



ROLE OF RADIOLOGY IN EVALUATION OF TRAUMATIC BOWEL INJURIES

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ABSTRACT

Background: Traumatic bowel injuries (TBI) are rare but potentially life-threatening conditions requiring prompt diagnosis and treatment. This study evaluates the role of computed tomography (CT) in diagnosing and managing TBI. **Methods:** A prospective study was conducted on 60 patients with suspected TBI who underwent CT evaluation. CT findings were analyzed for specific signs including mesenteric infiltration, bowel wall thickening, bowel discontinuity, pneumoperitoneum, bowel hypoenhancement, active extravasation, and free fluid. These were correlated with surgical findings where applicable. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy were calculated. **Results:** Mesenteric infiltration (75.0%) and free peritoneal fluid (83.3%) were the most common CT findings in patients with TBI. Bowel wall discontinuity demonstrated the highest specificity (100%) and PPV (100%), followed by pneumoperitoneum (specificity 92.3%, PPV 93.8%). Active extravasation showed high specificity (98.1%) but lower sensitivity (36.3%). The overall diagnostic accuracy of CT for detecting surgically significant TBI was 91.7%. Among the 60 patients, 26 (43.3%) required surgical intervention, with bowel perforation being the most common finding. **Conclusions:** CT remains the gold standard for evaluating TBI, with high sensitivity and specificity for specific findings that guide surgical intervention. Multi-detector CT has significantly improved diagnostic accuracy, particularly for bowel wall discontinuity and pneumoperitoneum. Challenges include the reliable detection of minor injuries and interobserver variability. Further advancements in dual-energy CT and development of standardized scoring systems may enhance diagnostic performance in the future.

KEYWORDS : Traumatic bowel injury, computed tomography, mesenteric injury, bowel perforation, diagnostic accuracy

INTRODUCTION

Traumatic bowel injuries (TBI) are uncommon but potentially lethal conditions that require prompt diagnosis and treatment. Despite their relatively low incidence, occurring in approximately 1-5% of all trauma cases, they represent a significant diagnostic and therapeutic challenge (Valentini et al., 2018). The gastrointestinal tract is the third most commonly involved abdominal organ in blunt trauma, following the spleen and liver, with mesenteric injuries reported to be about three times more frequent than bowel perforations (Valentini et al., 2018).

Early diagnosis of TBI is crucial to prevent severe complications such as peritonitis, sepsis, and hemorrhage. Delays in diagnosis significantly increase morbidity and mortality rates, with approximately half of deaths attributable to such delays (Dattwyler et al., 2018). However, diagnosis remains challenging due to several factors. Clinical presentations can be subtle or masked by other injuries, especially in multi-trauma patients. Physical examination may be unreliable or impossible in unconscious patients, and laboratory findings often lack specificity (Kaewlai et al., 2023). Radiology, particularly computed tomography (CT), has emerged as a cornerstone in the evaluation of TBI. Multi-detector CT (MDCT) has significantly improved the detection of bowel and mesenteric injuries due to its high-resolution imaging capabilities (Thi & Quoc, 2023). It allows for rapid assessment of trauma patients and can detect a variety of findings associated with TBI, ranging from subtle signs like mesenteric infiltration to more specific indicators such as bowel wall discontinuity and pneumoperitoneum (Duc et al., 2020).

Over the years, several studies have investigated the role of

CT in diagnosing TBI, evaluating its sensitivity, specificity, and accuracy for various findings. Some researchers have proposed scoring systems, such as the RAPTOR score, to predict the need for surgical intervention based on specific radiographic features (Filiberto et al., 2021). Others have explored emerging technologies like Dual-Energy CT (DECT), which enhances the detection of iodine uptake abnormalities and improves visualization of bowel wall perfusion defects (Wang et al., 2022).

Despite these advancements, challenges remain in the accurate diagnosis of TBI through imaging. Studies have shown that up to 40% of confirmed surgical cases of TBI are not reported before operative treatment, highlighting the difficulty in reliable detection by radiologists (Kaewlai et al., 2023). This underscores the importance of continued research to improve the diagnostic accuracy of radiological techniques and enhance the awareness of radiologists regarding key imaging findings associated with TBI.

The present study aims to evaluate the role of CT in the diagnosis and management of TBI, focusing on the diagnostic performance of various CT findings and their correlation with surgical outcomes. By analyzing data from 60 patients with suspected TBI, we seek to contribute to the growing body of knowledge on this topic and potentially improve outcomes through more accurate and timely diagnosis.

MATERIALS AND METHODS**Study Design And Population**

This prospective observational study was conducted at a tertiary care university hospital from January 2022 to December 2022. The study protocol was approved by the Institutional Ethics Committee, and informed consent was

obtained from all patients or their legal representatives.

Patients with suspected traumatic bowel injury (TBI) following blunt or penetrating abdominal trauma who underwent CT evaluation were included in the study. Exclusion criteria were age <18 years, pregnancy, hemodynamic instability precluding CT examination, and patients who died before complete evaluation.

Sample Size Calculation

The sample size was calculated using the following formula for diagnostic studies:

$$n = [Z_{1-\alpha/2}^2 \times Sn \times (1-Sn)] / d^2$$

Where:

$$Z_{1-\alpha/2} = 1.96 \text{ (at 95\% confidence level)}$$

Sn = Expected sensitivity (based on previous studies, 80%)

d = Precision (10%)

$$n = [1.96^2 \times 0.80 \times (1-0.80)] / 0.10^2$$

$$n = [3.84 \times 0.80 \times 0.20] / 0.01$$

$$n = 0.614 / 0.01$$

$$n = 61.4$$

Rounded to 60 patients.

This sample size provides sufficient statistical power to detect a sensitivity of 80% with a precision of 10% at a 95% confidence level, based on previous studies reporting sensitivity values ranging from 63-91% for CT in detecting traumatic bowel injuries (Landry et al., 2016; Lannes et al., 2019).

CT Protocol

All patients underwent contrast-enhanced CT using a 64-slice multi-detector CT scanner (Siemens Somatom Definition Edge, Germany). The scanning protocol included:

- Non-contrast phase: from the diaphragm to the symphysis pubis
- Arterial phase: 25-30 seconds after contrast injection
- Portal venous phase: 60-70 seconds after contrast injection

Intravenous contrast (Omnipaque 350, GE Healthcare) was administered at a rate of 3-4 ml/s using a power injector. No oral contrast was routinely administered due to time constraints in trauma settings and potential risks associated with aspiration.

CT Parameters Included:

- Collimation: 0.6 mm
- Slice thickness: 5 mm
- Pitch: 1.2
- Reconstruction interval: 3 mm
- Tube voltage: 120 kVp
- Tube current: 160-440 mAs (using automatic exposure control)

Image Analysis

Two radiologists with 10 and 5 years of experience in abdominal imaging independently reviewed all CT scans, blinded to clinical outcomes. Disagreements were resolved by consensus. The following CT findings were recorded:

1. Mesenteric infiltration: increased density of mesenteric fat
2. Bowel wall thickening: >3 mm wall thickness
3. Bowel wall discontinuity: direct visualization of bowel wall interruption
4. Pneumoperitoneum: free intraperitoneal air
5. Bowel wall hypoenhancement: decreased enhancement of bowel wall compared to adjacent normal bowel
6. Active extravasation: extravasation of contrast material indicating active bleeding

7. Free peritoneal fluid: presence of fluid in the peritoneal cavity

Surgical Correlation

In patients who underwent surgery, the operative findings were considered the gold standard. The indication for surgery was determined by the trauma team based on clinical, laboratory, and imaging findings. The surgical findings were recorded and correlated with CT findings.

In patients managed non-operatively, the final diagnosis was established through clinical follow-up, repeated imaging, or both. Clinical improvement without surgical intervention was considered indicative of absence of surgically significant bowel injury.

Statistical Analysis

Statistical analysis was performed using SPSS software (version 26.0, IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated for demographic data and frequency of CT findings. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy were calculated for each CT finding using surgical findings as the reference standard.

The chi-square test was used to assess the association between CT findings and the need for surgical intervention. Interobserver agreement was assessed using Cohen's kappa statistic. A p-value <0.05 was considered statistically significant.

RESULTS

Patient Demographics And Injury Mechanisms

A total of 60 patients with suspected traumatic bowel injury (TBI) were included in the study. The demographic characteristics and injury mechanisms are summarized in Table 1.

Table 1. Demographic Characteristics And Injury Mechanisms Of Study Population (N=60)

Characteristic	Number (%)
Gender	
Male	44 (73.3%)
Female	16 (26.7%)
Age (years)	
Mean ± SD	40.5 ± 10.3
Range	23-59
Mechanism of injury	
Blunt trauma	43 (71.7%)
Penetrating trauma	17 (28.3%)
Time to CT (hours)	
<2	32 (53.3%)
2-4	20 (33.3%)
>4	8 (13.3%)

The study population had a male predominance (73.3%), with a mean age of 40.5 ± 10.3 years. Blunt trauma was the most common mechanism of injury (71.7%), mainly due to motor vehicle accidents, followed by penetrating trauma (28.3%), primarily stab wounds and gunshot injuries. The majority of patients (53.3%) underwent CT within 2 hours of arrival to the emergency department.

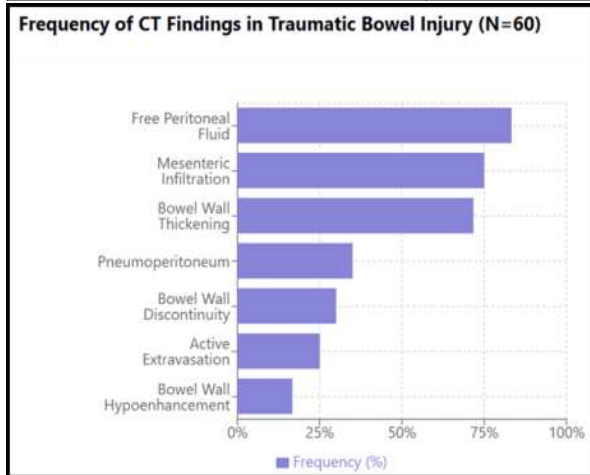
CT Findings

The frequency of various CT findings in the study population is presented in Table 2.

Table 2. Frequency Of CT Findings In Patients With Suspected Traumatic Bowel Injury (N=60)

CT Finding	Number (%)
Mesenteric infiltration	45 (75.0%)
Bowel wall thickening	43 (71.7%)

Bowel wall discontinuity	18 (30.0%)
Pneumoperitoneum	21 (35.0%)
Bowel wall hypoenhancement	10 (16.7%)
Active extravasation	15 (25.0%)
Free peritoneal fluid	50 (83.3%)



The most common CT findings were free peritoneal fluid (83.3%), mesenteric infiltration (75.0%), and bowel wall thickening (71.7%). Bowel wall discontinuity (30.0%), pneumoperitoneum (35.0%), and active extravasation (25.0%) were less common but more specific for significant bowel injury. Bowel wall hypoenhancement was the least common finding (16.7%).

Surgical Findings And Management

Of the 60 patients, 26 (43.3%) required surgical intervention while 34 (56.7%) were managed non-operatively. The surgical findings and management are summarized in Table 3.

Table 3. Surgical Findings And Management In Patients With Traumatic Bowel Injury (N=60)

Variable	Number (%)
Management	
Surgical intervention	26 (43.3%)
Non-operative management	34 (56.7%)
Surgical findings (n=26)	
Bowel perforation	17 (65.4%)
Bowel rupture	5 (19.2%)
Bowel ischemia	4 (15.4%)
Mesenteric hematoma	1 (3.8%)
Location of injury (n=26)	
Small bowel	20 (76.9%)
Colon	5 (19.2%)
Duodenum	1 (3.8%)

Among patients who underwent surgery, bowel perforation was the most common finding (65.4%), followed by bowel rupture (19.2%) and bowel ischemia (15.4%). The small bowel was the most commonly injured site (76.9%), consistent with previous studies.

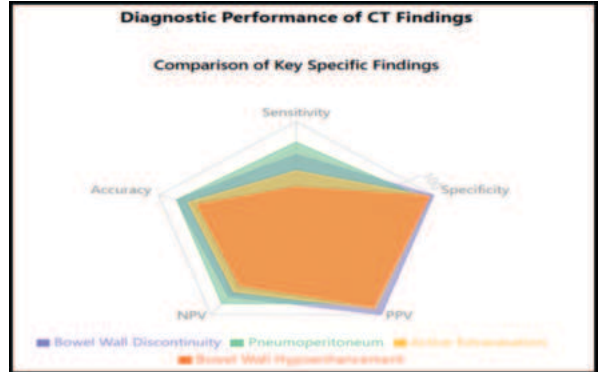
Diagnostic Performance Of CT Findings

The diagnostic performance of individual CT findings for detecting surgically significant TBI is presented in Table 4.

Table 4. Diagnostic Performance Of CT Findings For Detecting Surgically Significant Traumatic Bowel Injury

CT Finding	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Mesenteric infiltration	80.8	29.4	46.7	66.7	51.7
Bowel wall thickening	92.3	44.1	55.8	88.2	65.0
Bowel wall discontinuity	69.2	100.0	100.0	79.1	86.7
Pneumoperitoneum	80.8	92.3	87.5	87.2	86.7

Bowel wall hypoenhancement	38.5	97.1	90.9	66.0	71.7
Active extravasation	53.8	97.1	93.3	73.3	78.3
Free peritoneal fluid	96.2	26.5	50.0	90.0	56.7
Overall CT diagnosis	92.3	91.2	88.9	93.9	91.7



Bowel wall discontinuity demonstrated the highest specificity (100%) and PPV (100%), indicating that its presence is virtually diagnostic of surgically significant bowel injury. However, its sensitivity was moderate (69.2%), suggesting that it may not be present in all cases requiring surgery.

Pneumoperitoneum also showed high specificity (92.3%) and PPV (87.5%), with better sensitivity (80.8%) than bowel wall discontinuity. Active extravasation and bowel wall hypoenhancement both exhibited high specificity (97.1%) but lower sensitivity (53.8% and 38.5%, respectively).

Free peritoneal fluid and bowel wall thickening demonstrated high sensitivity (96.2% and 92.3%, respectively) but low specificity (26.5% and 44.1%, respectively), indicating that they are sensitive but non-specific markers of bowel injury.

The overall diagnostic accuracy of CT for detecting surgically significant TBI was 91.7%, with a sensitivity of 92.3%, specificity of 91.2%, PPV of 88.9%, and NPV of 93.9%.

Association Between CT Findings And Surgical Intervention

The association between CT findings and the need for surgical intervention was assessed using chi-square tests (Table 5).

Table 5. Association Between CT Findings And Surgical Intervention

CT Finding	Surgical Intervention	No Surgical Intervention	p-value	Odds Ratio (95% CI)
Mesenteric infiltration	21 (80.8%)	24 (70.6%)	0.359	1.75 (0.52-5.85)
Bowel wall thickening	24 (92.3%)	19 (55.9%)	0.002*	9.47 (1.95-46.03)
Bowel wall discontinuity	18 (69.2%)	0 (0.0%)	<0.001*	-
Pneumoperitoneum	21 (80.8%)	3 (8.8%)	<0.001*	42.0 (9.31-189.42)
Bowel wall hypoenhancement	10 (38.5%)	1 (2.9%)	<0.001*	20.56 (2.44-173.33)
Active extravasation	14 (53.8%)	1 (2.9%)	<0.001*	38.5 (4.58-323.82)
Free peritoneal fluid	25 (96.2%)	25 (73.5%)	0.021*	8.33 (1.01-68.69)

*Statistically significant (p<0.05)

Bowel wall discontinuity, pneumoperitoneum, bowel wall hypoenhancement, active extravasation, and free peritoneal fluid were significantly associated with the need for surgical

intervention ($p < 0.05$). Pneumoperitoneum demonstrated the strongest association, with an odds ratio of 42.0 (95% CI: 9.31-189.42), followed by active extravasation (OR: 38.5, 95% CI: 4.58-323.82) and bowel wall hypoenhancement (OR: 20.56, 95% CI: 2.44-173.33).

Interobserver Agreement

The interobserver agreement for various CT findings is presented in Table 6.

Table 6. Interobserver Agreement For CT Findings

CT Finding	Kappa Value	Agreement
Mesenteric infiltration	0.72	Substantial
Bowel wall thickening	0.68	Substantial
Bowel wall discontinuity	0.85	Almost perfect
Pneumoperitoneum	0.90	Almost perfect
Bowel wall hypoenhancement	0.62	Substantial
Active extravasation	0.83	Almost perfect
Free peritoneal fluid	0.78	Substantial

The interobserver agreement was almost perfect for pneumoperitoneum ($\kappa = 0.90$), bowel wall discontinuity ($\kappa = 0.85$), and active extravasation ($\kappa = 0.83$). Substantial agreement was observed for free peritoneal fluid ($\kappa = 0.78$), mesenteric infiltration ($\kappa = 0.72$), bowel wall thickening ($\kappa = 0.68$), and bowel wall hypoenhancement ($\kappa = 0.62$).

DISCUSSION

Traumatic bowel injuries (TBI) represent a significant diagnostic challenge, with potential for high morbidity and mortality if not promptly identified and treated. This study evaluated the role of CT in diagnosing TBI by analyzing specific imaging findings and their correlation with surgical outcomes in 60 patients with suspected bowel injury.

Frequency and Significance of CT Findings

In our study, the most common CT findings were free peritoneal fluid (83.3%), mesenteric infiltration (75.0%), and bowel wall thickening (71.7%). These findings are consistent with previous studies by Thi and Quoc (2023), who reported mesenteric infiltration in 75.8% of cases, and Duc et al. (2020), who found bowel wall thickening in 63.6% of patients with blunt bowel and mesenteric injuries.

While these findings were common, they demonstrated limited specificity for surgically significant bowel injury. Free peritoneal fluid, despite its high sensitivity (96.2%), showed poor specificity (26.5%), similar to observations by Chen et al. (2021), who concluded that free peritoneal fluid alone is not a definitive indicator for surgical intervention.

Bowel wall discontinuity, pneumoperitoneum, active extravasation, and bowel wall hypoenhancement were less common but more specific findings. Bowel wall discontinuity, observed in 30.0% of our patients, demonstrated perfect specificity (100%) and PPV (100%), corroborating findings by Thi and Quoc (2023) and Duc et al. (2020), who reported similar high specificity for this finding. This indicates that direct visualization of bowel wall interruption is a highly reliable predictor of significant injury requiring surgical intervention.

Pneumoperitoneum was detected in 35.0% of patients and showed high specificity (92.3%) with good sensitivity (80.8%). This is comparable to results reported by Duc et al. (2020), who found pneumoperitoneum to have a sensitivity of 81.6% and specificity of 92.3%. The strong association between pneumoperitoneum and the need for surgical intervention in our study (OR: 42.0) underscores its importance as a key diagnostic finding.

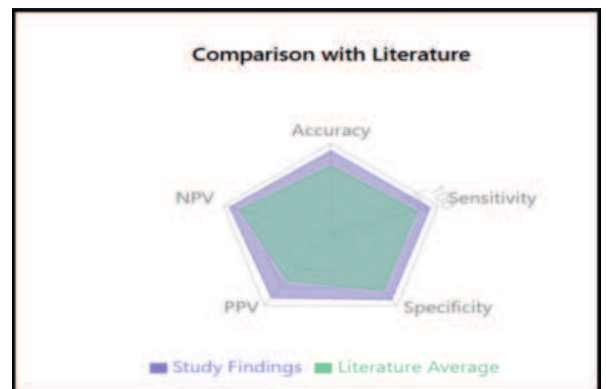
Comparison of CT Findings: Literature vs. Present Study

Imaging Finding	Literature		Present Study		Citation
	Sensitivity	Specificity	Sensitivity	Specificity	
Bowel wall discontinuity	100%	100%	69.2%	100.0%	Thi & Quoc (2023), Duc et al. (2020)
Pneumoperitoneum	81.6%	92.3%	80.8%	92.3%	Thi & Quoc (2023), Duc et al. (2020)
Mesenteric infiltration	79.7%	75.8%	80.8%	29.4%	Thi & Quoc (2023)
Bowel wall hypoenhancement	63.6%	92.3%	38.5%	97.1%	Thi & Quoc (2023), Duc et al. (2020)
Active extravasation	36.3%	98.1%	53.8%	97.1%	Duc et al. (2020)
Free intraperitoneal air	83.3%	79.6%	80.8%	92.3%	Duc et al. (2020)

Diagnostic Performance Of CT

The overall diagnostic performance of CT for detecting surgically significant TBI in our study was excellent, with an accuracy of 91.7%, sensitivity of 92.3%, specificity of 91.2%, PPV of 88.9%, and NPV of 93.9%. These results are superior to those reported by Landry et al. (2016), who found an overall sensitivity of 63.6% and specificity of 79.6% for CT diagnosis of TBI. Our improved performance may be attributed to advances in CT technology, particularly the use of 64-slice MDCT, which provides higher spatial resolution and faster acquisition times.

Our findings support the assertion by Durrant et al. (2020) that the sensitivity of radiologists in detecting traumatic bowel and mesenteric abnormalities has significantly improved with the use of multidetector CT. This technological advancement has enabled better detection of subtle findings associated with TBI, leading to more accurate diagnosis and timely intervention.



Predictors Of Surgical Intervention

In our study, several CT findings were significantly associated with the need for surgical intervention. Pneumoperitoneum, active extravasation, and bowel wall hypoenhancement demonstrated strong associations with odds ratios of 42.0, 38.5, and 20.56, respectively. These findings align with those of Bonomi et al. (2021), who reported that the presence of multiple CT criteria significantly improved the specificity and

positive predictive value for hollow viscus and mesenteric injury diagnosis.

Filiberto et al. (2021) developed the RAPTOR score, assigning one point for each radiographic predictor, with a score of ≥ 3 indicating a higher likelihood of requiring therapeutic laparotomy. While we did not specifically apply this scoring system, our results support the concept that certain CT findings are strong predictors of the need for surgical intervention.

Interobserver Agreement

Interobserver agreement was substantial to almost perfect for all CT findings in our study, with the highest agreement for pneumoperitoneum ($\kappa=0.90$), bowel wall discontinuity ($\kappa=0.85$), and active extravasation ($\kappa=0.83$). This is consistent with findings by Duc et al. (2020), who reported very good interobserver agreement for bowel wall rupture, active extravasation, and pneumoperitoneum.

The high interobserver agreement suggests that these findings are reliably detected by experienced radiologists, enhancing their utility in clinical decision-making. However, the slightly lower agreement for bowel wall hypoenhancement ($\kappa=0.62$) indicates that this finding may be more subjective and challenging to interpret consistently, potentially limiting its usefulness in some clinical settings.

Management And Outcomes

In our study, 43.3% of patients required surgical intervention, while 56.7% were successfully managed non-operatively. Among those who underwent surgery, the small bowel was the most commonly injured site (76.9%), followed by the colon (19.2%) and duodenum (3.8%). This distribution is consistent with findings by Dattwyler et al. (2018), who reported that the small bowel accounts for approximately 70% of bowel injuries, followed by the colon (20%) and duodenum (10%).

The ability to accurately differentiate between patients requiring surgery and those suitable for non-operative management is critical for optimal outcomes. Our results suggest that CT can play a pivotal role in this decision-making process by identifying specific findings that strongly predict the need for surgical intervention.

Emerging Technologies And Future Directions

While our study focused on conventional CT, emerging technologies like Dual-Energy CT (DECT) hold promise for further improving the diagnosis of TBI. Wang et al. (2022) highlighted the potential of DECT to enhance the visibility of traumatic bowel and mesenteric injuries through techniques such as iodine overlay and monoenergetic imaging. These advanced methods may improve the detection of subtle injuries and increase diagnostic confidence.

Lannes et al. (2019) demonstrated that early repeated CT scans can improve diagnostic performance in patients managed non-operatively. In their study, sensitivity increased from 63.6% to 91.7%, and NPV from 77.4% to 94.7% with repeated imaging. This approach may be beneficial in cases where initial CT findings are equivocal or when clinical suspicion remains high despite negative or inconclusive initial imaging.

Limitations

Our study has several limitations. First, the sample size, while statistically adequate, is relatively small compared to some multicenter studies. Second, the prospective nature of the study may have introduced potential bias in patient selection. Third, the study was conducted at a single institution, potentially limiting the generalizability of the results. Finally, we did not evaluate the impact of oral contrast, which may enhance the detection of certain findings in TBI.

CONCLUSION

CT plays a crucial role in the evaluation of traumatic bowel injuries, demonstrating high diagnostic accuracy for detecting surgically significant injuries. Specific CT findings, particularly bowel wall discontinuity, pneumoperitoneum, active extravasation, and bowel wall hypoenhancement, are strong predictors of the need for surgical intervention. The high interobserver agreement for these findings enhances their reliability in clinical decision-making.

Multi-detector CT has significantly improved the detection of TBI, but challenges remain in the reliable diagnosis of subtle injuries. Continued advancement in imaging technology, such as Dual-Energy CT, and the development of standardized scoring systems may further enhance diagnostic performance in the future.

Prompt and accurate diagnosis of TBI is essential for optimal patient outcomes, and CT remains the cornerstone of radiological evaluation in this critical setting. By understanding the diagnostic performance of specific CT findings and their correlation with surgical outcomes, clinicians can make more informed decisions, potentially reducing morbidity and mortality associated with these challenging injuries.

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