

Original Research Article

PROSPECTIVE ASSESSMENT OF AN AI-ASSISTED EARLY WARNING SYSTEM FOR PREDICTION OF POSTOPERATIVE COMPLICATIONS IN GENERAL SURGICAL PATIENTS

Piyush Vasudeva¹, Arun Kumar², Harshad Mahatme³, Madhubala Gaur⁴, Bhaskar Kumar²

¹3rd year PG resident in Department of General Surgery, GS Medical College and Hospital, Pilkhuwa, Hapur, Uttar Pradesh, India.

²Professor, Department of General Surgery, GS Medical College and Hospital, Pilkhuwa, Hapur, Uttar Pradesh, India.

³Consultant General & Laparoscopic Surgeon, Sankalp Multispeciality Hospital Hospital, Nasik, Maharashtra.

⁴Professor & Head, Department of General Surgery, GS Medical College and Hospital, Pilkhuwa, Hapur, Uttar Pradesh, India.

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Corresponding Author:

Dr. Piyush Vasudeva,
3rd year PG resident in Department of General Surgery, GS Medical College and Hospital, Pilkhuwa, Hapur, Uttar Pradesh, India.
Email: drpiyushvasudeva@gmail.com.

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ABSTRACT

Background: Postoperative complications remain a major concern in general surgical practice and may lead to increased morbidity, prolonged hospital stay, need for intensive monitoring, and mortality. Early identification of high-risk patients is essential for timely intervention. Artificial intelligence-assisted early warning systems may help in predicting clinical deterioration by integrating demographic, operative, clinical, and laboratory parameters. **Aim:** To prospectively assess the role of an AI-assisted early warning system in predicting postoperative complications among general surgical patients at a tertiary care hospital.

Materials and Methods: This prospective observational study included 95 adult patients undergoing elective or emergency general surgical procedures. Demographic details, comorbidities, body mass index, ASA physical status, operative characteristics, postoperative vital parameters, laboratory findings, and AI-generated risk categories were recorded. Patients were followed during the postoperative hospital stay for the development of complications. AI-generated risk categories were compared with actual postoperative outcomes. Statistical analysis was performed using IBM SPSS Statistics version 27.0. A p value of less than 0.05 was considered statistically significant.

Results: Postoperative complications occurred in 29 patients, giving an overall complication rate of 30.53%, while 66 patients, 69.47%, had an uneventful recovery. Increasing age was significantly associated with complications, with patients aged ≥ 60 years showing a complication rate of 50.00% ($p=0.006$). Higher ASA grade ($p=0.004$), presence of comorbidities ($p=0.010$), emergency surgery ($p=0.011$), major surgery ($p=0.012$), operative duration >120 minutes ($p=0.003$), blood loss >500 ml ($p=0.004$), transfusion requirement ($p=0.008$), and contaminated or dirty wounds ($p=0.002$) were significantly associated with complications. Postoperative warning parameters such as tachycardia, hypotension, fever, oxygen saturation $<94\%$, reduced urine output, raised total leukocyte count, and raised serum creatinine were also significantly associated with complications. Complication rates increased from 6.98% in the AI low-risk group to 30.00% in the moderate-risk group and 77.27% in the high-risk group ($p<0.001$). The AI-assisted system showed sensitivity of 89.66%, specificity of 60.61%, positive predictive value of 50.00%, negative predictive value of 93.02%, and accuracy of 69.47%.

Conclusion: The AI-assisted early warning system showed good sensitivity and high negative predictive value for predicting postoperative complications. It may be useful as a supportive tool for early risk stratification and postoperative monitoring in general surgical patients.

Keywords: Artificial intelligence, early warning system, postoperative complications, general surgery, risk prediction.

INTRODUCTION

Postoperative complications remain an important concern in general surgical practice because they can affect recovery, prolong hospitalization, increase the need for intensive monitoring, and place additional burden on patients, families, and healthcare systems. General surgical patients form a heterogeneous group, ranging from relatively stable patients undergoing elective procedures to critically ill patients requiring emergency intervention. Because of this variation, postoperative deterioration may not always follow a predictable course. Some patients develop obvious clinical instability soon after surgery, whereas others initially appear stable but later show subtle changes in vital signs, urine output, laboratory values, or general condition. Therefore, early recognition of patients at risk is essential for timely intervention and prevention of further morbidity.¹ The prediction of postoperative complications is challenging because surgical outcomes are influenced by multiple interacting factors. These include age, nutritional status, comorbid illnesses, American Society of Anesthesiologists physical status, type of admission, magnitude of surgery, intraoperative blood loss, wound contamination, and postoperative physiological changes. Traditional clinical assessment depends heavily on the experience and judgment of the treating team. Although clinical judgment remains central to surgical care, it may be limited when multiple variables need to be interpreted simultaneously. Conventional scoring systems and risk calculators have helped standardize assessment, but many of them are static and may not fully capture the dynamic postoperative condition of the patient.² Early warning systems were introduced to support bedside recognition of clinical deterioration by assigning scores to routinely measured physiological parameters such as pulse rate, blood pressure, respiratory rate, temperature, oxygen saturation, consciousness level, and urine output. These systems are useful because they convert bedside observations into a structured alert system and encourage escalation of care when predefined thresholds are reached. In postoperative surgical patients, however, clinical deterioration may be influenced not only by current vital signs but also by operative complexity, preoperative reserve, laboratory trends, and early inflammatory or renal changes. This creates a need for enhanced models that can combine clinical, operative, and laboratory data into a more comprehensive prediction tool.³ Artificial intelligence and machine learning have emerged as promising approaches for perioperative risk assessment because they can analyze complex and non-linear relationships among multiple variables. Unlike traditional models that rely on predefined assumptions, AI-based systems can identify patterns from large datasets and update predictions as new information becomes available. In

surgery, such systems may assist clinicians by identifying high-risk patients earlier, supporting individualized monitoring plans, and helping allocate ward, high-dependency, or intensive care resources more effectively. AI-assisted systems are not intended to replace clinical judgment but may function as decision-support tools that improve situational awareness during the vulnerable postoperative period.⁴ The use of AI in surgical risk prediction has particular relevance in tertiary care hospitals, where patients often present with complex pathology, advanced disease, multiple comorbidities, and variable operative risk. Emergency surgery, contaminated wounds, prolonged procedures, and postoperative sepsis risk are common clinical challenges in such settings. A dynamic early warning system assisted by AI may be useful because it can incorporate preoperative factors, intraoperative events, postoperative vital signs, and laboratory abnormalities into a single risk framework. This may help clinicians detect deterioration before severe complications become clinically established.⁵ Despite the increasing interest in AI-based prediction models, practical implementation in routine surgical practice requires careful evaluation. An ideal system should be clinically meaningful, easy to use, interpretable, and based on parameters that are routinely available in hospital settings. It should provide timely risk alerts without creating excessive false alarms, because alarm fatigue can reduce clinical usefulness. At the same time, the system should have good sensitivity so that patients likely to develop complications are not missed. Therefore, prospective assessment of such systems in real-world surgical populations is important before they can be incorporated into daily postoperative monitoring protocols.⁶

Materials and Methods

This study was designed as a prospective observational assessment of an AI-assisted early warning system for the prediction of postoperative complications in general surgical patients. The study was conducted in the Department of General Surgery at a tertiary care hospital. The objective was to evaluate the ability of the AI-assisted early warning system to identify patients at risk of developing postoperative complications during the postoperative period, using routinely available clinical and laboratory parameters. A total of 95 patients admitted under the Department of General Surgery and undergoing operative procedures were included in the study. Patients were enrolled prospectively after fulfilling the eligibility criteria. The study population included adult patients undergoing elective or emergency general surgical procedures who required postoperative monitoring in the surgical ward, high-dependency unit, or intensive care setting. All patients were followed during the postoperative hospital stay for the development of complications.

Inclusion Criteria

Patients aged 18 years and above who underwent general surgical procedures at the tertiary care

hospital were included in the study. Patients who provided informed consent and had adequate postoperative clinical data available for analysis were considered eligible. Both elective and emergency surgical cases were included to ensure representation of a broad spectrum of general surgical patients.

Exclusion Criteria

Patients below 18 years of age, patients who did not provide consent, and those with incomplete clinical or laboratory data required for assessment by the AI-assisted early warning system were excluded from the study. Patients who were transferred out immediately after surgery or whose postoperative outcomes could not be adequately assessed were also excluded.

Methodology

AI-Assisted Early Warning System: The AI-assisted early warning system was used as a clinical decision-support tool for postoperative risk prediction. The system analyzed routinely recorded patient parameters and generated a risk assessment for possible postoperative complications. The parameters incorporated into the system included demographic details, preoperative clinical status, intraoperative factors, postoperative vital signs, and relevant laboratory investigations. The AI-based prediction was used for assessment purposes and did not replace the clinical judgment of the treating surgical team.

Parameters Assessed: Demographic parameters included age, sex, body mass index, and relevant comorbidities such as diabetes mellitus, hypertension, chronic respiratory disease, chronic kidney disease, cardiovascular disease, and history of smoking or alcohol use. Preoperative parameters included American Society of Anesthesiologists physical status, diagnosis, type of admission, and preoperative hemoglobin, total leukocyte count, serum creatinine, serum electrolytes, serum albumin, and blood glucose levels. Operative parameters included type of surgery, elective or emergency nature of surgery, duration of operation, type of anesthesia, estimated blood loss, intraoperative hypotension, blood transfusion requirement, and wound classification.

Postoperative Monitoring: Postoperative clinical monitoring included pulse rate, systolic and diastolic blood pressure, respiratory rate, temperature, oxygen saturation, urine output, level of consciousness, pain score, and requirement of oxygen supplementation or ventilatory support. Laboratory parameters assessed during the postoperative period included hemoglobin, total leukocyte count, platelet count, serum creatinine, serum electrolytes, liver function tests, blood glucose, C-reactive protein where available, and arterial blood gas analysis when clinically indicated. These parameters were entered into or assessed by the AI-assisted early warning system to generate a risk alert for possible complications.

Outcome Measures: The primary outcome was the development of postoperative complications among

general surgical patients. Complications assessed included surgical site infection, wound dehiscence, postoperative bleeding, sepsis, respiratory complications, cardiac events, acute kidney injury, electrolyte imbalance, anastomotic leak, need for re-exploration, unplanned intensive care admission, prolonged hospital stay, and postoperative mortality. The occurrence of complications was confirmed by clinical examination, laboratory investigations, imaging findings, operative findings, and the judgment of the treating surgical team.

Assessment of AI Prediction: The predictive performance of the AI-assisted early warning system was assessed by comparing its risk alerts with actual postoperative outcomes. Patients were categorized according to the risk generated by the system, such as low-risk, moderate-risk, and high-risk groups, depending on the output format of the AI tool. The association between AI-generated risk categories and the occurrence of postoperative complications was analyzed. Diagnostic performance measures such as sensitivity, specificity, positive predictive value, negative predictive value, and overall accuracy were calculated.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics version 27.0. Continuous variables were expressed as mean and standard deviation or median and interquartile range, depending on the distribution of data. Categorical variables were expressed as frequency and percentage. The chi-square test or Fisher's exact test was used to assess associations between categorical variables. The independent t-test or Mann-Whitney U test was used for comparison of continuous variables between groups, as appropriate. Sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of the AI-assisted early warning system were calculated. Receiver operating characteristic curve analysis was performed where applicable, and the area under the curve was used to assess predictive performance. A p-value of less than 0.05 was considered statistically significant.

MATERIALS AND METHODS

This hospital-based comparative observational study was conducted in the Department of Surgery at a tertiary care hospital. The study included patients diagnosed with selected abdominal wall hernias who underwent either mesh repair or non-mesh anatomical repair. The objective was to compare postoperative pain, early and late postoperative complications, and recurrence between the two repair techniques. A total of 108 patients with selected abdominal wall hernias were included in the study. Patients were divided into two groups based on the type of surgical repair performed. Group A included patients who underwent mesh repair, while Group B included patients who underwent non-mesh repair.

The decision regarding the type of repair was made according to the clinical condition of the patient, type and size of hernia defect, tissue quality, surgeon's assessment, and suitability for mesh placement.

Inclusion Criteria

Patients of adult age group presenting with selected abdominal wall hernias and planned for elective surgical repair were included in the study. Patients who were clinically fit for surgery and willing to undergo postoperative follow-up were considered eligible. Cases included commonly encountered abdominal wall hernias such as paraumbilical hernia, umbilical hernia, epigastric hernia, and incisional hernia, depending on institutional case selection.

Exclusion Criteria

Patients with strangulated hernia, obstructed hernia requiring emergency surgery, recurrent hernia previously repaired with mesh, gross local infection, uncontrolled systemic illness, severe immunocompromised state, malignancy, pregnancy, and patients not willing for follow-up were excluded from the study. Patients in whom adequate postoperative assessment could not be performed were also excluded.

Methodology

All patients underwent detailed clinical evaluation including history, duration of swelling, pain, reducibility, cough impulse, previous abdominal surgery, and associated comorbidities such as diabetes mellitus, hypertension, chronic cough, constipation, obesity, smoking, and urinary symptoms. General physical examination, systemic examination, and local examination of the hernia were performed. Baseline investigations included complete blood count, renal function tests, liver function tests, blood sugar levels, coagulation profile, urine examination, chest X-ray, electrocardiogram, and other investigations as required. Ultrasonography of the abdomen and abdominal wall was performed wherever indicated to assess defect size, contents of sac, and associated pathology.

Surgical Procedure: All patients underwent surgical repair under appropriate anaesthesia after obtaining fitness for surgery. In the mesh repair group, the hernia sac was dissected, contents were reduced, excess sac was excised or dealt with appropriately, and the defect was reinforced using a suitable prosthetic mesh. Mesh placement was performed according to the type of hernia and intraoperative findings, such as onlay, sublay, or preperitoneal placement, as per standard surgical principles. In the non-mesh repair group, anatomical repair was performed by approximating healthy fascial margins with non-absorbable or delayed absorbable sutures without use of prosthetic material. Proper haemostasis was achieved in all cases, and drains were placed when required.

Postoperative Management: Postoperative care was provided according to standard hospital protocol. Patients were monitored for pain, wound condition, fever, seroma, haematoma, surgical site infection, urinary retention, respiratory complications, and

other postoperative events. Analgesics, antibiotics, wound care, early ambulation, and supportive treatment were given as required. Drains, if placed, were removed based on drain output and clinical assessment. Patients were advised regarding wound care, avoidance of heavy lifting, control of cough or constipation, and regular follow-up.

Parameters Studied: The main parameters assessed were demographic profile, age, sex, body mass index, type of hernia, size of hernia defect, reducibility, associated comorbidities, history of previous abdominal surgery, type of repair performed, operative time, need for drain placement, duration of hospital stay, postoperative pain, wound complications, seroma, haematoma, surgical site infection, mesh-related complications, return to routine activity, and recurrence. Postoperative pain was assessed using a visual analogue scale or standard pain scoring system during the early postoperative period and follow-up visits. Complications were recorded clinically and classified as early or late postoperative complications.

Assessment of Postoperative Pain: Postoperative pain was assessed using a standard pain scoring method such as the Visual Analogue Scale, where patients were asked to grade their pain intensity. Pain was recorded in the immediate postoperative period and during follow-up visits. Requirement of analgesics and persistence of pain were also noted. Pain severity was compared between mesh and non-mesh repair groups to evaluate whether the type of repair influenced postoperative discomfort.

Assessment of Complications: Postoperative complications were assessed by clinical examination and patient symptoms. Early complications included wound pain, seroma, haematoma, surgical site infection, wound dehiscence, urinary retention, and fever. Late complications included chronic pain, foreign body sensation, mesh infection, sinus formation, and recurrence. Each complication was recorded separately in both groups and compared to evaluate the safety and outcome of mesh versus non-mesh repair.

Assessment of Recurrence: Recurrence was assessed during follow-up by clinical examination. A recurrent hernia was defined as the reappearance of a swelling or fascial defect at or near the previous operative site with or without cough impulse. Patients were examined for local swelling, pain, impulse on coughing, and reducibility. Ultrasonography was used when clinical findings were doubtful. Recurrence rates were compared between mesh and non-mesh repair groups.

Statistical Analysis

Data were entered into Microsoft Excel and analysed using **SPSS version 27.0**. Continuous variables such as age, operative time, postoperative pain score, and hospital stay were expressed as mean and standard deviation. Categorical variables such as sex, type of hernia, complications, and recurrence were expressed as frequency and percentage. Comparison between

mesh and non-mesh repair groups was performed using the Chi-square test or Fisher's exact test for categorical variables and Student's t-test or Mann-Whitney U test for continuous variables, depending on data distribution. A p-value of less than 0.05 was considered statistically significant.

RESULTS

A total of 95 patients undergoing general surgical procedures were included in the study. Among them, 29 patients developed postoperative complications, giving an overall complication rate of 30.53%. The remaining 66 patients, accounting for 69.47%, had an uneventful postoperative recovery.

Table 1: Baseline demographic and clinical characteristics

Table 1 shows the relationship between baseline patient characteristics and postoperative complications. Age was significantly associated with complications, with the highest complication rate observed among patients aged 60 years and above. In this group, 16 out of 32 patients developed complications, giving a complication rate of 50.00%. In comparison, only 12.00% of patients below 40 years and 26.32% of patients aged 40–59 years developed complications. This association was statistically significant with a p value of 0.006, suggesting that increasing age was an important risk factor for postoperative complications. Sex was not significantly associated with postoperative complications. Among males, 19 out of 58 patients developed complications, giving a rate of 32.76%, while among females, 10 out of 37 patients developed complications, giving a rate of 27.03%. The p value was 0.717, indicating that the difference between male and female patients was not statistically significant. Body mass index showed an increasing trend in complication rate from normal-weight to obese patients. Complications occurred in 20.00% of patients with normal BMI, 31.43% of overweight patients, and 50.00% of obese patients. However, the p value was 0.058, which was slightly above the level of statistical significance. ASA physical status was significantly associated with postoperative complications. Among patients with ASA I–II status, 12 out of 61 patients developed complications, giving a rate of 19.67%. In contrast, among patients with ASA III–IV status, 17 out of 34 patients developed complications, giving a rate of 50.00%. The p value was 0.004, indicating that patients with poorer preoperative physical status had a significantly higher risk of postoperative complications. The presence of comorbidities was also significantly associated with complications. Among patients with comorbidities, 20 out of 45 developed complications, giving a rate of 44.44%. Among patients without comorbidities, only 9 out of 50 developed complications, giving a rate of 18.00%. The p value was 0.010, showing that comorbid illnesses were important contributors to postoperative morbidity.

Table 2: Operative characteristics

Table 2 describes operative factors associated with postoperative complications. Emergency surgery was associated with a significantly higher complication rate compared with elective surgery. Among emergency cases, 18 out of 39 patients developed complications, giving a rate of 46.15%. In elective cases, 11 out of 56 patients developed complications, giving a rate of 19.64%. The p value was 0.011, indicating a significant association between emergency surgery and postoperative complications. The magnitude of surgery was also significantly related to complications. Among patients who underwent major surgery, 24 out of 59 developed complications, giving a rate of 40.68%. In contrast, only 5 out of 36 patients undergoing minor or intermediate procedures developed complications, giving a rate of 13.89%. The p value was 0.012, suggesting that more extensive surgical procedures carried a higher postoperative risk. Operative duration showed a significant association with complications. Patients with operative duration greater than 120 minutes had a complication rate of 46.67%, while those with duration of 120 minutes or less had a complication rate of 16.00%. The p value was 0.003, indicating that prolonged operative time was significantly associated with postoperative complications. Estimated blood loss was another significant operative factor. Patients with blood loss greater than 500 ml had a complication rate of 53.57%, compared with 20.90% among those with blood loss of 500 ml or less. The p value was 0.004, showing that increased intraoperative blood loss was significantly associated with adverse postoperative outcomes. Blood transfusion requirement was significantly associated with postoperative complications. Among patients requiring transfusion, 13 out of 24 developed complications, giving a rate of 54.17%. Among those who did not require transfusion, 16 out of 71 developed complications, giving a rate of 22.54%. The p value was 0.008, indicating a significant relationship between transfusion requirement and postoperative morbidity. Wound class showed a strong association with complications. Patients with contaminated or dirty wounds had a complication rate of 51.43%, while patients with clean or clean-contaminated wounds had a complication rate of 18.33%. The p value was 0.002, suggesting that wound contamination was a major predictor of postoperative complications.

Table 3: Postoperative clinical and laboratory warning parameters

Table 3 shows the association between postoperative warning parameters and complications. Tachycardia was observed in 40 patients, of whom 22 developed complications, giving a complication rate of 55.00%. Hypotension was present in 19 patients, and 12 of them developed complications, giving a rate of 63.16%. The p value was 0.001, showing a statistically significant association between hypotension and postoperative complications. Fever was seen in 35 patients, of whom 20 developed

complications, giving a complication rate of 57.14%. The p value was less than 0.001, indicating a highly significant association. Fever may reflect infection, inflammatory response, or sepsis in the postoperative period. Oxygen saturation below 94% was observed in 19 patients, with complications occurring in 11 patients, giving a rate of 57.89%. The p value was 0.009, showing a significant association between oxygen desaturation and postoperative complications, particularly respiratory or systemic complications. Reduced urine output was noted in 22 patients. Among them, 13 developed complications, giving a rate of 59.09%. The p value was 0.002, indicating that reduced urine output was significantly associated with complications and may reflect hypovolemia, renal dysfunction, or systemic deterioration. Raised total leukocyte count was found in 35 patients, among whom 21 developed complications, giving a rate of 60.00%. The p value was less than 0.001, showing a highly significant association. Raised serum creatinine was observed in 17 patients, of whom 10 developed complications, giving a rate of 58.82%. The p value was 0.012, indicating a significant association between renal dysfunction and postoperative morbidity.

Table 4: AI-assisted early warning risk category

Table 4 demonstrates the relationship between AI-generated risk category and actual postoperative complications. Among 43 patients categorized as low risk, only 3 developed complications, giving a complication rate of 6.98%, while 40 patients, 93.02%, had no complications. Among 30 patients categorized as moderate risk, 9 developed complications, giving a complication rate of 30.00%, while 21 patients, 70.00%, did not develop

complications. Among 22 patients categorized as high risk, 17 developed complications, giving a complication rate of 77.27%, while only 5 patients, 22.73%, had no complications. The p value was less than 0.001, indicating a highly significant association between AI-generated risk category and actual postoperative outcome.

Table 5: Predictive performance of the AI-assisted early warning system

Table 5 presents the diagnostic performance of the AI-assisted early warning system. Moderate-risk and high-risk alerts were considered positive alerts, while low-risk alerts were considered negative alerts. The system correctly identified 26 patients who developed complications as true positives. It also correctly identified 40 patients who did not develop complications as true negatives. There were 26 false-positive cases, meaning these patients were flagged as moderate or high risk by the AI system but did not develop complications. There were only 3 false-negative cases, meaning these patients were classified as low risk but later developed complications. The sensitivity of the AI system was 89.66%, indicating that it was able to correctly identify most patients who developed postoperative complications. The specificity was 60.61%, showing a moderate ability to correctly identify patients without complications. The positive predictive value was 50.00%, meaning that half of the patients with a positive AI alert actually developed complications. The negative predictive value was high at 93.02%, indicating that patients classified as low risk were very unlikely to develop complications. The overall diagnostic accuracy was 69.47%.

Table 1: Baseline demographic and clinical characteristics of patients

Variable	Total patients n=95	Complication present n=29	No complication n=66	p value
Age group				0.006
<40 years	25 (26.32%)	3 (12.00%)	22 (88.00%)	
40–59 years	38 (40.00%)	10 (26.32%)	28 (73.68%)	
≥60 years	32 (33.68%)	16 (50.00%)	16 (50.00%)	
Sex				0.717
Male	58 (61.05%)	19 (32.76%)	39 (67.24%)	
Female	37 (38.95%)	10 (27.03%)	27 (72.97%)	
Body mass index				0.058
Normal	40 (42.11%)	8 (20.00%)	32 (80.00%)	
Overweight	35 (36.84%)	11 (31.43%)	24 (68.57%)	
Obese	20 (21.05%)	10 (50.00%)	10 (50.00%)	
ASA physical status				0.004
ASA I–II	61 (64.21%)	12 (19.67%)	49 (80.33%)	
ASA III–IV	34 (35.79%)	17 (50.00%)	17 (50.00%)	
Comorbidity present				0.010
Yes	45 (47.37%)	20 (44.44%)	25 (55.56%)	
No	50 (52.63%)	9 (18.00%)	41 (82.00%)	

Table 2: Operative characteristics and association with postoperative complications

Variable	Total patients n=95	Complication present n=29	No complication n=66	p value
Type of admission				0.011
Elective surgery	56 (58.95%)	11 (19.64%)	45 (80.36%)	
Emergency surgery	39 (41.05%)	18 (46.15%)	21 (53.85%)	
Magnitude of surgery				0.012
Major surgery	59 (62.11%)	24 (40.68%)	35 (59.32%)	
Minor/intermediate surgery	36 (37.89%)	5 (13.89%)	31 (86.11%)	
Operative duration				0.003

≤120 minutes	50 (52.63%)	8 (16.00%)	42 (84.00%)	
>120 minutes	45 (47.37%)	21 (46.67%)	24 (53.33%)	
Estimated blood loss				0.004
≤500 ml	67 (70.53%)	14 (20.90%)	53 (79.10%)	
>500 ml	28 (29.47%)	15 (53.57%)	13 (46.43%)	
Blood transfusion required				0.008
Yes	24 (25.26%)	13 (54.17%)	11 (45.83%)	
No	71 (74.74%)	16 (22.54%)	55 (77.46%)	
Wound class				0.002
Clean/clean-contaminated	60 (63.16%)	11 (18.33%)	49 (81.67%)	
Contaminated/dirty	35 (36.84%)	18 (51.43%)	17 (48.57%)	

Table 3: Postoperative clinical and laboratory warning parameters

Postoperative parameter	Total patients n=95	Complication present n=29	No complication n=66	p value
Tachycardia	40 (42.11%)	22 (55.00%)	18 (45.00%)	<0.001
Hypotension	19 (20.00%)	12 (63.16%)	7 (36.84%)	0.001
Fever	35 (36.84%)	20 (57.14%)	15 (42.86%)	<0.001
Oxygen saturation <94%	19 (20.00%)	11 (57.89%)	8 (42.11%)	0.009
Reduced urine output	22 (23.16%)	13 (59.09%)	9 (40.91%)	0.002
Raised total leukocyte count	35 (36.84%)	21 (60.00%)	14 (40.00%)	<0.001
Raised serum creatinine	17 (17.89%)	10 (58.82%)	7 (41.18%)	0.012

Table 4: AI-assisted early warning risk category and postoperative complications

AI-generated risk category	Total patients n=95	Complication present n=29	No complication n=66	p value
Low risk	43 (45.26%)	3 (6.98%)	40 (93.02%)	<0.001
Moderate risk	30 (31.58%)	9 (30.00%)	21 (70.00%)	
High risk	22 (23.16%)	17 (77.27%)	5 (22.73%)	

Table 5: Predictive performance of the AI-assisted early warning system

Parameter	Value
True positive	26
False positive	26
True negative	40
False negative	3
Sensitivity	89.66%
Specificity	60.61%
Positive predictive value	50.00%
Negative predictive value	93.02%
Overall diagnostic accuracy	69.47%

DISCUSSION

In the present study, postoperative complications were observed in 29 out of 95 patients, giving an overall complication rate of 30.53%, while 66 patients, 69.47%, recovered without complications. This finding is very close to the study by Dharap et al. (2022), who reported postoperative complications in 31.50% of general surgery patients, with minor complications in 19.75%, major complications in 8.00%, and mortality in 3.75%. The similarity between the present complication rate of 30.53% and the 31.50% reported by Dharap et al. suggests that the postoperative morbidity observed in the present tertiary care hospital population was comparable to published general surgical data.^[7] Age showed a significant association with postoperative complications in the present study, with the highest complication rate among patients aged ≥60 years, where 16 out of 32 patients developed complications, giving a rate of 50.00%. This was higher than the rates observed in patients aged <40 years, 12.00%, and 40–59 years, 26.32%, with a significant p value of 0.006. This finding is supported by Payá-Llorente et al. (2020), who studied patients undergoing emergency surgery for complicated intra-abdominal

infections and reported that age-adjusted comorbidity had a strong impact on postoperative outcome, with patients having higher age-adjusted Charlson Comorbidity Index showing approximately 3.5 times greater odds of severe postoperative complications. Thus, the present study and Payá-Llorente et al. both indicate that increasing age and cumulative physiological burden increase postoperative morbidity.^[8] In the present study, sex was not significantly associated with complications, as complications occurred in 32.76% of males and 27.03% of females, with a p value of 0.717. Body mass index showed a rising trend, with complications in 20.00% of normal BMI patients, 31.43% of overweight patients, and 50.00% of obese patients, although this did not reach statistical significance, with p=0.058. Mashayekhi et al. (2025), in a multicenter study on elective general surgery patients, reported an overall complication rate of 25.90%, with the highest complication rate among obese patients at 36.40% compared with 18.50% in normal-weight patients, and the association was statistically significant with p=0.003. The present study similarly showed higher complications among obese patients, although the smaller sample size may explain why the association remained borderline

rather than statistically significant.^[9] ASA physical status was significantly associated with postoperative complications in the present study. Patients with ASA III–IV status had a complication rate of 50.00%, whereas those with ASA I–II status had a complication rate of 19.67%, with $p=0.004$. Bilimoria et al. (2013), while developing the universal ACS NSQIP surgical risk calculator, used variables such as age, ASA class, functional status, emergency status, and procedure type to estimate patient-specific postoperative risks. The significant association of higher ASA class with postoperative complications in the present study supports the ACS NSQIP model concept that preoperative physiological status is a key determinant of surgical outcome.^[10] Comorbidities were significantly associated with postoperative complications in the present study. Among patients with comorbidities, 20 of 45 developed complications, giving a rate of 44.44%, compared with only 18.00% among patients without comorbidities, with $p=0.010$. This finding is consistent with the study by Sinha et al. (2025), who reported a postoperative complication rate of 31.50% and observed that complications were more frequent in patients with comorbidities, increased BMI, emergency surgery, prolonged operative duration, higher blood loss, and contaminated wounds. The present study therefore confirms that comorbid illness remains an important contributor to postoperative morbidity in general surgical patients.^[11] Emergency surgery was significantly associated with postoperative complications in the present study, with complications in 46.15% of emergency cases compared with 19.64% of elective cases, with $p=0.011$. Ylimartimo et al. (2023) reported a much higher complication burden after emergency laparotomy, with 389 of 674 patients, 58.00%, developing postoperative complications, including operation-related complications in 32.00% and medical complications in 54.00%. Although the complication rate in the present emergency group was lower at 46.15%, both studies demonstrate that emergency surgical procedures carry a substantially higher postoperative risk than elective operations.^[12] Operative factors were strongly associated with complications in the present study. Major surgery had a complication rate of 40.68% compared with 13.89% in minor or intermediate surgery, operative duration >120 minutes had a complication rate of 46.67% compared with 16.00% for ≤ 120 minutes, blood loss >500 ml had a complication rate of 53.57% compared with 20.90%, transfusion requirement had a complication rate of 54.17% compared with 22.54%, and contaminated or dirty wounds had a complication rate of 51.43% compared with 18.33% in clean or clean-contaminated wounds. These findings are comparable with Castañeda-Márquez et al. (2024), who studied postoperative complications in emergency surgeries and found that complications were associated with hypertension, midline surgical approach, hypoalbuminemia, peritonitis due to hollow viscus perforation, and

trauma. Both studies emphasize that operative severity, tissue contamination, and physiological stress significantly influence postoperative outcome.^[13] Postoperative clinical and laboratory warning signs were significantly associated with complications in the present study. Tachycardia was associated with complications in 55.00%, hypotension in 63.16%, fever in 57.14%, oxygen saturation $<94\%$ in 57.89%, reduced urine output in 59.09%, raised total leukocyte count in 60.00%, and raised serum creatinine in 58.82%. Foy et al. (2020), in a prospective observational study of 254 emergency surgical patients, found that 18 patients, 7.50%, died within 30 days and that early warning scores predicted mortality, with NEWS showing an AUROC of 0.805, MEWS 0.760, mHOTEL 0.759, and TOTAL 0.782, all with $p<0.001$. The present study similarly supports the clinical value of deranged vital signs and laboratory abnormalities as early indicators of postoperative deterioration.^[14] The AI-assisted early warning system in the present study showed a strong association between AI-generated risk category and actual complications. Complications occurred in only 6.98% of low-risk patients, 30.00% of moderate-risk patients, and 77.27% of high-risk patients, with $p<0.001$. For diagnostic performance, the AI system showed sensitivity of 89.66%, specificity of 60.61%, positive predictive value of 50.00%, negative predictive value of 93.02%, and overall accuracy of 69.47%. Mahajan et al. (2023), in a large machine-learning study including 1,477,561 surgical patients, reported prospective AUROC of 0.956 for mortality prediction, sensitivity of 85.30%, specificity of 91.40%, and negative predictive value of 99.80%. Compared with Mahajan et al., the present study showed slightly higher sensitivity, 89.66% versus 85.30%, but lower specificity, 60.61% versus 91.40%; however, the high negative predictive value of 93.02% in the present study indicates that the AI-assisted system was particularly useful for ruling out complications among low-risk patients.^[15]

CONCLUSION

The present study showed that postoperative complications occurred in a considerable proportion of general surgical patients. Increasing age, higher ASA grade, presence of comorbidities, emergency surgery, major procedures, prolonged operative duration, increased blood loss, transfusion requirement, and contaminated wounds were significantly associated with postoperative complications. Postoperative warning signs such as tachycardia, hypotension, fever, oxygen desaturation, reduced urine output, leukocytosis, and raised serum creatinine were important indicators of deterioration. The AI-assisted early warning system showed good sensitivity and high negative predictive value for predicting postoperative complications.

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