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A Prospective Study on Conservative Management of Solid Organ Injuries in Blunt Abdominal Trauma

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HIGHLIGHTS

- Conservative management successful
- Liver injuries predominated
- Grade I injuries common
- Hematological markers correlated
- Non-operative management effective

Key Words:
Blunt abdominal trauma
Non-operative management
Solid organ injury
AAST grade

ABSTRACT

Introduction: Blunt abdominal trauma (BAT) is a leading cause of morbidity and mortality worldwide, with solid organ injuries traditionally managed operatively. Recent trends favor non-operative management (NOM) in hemodynamically stable patients. This study evaluates the feasibility, outcomes, and laboratory correlates of conservative management in solid organ injuries following BAT. **Aims & Objectives:** To analyze the grades of solid organ injuries, study healing and recovery patterns, and evaluate outcomes of conservative management in BAT patients. **Materials & Methods:** A prospective observational study was conducted at KD Medical College, Mathura from May 2024 to October 2025. Eighty-seven hemodynamically stable patients with blunt abdominal solid organ injuries (liver, spleen, kidney, pancreas, adrenal) were enrolled. All patients underwent detailed clinical assessment, CECT abdomen, and serial monitoring of hematological parameters. Conservative management included immobilization, vitals monitoring, and symptomatic treatment. Statistical analysis employed SPSS v26, with Friedman test for trends and Spearman's correlation. **Results:** Mean age was 46.15±16.77 years with equal sex distribution. Liver (33.3%) was most injured, followed by kidney (25.3%). Grade I injuries predominated (42.5%). Assault (27.6%) and falls (26.4%) were commonest mechanisms. All patients were hemodynamically stable at admission. Serial hemoglobin, platelet, and lymphocyte percentages showed significant declining trends ($p<0.001$). Significant negative correlations existed between AAST grade and hemoglobin ($r=-0.241$ to -0.263) and platelet count ($r=-0.289$ to -0.312); positive correlation with lymphocyte percentage ($r=0.234$-0.277). Conservative management success rate was 100% (95% CI: 0.958-1.000), with no failures requiring surgery. **Conclusion:** Conservative management of solid organ injuries in hemodynamically stable BAT patients is highly effective, with excellent success rates. Hematological parameters correlate significantly with injury severity and serve as useful monitoring tools.

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INTRODUCTION

Trauma is a major global public health challenge and remains one of the leading causes of death and disability across all age groups. According to the World Health Organization (WHO), trauma accounts for more than five million deaths annually, representing nearly 9% of all global mortality, with the greatest impact among individuals aged 1-44 years, the most economically productive segment of the population. In addition to mortality, trauma results in significant physical disability, psychological distress, prolonged hospitalization, & substantial socioeconomic losses affecting patients, families, and healthcare systems. The burden is particularly high in low- and middle-income countries, where rapid urbanization, increasing motorization, industrial expansion, and inadequate trauma care infrastructure contribute to rising injury rates. In India, road traffic accidents constitute the leading cause of blunt trauma, while falls, workplace injuries, and interpersonal violence also contribute significantly to the increasing incidence of trauma-related hospital admissions & deaths. These factors collectively place considerable strain on healthcare resources and emphasize the need for effective trauma prevention and management strategies [1,2]. Among traumatic injuries, abdominal trauma represents a significant cause of morbidity and mortality because of the presence of multiple vital organs within the abdominal cavity. Blunt abdominal trauma (BAT) is considerably more common than penetrating trauma and is frequently associated with road traffic accidents, falls from height, sports injuries, industrial accidents, & assault. Abdominal injuries account for approximately 2–5% of all trauma cases and are responsible for a substantial proportion of trauma-related deaths. The liver and spleen are the most injured solid organs because of their large size, rich vascular supply, and anatomical location beneath the lower ribs. Renal injuries constitute approximately 10% of abdominal trauma, whereas pancreatic and adrenal injuries are less frequent but often present diagnostic and therapeutic challenges. The mechanisms of BAT include direct compression, crushing forces, rapid deceleration, and shearing stress, which may produce contusions, lacerations, hematomas, vascular injuries, or multiple simultaneous organ injuries. Owing to the highly vascular nature of these organs, uncontrolled hemorrhage remains the principal cause of morbidity and mortality following blunt abdominal trauma [3-5].

The diagnosis of blunt abdominal trauma has evolved remarkably over recent decades. Clinical examination alone is often insufficient because abdominal signs may be subtle, delayed, or obscured by associated head, chest, or orthopedic injuries. Historically, diagnostic peritoneal lavage was widely employed for detecting intra-abdominal bleeding but lacked specificity and frequently resulted in unnecessary exploratory laparotomies. The introduction of Focused Assessment with Sonography for Trauma (FAST) significantly improved the rapid bedside detection of free intraperitoneal fluid in emergency settings. Nevertheless, contrast-enhanced computed tomography (CECT) has become the imaging modality of choice for hemodynamically stable patients because it accurately identifies injured organs, grades injury severity according to established classifications, detects active bleeding, evaluates vascular injuries, and identifies associated intra-

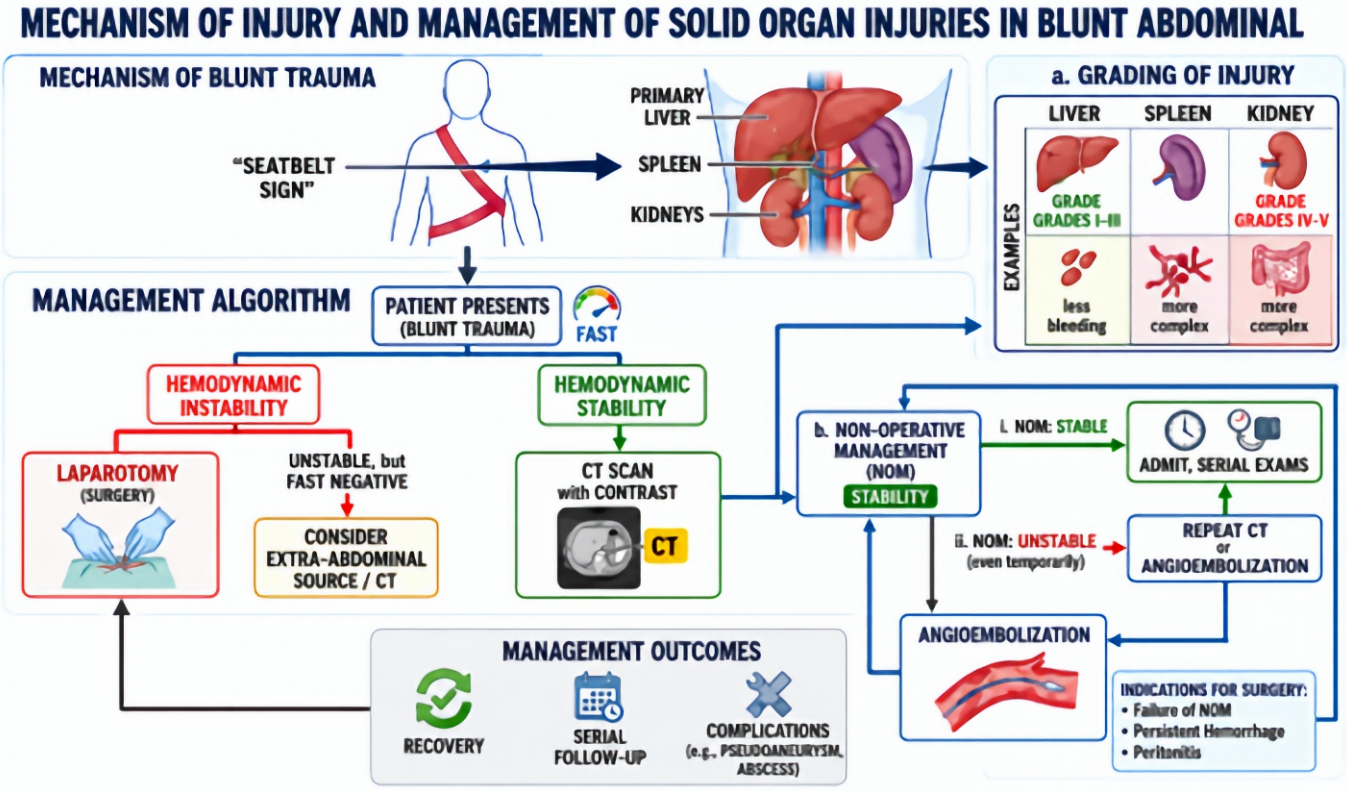

Figure 1: Mechanism of injury, grading, and management algorithm for solid organ injuries following blunt abdominal trauma (BAT).

abdominal lesions. The availability of high-resolution CT imaging has transformed trauma management by enabling accurate patient selection for conservative treatment while minimizing unnecessary surgical intervention [6,7].

Management strategies for blunt abdominal solid organ injuries have undergone a substantial paradigm shift over the last three decades. Previously, exploratory laparotomy was routinely performed because of limited diagnostic capabilities and concern regarding missed injuries. Although lifesaving in unstable patients, operative management is associated with significant postoperative morbidity, including wound infection, intra-abdominal abscess formation, adhesions, prolonged hospitalization, increased healthcare costs, and delayed functional recovery. Advances in imaging, intensive care monitoring, blood transfusion practices, and interventional radiology have established non-operative management (NOM) as the standard treatment for hemodynamically stable patients with solid organ injuries. Current evidence demonstrates successful conservative management in more than 80% of liver injuries, 50–60% of splenic injuries, and nearly all low-grade renal injuries, with overall success rates exceeding 90% in appropriately selected patients. The addition of angiographic embolization has further improved outcomes in patients with active arterial bleeding or high-grade hepatic and splenic injuries, reducing the need for operative intervention while preserving organ function. Patients treated conservatively generally experience shorter hospital stays, fewer complications, faster recovery, and improved quality of life compared with those undergoing surgery [8-10].

Despite these encouraging outcomes, successful non-operative management requires meticulous patient selection and continuous clinical surveillance. Hemodynamic instability remains the primary indication for emergency laparotomy, while delayed hemorrhage, missed hollow viscus injuries, expanding hematomas, and persistent hemodynamic deterioration are the principal causes of NOM failure. Regular monitoring of vital signs, serial abdominal examinations, laboratory investigations, and repeat imaging when indicated are essential components of conservative management. Effective implementation also depends on the availability of multidisciplinary trauma teams, including trauma surgeons, emergency physicians, radiologists, intensivists, and interventional radiologists capable of providing prompt intervention whenever clinical deterioration occurs. Therefore, institutional protocols, adequate monitoring facilities, and timely access to operative and radiological services are critical determinants of successful outcomes [11].

Considering the increasing incidence of blunt abdominal trauma and the expanding role of conservative treatment, continuous evaluation of non-operative management remains essential, particularly in resource-limited healthcare settings. Variations in patient demographics, injury patterns, trauma systems, and institutional expertise may influence treatment success and clinical outcomes. Prospective clinical studies evaluating the effectiveness, safety, predictors of treatment failure, morbidity, mortality, and duration of hospitalization are therefore necessary to strengthen existing evidence. Such investigations provide valuable region-specific data that can refine clinical protocols, optimize patient selection, reduce unnecessary surgical interventions, preserve organ function, improve survival, and enhance the overall quality of trauma care, particularly in developing countries where the burden of blunt abdominal trauma continues to increase [8-11]. **Figure 1**. Management pathway for solid organ injuries in blunt abdominal trauma.

The study aimed to evaluate the effectiveness of non-operative management in patients with solid organ injuries following blunt abdominal trauma. The objectives were to analyze the severity of solid organ injuries based on injury grading, assess the healing process & clinical recovery of patients managed conservatively, & evaluate the overall outcomes of non-operative management, including its safety, effectiveness, and success in appropriately selected hemodynamically stable patients.

MATERIAL & METHODS

This prospective observational study was conducted at the Department of General Surgery, K.D. Medical College and Research Centre, Mathura (Uttar Pradesh) from May 2024 to Oct 2025. Ethical approval has been obtained from the Ethical Approval Committee of K.D. Medical College and Research Centre, Mathura (Uttar Pradesh).

Study Population

The study population comprised hemodynamically stable patients presenting to the KDMCH outpatient department or emergency department with a history of blunt abdominal trauma and radiological evidence of solid organ injuries involving the liver, spleen, kidneys, adrenal glands, or pancreas. Patients with bowel perforation, pregnant women, hemodynamically unstable patients requiring immediate surgical intervention on the day of admission, and those unwilling to provide informed consent were excluded from the study.

Data Analysis

Data were entered into SPSS version 26 and Microsoft Excel for data management, report generation, and statistical analysis. Quantitative variables were summarized using descriptive statistics, including rates, ratios, proportions, and measures of central tendency. Continuous variables were expressed as mean ± standard deviation, while categorical variables were analyzed using the chi-square test. Statistical significance was determined using a p-value of less than 0.05, with results considered significant at this threshold.

RESULT

Among the 87 patients with blunt abdominal trauma included in this study, the mean age was 46.15 ± 16.77 years, with the highest proportion belonging to the >60 years age group (25.3%), followed by 51–60 years (21.8%) and 21–30 years (19.5%), indicating a predominance of middle-aged and elderly patients.

Males (50.6%) and females (49.4%) were almost equally represented, with no significant gender difference (p = 0.130). Assault (27.6%), fall from height (26.4%), road traffic accidents (25.3%), and fall from cycle (20.7%) contributed nearly equally to the mechanism of injury (p = 0.813). The liver was the most injured organ (33.3%), followed by the kidney (25.3%), pancreas (23.0%), and spleen (18.4%). Most injuries were low-grade, with AAST Grade I accounting for 42.5%, Grade II for 29.9%, and Grade III for 27.6% of cases. No significant association was observed between AAST grade and injured organ (p = 0.847) or mode of injury (p = 0.912), suggesting a relatively uniform distribution of injury severity. All patients were hemodynamically stable at admission, with mean systolic blood pressure of 113.77 ± 9.05 mmHg, diastolic blood pressure of 72.29 ± 7.11 mmHg, pulse rate of 93.34 ± 11.42 beats/min, and oxygen saturation of 97.20 ± 1.63%, with no significant variation across AAST grades (p > 0.05). Mental status was also comparable among different injury grades (p = 0.433), indicating preserved neurological status irrespective of injury severity. Overall, the findings demonstrate that most patients had low-to-moderate solid organ injuries, stable clinical parameters, and favorable characteristics for successful conservative management.Mild abdominal examination findings predominated across all AAST grades, with no significant association between examination severity and injury grade (p = 0.274). Although moderate findings increased slightly with higher grades, most patients presented with mild abdominal signs regardless of injury severity **(Table 1)**.

During the five-day in-patient follow-up, mean hemoglobin, platelet count, and lymphocyte percentage showed a gradual but statistically significant decline (all p < 0.001). Despite these changes, the values remained within clinically acceptable limits, indicating physiological responses to trauma and supporting the stability and successful conservative management of the patients **(Table 2)**. A significant correlation was observed between AAST injury grade and serial laboratory parameters during follow-up. Higher AAST grades were consistently associated with lower hemoglobin and platelet counts (all p < 0.05), while lymphocyte percentage showed a significant positive correlation with injury severity throughout Days 1–5, indicating that these hematological parameters may serve as useful indicators of injury severity during conservative management **(Table 3)**. Hemoglobin and platelet count showed significant negative correlations with AAST grade, while lymphocyte percentage demonstrated a significant positive correlation (all p < 0.05). Platelet count exhibited the strongest association with injury severity, indicating that serial hematological parameters may serve as useful supportive markers for assessing injury severity during conservative management of blunt abdominal trauma **(Figure 2)**. From Day 1 to Day 5, hemoglobin, platelet count, and lymphocyte percentage demonstrated a significant declining trend (all p < 0.001), with lymphocyte percentage showing the greatest reduction, followed by platelet count and hemoglobin. Despite these statistically significant changes, the declines remained clinically moderate, supporting the stability and effectiveness of conservative management in patients with blunt abdominal trauma **(Table 4)**. All 87 patients (100%) were successfully managed with non-operative treatment, with no cases requiring surgical intervention, yielding a NOM success rate of 100% (95% CI: 95.8%–100%). These findings demonstrate that conservative management is a safe and highly effective approach for carefully selected hemodynamically stable patients with blunt abdominal solid organ injuries **(Figure 3)**. Significant temporal changes were observed in hemoglobin, platelet count, and lymphocyte percentage throughout the five-day follow-up (all p < 0.001). Additionally, higher AAST grades showed a significant positive correlation with lymphocyte percentage on each follow-up day (all p < 0.05), indicating that serial hematological parameters are valuable markers for monitoring injury severity and patient progress during conservative management **(Table 5)**.

Table 1: Abdominal examination severity category and association with AAST grade

AAST grade	Mild	Moderate	Row total
1	30	7	37
2	19	7	26
3	15	9	24
Total	64	23	87

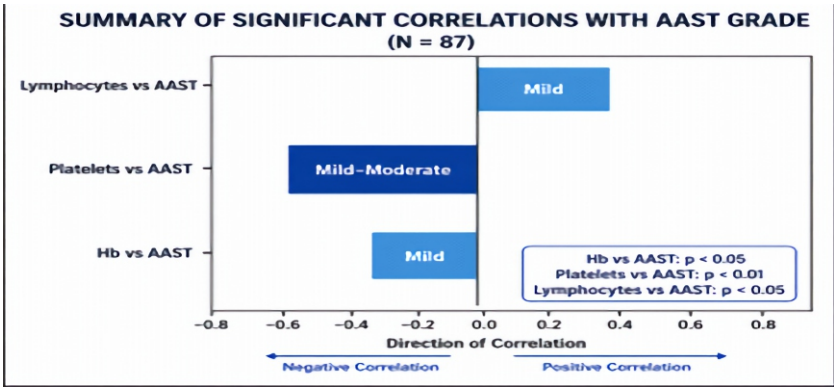

Figure 2: Summary of Significant Correlations Between Laboratory Parameters and AAST Grade (N = 87)

Table 2: Trend of Hemoglobin, Platelet Count, and Lymphocyte Percentage During In-Patient Follow-up (Day 1–5) (N = 87)

Day	Hemoglobin (g/dL) Mean ± SD	Hemoglobin Median (IQR)	Platelet Count (/µL) Mean ± SD	Platelet Count Median (IQR)	Lymphocyte (%) Mean ± SD	Lymphocyte (%) Median (IQR)
Day 1	11.96 ± 1.42	11.70 (10.75 – 13.20)	302069.92 ± 71302.71	306863.00 (255902.50 – 360793.00)	28.10 ± 6.04	29.00 (23.00 – 33.00)
Day 2	11.77 ± 1.40	11.60 (10.55 – 13.00)	293864.63 ± 71350.94	300457.00 (244310.50 – 350392.00)	27.31 ± 5.89	28.00 (22.00 – 32.00)
Day 3	11.56 ± 1.40	11.30 (10.35 – 12.85)	286292.75 ± 70598.02	290565.00 (241707.50 – 340422.50)	26.34 ± 5.79	27.00 (22.00 – 30.00)
Day 4	11.36 ± 1.42	11.10 (10.10 – 12.70)	278111.20 ± 71313.23	280509.00 (229055.50 – 335064.50)	25.24 ± 5.87	26.00 (20.00 – 30.00)
Day 5	11.15 ± 1.42	10.90 (9.90 – 12.40)	269626.48 ± 71567.59	274078.00 (222193.50 – 323767.50)	24.48 ± 5.85	25.00 (19.50 – 29.00)

Table 3: Correlation Between AAST Grade and Hemoglobin, Platelet Count, and Lymphocyte Percentage During In-Patient Follow-up (Day 1–5) (Spearman Correlation, N = 87)

Day	Hemoglobin r	p-value	Platelet Count r	p-value	Lymphocyte Percentage r	p-value
Day 1	−0.241	0.022	−0.289	0.006	0.257	0.016
Day 2	−0.254	0.017	−0.301	0.004	0.234	0.029
Day 3	−0.263	0.014	−0.312	0.002	0.277	0.009
Day 4	−0.249	0.019	−0.298	0.005	0.251	0.019
Day 5	−0.257	0.016	−0.305	0.004	0.263	0.014

Table 4: Trend Summary (Day 1 → Day 5): Direction of Change (N=87)

Parameter	Day 1 Mean	Day 5 Mean	Overall Trend	Test	p-value
Hemoglobin (g/dL)	11.96	11.15	Decreasing	Friedman	<0.001
Lymphocyte (%)	28.1	24.48	Decreasing	Friedman	<0.001
Platelets (/mm³)	302069.92	269626.48	Decreasing	Friedman	<0.001

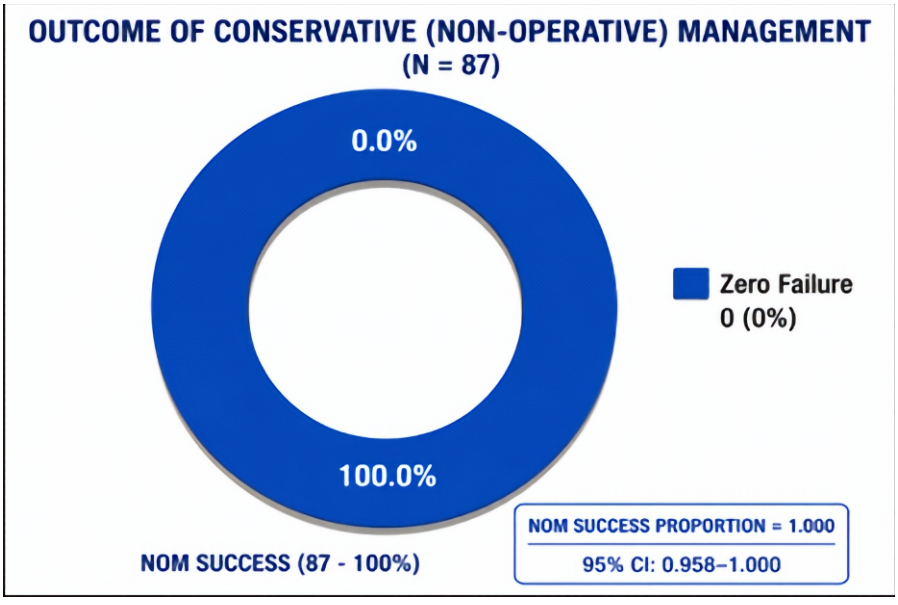

Figure 3: Outcome of Conservative (Non-Operative) Management in Blunt Abdominal Trauma (N = 87)

Table 5: Summary of statistically significant associations (p < 0.05)

Parameter/relationship	Test used	p-value	Interpretation
Hb trend (Day 1–5)	Friedman test (repeated measures)	<0.001	Significant change across days
Platelets trend (Day 1–5)	Friedman test (repeated measures)	<0.001	Significant change across days
Lymphocyte % trend (Day 1–5)	Friedman test (repeated measures)	<0.001	Significant change across days
AAST grade vs Day 1 Lymphocyte (%)	Spearman r=0.257	0.016	Higher grade associated with higher lymphocyte %
AAST grade vs Day 2 Lymphocyte (%)	Spearman r=0.234	0.029	Higher grade associated with higher lymphocyte %
AAST grade vs Day 3 Lymphocyte (%)	Spearman r=0.277	0.009	Higher grade associated with higher lymphocyte %
AAST grade vs Day 4 Lymphocyte (%)	Spearman r=0.251	0.019	Higher grade associated with higher lymphocyte %
AAST grade vs Day 5 Lymphoc yte (%)	Spearman r=0.263	0.014	Higher grade associated with higher lymphocyte %

DISCUSSION

The present prospective study evaluated 87 hemodynamically stable patients with blunt abdominal trauma who were managed conservatively for solid organ injuries. The mean age of the study population was 46.15 ± 16.77 years, with most patients aged over 50 years, indicating an older demographic than that reported in the studies by **Patel P, et. al; 2016** and **Behera BK, et. al; 2024,** and **Mukharjee S, et. al; 2024**, where blunt abdominal trauma predominantly affects younger adults between 20 and 40 years of age. Unlike earlier reports that demonstrated marked male predominance because of greater occupational exposure and road traffic accidents, the present study observed an almost equal distribution of males and females, suggesting possible regional and demographic differences in injury patterns. The mechanisms of injury were also relatively evenly distributed among assault, falls, road traffic accidents, and bicycle-related trauma, whereas previous studies consistently identified road traffic accidents as the principal cause of blunt abdominal trauma worldwide. These findings emphasized that local epidemiological characteristics may significantly influence the demographic profile and injury mechanisms observed in trauma patients managed non-operatively [12-14]. The liver was the most frequently injured organ, followed by the kidney, pancreas, and spleen. This pattern is generally consistent with previous literature identifying the liver and spleen as the most injured abdominal solid organs because of their anatomical location and rich vascularity, although the relatively higher frequency of renal and pancreatic injuries in the present study differs from several published reports. Most injuries were classified as low-grade according to the American Association for the Surgery of Trauma (AAST) grading system, with Grades I and II accounting for more than two-thirds of all injuries. Neither the injured organ nor the mechanism of trauma demonstrated a significant association with injury grade, indicating that injury severity was independent of these factors within the study population**. Giannopoulos GA, et. al; 2009** and **Chowdhary SA, et. al; 2024,** reported a greater proportion of Grade II and III injuries; the present cohort exhibited a comparatively milder injury profile, which may have contributed to the favorable outcomes achieved through conservative management [15,16].

All patients included in the study were hemodynamically stable at admission, fulfilling the primary criterion for non-operative management. Mean systolic and diastolic blood pressures remained within normal physiological limits, oxygen saturation exceeded 94% in all patients, and no patient presented with hypotension requiring immediate surgical intervention. Admission vital signs showed no statistically significant differences across AAST injury grades, reinforcing previous evidence that physiological stability rather than injury grade alone determines eligibility for conservative treatment. Similarly, mental status and abdominal examination findings demonstrated no significant association with injury severity. Most patients remained conscious or only mildly drowsy, while abdominal examination predominantly revealed mild tenderness despite varying injury grades. **Nair IP. 2020** and **Ibrahim W, et. al; 2020,** supported earlier investigations that indicated clinical examination alone may underestimate the severity of intra-abdominal injury, thereby emphasizing the indispensable role of contrast-enhanced computed tomography (CECT) in accurately grading injuries and guiding treatment decisions in hemodynamically stable patients [17,18].

Serial laboratory evaluation throughout hospitalization demonstrated significant yet predictable hematological changes. Mean hemoglobin, platelet count, and lymphocyte percentage declined progressively from Day 1 to Day 5, reflecting physiological responses to trauma, fluid resuscitation, and healing processes. Despite these statistically significant reductions, none of the patients developed clinical deterioration requiring operative intervention. Correlation analysis demonstrated a weak but significant negative association between AAST grade and both hemoglobin and platelet counts, indicating that higher-grade injuries were associated with greater hematological decline. Conversely, lymphocyte percentage showed a mild positive correlation with injury severity, suggesting trauma-related immunological modulation. **Ibrahim W et al. (2020) and John S et al. (2016)** reported that serial monitoring of hemoglobin and complete blood counts was considered essential for detecting occult bleeding, assessing treatment response, and identifying patients at risk of failure of conservative management.

Stable laboratory trends, together with preserved hemodynamic status, have consistently been associated with successful non-operative outcomes [18,19].

One of the most important findings of the present study was the exceptionally high success of conservative treatment. All 87 patients recovered without requiring operative intervention, resulting in a non-operative management success rate of 100%. This outcome exceeds the success rates of approximately 90–95% reported in most contemporary studies and compares favorably with prospective investigations documenting success rates of nearly 92% among carefully selected hemodynamically stable patients. The excellent results observed in the present study may be attributed to appropriate patient selection, predominance of low-grade injuries, meticulous clinical observation, serial laboratory monitoring, timely radiological assessment, and strict adherence to institutional management protocols. **John S, et. al; 2016** and **Coccolini F, et. al; 2017** reinforced the growing evidence supporting conservative management as the preferred treatment strategy for stable patients with blunt abdominal solid organ injuries while minimizing the risks associated with unnecessary laparotomy, postoperative complications, prolonged hospitalization, and loss of organ function [19,20].

Overall, the findings of this study strengthen current evidence supporting non-operative management as a safe, effective, and organ-preserving strategy for hemodynamically stable patients with blunt abdominal solid organ injuries. The absence of treatment failure, combined with favorable clinical and laboratory outcomes, demonstrates that careful patient selection, continuous hemodynamic surveillance, serial hematological assessment, and appropriate radiological evaluation are fundamental to successful conservative management. These observations are consistent with contemporary trauma guidelines advocating individualized, evidence-based treatment protocols. Furthermore, the study provides valuable regional data that may assist tertiary care centers in refining institutional management strategies, reducing unnecessary surgical interventions, optimizing resource utilization, and improving patient outcomes in resource-limited healthcare settings [12,18,20].

CONCLUSION

The present study demonstrates that non-operative management is a safe, effective, and reliable approach for hemodynamically stable patients with blunt abdominal solid organ injuries. Most patients had low-to-moderate AAST injury grades, with injury severity showing no significant association with the mechanism of trauma or the injured organ. Radiological evaluation using contrast-enhanced computed tomography proved essential for accurate assessment, while serial laboratory parameters, including hemoglobin, platelet count, and lymphocyte levels, correlated significantly with injury severity. The 100% success rate of conservative management supports its wider implementation in tertiary trauma centers, minimizing surgical risks, preserving organ function, reducing healthcare costs, and promoting favorable patient outcomes.

CLINICAL SIGNIFICANCE

The clinical significance of this study lies in its potential to bridge the gap between research findings and practical healthcare applications. It emphasizes the importance of translating scientific observations into meaningful improvements in patient care, diagnosis, and treatment outcomes. By highlighting real world relevance, the study contributes to evidence based medical practice and supports informed clinical decision making. Ultimately, the findings aim to enhance patient quality of life, optimize therapeutic strategies, and promote better disease management in clinical settings.

ABBREVIATIONS

BAT: Blunt Abdominal Trauma
NOM: Non-Operative Management
AAST: American Association for the Surgery of Trauma
CECT: Contrast-Enhanced Computed Tomography
CI: Confidence Interval
Hb: Hemoglobin
PLT: Platelet Count
LYM: Lymphocyte Percentage
SPSS: Statistical Package for the Social Sciences

AUTHOR INFORMATION

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AUTHOR CONTRIBUTIONS

All authors significantly contributed to the study conception and design, data acquisition, or data analysis and interpretation. They participated in drafting the manuscript or critically revising it for important intellectual content, consented to its submission to the current journal, provided final approval for the version to be published, and accepted responsibility for all aspects of the work. Additionally, all authors meet the authorship criteria outlined by the International Committee of Medical Journal Editors (ICMJE) guidelines.

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CONFLICT OF INTEREST

Authors declared that there is no conflict of interest.

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None

ETHICAL APPROVAL & CONSENT TO PARTICIPATE

All necessary consent & approval was obtained by authors.

CONSENT FOR PUBLICATION

All necessary consent for publication was obtained by authors.

DATA AVAILABILITY

All data generated and analyzed are included within this research article. The datasets utilized and/or analyzed in this study can be obtained from the corresponding author upon a reasonable request.

USE OF ARTIFICIAL INTELLIGENCE (AI) & LARGE LANGUAGE MODEL (LLM)

The authors confirm that no AI & LLM tools were used in the writing or editing of the manuscript, and no images were altered or manipulated using AI & LLM.

AUTHOR'S NOTE

This article serves as an important educational tool for the scientific community, offering insights that may inspire future research directions. However, they should not be relied upon independently when making treatment decisions or developing public health policies.

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