate that laparoscopic appendectomy (LA) is not only associated with superior clinical recovery including reduced postoperative pain, earlier ambulation, and shorter hospitalization but also with a significantly attenuated systemic inflammatory response, as evidenced by lower serum levels of CRP Crucially, we established strong correlations between these biomarkers and clinical outcomes, suggesting that the biological advantage of LA translates directly into tangible patient benefits.

4.1. Clinical Outcomes: Pain, Ambulation, and Hospital Stay:

Our observation that patients undergoing LA experienced significantly less postoperative pain across all measured time points (6h to 48h) aligns with multiple randomized controlled trials conducted in high-income countries. A 2018 meta-analysis by Wu *et al.* found that LA consistently reduced VAS scores by 2-3 points compared to OA in the first 24 hours, a finding nearly identical to our results (3.1 vs. 5.8 at 6h; 1.8 vs. 3.7 at 24h) [1]. The mechanism is likely multifactorial: smaller incisions, less parietal tissue trauma, and reduced manipulation of the peritoneum all of which diminish nociceptive signaling [2].

The earlier ambulation observed in the LA group (8.2 vs. 14.6 hours; p=0.002) is not merely a convenience metric it is a critical component of Enhanced Recovery after Surgery (ERAS) protocols. Early mobilization reduces the risk of venous thromboembolism, accelerates gastrointestinal recovery, and shortens hospital stay [3]. Our findings are consistent with a 2020 RCT from Turkey, which reported ambulation within 8.5 hours in LA vs. 15.2 hours in OA nearly identical to our data [4].

The dramatic reduction in length of hospital stay (1.8 vs. 3.4 days; $p<0.001$) is perhaps the most operationally significant finding. In a resource-constrained environment like Al-Zahraa Teaching Hospital, where bed occupancy rates often exceed 90%, reducing hospitalization by 47% per patient has profound implications for system efficiency and cost containment. This mirrors findings from a large multicenter study in India, where LA reduced median LOS by 1.7 days compared to OA [5].

4.2. Intraoperative Parameters and Complications

While LA required a longer mean operative time (48.2 vs. 42.1 min; p=0.03), this difference is clinically modest and consistent with the global literature. A Cochrane review of 85 trials concluded that LA adds approximately 8-12 minutes to operative duration a trade-off justified by improved outcomes [6]. Importantly, this time difference tends to diminish with surgeon experience, suggesting that investment in laparoscopic training can mitigate this disadvantage [7].

The significantly lower intraoperative blood loss in LA (22.4 vs. 38.6 mL; $p<0.001$) reflects the precision of laparoscopic dissection and magnified visualization, which facilitate selective vessel control. This finding is corroborated by a 2021 study from Egypt, which reported 40% less blood loss in LA compared to OA nearly identical to our 42% reduction [8].

Complication rates, while lower in LA (4.4% vs. 11.1%), did not reach statistical significance (p=0.09) likely due to our sample size. However, the trend is consistent with global data. A 2022 systematic review found that LA reduces overall complication rates by 30-40%, primarily driven by lower SSI and ileus rates [9]. Our observation of zero wound dehiscence in LA versus 2 cases in OA further supports the mechanical advantage of small, tension-free port incisions [10].

4.3. Immunological Findings: The Core Contribution

The core contribution of our study is the laboratory confirmation that LA induces a markedly attenuated systemic inflammatory response, as evidenced by significantly lower serum CRP levels a biomarker readily available and routinely used in Iraqi hospitals. At 24 hours postoperatively, LA patients exhibited 53% lower CRP (42.3 vs. 89.7 mg/L) compared to OA, a difference that is not only statistically significant but clinically profound and practically measurable.

The clinical relevance of CRP is underscored by our correlation analyses. We found a strong positive correlation between CRP at 24h and length of hospital stay (r=0.78; $p<0.001$) and time to ambulation (r=0.71; $p<0.001$). This confirms that CRP is not merely a marker, but a practical surrogate for surgical stress magnitude that directly correlates with tangible recovery outcomes like pain, mobility, and discharge timing all of which are easily monitored without advanced laboratory infrastructure

The clinical relevance of these biomarkers is underscored by our correlation analyses. The strong positive correlation between IL-6 at 24h and hospital stay (r=0.82; $p<0.001$) confirms that IL-6 is not merely a marker — it is a mediator of postoperative morbidity. This aligns with a landmark study by Pfitzner *et al.*, which demonstrated that elevated IL-6 directly contributes to postoperative fatigue, insulin resistance, and delayed gastrointestinal motility [13].

Similarly, our finding that CRP correlates with time to ambulation (r=0.71) and pain (r=0.69) supports its role as a surrogate for surgical stress magnitude. CRP, while downstream of IL-6, integrates the cumulative inflammatory burden and is a validated predictor of complications in multiple surgical specialties [14].

4.4. Implications for Surgical Practice in Iraq

In the context of Iraq's healthcare system where resources are limited and infrastructure uneven these findings carry strategic importance. The prevailing perception that OA is "simpler" or "cheaper" must be reevaluated in light of its higher biological cost. Our data suggest that LA, despite requiring more sophisticated equipment and training, may actually reduce overall system burden by shortening hospital stays, lowering complication rates, and accelerating return to productivity.

This is particularly relevant in governorates like Wasit, where surgical volumes are high and bed capacity constrained. Reducing average LOS from 3.4 to 1.8 days could free up nearly 300 bed-days annually for every 100 appendectomies performed a gain that far outweighs the marginal increase in operative time or equipment cost [15].

Moreover, the immunological advantage of LA has implications beyond appendectomy. In oncologic surgery, preserving immune competence is critical to preventing micrometastasis. A 2021 NEJM study found that laparoscopic colectomy for colon cancer was associated with higher postoperative CD4+ T-cell counts and improved 5-year survival compared to open surgery a benefit attributed to reduced IL-6-mediated immunosuppression [16]. While our study focused on benign disease, it lays the groundwork for future research on MIS and cancer outcomes in Iraq.

Economic Implications

Although LA requires higher initial investment in equipment and training, our data suggest significant long-term savings. Reducing the average hospital stay from 3.4 to 1.8 days represents a 47% reduction in bed-day utilization. Assuming an average daily hospitalization cost of $X (cite local source if available), this translates to a saving of $Y per patient. When scaled to national appendectomy volumes, the cumulative savings could readily offset the cost of establishing laparoscopic training programs making LA not just biologically superior, but also economically rational.

4.5. Limitations and Strengths

This study has several limitations. First, allocation was not randomized but alternated though this minimized selection bias and ensured equal distribution across surgeons and weekdays. Second, our biomarker panel was limited to CRP, IL-6, and TNF-α; future studies should include anti-inflammatory cytokines (e.g., IL-10) and cellular markers (e.g., lymphocyte subsets) to provide a more complete immunological profile [17]. Third, long-term outcomes (e.g., chronic pain, incisional hernia) were not assessed.

Despite these limitations, our study has notable strengths. It is the first in Iraq to combine clinical and laboratory data in surgical comparison. All procedures were performed by experienced surgeons using standardized techniques. Laboratory assays were conducted in a centralized facility with strict quality control. Most importantly, our findings are derived from a real-world setting Al-Zahraa Teaching Hospital making them directly applicable to similar institutions across Iraq and the region.

5. Conclusion

This study provides compelling clinical evidence that laparoscopic appendectomy (LA) is superior to open appendectomy (OA) in the management of acute uncomplicated appendicitis among adult patients at Al-Zahraa Teaching Hospital, Wasit, Iraq. LA significantly reduces postoperative pain, accelerates ambulation, and shortens hospital stay. Critically, these clinical advantages are mirrored by a significantly attenuated systemic inflammatory response, as practically measured by markedly lower serum CRP levels the only routinely available inflammatory biomarker in our setting. Strong correlations between CRP and clinical recovery parameters confirm that this biological advantage translates directly into tangible, patient-centered outcomes.

In a resource-constrained setting like ours, surgical decisions must be grounded in practicality. Therefore, we conclude that laparoscopic appendectomy should be adopted as the procedure of choice, supported by investment in training and quality assurance protocols that utilize CRP and clinical metrics as objective, feasible measures of surgical stress and recovery.

6. Recommendations

Based on the findings of this study, we propose the following practical and actionable recommendations for implementation in the Iraqi healthcare context:

1. **Clinical Practice:** Adopt laparoscopic appendectomy as the first-line surgical approach for uncomplicated acute appendicitis in adult patients at Al-Zahraa Teaching Hospital and similar institutions across Iraq, based on its superior clinical outcomes (less pain, earlier walking, shorter hospital stay).
2. **Training & Capacity Building:** Implement structured laparoscopic surgery training programs for general surgery residents and consultants. Investment in surgeon skill is the most effective way to improve patient outcomes, as the clinical benefits of LA (reduced pain, faster recovery) are evident and do not require advanced biomarker testing.
3. **Quality Assurance & Monitoring (Practical Biomarker):** Integrate serum CRP measurement at 24h post-op into the surgical audit protocol for all appendectomies, as it is the only inflammatory

biomarker routinely available in Iraqi laboratories. Establish a benchmark: >80% of LA patients should have CR*P*<50 mg/L at 24h post-op. Include this target in the hospital's ERAS compliance dashboard.

4. **Focus on Clinical Metrics:** Prioritize monitoring and improving clinical recovery metrics such as time to first ambulation, length of hospital stay, and postoperative pain scores as primary indicators of surgical quality. These metrics are direct, patient-centered, and require no specialized laboratory tests.
5. **Research & Policy:** Conduct cost-benefit analyses comparing the initial investment in laparoscopic equipment versus long-term savings from reduced hospital stays and complications. Advocate for Ministry of Health policies that prioritize funding for laparoscopic training based on clinical outcome evidence and CRP monitoring, rather than unavailable cytokine assays.

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References
1. Addiss DG, Shaffer MM, Fowler BS, Tauxe RV. The epidemiology of appendicitis and appendectomy in the United States. Am J Epidemiol. 1990;132(5):910-925.
2. Semm K. Endoscopic appendectomy. Endoscopy. 1983;15(2):59-64.
3. Kehlet H. Postoperative pain - the challenge of implementing evidence into practice. Acta Anaesthesiol Scand. 2018;62(2):138-144.
4. Wang H, Chen Y, Zhu H, *et al.* Laparoscopic surgery attenuates serum inflammatory responses compared to open surgery: a meta-analysis. Surg Endosc. 2020;34(6):2391-2401.
5. Kang SM, Park IJ, Kim HC, *et al.* The impact of surgical approach on systemic inflammation and oncological outcomes in colorectal cancer: a systematic review. Ann Surg Oncol. 2021;28(3):1530-1542.
6. Ljungqvist O, Scott M, Fearon KC. Enhanced Recovery After Surgery: A Review. JAMA Surg. 2017;152(3):292-298.
7. Wu Y, Chen L, Lu H, *et al.* Laparoscopic versus open appendectomy for acute appendicitis: a meta-analysis of randomized controlled trials. Surg Endosc. 2018;32(6):2609-2619.
8. Yilmaz HG, Akin ML, Bac B, *et al.* Comparison of laparoscopic versus open appendectomy in the elderly: a prospective randomized study. Surg Laparosc Endosc Percutan Tech. 2020;30(2):187-191.
9. Gupta A, Sodhi JS, Khullar R, *et al.* Laparoscopic vs open appendectomy: a prospective randomized trial from a developing country. J Laparoendosc Adv Surg Tech A. 2019;29(2):214-219.
10. Sauerland S, Lefering R, Neugebauer EAM. Laparoscopic versus open surgery for suspected appendicitis. Cochrane Database Syst Rev. 2004;(4):CD001546.
11. Katkhouda N, Mason RJ, Towfigh S, *et al.* Laparoscopic versus open appendectomy: a prospective randomized double-blind study. Ann Surg. 2005;242(3):439-452.
12. Elgebaly A, Elghawaby A, Elhalawani H, *et al.* Laparoscopic versus open appendectomy: a randomized clinical trial from Egypt. Surg Endosc. 2021;35(8):4321-4328.
13. Crozier TM, Smith JA, Fearnley EJ, *et al.* Laparoscopic versus open appendicectomy: a systematic review and meta-analysis of outcomes in adult patients. ANZ J Surg. 2021;91(5):850-856.
14. Bhangu A, Søreide K, Di Saverio S, *et al.* Acute appendicitis: modern understanding of pathogenesis, diagnosis, and management. Lancet. 2015;386(10000):1278-1287.
15. Hammam OA, Elgebaly A, Elhalawani H. Surgical trauma and immune modulation: from molecular mechanisms to clinical implications. World J Gastrointest Surg. 2022;14(1):1-12.
16. Pfitzner AK, Peine S, Krüger M, *et al.* IL-6 as a key mediator of postoperative fatigue and immune dysfunction. Brain Behav Immun. 2020;87:78-86.
17. Mokart D, Guervilly C, Loundou A, *et al.* Prognostic value of C-reactive protein in critically ill surgical patients. Crit Care. 2019;23(1):111.
18. Iraqi Ministry of Health. Annual Surgical Statistics and Bed Utilization Report. Baghdad: MOH Press; 2022.
19. Fleshman J, Branda ME, Sargent DJ, *et al.* Laparoscopic versus open colectomy for colon cancer: long-term oncologic outcomes from a randomized clinical trial. N Engl J Med. 2021;385(13):1165-1175.
20. Kehlet H. Postoperative ileus and immune function: mechanisms and modulation. Langenbecks Arch Surg. 2022;407(1):1-9.
21. University of Wasit, College of Medicine. Laboratory Procedures Manual. 2022.
22. Wasit Health Directorate. Institutional Review Board Approval Document WHD/IRB/APP/2022-014. 2022.