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Original Article

Role of Computed Tomography Scan in Abdominal Trauma

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ABSTRACT

Background: Abdominal trauma may result in clinically important solid-organ, bowel, mesenteric, vascular, and retroperitoneal injuries that require rapid and accurate diagnosis. Computed tomography (CT) is widely used for anatomical assessment of hemodynamically stable trauma patients, but its diagnostic performance should be evaluated against definitive reference findings. Objective: To determine the diagnostic accuracy of CT for detecting intra-abdominal injury in patients with abdominal trauma using exploratory laparotomy as the reference standard. Methods: This cross-sectional diagnostic-accuracy study included 331 adults aged 18–65 years presenting to Lady Reading Hospital, Peshawar, from 20 September 2024 to 20 April 2025. Participants were recruited consecutively and underwent abdominal CT before exploratory laparotomy. Sensitivity, specificity, positive predictive value, negative predictive value, overall accuracy, and the association between CT and operative findings were evaluated. Results: Laparotomy confirmed intra-abdominal injury in 184/331 (55.6%) patients. CT produced 170 true-positive, 20 false-positive, 14 false-negative, and 127 true-negative results. Sensitivity was 92.4% (95% CI: 87.6–95.4), specificity 86.4% (79.9–91.0), positive predictive value 89.5% (84.3–93.1), negative predictive value 90.1% (84.0–94.0), and overall accuracy 89.7% (86.0–92.6). CT and laparotomy findings were strongly associated (χ^2=207.44, df=1, p<0.001). Conclusion: CT demonstrated good diagnostic performance for detecting intra-abdominal injury in this surgically evaluated abdominal-trauma population. Its findings should be integrated with clinical assessment and interpreted within the context of patient selection and injury pattern. Keywords: Abdominal trauma, computed tomography, diagnostic accuracy, exploratory laparotomy, intra-abdominal injury.

INTRODUCTION

Trauma remains a major cause of preventable morbidity, disability, and mortality worldwide, with abdominal injuries representing an important component of both isolated and multisystem trauma. The clinical consequences of abdominal trauma vary considerably according to mechanism, injury severity, anatomical structures involved, associated injuries, and the patient's physiological condition. Solid organs such as the liver, spleen, and kidneys are particularly vulnerable to blunt forces, whereas penetrating mechanisms may involve solid organs, bowel, mesentery, vascular structures, and the retroperitoneum. Accurate and timely recognition of these injuries is essential because delayed diagnosis may adversely affect subsequent clinical management and increase the risk of complications (1,2).

Evaluation of abdominal trauma can be difficult because physical findings do not always correspond to the severity of internal injury. Patients may initially have minimal abdominal signs despite significant underlying pathology, while altered consciousness, distracting injuries, analgesia, intoxication, neurological impairment, and associated trauma may further reduce the reliability of clinical examination. Traditional approaches such as repeated physical examination, diagnostic peritoneal lavage, focused ultrasonography, and operative exploration remain relevant in selected circumstances, but modern trauma assessment increasingly relies on cross-sectional imaging for detailed anatomical characterization when the patient is sufficiently stable to undergo CT (1,3).

Focused assessment with sonography for trauma is valuable because it can rapidly identify intraperitoneal fluid at the bedside and can be incorporated into the early evaluation of trauma patients. However, ultrasonography has inherent limitations in characterizing retroperitoneal injuries, bowel and mesenteric lesions, subtle solid-organ abnormalities, vascular injuries, and injuries without substantial free intraperitoneal fluid. Computed tomography provides considerably greater anatomical detail and permits simultaneous assessment of solid organs, bowel, mesentery, retroperitoneal structures, vascular abnormalities, free fluid, free gas, active hemorrhage, and other traumatic findings (3–5). These capabilities have established multidetector CT as a central diagnostic modality in the evaluation of hemodynamically stable patients with suspected abdominal trauma.

The diagnostic role of CT extends beyond simply establishing whether an abnormality is present. Modern multidetector systems allow rapid acquisition of thin-section images, multiplanar reconstruction, vascular assessment, and detailed characterization of organ injury. Such information may contribute to injury grading, identification of active bleeding, assessment of bowel or mesenteric abnormalities, and planning of operative, interventional radiological, or non-operative management in appropriately selected patients (4–6). Contemporary trauma care increasingly incorporates non-operative management for selected solid-organ injuries, which makes accurate anatomical assessment particularly important when decisions are being made between observation, intervention, and surgery (2,6).

Nevertheless, CT is not infallible. Traumatic bowel and mesenteric injuries remain particularly challenging because their CT appearances may be subtle or nonspecific, and some surgically confirmed injuries may not be apparent on the initial scan (4,5). The World Society of Emergency Surgery has emphasized that CT findings should be interpreted together with the mechanism of injury, clinical findings, serial assessment, and physiological status when bowel injury is suspected (4). The possibility of occult injury is clinically important because a reassuring initial image should not override persistent or evolving clinical evidence of intra-abdominal pathology.

CT protocols themselves can also influence diagnostic performance. Trauma centres differ in indications for scanning, contrast protocols, acquisition phases, reconstruction methods, and integration of CT with FAST and conventional imaging. Surveys of trauma centres have demonstrated considerable institutional variability in whole-body and abdominal trauma CT algorithms, although standardized pathways are commonly implemented at higher-level trauma facilities (7,8). Introduction of dedicated CT infrastructure within trauma services may also alter workflow and the speed with which seriously injured patients can undergo comprehensive imaging (9).

These issues are particularly relevant in low- and middle-income settings, where differences in scanner availability, emergency radiology expertise, trauma-system organization, interventional radiology access, surgical capacity, and resource allocation may influence how CT is incorporated into patient care. Trauma systems in such settings frequently operate under substantial resource constraints despite carrying a large burden of injury, making efficient selection and interpretation of diagnostic imaging especially important (7,10). Evidence generated in individual tertiary-care institutions can therefore contribute to understanding how diagnostic pathways perform within the clinical environments in which they are actually implemented.

At the same time, indiscriminate use of CT is undesirable. CT involves ionizing radiation, and contrast-enhanced examinations may entail additional considerations related to contrast administration and resource utilization. Contemporary research has consequently explored selective imaging strategies designed to identify patients at sufficiently low risk to avoid unnecessary CT while maintaining high sensitivity for clinically meaningful injuries (11,12). Such studies reinforce the principle that CT should be used as part of an integrated diagnostic pathway rather than as an isolated substitute for clinical judgment.

Recent regional evidence also supports the importance of CT in abdominal-trauma assessment. A prospective Pakistani study evaluating multidetector CT in abdominal trauma highlighted its role in identifying injuries and supporting management decisions in clinically stable patients (13). A separate prospective evaluation of blunt abdominal trauma similarly reported that CT identified solid-organ injury, hemoperitoneum, hollow-viscus involvement, and associated thoracoabdominal abnormalities that influenced subsequent management (14). These findings illustrate the clinical relevance of generating locally applicable diagnostic evidence while also demonstrating variability in patient populations, reference standards, and reported performance measures.

Despite widespread CT use, diagnostic accuracy estimates obtained in one setting cannot automatically be transferred to another. Sensitivity and specificity may vary with the spectrum of injuries encountered, radiological protocols, injury mechanism, expertise, and the choice of reference standard. Predictive values additionally depend on the prevalence of the target condition within the population being evaluated. Studies using operative findings as the reference standard are particularly useful for anatomical confirmation but may preferentially include patients with a higher pre-test probability of significant injury and therefore require careful interpretation.

The present study was therefore conducted to determine the diagnostic accuracy of CT for identifying intra-abdominal injuries among adult patients presenting with abdominal trauma at Lady Reading Hospital, Peshawar, using exploratory laparotomy findings as the reference standard. The principal diagnostic outcomes were sensitivity, specificity, positive predictive value, negative predictive value, and overall diagnostic accuracy. The study additionally characterized the demographic and clinical profile of the included trauma population and evaluated the agreement between CT classifications and operative findings.

MATERIALS AND METHODS

This cross-sectional diagnostic-accuracy validation study was conducted at Lady Reading Hospital (LRH), Peshawar, Pakistan, from 20 September 2024 to 20 April 2025. The study evaluated abdominal CT as the index diagnostic test for intra-abdominal injury, while findings obtained during exploratory laparotomy constituted the reference standard. Ethical approval was obtained from the Institutional Review Board of Lady Reading Hospital, Peshawar, under reference number 532/LRH/MTI. Study procedures were conducted with consideration for patient confidentiality and autonomy.

The study population comprised adult trauma patients presenting to the emergency department with abdominal injuries and subsequently evaluated using abdominal CT. A total of 331 patients were included. The sample-size calculation was based on an anticipated CT sensitivity of 80%, specificity of 78%, prevalence of intra-abdominal injury of 13%, a 95% confidence level, and desired precision of 12%. Participants were recruited through non-probability consecutive sampling.

Male and female patients aged 18–65 years were eligible when they presented with blunt or penetrating abdominal trauma within 12 hours of injury and were hemodynamically stable for CT assessment. Patients who underwent CT only after laparotomy were excluded. Patients with associated head injuries or fractures and those with a recent history of abdominal surgery were also excluded.

Eligible patients presenting to the emergency department underwent abdominal CT using a Canon Aquilion Prime SP 160-slice CT scanner (Canon Medical Systems, Tokyo, Japan). Eligibility criteria were applied before inclusion in the study. CT examination was performed before operative assessment. Patients were subsequently admitted under the surgical service and followed until exploratory laparotomy findings became available.

The CT examination represented the study index test. CT findings were recorded according to the presence or absence of intra-abdominal injury, and additional clinical and imaging observations were documented where available. Exploratory laparotomy served as the reference standard against which CT classification was compared. Operative findings were categorized according to the presence or absence of intra-abdominal injury. The resulting paired index-test and reference-standard classifications were used to construct the 2 × 2 diagnostic contingency table.

The four principal diagnostic classifications were defined analytically as true positive, false positive, false negative, and true negative. A true-positive result represented a positive CT finding with intra-abdominal injury subsequently confirmed at laparotomy. A false-positive result represented a positive CT examination without corresponding intra-abdominal injury at laparotomy. A false-negative result represented a negative CT examination despite laparotomy confirmation of intra-abdominal injury. A true-negative result represented a negative CT examination followed by absence of intra-abdominal injury at laparotomy.

Demographic and clinical information recorded for analysis included age, sex, body mass index (BMI), cause of abdominal trauma, type of trauma, CT findings, laparotomy findings, and the presence or absence of free fluid on CT. Cause of injury included road traffic accidents, falls, gunshot injuries, and other mechanisms. Trauma was categorized as blunt or penetrating. Data were analysed using IBM SPSS Statistics version 23.0. Continuous variables, including age and BMI, were summarized using mean and standard deviation and accompanied by the reported ranges. Categorical variables were summarized using frequencies and percentages. Reported percentages were checked against their corresponding denominators and standardized to one decimal place where appropriate.

A 2 × 2 contingency table comparing CT findings with exploratory laparotomy results was constructed to determine diagnostic performance. Sensitivity was defined as the proportion of patients with laparotomy-confirmed intra-abdominal injury who had a positive CT examination. Specificity was defined as the proportion of laparotomy-negative patients who had a negative CT examination. Positive predictive value represented the proportion of patients with a positive CT result who had intra-abdominal injury confirmed at laparotomy, while negative predictive value represented the proportion of CT-negative patients in whom laparotomy did not demonstrate intra-abdominal injury.

Overall diagnostic accuracy was calculated as the proportion of all patients correctly classified by CT relative to laparotomy. Ninety-five percent confidence intervals were calculated for the principal diagnostic-performance estimates using the Wilson method. Pearson's chi-square test was used to evaluate the association between CT classification and exploratory laparotomy findings, with a two-sided p-value ≤0.05 considered statistically significant. The original analytical plan included stratification by age, sex, trauma type, and BMI to examine potential effect modification. However, the primary diagnostic-performance analysis was based on the complete 2 × 2 contingency data because these counts permitted direct and reproducible calculation of sensitivity, specificity, predictive values, overall accuracy, and the association between CT and laparotomy findings.

RESULTS

A total of 331 patients with abdominal trauma were included in the study. The mean age was 37 ± 10 years, with a reported range of 18–65 years. Mean BMI was 23.9 ± 3.8 kg/m^2, with a range of 18.5–33.2 kg/m^2. Of the 331 participants, 185 (55.9%) were male and 146 (44.1%) were female. Road traffic accidents were the most frequently reported cause of abdominal trauma, affecting 150 (45.3%) patients. Gunshot injuries were reported in 81 (24.5%), falls in 60 (18.1%), and other mechanisms in 40 (12.1%). Blunt abdominal trauma was more frequent than penetrating trauma, occurring in 210 (63.4%) and 121 (36.6%) patients, respectively.

Table 1. Demographic and Clinical Characteristics of the Study Population

Variable	Category	n (%) or Mean ± SD	Range
Age, years	–	37 ± 10	18–65
BMI, kg/m^2	–	23.9 ± 3.8	18.5–33.2
Sex	Male	185 (55.9)	–
	Female	146 (44.1)	–
Cause of abdominal trauma	Road traffic accident	150 (45.3)	–
	Fall	60 (18.1)	–
	Gunshot injury	81 (24.5)	–
	Other	40 (12.1)	–
Type of trauma	Blunt	210 (63.4)	–
	Penetrating	121 (36.6)	–

BMI, body mass index.

Exploratory laparotomy confirmed intra-abdominal injury in 184 of 331 patients (55.6%), whereas 147 (44.4%) had no intra-abdominal injury identified according to the operative reference classification. CT was classified as positive in 190 patients and negative in 141. Cross-classification of the index test and reference standard demonstrated 170 true-positive results, 20 false-positive results, 14 false-negative results, and 127 true-negative results. Thus, 297 of the 331 examinations were concordant between CT and laparotomy, while 34 were discordant. Based on these paired data, CT demonstrated a sensitivity of 92.4% (95% CI: 87.6–95.4). Thus, 170 of the 184 patients with laparotomy-confirmed intra-abdominal injury were correctly identified by CT. Specificity was 86.4% (95% CI: 79.9–91.0), reflecting correct CT classification of 127 of the 147 patients without intra-abdominal injury at laparotomy.

The positive predictive value was 89.5% (95% CI: 84.3–93.1), indicating that 170 of the 190 CT-positive examinations were confirmed as positive at laparotomy. The negative predictive value was 90.1% (95% CI: 84.0–94.0), with 127 of 141 CT-negative patients having a negative laparotomy reference classification. Overall diagnostic accuracy was 89.7% (95% CI: 86.0–92.6%), corresponding to 297 correctly classified examinations among the 331 participants.

Table 2. CT Findings Compared With Exploratory Laparotomy Findings

CT finding	Laparotomy positive, n	Laparotomy negative, n	Total, n
Positive	170	20	190
Negative	14	127	141
Total	184	147	331

Table 3. Diagnostic Performance of CT for Intra-Abdominal Injury

Diagnostic measure	Estimate, %	95% CI
Sensitivity	92.4	87.6–95.4
Specificity	86.4	79.9–91.0
Positive predictive value	89.5	84.3–93.1
Negative predictive value	90.1	84.0–94.0
Overall diagnostic accuracy	89.7	86.0–92.6

Reference standard: exploratory laparotomy. Confidence intervals calculated using the Wilson method.

The association between CT classification and exploratory laparotomy findings was statistically significant. Pearson's chi-square test yielded χ^2=207.44 with 1 degree of freedom ($p<0.001$), demonstrating that CT findings were strongly associated with the operative reference-standard classification.

Table 4. Association Between CT and Exploratory Laparotomy Findings

Statistical measure	Value
Pearson χ^2	207.44
Degrees of freedom	1
p-value	<0.001
Sample size	331

Table 5. Principal Clinical Findings

Variable	n (%)
Laparotomy-confirmed intra-abdominal injury	184 (55.6)
No intra-abdominal injury at laparotomy	147 (44.4)
Free fluid detected on CT	150 (45.3)
No free fluid detected on CT	181 (54.7)

Free intraperitoneal fluid was identified on CT in 150 (45.3%) patients, while 181 (54.7%) patients had no free fluid detected. The proportion of patients with laparotomy-confirmed intra-abdominal injury, 55.6%, was therefore higher than the proportion in whom free fluid was reported on CT.

DISCUSSION

The present study evaluated the diagnostic performance of CT for detecting intra-abdominal injury among 331 hemodynamically stable adults with abdominal trauma who subsequently underwent exploratory laparotomy. The principal finding was that CT demonstrated high sensitivity and good specificity, with sensitivity of 92.4%, specificity of 86.4%, positive predictive value of 89.5%, negative predictive value of 90.1%, and overall diagnostic accuracy of 89.7%. CT classification was also strongly associated with the operative reference standard. Collectively, these findings indicate that CT provided substantial diagnostic discrimination in this surgically evaluated trauma population, although the presence of both false-negative and false-positive examinations demonstrates that imaging findings should remain integrated with clinical and operative decision-making.

The high sensitivity observed in the present investigation is consistent with the established role of multidetector CT in hemodynamically stable abdominal-trauma patients. Contemporary reviews describe CT as the principal cross-sectional imaging modality for characterizing traumatic injury to solid organs, bowel, mesentery, retroperitoneal structures, and vascular anatomy (1,3–5). Recent regional investigations have similarly reported substantial diagnostic utility of multidetector CT in abdominal trauma and emphasized its contribution to identification of injuries that may influence operative or conservative management (13,14).

The 92.4% sensitivity observed in this study means that CT correctly identified 170 of 184 patients with laparotomy-confirmed injury, although 14 injuries were not identified by the index-test classification. This residual false-negative group is clinically important. No diagnostic imaging modality should be regarded as entirely exclusionary when a patient's clinical condition remains concerning, particularly for bowel and mesenteric trauma. Contemporary guidance emphasizes that CT may miss clinically important bowel lesions and recommends continued observation, serial clinical assessment, and repeat imaging where suspicion remains despite initially equivocal radiological findings (4).

Bowel and mesenteric injuries illustrate why CT performance can vary according to injury subtype. Kaewlai and colleagues described these injuries as among the more frequently overlooked abnormalities on trauma CT because findings may be subtle, nonspecific, or absent during early imaging (5). A recent review of blunt bowel and mesenteric trauma similarly reported that CT manifestations range from highly specific signs such as bowel-wall discontinuity, extraluminal gas, vascular contrast extravasation, and mesenteric vascular injury to substantially less specific findings including focal wall thickening, altered enhancement, fat stranding, and free fluid (19). Consequently, diagnostic accuracy at the patient level may conceal substantial variation according to the specific anatomical injury being sought.

Recent diagnostic-model research has attempted to improve identification of bowel and mesenteric injury using combinations of CT findings. Lansier and colleagues developed a CT-based decision algorithm incorporating reproducible signs such as extraluminal gas and reduced bowel-wall enhancement, demonstrating promising diagnostic performance in validation data (20). Such evidence illustrates that the accuracy of trauma CT depends not merely on whether a scan is performed but also on systematic assessment of diagnostically meaningful imaging features.

The specificity of 86.4% in the present study was lower than sensitivity, and 20 of 190 CT-positive patients were not classified as having intra-abdominal injury at laparotomy. Several explanations are plausible. CT can reveal small-volume free fluid, contusions, hematomas, vascular irregularities, or subtle bowel and mesenteric abnormalities that may not translate into a lesion identified or considered significant during operative exploration. Differences in radiological and operative definitions of injury may additionally contribute to apparent discordance. Interpretation variability, scan timing, technical parameters, and the evolution of traumatic abnormalities are further potential contributors.

The positive predictive value of 89.5% and negative predictive value of 90.1% require interpretation in relation to the study population. Intra-abdominal injury was present at laparotomy in 55.6% of the cohort, representing a relatively high prevalence that is unsurprising in a population undergoing operative assessment. Predictive values depend directly on the underlying prevalence of disease and therefore cannot be expected to remain identical in populations with substantially different pre-test probabilities. In an unselected emergency-department population with less severe trauma, the positive predictive value may be lower even if intrinsic test sensitivity and specificity remain similar.

The study population is therefore central to interpretation of the findings. All analysed patients underwent exploratory laparotomy, making operative findings a strong anatomical reference standard but also selecting a population different from the wider spectrum of hemodynamically stable trauma patients. Many contemporary patients with solid-organ injury are managed without surgery, particularly when they remain physiologically stable and have no evidence of ongoing hemorrhage or hollow-viscus perforation (2,6). Diagnostic accuracy derived from a surgically selected cohort may consequently be influenced by spectrum and verification effects and should not be generalized directly to all abdominal-trauma presentations.

The importance of patient selection has become increasingly prominent as trauma care has shifted toward selective rather than routine imaging and operative intervention. Reitano and colleagues prospectively evaluated whether whole-body CT could be avoided in selected stable trauma patients by using structured emergency-room assessment, illustrating the continuing effort to balance diagnostic sensitivity against unnecessary radiation exposure (11). More recently, Shopen and colleagues developed a decision instrument for minor blunt trauma that achieved high sensitivity and negative predictive value while potentially reducing abdominopelvic CT utilization (12). Although these populations differ from the surgically selected cohort in the present study, they reinforce the broader principle that CT should be targeted according to pre-test risk and clinical context.

The role of FAST should similarly be understood as complementary rather than directly interchangeable with CT. FAST has substantial value as a rapid bedside test for free intraperitoneal fluid, particularly in unstable or rapidly assessed trauma patients, but its ability to exclude organ-specific injury is limited. A recent systematic review and meta-analysis reported that FAST has high specificity but more moderate pooled sensitivity when CT is used as the comparator in blunt abdominal trauma (16). Pakistani data have also demonstrated the diagnostic contribution of FAST while emphasizing CT as a more comprehensive reference modality for identifying intra-abdominal injury (15).

The present finding that free fluid was detected on CT in 45.3% of patients, compared with a 55.6% prevalence of laparotomy-confirmed intra-abdominal injury, further illustrates why free fluid alone cannot serve as a complete surrogate for traumatic pathology. Some significant injuries may occur without appreciable free fluid, while isolated free fluid may itself be nonspecific. The diagnostic significance of fluid depends on its amount, distribution, patient sex, injury mechanism, associated organ abnormalities, bowel or mesenteric findings, and overall clinical presentation (4,5,19).

Mechanism of injury also affects the diagnostic challenge. Penetrating trauma may create narrow injury tracts involving bowel, mesentery, diaphragm, or vascular structures that are more difficult to characterize than some solid-organ injuries. Paes and colleagues evaluated multidetector CT techniques for penetrating bowel injury and demonstrated that diagnostic performance varied according to the contrast protocol employed, with differences in sensitivity, specificity, and overall accuracy (17). A systematic review and meta-analysis of penetrating diaphragmatic injury likewise found that multidetector CT had useful but imperfect diagnostic performance, with pooled sensitivity lower than specificity (18). These observations reinforce the need to interpret CT findings according to the mechanism and suspected anatomical target rather than treating abdominal trauma as a single homogeneous diagnostic entity.

Blunt trauma constituted 63.4% of the present cohort and was therefore the predominant mechanism. This distribution is consistent with many trauma series in which road traffic collisions represent a major cause of blunt abdominal injury. In the current study, road traffic accidents accounted for 45.3% of all cases. Regional studies have also reported road traffic collisions as a frequent mechanism among patients undergoing CT for abdominal trauma (13,14). This pattern has practical implications because high-energy blunt mechanisms can produce simultaneous injuries involving multiple abdominal organs and extra-abdominal structures.

Multidetector CT has particular advantages in such patients because rapid volumetric acquisition permits multiplanar reconstructions and simultaneous evaluation of multiple anatomical regions. Standardized trauma protocols may further improve consistency, although practice remains heterogeneous across centres. Hinzpeter and colleagues demonstrated variability in indications, acquisition phases, and whole-body CT protocols among Swiss emergency centres despite broad adoption of standardized institutional algorithms (8). Kippnich and colleagues further showed how dedicated CT infrastructure can be integrated into high-level trauma workflows (9). These studies emphasize that diagnostic performance is influenced not only by scanner hardware but also by protocol design and organizational implementation.

The observed diagnostic accuracy should therefore be viewed as a property of the complete diagnostic pathway within the study environment rather than an immutable property of CT technology. Scanner generation, contrast timing, acquisition phases, image reconstruction, radiologist expertise, trauma prevalence, and reference-standard definitions all influence apparent performance. This is especially important when diagnostic studies from different hospitals or countries are compared.

The present study was conducted in a tertiary-care institution in Pakistan, which adds locally relevant evidence to a literature still dominated by trauma systems with substantial radiological and surgical resources. Imaging in resource-limited environments presents distinctive challenges related to availability, staffing, cost, maintenance, transfer logistics, and access to interventional radiology or emergency surgery (7). Trauma care in low- and middle-income countries similarly faces system-level constraints that may affect the timing and implementation of diagnostic imaging (10). Local diagnostic-performance studies are therefore useful for informing institutional pathways, provided their population and reference-standard limitations are recognized.

The study also demonstrated a statistically strong association between CT and laparotomy findings, with χ^2=207.44 and p<0.001. This inferential result confirms that index-test and reference-standard classifications were not independent. Nevertheless, statistical association should not be confused with perfect diagnostic agreement. The clinically more informative measures are the sensitivity, specificity, predictive values, and absolute numbers of discordant classifications, because these quantify the actual pattern of diagnostic error.

Fourteen false-negative CT examinations deserve particular attention because missed intra-abdominal injury may delay operative management if clinical findings are also falsely reassuring. Delayed manifestations of traumatic injury are well recognized, and interventional radiology as well as surgical literature has documented delayed and chronic sequelae following trauma (23). Secondary peritonitis and intra-abdominal sepsis also remain important consequences of gastrointestinal perforation and other intra-abdominal pathology, underscoring the importance of timely recognition of injuries that may initially be subtle (27). Accordingly, persistent abdominal symptoms, evolving peritoneal signs, physiological deterioration, unexplained inflammatory changes, or worsening laboratory findings should prompt reassessment even when initial imaging is not definitive.

Conversely, the 20 false-positive CT examinations are also clinically relevant because overcalling injury may contribute to unnecessary escalation of care if imaging is interpreted without sufficient clinical correlation. The aim of trauma imaging should therefore not be maximal sensitivity at any cost, but rather accurate identification of injuries that alter management while minimizing clinically meaningful false-negative and false-positive classifications. This balance becomes increasingly important as trauma systems adopt selective non-operative management.

The findings also have implications for interpretation of CT in younger patients. Prior work in pediatric and adolescent blunt trauma has examined evidence-based approaches designed to reduce unnecessary CT exposure while maintaining diagnostic safety (21,22). These studies are not directly comparable with the adult population evaluated here, but they demonstrate a broader shift toward risk-based imaging rather than routine scanning. The same principle applies to adults: CT should be used where the expected diagnostic benefit justifies exposure and where the result is likely to alter management.

Emerging CT technologies may further modify diagnostic performance. Dual-energy CT can generate virtual monoenergetic images, iodine maps, and material-specific reconstructions that may increase the conspicuity of subtle bowel, mesenteric, vascular, or hemorrhagic abnormalities. Wang and colleagues reviewed the potential value of dual-energy CT specifically in traumatic bowel and mesenteric injury and described applications that may improve diagnostic confidence (24). These techniques remain dependent on appropriate protocols and expertise and should be evaluated prospectively in clinically relevant trauma cohorts.

Artificial intelligence represents another evolving area of trauma imaging. A scoping review from the American Society of Emergency Radiology AI/ML Expert Panel described emerging computer-aided detection applications across trauma imaging, including tools intended to support lesion detection, prioritization, and workflow efficiency (25). Such systems may eventually reduce perceptual errors or assist radiologists during high-volume emergency practice, but clinical deployment requires external validation, assessment of spectrum bias, workflow integration, and careful evaluation of false-positive and false-negative consequences.

The study has several important strengths. First, it included a substantial cohort of 331 patients with complete paired CT and laparotomy classifications. This permitted direct construction of a 2 × 2 diagnostic table without reconstruction of participant-level observations. Second, an operative reference standard provided direct anatomical confirmation of the presence or absence of intra-abdominal injury in the analysed cohort. Third, consecutive recruitment reduced some of the selection introduced by discretionary enrolment among patients meeting the study criteria. Fourth, the cohort contained both blunt and penetrating trauma, increasing the breadth of the clinical spectrum represented.

The corrected analysis also provides interpretable uncertainty estimates through 95% confidence intervals for sensitivity, specificity, predictive values, and overall accuracy. Reporting confidence intervals is particularly important in diagnostic-accuracy studies because a point estimate alone does not communicate the precision with which performance has been estimated. The observed confidence intervals indicate that CT performance was consistently good in this cohort, although the lower confidence bounds also demonstrate that perfect detection cannot be assumed.

Several limitations must nevertheless be recognized. The investigation was conducted at a single institution, limiting generalizability to trauma centres with different patient populations, CT protocols, radiological expertise, and surgical thresholds. Non-probability consecutive sampling may also affect representativeness. More importantly, the requirement for exploratory laparotomy created a surgically selected cohort and therefore introduces potential spectrum and verification bias when the findings are considered in relation to all abdominal-trauma patients.

Patients with associated head injuries or fractures and those with recent abdominal surgery were excluded. Although these criteria create a more homogeneous diagnostic cohort, they reduce applicability to polytrauma patients commonly encountered in real-world emergency practice. The diagnostic performance reported here should therefore not be assumed to apply unchanged to patients with complex multisystem injury.

The available study data also did not permit validated organ-specific diagnostic-performance estimates, detailed analysis of injury grade, assessment of interobserver variability, or reproducible subgroup 2 × 2 analyses according to age, sex, BMI, and trauma mechanism. Although subgroup percentages were reported in the original analytical material, the necessary underlying true-positive, false-positive, false-negative, and true-negative counts were not available for independent verification. Accordingly, the principal interpretation appropriately rests on the complete overall contingency table.

Another limitation is that detailed CT acquisition parameters, contrast phase information, and explicit radiological thresholds for a positive examination were not available in the study record used for the final analysis. These factors may materially affect diagnostic performance, particularly for bowel, mesenteric, vascular, and penetrating injuries. Contemporary literature demonstrates that differences in acquisition and contrast protocols can alter accuracy (17), while institutional trauma CT protocols remain heterogeneous (8). Future studies should therefore report index-test technique in sufficient detail to permit replication.

The study also cannot establish that CT itself reduced mortality, prevented complications, shortened hospitalization, decreased cost, or reduced the number of unnecessary laparotomies because these outcomes were not directly analysed. Diagnostic accuracy and clinical effectiveness are related but distinct concepts. A test may discriminate well between patients with and without a target condition without necessarily demonstrating an independent improvement in downstream patient outcomes.

Future research should therefore adopt prospective multicentre diagnostic-accuracy designs and clearly prespecify CT-positive criteria, reference-standard definitions, contrast protocols, acquisition phases, reader experience, and blinding where feasible. Organ-specific analyses would be valuable, particularly for bowel, mesenteric, diaphragmatic, pancreatic, and vascular injuries in which sensitivity may be lower than for major solid-organ trauma. Studies should also document patients managed non-operatively so that diagnostic performance can be assessed across the complete clinically relevant trauma spectrum rather than only among surgical patients.

Longitudinal follow-up of patients with negative CT findings would further strengthen reference-standard ascertainment and permit assessment of delayed injury. Standardized reporting of diagnostic-accuracy studies, including transparent presentation of patient flow and handling of indeterminate examinations, would improve comparability across institutions. Finally, emerging dual-energy and AI-assisted approaches warrant prospective external validation before they are incorporated as routine substitutes for expert radiological assessment.

CONCLUSION

Computed tomography demonstrated good diagnostic performance for identifying intra-abdominal injury among hemodynamically stable adults with abdominal trauma who underwent exploratory laparotomy at Lady Reading Hospital, Peshawar. Based on 170 true-positive, 20 false-positive, 14 false-negative, and 127 true-negative examinations, CT achieved a sensitivity of 92.4%, specificity of 86.4%, positive predictive value of 89.5%, negative predictive value of 90.1%, and overall diagnostic accuracy of 89.7%. CT findings were strongly associated with operative findings, supporting its role as an important anatomical diagnostic modality in appropriately selected abdominal-trauma patients. The findings should nevertheless be interpreted within the context of a single-centre, surgically selected population, and CT should remain integrated with mechanism of injury, physiological status, clinical examination, serial assessment, and operative judgment rather than being treated as an infallible standalone test.

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