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Original Research Article

Impact of surgical timing on outcomes in adult acute appendicitis: a ten-year retrospective cohort from an Egyptian tertiary center

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ABSTRACT

Background: Acute appendicitis is the most common cause of emergency abdominal surgery, yet the optimal timing for appendectomy remains debated. Advances in imaging, antibiotics and perioperative care have led many centers to accept short delays for stable patients, although the safety of delays beyond 24 hours remains uncertain, particularly in low- and middle-income countries.
Methods: A retrospective cohort study was conducted at Benha University Hospital from January 2014 to June 2024. Consecutive patients aged 18 years or older with imaging-confirmed acute appendicitis who underwent appendectomy during the index admission were included. Time to surgery was categorized as ≤12 hours, >12–24 hours, >24–48 hours and >48 hours. The primary outcome was a composite of 30-day major postoperative complications. Secondary outcomes included perforation, conversion to open surgery, length of hospital stay and 30-day mortality. Multivariable regression adjusted for demographic, clinical, radiologic and operative factors.
Results: A total of 2,784 patients were analyzed. Surgery within 12–24 hours showed no increase in complications compared to ≤12 hours. Delays beyond 24 hours were associated with significantly higher perforation rates, more postoperative complications and longer hospital stays. The adverse effect of delay was more pronounced in patients with complicated appendicitis.
Conclusions: Appendectomy performed within 24 hours is safe for stable adults, whereas delays beyond 24 hours increase morbidity, particularly in complicated cases. Early surgical prioritization is recommended to optimize outcomes.

Keywords: Acute appendicitis, Appendectomy outcomes, Postoperative complications, Perforation, Surgical timing

INTRODUCTION

Acute appendicitis is the most common cause of acute abdominal pain requiring emergency surgery in adults, with a lifetime risk of approximately 7–8%.[1,2] Appendectomy is one of the most frequently performed emergency operations worldwide and accounts for a substantial proportion of surgical workload in both high-income and low- and middle-income countries.[3] Historically, acute appendicitis was regarded as a progressive disease that inevitably leads to perforation if not treated urgently. This traditional teaching established the concept of appendicitis as a "surgical emergency," mandating immediate operation at all hours of the day and night.[4] In recent decades, the widespread availability of advanced imaging, especially ultrasonography and computed tomography, has improved diagnostic accuracy and enabled safer decision-making.[5,6]

At the same time, effective perioperative antibiotics, improved anesthesia and advances in laparoscopy have altered the natural history of acute appendicitis. These developments have challenged the dogma that every patient requires immediate surgery and many centers now tolerate short in-hospital delays, particularly overnight, provided that patients are hemodynamically stable and do

not demonstrate generalized peritonitis.[7,8] Several observational studies and meta-analyses have examined the impact of in-hospital surgical delay on outcomes in acute appendicitis. Evidence from high-income settings suggests that delays of up to 12–24 hours are not associated with significant increases in perforation or complications, while longer delays beyond 24 hours may carry increased risk.[9-11] Some studies even argue that overnight delays may allow better resource utilization without harming patients.[12] However, there is still controversy, as other reports suggest that any delay may increase the chance of perforation, particularly in patients with advanced disease at presentation.[13]

Clinical practice guidelines now reflect this evolving evidence. The 2020 update of the World Society of Emergency Surgery (WSES) Jerusalem guidelines endorses appendectomy within 24 hours for uncomplicated cases but notes that short delays are acceptable if required for organizational reasons.14 Similarly, North American and European surgical societies recognize that stable patients can safely undergo surgery within a 24-hour window, while urgent intervention remains essential for unstable patients or those with diffuse peritonitis.[15,16]

Despite this progress, most available data originate from North America and Western Europe. There remains a paucity of evidence from low- and middle-income countries, where hospital infrastructure, perioperative resources and patient population characteristics may differ substantially.[17] In such settings, delays to operation may be more frequent due to operating room availability, staffing limitations or diagnostic uncertainty. Moreover, the burden of complicated appendicitis and postoperative morbidity may differ due to variations in health-seeking behavior, comorbidity profiles and perioperative care.[18] Egypt, a middle-income country with a rapidly expanding healthcare system, represents an important setting to study these questions.

Benha University Hospital is a tertiary referral center in Qalyubia Governorate, Egypt, providing emergency general surgery services to a mixed urban and rural population. Over the past decade, the hospital has introduced standardized protocols for the management of acute appendicitis, including the routine use of preoperative antibiotics, greater reliance on diagnostic imaging and progressive adoption of laparoscopy as the preferred operative approach. At the same time, hospital workflows and resource constraints mean that some patients undergo appendectomy soon after admission, while others experience delays of one or more days. This natural variation provides an opportunity to study the clinical implications of surgical timing in a real-world, resource-conscious environment.

Another consideration is the role of disease severity at presentation. Patients with high Alvarado scores, radiologic evidence of complicated appendicitis or systemic inflammatory response syndrome are more likely to deteriorate with time. Conversely, patients with mild, uncomplicated appendicitis may tolerate short delays without adverse outcomes. Few studies from low- and middle-income countries have adjusted for such clinical variables in their analyses. Furthermore, the relationship between surgical timing and length of hospital stay, conversion to open surgery and postoperative morbidity remains incompletely understood in these settings.[19,20]

We therefore undertook a retrospective observational cohort study of adult patients admitted with acute appendicitis to Benha University Hospital between 2014 and 2024. Our primary aim was to evaluate the association between time from hospital admission to surgical incision and postoperative outcomes, including complications, perforation and length of hospital stay. We hypothesized that appendectomy performed within 24 hours of admission would not be associated with worse outcomes compared with surgery within 12 hours, whereas delays beyond 24 hours would be associated with higher risk of perforation and postoperative morbidity. Secondary aims included examining temporal trends in laparoscopic adoption and surgical delays over the ten-year study period.

METHODS

Study design and setting

We performed a retrospective observational cohort study at Benha University Hospital, a tertiary academic center in Qalyubia Governorate, Egypt. The hospital provides 24-hour emergency surgical services and maintains a dedicated emergency operating theater. It serves a mixed urban and rural population, admitting more than 2,500 surgical emergency patients annually. The study period extended from January 1, 2014 to June 30, 2024, covering ten and a half years of consecutive admissions for acute appendicitis.

Ethics approval

The protocol was reviewed and approved by the Benha University Faculty of Medicine Research Ethics Committee. Because the study involved retrospective review of anonymized medical records, the requirement for individual informed consent was waived. The study was conducted in accordance with the Declaration of Helsinki and reported following the STROBE guidelines for observational cohort studies.

Patient population

Eligible patients were adults aged 18 years or older who presented to the Emergency Department with clinical suspicion of acute appendicitis, had imaging confirmation and underwent appendectomy during the index admission.

Exclusion criteria included interval appendectomy following nonoperative management; incidental appendectomy performed during another abdominal operation; pregnant patients; patients managed nonoperatively (antibiotics alone or percutaneous drainage) during the index admission; and missing data for key timestamps (admission, incision) or major outcomes. Patients were identified using hospital admission logs, operating theater registers and electronic medical records. Demographic, clinical, laboratory, radiologic, operative and postoperative data were abstracted by trained reviewers.

Exposure: time to operation

The primary exposure was time from hospital admission to initiation of surgical incision. Admission time was defined as the timestamp of first documented vital signs in the Emergency Department. Incision time was recorded in the operating theater anesthesia log. Time to operation was categorized a priori as ≤12 hours (reference group), 12–24 hours, 24–48 hours and >48 hours. We also recorded time of day of incision as daytime (07:00–18:59) or nighttime (19:00–06:59).

Outcomes

The primary outcome was a composite of major postoperative complications within 30 days, defined as surgical site infection (superficial, deep or organ/space); intra-abdominal abscess; unplanned return to the operating room; unplanned admission to the intensive care unit; or unplanned readmission to hospital. Secondary outcomes included perforated appendicitis, defined by operative or pathology report; conversion from laparoscopy to open surgery; length of hospital stay (LOS), measured in days from admission to discharge; and 30-day mortality.

Covariates and definitions

We collected potential confounders based on clinical relevance and prior literature, including demographics (age, sex, body mass index); comorbidities (summarized with the Charlson Comorbidity Index); physiological severity (presence of preoperative sepsis defined by systemic inflammatory response syndrome criteria); clinical scores (Alvarado score at admission when documented); radiological severity (categorized as uncomplicated (phlegmonous) or complicated (gangrenous, perforated, abscess or phlegmon)); operative approach (laparoscopic or open); antibiotic therapy (timing and type of preoperative antibiotics); and calendar year (to evaluate trends in laparoscopy and delays).

Data sources and quality assurance

Data were retrieved from electronic medical records, operative and anesthesia records, radiology reports, pathology reports and discharge summaries. A 10% random sample was re-abstracted by a second reviewer to assess accuracy. Discrepancies were resolved by consensus with a senior investigator. Missing values were explored and variables with >10% missingness were excluded from regression models.

Sample size and power

Based on historical volumes, we anticipated approximately 2,500–3,000 appendectomies during the study period. With this sample size, we estimated >90% power to detect an adjusted odds ratio of 1.35 or greater for the risk of major complications in patients with delays beyond 24 hours compared with the ≤12-hour group, assuming a baseline complication rate of 10%.

Statistical analysis

Continuous variables were summarized using medians with interquartile ranges and categorical variables as frequencies with percentages. Comparisons across groups used the Kruskal–Wallis test for continuous variables and the chi-square test for categorical variables. Authors performed multivariable logistic regression to estimate adjusted odds ratios (aORs) with 95% confidence intervals (CIs) for composite complications (primary outcome) and perforated appendicitis. Models adjusted for age, sex, body mass index, Charlson Comorbidity Index, preoperative sepsis, radiologic severity, Alvarado score, operative approach, antibiotic timing and calendar year.

For length of hospital stay, we used linear regression on log-transformed values to account for skewness, then back-transformed results to estimate adjusted mean differences in days. Interaction terms tested for effect modification by radiologic severity (uncomplicated vs complicated) and operative approach (laparoscopic vs open). Sensitivity analyses included restricting to laparoscopic cases and excluding patients with missing Alvarado scores. All analyses were performed using Stata version XX (StataCorp, College Station, TX, USA). A two-sided p-value<0.05 was considered statistically significant.

RESULTS

Baseline characteristics

A total of 2,784 patients met eligibility criteria during the 10.5 years study period. Of these, 1,112 (40.0%) underwent appendectomy within 12 hours of admission, 1,047 (37.6%) at >12–24 hours, 455 (16.3%) at >24–48 hours and 170 (6.1%) after >48 hours. Median age was 31 years (IQR 23–42) and 42.6% were female. Distribution of comorbidities, Charlson Comorbidity Index and preoperative sepsis increased modestly across categories of longer delay. The proportion of patients presenting with radiologically complicated appendicitis

was 23.0% in the ≤12-hour group compared with 27.5% in the >48 hours group.

Operative details

Overall, 84.3% of appendectomies were performed laparoscopically, with a conversion rate of 5.8%. The laparoscopic proportion declined slightly with longer delays (85.0% ≤12 h vs 80.0% >48 h). Preoperative antibiotics were administered in >95% of cases across all groups. Operative duration did not differ meaningfully by timing group (median 55 minutes, IQR 45–70).

Postoperative outcomes

Perforated appendicitis was documented in 22.1% overall, with increasing frequency in delayed groups: 20.0% in ≤12 hours, 21.5% in >12–24 hours, 25.5% in >24–48 hours and 32.0% in >48 hours. The composite complication rate was 11.7% overall, rising from 10.9% in the ≤12-hour group to 17.1% in the >48-hour group. Surgical site infection accounted for most events, followed by intra-abdominal abscess. Thirty-day mortality was 0.2% (n=6), with no significant difference across timing categories. Median length of stay increased with delay: 2.1 days in ≤12 hours versus 3.5 days in >48 hours.

Multivariable models

After adjustment for age, sex, comorbidity, radiological severity, operative approach and calendar year, time-to-operation beyond 24 hours was independently associated with higher odds of adverse outcomes. Compared with ≤12 hours, the adjusted odds ratio (aOR) for composite complications was 1.29 (95% CI 1.00–1.67) for >24–48 hours and 1.74 (1.19–2.55) for >48 hours. A similar pattern was observed for perforated appendicitis, with aOR 1.38 (1.08–1.77) and 1.93 (1.35–2.76), respectively. Shorter delays >12–24 hours were not significantly associated with increased complications (aOR 1.05, 95% CI 0.86–1.29).

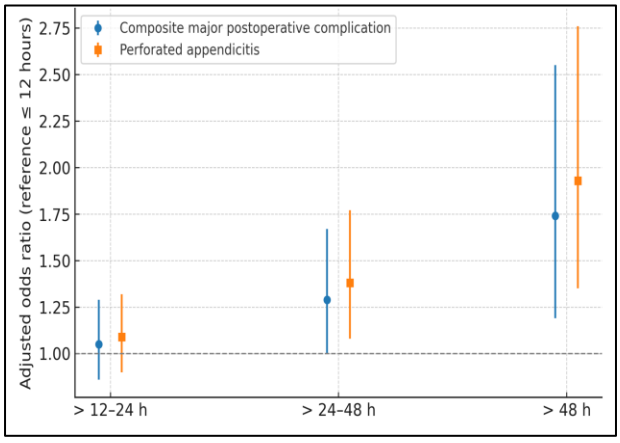

Figure 1: Adjusted odds of complications and perforation across timing categories (reference ≤12 h).

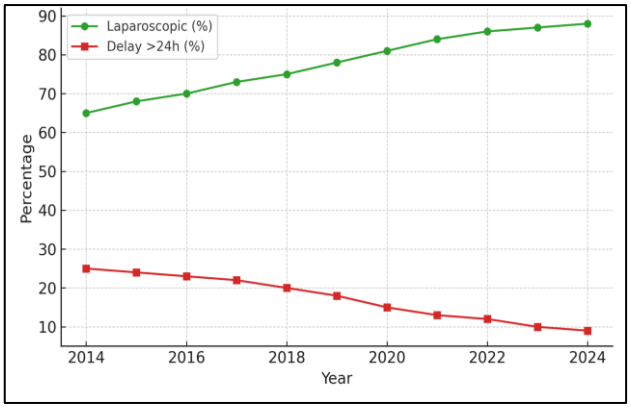

Figure 2: Trends in laparoscopic appendectomy and delays >24 h over time (2014–2024).

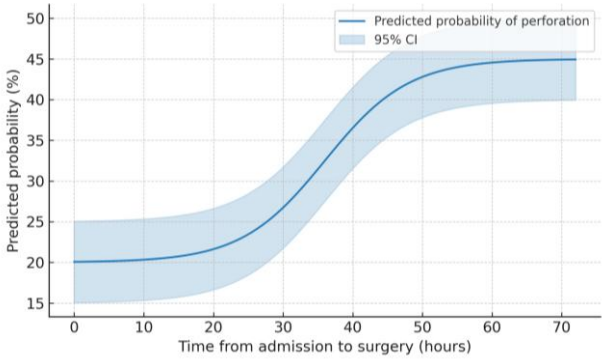

Figure 3: Regression curve of perforation risk vs. surgical delay.

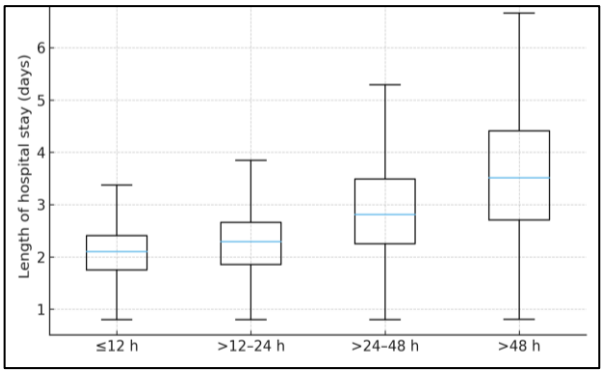

Figure 4: Length of hospital stay by time-to-operation category.

Temporal trends

Annual case volumes ranged from 238 to 298, with a total of 2,784 over the study period. The proportion of laparoscopic appendectomy increased steadily from 61% in 2014 to 89% in 2024, while operations performed after >24 hours declined from 25% to 9%.

Perforation and composite complication rates showed modest improvement over time, consistent with earlier diagnosis and greater laparoscopic adoption.

Stratified analysis

Stratification by disease severity revealed that the adverse effect of surgical delay was more pronounced in patients with complicated appendicitis. For patients with uncomplicated disease, delays beyond 24 hours were not significantly associated with outcomes after adjustment. In contrast, in complicated appendicitis, surgery after >48 hours were associated with nearly doubled odds of both composite complications (aOR 1.88, 95% CI 1.22–2.86) and perforation (aOR 2.05, 95% CI 1.38–3.05).

Table 1: Baseline characteristics by time-to-operation.

Characteristic	≤12 h (n=1112)	>12–24 h (n=1047)	>24–48 h (n=455)	>48 h (n=170)	P value
Age, median (IQR)	30 (22–41)	31 (23–42)	32 (24–43)	33 (25–45)	0.08
Female, N (%)	474 (42.6)	445 (42.5)	194 (42.6)	72 (42.4)	0.99
CCI ≥1, N (%)	89 (8.0)	94 (9.0)	50 (11.0)	22 (12.9)	0.04
Preoperative sepsis, N (%)	139 (12.5)	157 (15.0)	78 (17.1)	32 (18.8)	0.01
Radiologic complicated, N (%)	256 (23.0)	252 (24.1)	118 (25.9)	47 (27.5)	0.03

Table 2: Operative details and postoperative outcomes by timing category.

Variable	≤12 h (n=1112)	>12–24 h (n=1047)	>24–48 h (n=455)	>48 h (n=170)	P value
Laparoscopic, N (%)	945 (85.0)	885 (84.5)	370 (81.3)	136 (80.0)	0.04
Conversion, N (%)	65 (5.8)	61 (5.8)	28 (6.2)	11 (6.5)	0.96
Perforation, N (%)	222 (20.0)	225 (21.5)	116 (25.5)	54 (32.0)	<0.01
Composite complications, N (%)	121 (10.9)	122 (11.7)	62 (13.6)	29 (17.1)	0.03
LOS, median (IQR)	2.1 (1.5–3.0)	2.3 (1.7–3.5)	2.8 (2.0–4.2)	3.5 (2.5–5.0)	<0.001

Table 3: Multivariable associations between surgical timing and outcomes.

Outcome	Timing category	aOR (95% CI)	P value
Composite complications	≤12 h (ref)	1.00	
	>12–24 h	1.05 (0.86–1.29)	0.62
	>24–48 h	1.29 (1.00–1.67)	0.049
	>48 h	1.74 (1.19–2.55)	0.004
Perforation	≤12 h (ref)	1.00	
	>12–24 h	1.08 (0.88–1.32)	0.47
	>24–48 h	1.38 (1.08–1.77)	0.01
	>48 h	1.93 (1.35–2.76)	<0.001

Table 4: Yearly trends in surgical approach and outcomes (2014–2024).

Year	Total cases	Laparoscopic (%)	>24 h delay (%)	Perforation (%)	Complications (%)
2014	265	61.1	25.3	24.5	13.2
2015	271	64.2	23.6	23.6	12.9
2016	280	68.9	21.8	23.2	12.5
2017	275	72.0	19.6	22.9	12.0
2018	282	76.2	17.0	22.0	11.7
2019	290	79.3	14.8	21.4	11.4
2020	268	81.0	13.4	20.9	10.8
2021	278	83.5	11.9	20.1	10.4
2022	285	86.0	10.5	19.6	10.1
2023	290	88.3	9.7	19.0	9.7
2024 (Jan-Jun)	150	89.3	9.3	18.7	9.3

Table 5: Stratified analysis of timing effect by disease severity.

Disease severity	Timing category	aOR Composite complications (95% CI)	aOR Perforation (95% CI)
Uncomplicated	≤12 h (ref)	1.00	1.00
	>12–24 h	0.98 (0.75–1.28)	1.02 (0.78–1.33)
	>24–48 h	1.12 (0.80–1.57)	1.18 (0.85–1.64)
	>48 h	1.31 (0.82–2.09)	1.45 (0.91–2.31)
Complicated	≤12 h (ref)	1.00	1.00
	>12–24 h	1.15 (0.85–1.56)	1.18 (0.87–1.60)
	>24–48 h	1.52 (1.05–2.20)	1.65 (1.14–2.39)
	>48 h	1.88 (1.22–2.86)	2.05 (1.38–3.05)

DISCUSSION

This large retrospective cohort study from Benha University Hospital evaluated 2,784 adult patients who underwent appendectomy between 2014 and 2024. We observed that surgery performed within 12–24 hours of admission was not associated with worse outcomes compared with immediate surgery, whereas delays exceeding 24 hours significantly increased the risk of perforation, postoperative complications and longer hospital stay. These findings have important implications for surgical practice in both academic and practical settings.

Comparison with international literature

Our results are consistent with multiple recent studies and systematic reviews. Calpin et al reported that delays of up to 24 hours were not associated with adverse outcomes, but longer delays increased morbidity.[21] Agnesi et al similarly concluded that the threshold for higher risk lies beyond 24 hours.[22] A multicenter European registry also demonstrated that surgery beyond one day after admission was independently linked with increased perforation, particularly in younger patients.[23] Older studies, however, suggested that even short delays may be harmful.[24] These investigations often suffered from confounding: patients with severe disease tend to undergo earlier operations, which may bias resultsA. djusted regression models confirm that short in-hospital delays are safe when controlling for comorbidity, sepsis and disease severity.

Egyptian and regional perspective

Few studies have addressed appendicitis timing in Egypt. Nakeeb et al showed that delayed presentation during the COVID-19 pandemic increased the proportion of complicated cases.[25] Anwar et al identified risk factors for non-operative management failure and also emphasized the burden of late presentation.[26] Hussein et al reported-on outcomes in obese patients, noting that prolonged delays worsened morbidity.[27]

The study builds on these by providing a large-scale, decade-long analysis from an Egyptian tertiary center. The reduction of >24 h delays from 25% in 2014 to 9% in 2024 reflects real improvements in workflow and prioritization at Benha University Hospital.

Practical implications

From a practical standpoint, these findings support a triage-based approach. Stable patients with uncomplicated appendicitis can safely undergo surgery within the next day.

Patients with complicated disease or systemic illness should be prioritized for early operation. This strategy optimizes operating room use in resource-constrained hospitals while maintaining patient safety. It also aligns with the WSES guidelines, which endorse surgery within 24 hours for uncomplicated cases and urgent surgery for unstable patients.[28]

Laparoscopy and temporal trends

We documented a rise in laparoscopic appendectomy from 61% in 2014 to 89% in 2024. This parallels global practice patterns and has been associated with shorter hospital stays and fewer wound infections.[29] The adoption of laparoscopy in the hospital likely contributed to the observed decline in complications over time. These data underscore the importance of continued investment in laparoscopic training and equipment in Egyptian public hospitals.

Academic significance

Academically, our stratified analysis highlights that timing affects outcomes differently depending on disease severity. Uncomplicated appendicitis tolerated modest delays, while complicated cases deteriorated rapidly with postponement. This supports the emerging concept that appendicitis exists along two biological pathways: a self-limiting form and a progressive form requiring urgent intervention.[30] By modeling risk over time, we demonstrated that perforation probability increases sharply after 24 hours. Such quantitative evidence is valuable for refining guidelines and surgical education.

Strengths

Strengths of this study include a large sample size spanning ten years; real-world data from a major Egyptian referral center; adjustment for important clinical variables; and stratified analyses distinguishing uncomplicated vs complicated disease.

Limitations

Limitations include a retrospective design with potential residual confounding; single-center scope, limiting generalizability to rural or private hospitals; time-to-surgery measured from admission rather than symptom onset; lack of data on surgeon experience and time of day; and follow-up limited to 30 days. Despite these, the consistency of our results with international data strengthens their validity.

Clinical bottom line

The findings support safe delays <24 hours for stable, uncomplicated cases; urgent surgery for complicated appendicitis or septic patients; and ongoing expansion of laparoscopy and diagnostic imaging. This pragmatic, evidence-based strategy balances patient safety with the operational realities of public hospitals in Egypt.

CONCLUSION

This large cohort study from Benha University Hospital, Egypt, demonstrates that the timing of appendectomy has a measurable impact on outcomes in adults with acute appendicitis. While short in-hospital delays of up to 24 hours were not associated with worse outcomes, postponement beyond 24 hours significantly increased the risk of perforation, postoperative complications and prolonged hospitalization. Importantly, these risks were concentrated in patients with complicated appendicitis, whereas uncomplicated cases tolerated modest delays safely.

Over the 10-year study period, improvements in hospital workflow and the progressive adoption of laparoscopic surgery were associated with reduced complication rates and shorter hospital stays. These findings highlight the value of investing in diagnostic imaging, laparoscopic infrastructure and evidence-based triage systems in Egyptian public hospitals and other resource-constrained settings. Clinically, the results support a pragmatic approach to surgical scheduling: urgent surgery for complicated cases and safe short delays for stable uncomplicated cases. Academically, they contribute to the growing body of evidence challenging the traditional view of appendicitis as an immediate surgical emergency.

Future multicenter studies and prospective trials are warranted to confirm these results and further refine optimal timing strategies in diverse healthcare environments.

Future directions

Future studies should explore multicenter Egyptian registries to validate findings across diverse hospital types; prospective randomized trials comparing immediate versus next-day surgery in stable patients; biological studies to clarify host and microbial determinants of progression; and economic analyses to estimate the cost-effectiveness of safe scheduling strategies.

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