Use of Enteric Contrast Material for Abdominopelvic CT in Penetrating Traumatic Injury in Adults: Comparison of Diagnostic Accuracy Systematic Review and Meta-Analysis

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Evidence Synthesis and Decision Analysis · Systematic Review/Meta-Analysis

Keywords

bowel, MDCT, meta-analysis, penetrating trauma, systematic review

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BACKGROUND. Scarce evidence exists on the diagnostic benefit of enteric contrast administration for abdominopelvic CT performed in the setting of penetrating trauma.

OBJECTIVE. The purpose of this systematic review and meta-analysis is to compare the diagnostic accuracy of CT using enteric contrast material with that of CT not using enteric contrast material in penetrating traumatic abdominopelvic injury in adults.

EVIDENCE ACQUISITION. A protocol was registered a priori (PROSPERO CRD42019139613). MEDLINE and EMBASE databases were searched until June 25, 2019. Studies were included that evaluated the diagnostic accuracy of abdominopelvic CT either with or without enteric (oral and/or rectal) contrast material in patients presenting with penetrating traumatic injury. Relevant study data metrics and risk of bias were assessed. Bivariate random-effects meta-analyses and meta-regression modeling were performed to assess and compare diagnostic accuracies.

EVIDENCE SYNTHESIS. From an initial sample of 829 studies, 12 studies were included that reported on 1287 patients with penetrating injury (389 with confirmed bowel, mesenteric, or other abdominopelvic organ injury). The enteric contrast material group (seven studies; 506 patients; 124 patients with confirmed penetrating injury) showed a sensitivity of 83.8% (95% CI, 73.7–90.5%) and specificity of 93.8% (95% CI, 83.6–97.8%). The group without enteric contrast administration (six studies; 781 patients; 265 patients with confirmed penetrating injury) showed a sensitivity of 93.0% (95% CI, 86.8–96.4%) and a specificity of 90.3% (95% CI, 81.4–95.2%). No statistically significant difference was identified for sensitivity (p = .07) or specificity (p = .37) between the groups with and without enteric contrast material according to meta-regression. Nine of 12 studies showed risk of bias in at least one QUADAS-2 domain (most frequently limited reporting of blinding of radiologists or lack of blinding of radiologists, insufficient clinical follow-up for the reference standard, and limited reporting of sampling methods).

CONCLUSION. The use of enteric contrast material for CT does not provide a significant diagnostic benefit for penetrating traumatic injury.

CLINICAL IMPACT. Eliminating enteric contrast administration for CT in penetrating traumatic injury can prevent delays in imaging and surgery and reduce cost.

Penetrating traumatic injuries are associated with substantial premature mortality and permanent disability [1]. Studies have reported incidence rates of penetrating traumatic injury as high as 21.0% and mortality rates as high as 15.4% in urban centers [1]. CT serves as a valuable tool in assessing victims of penetrating injury and accurately characterizes the degree of solid and hollow visceral injury [2]. One meta-analysis reported that in the setting of penetrating abdominal trauma, CT had a sensitivity of 94.9% and specificity of 95.4% in predicting the need for laparotomy [3]. However, details of the scanning protocol, including the use of contrast material, was not made available for individual studies in the analysis [3].

The justification for intraluminal (oral and/or rectal) contrast material in penetrating injury is the high specificity of intraperitoneal extravasation or leakage of contrast material for bowel perforation [4]. However, limitations of intraluminal contrast administration include the time required for administration and the risk of aspiration [5]. This additional time for administration may cause a diagnostic delay [6]. As a result, the optimal CT protocol for penetrating trauma is controversial. A recent international survey performed

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through the American Society of Emergency Radiology (ASER) found enteric contrast material is not frequently administered for CT performed in the setting of penetrating trauma [4].

The use of oral contrast material in blunt abdominal injury has been thoroughly assessed [7–9]. A randomized controlled trial by Stafford et al. [7] and a systematic review and meta-analysis by Lee et al. [8] found no added benefit of oral contrast administration in blunt abdominal injury. These findings are reflected in the American College of Radiology (ACR) guidelines [10] that state "CT evaluation of the abdomen and pelvis for blunt trauma does not require the use of oral contrast." However, scarce published evidence directly compares IV contrast material alone versus IV contrast material with oral and/or rectal contrast material for CT in penetrating traumatic abdominal injury. Moreover, the current ACR guidelines do not provide a recommendation on the use of intraluminal contrast material in penetrating traumatic injury [10]. Therefore, a systematic review and meta-analysis was performed to compare the diagnostic test accuracy of CT using enteric (oral and/or rectal) contrast material with that of CT not using enteric contrast material in penetrating traumatic abdominopelvic injury in adults.

Evidence Acquisition

A protocol was created and registered a priori (PROSPERO CRD42019139613). A diagnostic text accuracy systematic review and meta-analysis was performed [11–15]. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed [15, 16].

Literature Search

The electronic databases MEDLINE (U.S. National Library of Medicine) and EMBASE (Elsevier) were searched for relevant studies until June 25, 2019; no limitation was placed on the start date. The search was limited to English-language studies. The search strategies are provided in the Supplementary Methods, which can be viewed in the electronic supplement to this article available at doi.org/10.2214/AJR.20.24636. The references of included studies were searched for potentially relevant studies. Any additionally identified potentially relevant studies that were published after the end date of the literature search were also assessed for inclusion.

Eligibility Criteria

The inclusion criteria were that the patients were adults (≥ 18 years) with previous penetrating trauma/injury; the patients underwent abdominopelvic CT with or without oral and/or rectal contrast material; the reference standard was defined as surgical, clinical, or imaging follow-up; and sufficient 2 × 2 contingency table data were reported to determine sensitivity and specificity. The exclusion criteria used were the study included only patients with no history of trauma or only patients with blunt abdominal trauma; the study only reported on a sample of pediatric patients; and the study did not report the route(s) of contrast administration for each patient. For studies with overlapping patient samples, the study with the larger sample size was used for this analysis.

Study Selection

Literature search results were imported into a reference manager software (Reference Manager 11, Thomson Reuters). Title and abstract review was completed on the literature search results by two investigators independently (M.A. and N.Z., radiology residents with 8 and 3 years of experience performing systematic reviews, respectively). These two investigators compared results after initial independent pilot screens of the first 50 studies to improve consistency for the subsequent studies. Discrepancies were resolved by discussion with a third reviewer (M.N.P., an emergency radiologist with 2 years of experience) to reach consensus. Subsequently, eligible articles underwent full-text screening by a single reviewer (M.A.).

HIGHLIGHTS

Key Finding

- *Enteric contrast material does not improve the accuracy of abdominopelvic CT in penetrating trauma.*

Importance

- *Eliminating enteric contrast material in penetrating trauma can reduce examination times, reduce costs, and prevent surgical delay because of aspiration risk.*

Data Extraction

Studies found to be eligible after full-text screening underwent data extraction performed by a single reviewer (M.A.). Study-level data metrics were collected including general study identifiers (title, first author, journal, and other publication data), prospective versus retrospective design, single center versus multicenter trial, patient demographics (sample size, mean or median age of included patients, and reasons for patient exclusion), mechanism of injury (gunshot, stabbing, or any other penetrating injury), diagnostic accuracy metrics (number of true-positives, false-negatives, true-negatives, and false-positives), imaging protocol (phases of scan and contrast material use, number of CT detectors, and slice thickness), outcome assessed (bowel or mesenteric injury only or any abdominopelvic organ injury), reference standard (clinical, surgical, or imaging follow-up), and study funding. A true-positive result was defined as a positive CT result for bowel and/or mesenteric injury that was confirmed on surgical follow-up (intraoperative findings); a false-negative finding was defined as a negative CT result for bowel and/or mesenteric injury with subsequent imaging and/or surgical follow-up findings indicating the presence of underlying injury; a true-negative result was defined as a negative CT result for bowel and/or mesenteric injury with subsequent clinical or imaging follow-up for at least 1 week or any subsequent surgical follow-up showing no underlying injury; a false-positive result was defined as a positive CT result for bowel and/or mesenteric injury with subsequent clinical or imaging follow-up for at least 1 week or any subsequent surgical follow-up showing no underlying injury. If specific data for bowel and/or mesenteric injury was not provided in a study, data for injury to any abdominopelvic structure was used. If clinical or imaging follow-up was performed for less than 1 week, the study was included in the analysis, but the study was considered at high risk of bias.

Quality Assessment

Study level risk of bias assessment was performed according to the QUADAS-2 tool [17]. The criteria that were assessed for each in-

cluded study were patient selection, index test, reference standard, and flow and timing [17]. For patient selection, a study was considered at low risk of bias if a random or consecutive sample was used. A sample was considered consecutive if all sequential patients with penetrating trauma who were considered eligible for CT were included in the study. Patients with penetrating trauma who were deemed unstable and who were clinically or surgically managed without CT were not considered to represent a consecutive sample. For the index test, blinding of radiologists to previous clinical and imaging information was considered at low risk of bias. For the reference standard, the use of intraoperative findings or clinical and imaging follow-up for at least 1 week was considered at low risk of bias. For flow and timing, if comparative index tests were performed in the same patient, the study was considered at a low risk of bias if these were performed within 24 hours of each other. Studies that showed a low risk of bias for all the categories of the QUADAS-2 tool were considered at a low risk for bias overall. Studies that reported a high risk or unclear risk of bias in at least one QUADAS-2 category were considered at a high risk for bias overall.

Outcomes and Statistical Methods

Diagnostic accuracy of CT with and without the use of enteric contrast material in the setting of penetrating traumatic injury in adult patients was defined as the primary outcome. Bivariate random-effects model meta-analyses were performed to determine estimates of the mean sensitivity and specificity with 95% CIs for abdominopelvic CT. Pooling was performed independently for two groups: those that used enteric contrast material and those that did not use enteric contrast material. Coupled forest plots and hierarchic summary ROC curves were synthesized. AUCs were calculated for the hierarchic summary ROC curves. Sources of variability for diagnostic accuracy were explored via meta-regression in addition to independent pooling of studies according to the use of enteric contrast material, rather than through statistical quantification. The following covariates were

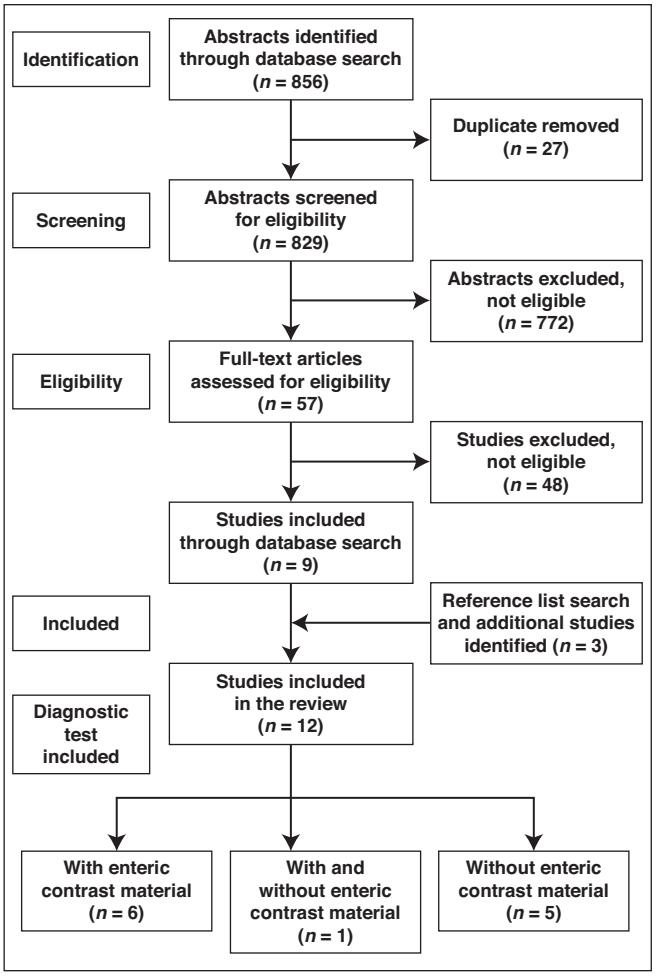

Fig. 1—Flow diagram of included studies.

TABLE 1: Study Characteristics of Included Studies

First Author [Reference]	Year	Type of AP Injury Assessed	Mechanism of Injury	Country of Patient Sample	Study Design	Study Funding
Shanmuganathan [20]	2004	Any AP organ	Penetrating	USA	Prospective	NR
Múnera [21]	2004	Bowel/mesentery	Gunshot	USA	Prospective	NR
Salim [22]	2006	Bowel/mesentery	Stabbing	USA	Prospective	NR
Rozen [23]	2007	Bowel/mesentery	Stabbing	Australia	Retrospective	None
Ramirez [24]	2009	Any AP organ	Penetrating	USA	Retrospective	NR
Berardoni [25]	2011	Bowel/mesentery	Stabbing	USA	Retrospective	NR
Melo [26]	2012	Bowel/mesentery	Gunshot	Brazil	Prospective	NR
Landry [27]	2016	Bowel/mesentery	Penetrating	Canada	Retrospective	NR
Saksobhavivat [28]	2016	Bowel/mesentery	Penetrating	USA	Prospective	None
Fouda [29]	2018	Any AP organ	Stabbing	Egypt	Retrospective	None
Jawad [30]	2018	Bowel/mesentery	Penetrating	USA	Retrospective	NR
Thorisdottir [31]	2020	Bowel/mesentery	Penetrating	Sweden	Retrospective	None

Note—AP = abdominopelvic, NR = not reported.

TABLE 2: Imaging Characteristics and Findings of Included Studies

First Author [Reference]	Use of Enteric Contrast Material	Patients With Penetrating Trauma	Patients With Confirmed Organ Injury	TP	FN	TN	FP	CT Characteristics	
								No. of Detectors	Slice Thickness (mm)
Shanmuganathan [20]	Yes	200	26	21	5	170	4	NR	2.5
Múnera [21]	Yes	47	12	11	1	34	1	NR	NR
Salim [22]	No	67	8	7	1	55	4	1	NR
Rozen [23]	Yes	20	14	11	3	6	0	64	NR
Ramirez [24]	No	306	69	68	1	225	12	1 or 8	NR
Berardoni [25]	No	98	13	12	1	80	5	16	5
Melo [26]	Yes	31	9	9	0	22	0	8	2.5
Landry [27]	No	14	5	4	1	7	2	64	3
Saksobhavivat [28]	Yes	171	35	32	3	124	12	40 or 64	0.625
Fouda [29]	Yes	12	10	7	3	1	1	NR	NR
Jawad [30]	No	274	162	142	20	81	31	40 or 64	3 or 5
Thorisdottir [31]	Yes	25	18	12	6	5	2	NR	NR
Thorisdottir [31]	No	22	8	6	2	14	0	NR	NR

Note—Unless otherwise indicated, values are numbers of patients. TP = true-positive, FN = false-negative, TN = true-negative, FP = false-positive, NR = not reported.

assessed within a meta-regression model if there were sufficient studies and granular enough data to do so: use of enteric contrast material, study design, mechanism of penetrating injury, outcome assessed (bowel and/or mesenteric injury only versus injury to any abdominopelvic structure), imaging protocol, reference standard, and risk of bias. Both unadjusted and adjusted beta coefficients were reported for the meta-regression. Unadjusted beta coefficients did not account for other covariates in the model, whereas the adjusted beta coefficients accounted for other covariates. Publication bias was not assessed in accordance with current guidelines for diagnostic test accuracy systematic reviews [15]. Agreement between the two investigators in the initial screen of 50 studies for full-text review was assessed using Cohen kappa coefficient. The midas and metandi packages in STATA version 11.2 (STATA), and the mada package in R version 3.5.1 (R Project for Statistical Computing) were used for meta-analysis and meta-regression [18, 19].

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Evidence Synthesis

Study Demographics and Risk of Bias

A study flow diagram is shown in Figure 1. A total of 829 studies underwent title and abstract screening, of which 57 studies were

TABLE 3: Summary of Risk of Bias Based on QUADAS-2 Tool for Each Included Study

First Author [Reference]	Year Published	Patient Selection	Index Test	Reference Standard	Flow and Timing	Overall Assessment
Shanmuganathan [21]	2004	Unclear	Unclear	Low	Low	High
Múnera [22]	2004	Low	High	Low	Low	High
Salim [23]	2006	Low	High	High	Low	High
Rozen [24]	2007	Low	Unclear	Unclear	Low	High
Ramirez [25]	2009	Unclear	High	Low	Unclear	High
Berardoni [26]	2011	Low	Low	High	Low	High
Melo [27]	2012	Low	Low	Low	Low	Low
Landry [28]	2016	Low	High	Low	Low	High
Saksobhavivat [29]	2016	Low	Low	Low	Low	Low
Fouda [30]	2018	Low	Unclear	Low	Low	High
Jawad [31]	2018	Low	Unclear	Low	Low	High
Thorisdottir [32]	2020	Low	Low	Low	Low	Low

retrieved for full-text assessment. The assessment of agreement between the two investigators in the initial screen of 50 studies had a Cohen kappa of 0.81. Ultimately, 12 studies published between 1947 and 2020 with a total of 1287 patients with penetrating abdominopelvic injury (389 with confirmed bowel, mesenteric, or other abdominopelvic injury) were included [20–31]. Two studies had been excluded because of overlapping patient samples with an included study [20, 32, 33]. The enteric contrast material group included seven studies reporting on 506 patients with penetrating injury (124 with confirmed bowel, mesenteric, or other abdominopelvic organ injury) [20, 21, 23, 26, 28, 29, 31], whereas the group without enteric contrast material included six studies reporting on 781 patients with penetrating injury (265 with confirmed bowel, mesenteric, or other abdominopelvic organ injury) [22, 24, 25, 27, 30, 31]. Only one study directly compared the use of enteric contrast material with the use of IV contrast material alone, reporting on 47 patients with penetrating injury (26 with confirmed bowel, mesenteric, or other abdominopelvic organ injury) in total [31]. A summary of study characteristics for the included studies is provided in Table 1, and a summary of imaging characteristics and findings for each included study is provided in Table 2. Nine studies reported on the detection of traumatic bowel and/or mesenteric injury alone [21–23, 25–28, 30, 31], and the remaining three studies reported on the presence of any traumatic abdominopelvic injury [20, 24, 29]. All included studies were conducted at a single center. The proportion of male patients in each study ranged from 78% to 100%, and the proportion of female patients ranged from 0% to 22%. The mean or median patient age across the studies ranged from 24 to 44 years. With respect to mechanism of injury, four studies only included stab wounds [22, 23, 25, 29], two studies only included gunshot wounds [21, 26], and the remaining six studies included any type of penetrating injury [20, 24, 27, 28, 30, 31]. Only four studies reported funding status [23, 28, 29, 31].

A summary of the risk of bias assessment for the included studies is provided in Table 3. Nine of the 12 studies showed a high or unclear risk of bias in at least one QUADAS-2 domain [20–25, 27, 29, 30], whereas three studies showed a low risk of bias in all QUADAS-2 domains [26, 28, 31]. The most frequent sources of bias included limited reporting of blinding of radiologists or lack of blinding of radiologists, insufficient clinical follow-up for the reference standard (as low as 5 hours or until the patient was discharged), and limited reporting of sampling methods (i.e., potential volunteer bias).

Data Pooling and Meta-Regression

Pooled sensitivity and specificity forest plots and hierarchic summary ROC curves for the groups with and without enteric contrast material are shown in Figure 2. The group with enteric contrast material showed a sensitivity of 83.8% (95% CI, 73.7–90.5%), a specificity of 93.8% (95% CI, 83.6–97.8%), and an AUC of 0.93 (95% CI, 0.90–0.95) for the hierarchic summary ROC. The group without enteric contrast material showed a sensitivity of 93.0% (95% CI, 86.8–96.4%), a specificity of 90.3% (95% CI, 81.4–95.2%), and an AUC of 0.97 (95% CI, 0.95–0.98) for the hierarchic summary ROC.

A summary of the comparative meta-regression model assessing the impact of multiple covariates on the diagnostic accuracy of CT in detecting penetrating traumatic injury is provided in Table 4. Within the unadjusted meta-regression model, sensitivi-

TABLE 4: Meta-Regression Model Evaluating the Impact of Different Covariates on the Diagnostic Accuracy of CT in the Detection of Penetrating Traumatic Injury

Covariate	Reference	Unadjusted Model			Adjusted Model		
		β Coefficient (95% CI)	SE	*p*	β Coefficient (95% CI)	SE	*p*
Sensitivity							
No enteric contrast material	Enteric contrast material	0.77 (0.08–1.46)	0.35	.03[a]	0.94 (–0.09 to 1.96)	0.53	.07
Retrospective study design	Prospective	–0.29 (–1.32 to 0.75)	0.53	.59	–0.09 (–1.46 to 1.28)	0.70	.89
Bowel and mesentery injury	Any AP structure	–0.08 (–1.19 to 1.04)	0.57	.89	–0.18 (–1.41 to 1.06)	0.63	.78
Penetrating mechanism	Gunshot	–0.62 (–2.40 to 1.16)	0.91	.50	–0.94 (–2.88 to 1.00)	0.99	.34
Stabbing mechanism	Gunshot	–0.98 (–2.89 to 0.93)	0.98	.32	–1.52 (–3.80 to 0.76)	1.16	.19
Low QUADAS-2 risk of bias	High risk of bias	–0.23 (–1.23 to 0.78)	0.51	.66	–0.67 (–2.13 to 0.80)	0.75	.37
1 – Specificity							
No enteric contrast material	Enteric contrast material	0.28 (–1.01 to 1.57)	0.66	.67	–0.65 (–2.06 to 0.76)	0.72	.37
Retrospective study design	Prospective	1.27 (0.12–2.41)	0.58	.03[a]	1.16 (–0.41 to 2.72)	0.80	.15
Bowel and mesentery injury	Any AP structure	0.53 (–0.722 to 1.949)	0.71	.45	0.77 (–0.79 to 2.32)	0.79	.34
Penetrating mechanism	Gunshot	1.36 (–0.79 to 3.51)	1.10	.22	1.15 (–1.10 to 3.39)	1.15	.32
Stabbing mechanism	Gunshot	1.28 (–1.05 to 3.61)	1.08	.28	1.14 (–1.38 to 3.67)	1.29	.38
Low QUADAS-2 risk of bias	High risk of bias	1.14 (0.06–2.22)	0.55	.04[a]	0.33 (–1.42 to 2.08)	0.89	.71

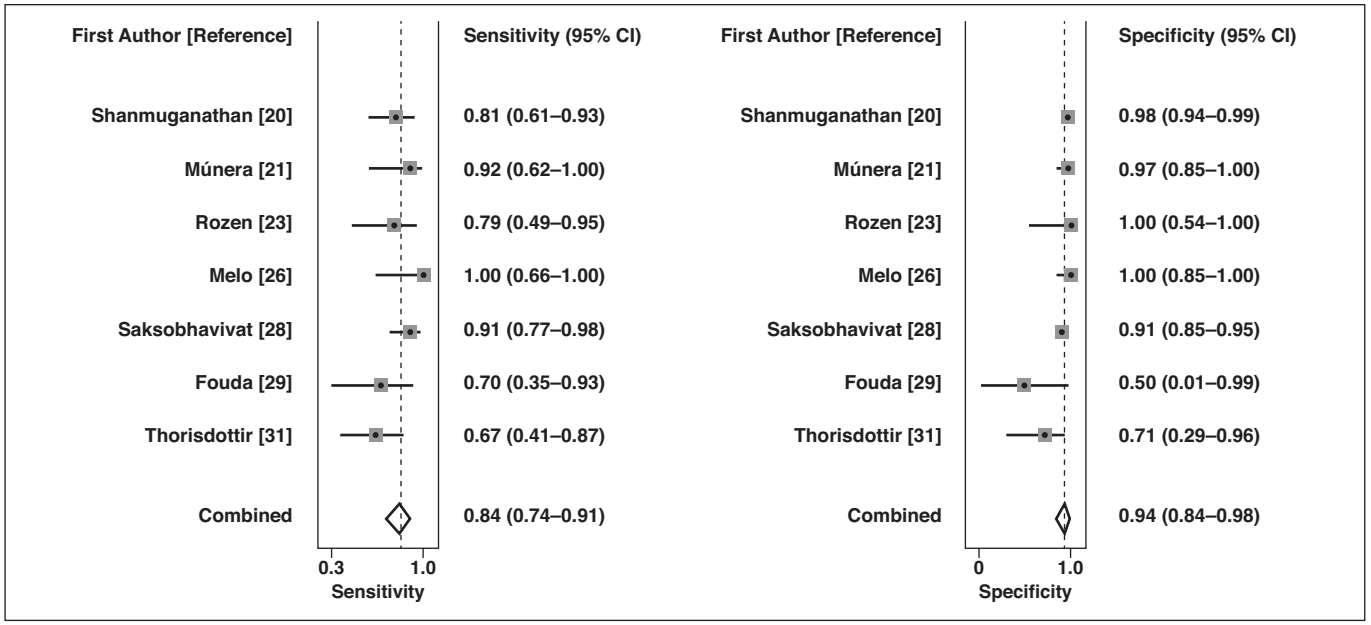
Note—Unadjusted beta coefficients did not account for other covariates in the model, whereas the adjusted beta coefficients accounted for other covariates. AP = abdominopelvic.

[a]Denotes statistically significant result ($p < .05$)

ty was significantly greater in the group without enteric contrast material in comparison with the group with enteric contrast material (p = .03). However, when accounting for other covariates within the adjusted meta-regression, this difference in sensitivity was no longer observed (p = .07). Specificity was not significantly different between the group with enteric contrast material and that without in both the unadjusted (p = .67) and adjusted (p = .37) meta-regression models. Studies with prospective designs showed a higher specificity than those with retrospective designs in the unadjusted meta-regression model (p = .03). However, no difference was identified in the adjusted meta-regression model (p = .15). Study design did not impact sensitivity in the unadjusted (p = .59) and adjusted models (p = .89). A high risk of bias was associated with a higher specificity in the unadjusted model (p = .04), although this difference was not observed when accounting for other covariates in the adjusted meta-regression model (p = .71). Risk of bias did not impact sensitivity in the unadjusted (p = .66) or adjusted (p = .37) meta-regression models. Assessment for bowel and mesenteric versus any abdominopelvic injury (p = .34–.89) and mechanism of penetrating injury (p = .19–.50) were not significant covariates within the unadjusted and adjusted meta-regression models.

Discussion

This systematic review and meta-analysis evaluated the utility of enteric contrast material for CT in the detection of penetrating traumatic abdominopelvic injuries and reported on 12 studies with a total of 1287 patients with penetrating traumatic injury (389 with confirmed bowel, mesenteric, or other abdominopelvic organ injury). The study findings indicate that enteric contrast material provides no additional diagnostic benefit in the detection of penetrating traumatic abdominopelvic injuries in adults.



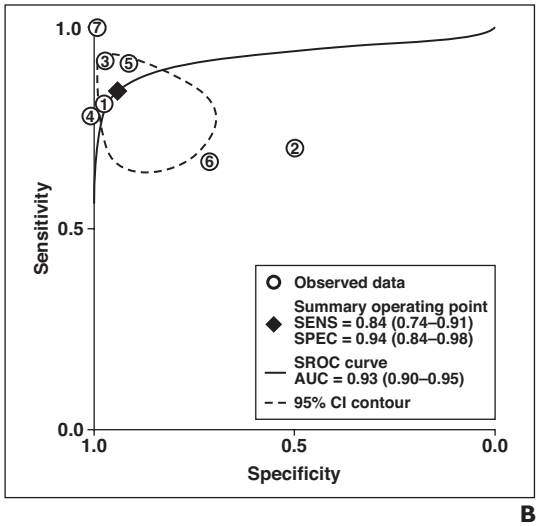


Fig. 2—Pooled sensitivity and specificity forest plots and hierarchic summary ROC curves for the groups with and without enteric contrast material.
A, Summary forest plot shows sensitivity and specificity of penetrating traumatic injury CT of group with enteric contrast material. Dashed lines indicate pooled estimate of mean sensitivity or specificity, boxes with dots represent sensitivity or specificity for each corresponding individual study, whiskers represent 95% CIs for sensitivity or specificity of corresponding individual study, and diamond at combined results represents pooled estimate of mean sensitivity or specificity with associated 95% CI (widest point of diamond).
B, Hierarchic summary ROC curve shows sensitivity (SENS) and specificity (SPEC) of penetrating traumatic injury CT of group with enteric contrast material. Numbers within circles represent arbitrary numbering system for included studies. SROC = summary ROC.

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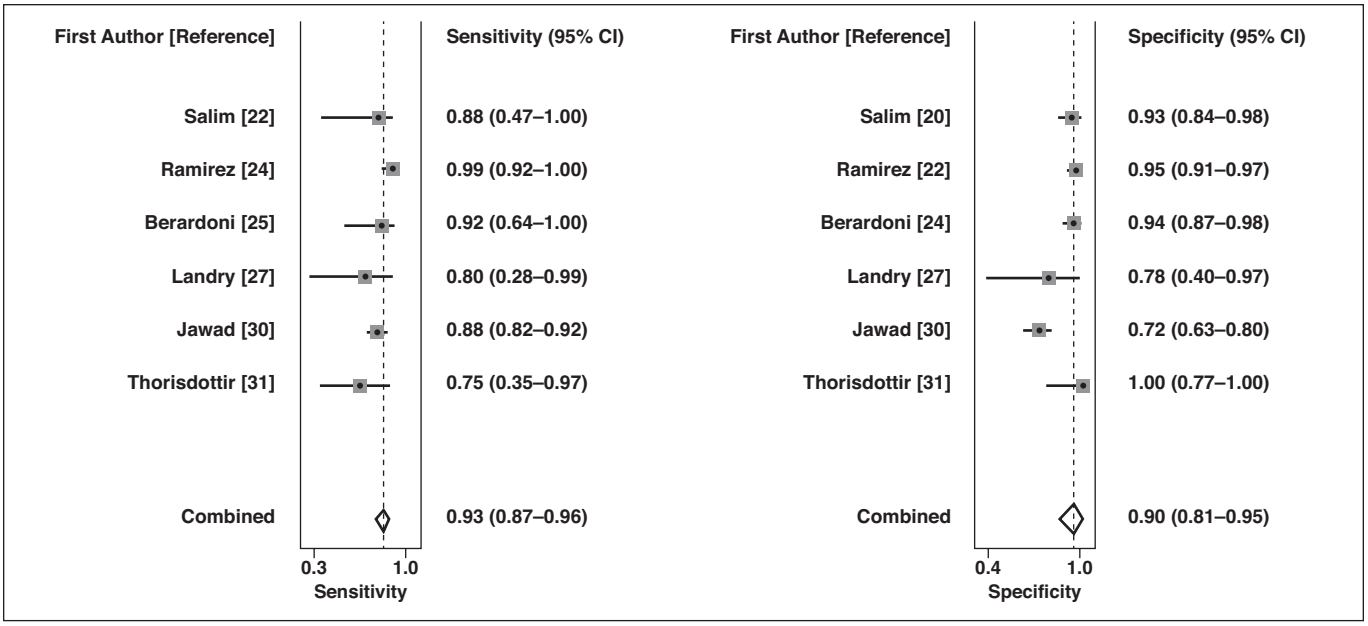

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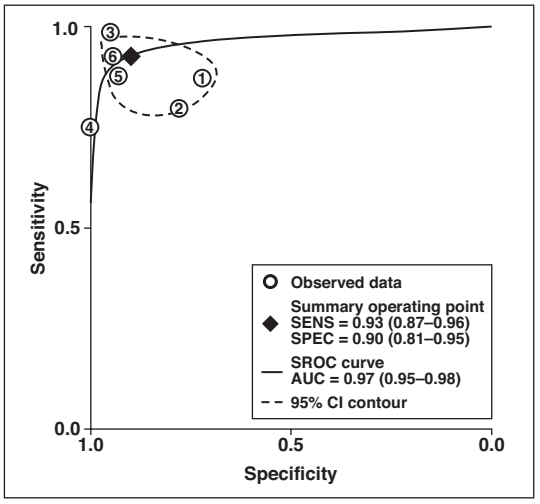

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Fig. 2 (continued)—Pooled sensitivity and specificity forest plots and hierarchic summary ROC curves for the groups with and without enteric contrast material.
C, Summary forest plot shows sensitivity and specificity of penetrating traumatic injury CT of group without enteric contrast material. Dashed lines indicate pooled estimate of mean sensitivity or specificity, boxes with dots represent sensitivity or specificity for each corresponding individual study, whiskers represent 95% CIs for sensitivity or specificity of corresponding individual study, and diamond at combined results represents pooled estimate of mean sensitivity or specificity with associated 95% CI (widest point of diamond).
D, Hierarchic summary ROC curve shows sensitivity (SENS) and specificity (SPEC) of penetrating traumatic injury CT of group without enteric contrast material. Numbers within circles represent arbitrary numbering ID system for included studies. SROC = summary ROC.

These findings were observed in the pooled meta-analysis and in both the unadjusted and adjusted meta-regression models accounting for multiple potential confounding variables.

In the current literature, only a single primary study has directly compared the use of enteric contrast material and IV contrast material alone for CT in the setting of penetrating trauma [31]. Thorisdottir et al. [31] assessed 47 patients, 25 of whom received enteric contrast material and 22 of whom received IV contrast material only, and also found no additional benefit of oral contrast material for sensitivity (enteric, 67%; IV, 75%) or specificity (enteric; 71%; IV, 100%). Given the scarcity of comparative design primary studies on the utility of enteric contrast material in penetrating trauma and the lack of current recommendations, the findings of our study may support future change in imaging guidelines [10]. Furthermore, our findings are concordant with the recent ASER international survey of 124 institutions that found that 74% of respondents do not routinely administer oral contrast material, and 68% do not administer rectal contrast material in the setting of penetrating trauma [4]. Moreover, a survey of 106 academic institutions in the United States found similar results, with only 21% using oral contrast material and 3% using rectal contrast material for penetrating abdominal trauma [34]. These findings are also reflected in practice at trauma centers that have eliminated the use of enteric contrast material altogether to limit diagnostic delays [6]. Although intraperitoneal enteric contrast material leak in the setting of penetrating trauma provides definitive documentation of hollow viscus injury, our results indicate that the diagnostic accuracy is not significantly different without enteric contrast material according to secondary signs alone. This does not exclude potential rare cases in which enteric contrast material may provide additional diagnostic benefit.

Although enteric contrast material does not provide any additional diagnostic utility, eliminating its use in penetrating trauma can provide valuable time- and cost-saving benefits [5, 6, 35, 36]. A re-

gional medical center emergency department that assessed 183 patients found an extra 68-minute difference from the time of ordering to scanning in CT performed with oral contrast material compared to without it [5]. The use of oral contrast material may also delay any required surgery because of risk of aspiration. A single institution study conducted in the United States in 2016 reported an annual base cost estimate of $82,552 (USD) for enteric contrast administration in a total of 4541 abdominopelvic CT examinations [36]. This could be translated to an estimated $18.18 (USD) in savings per single CT requiring enteric contrast administration. Meanwhile, studies have reported a time delay of 60–90 minutes after oral contrast administration for optimal distal bowel opacification [35]. These studies have also found improved examination completion rate and overall patient experience through the elimination of oral contrast material use [5, 35]. Finally, previous studies on blunt abdominal trauma have suggested the use of enteric contrast material may preclude assessment of the bowel mucosa for enhancement, which may also be the case in penetrating trauma [9, 37].

The main limitation of this study is the lack of comparative design diagnostic accuracy primary studies, which would provide the highest quality data for meta-analysis [38]. Further assessment of the utility of enteric contrast material with optimized comparative design studies, including randomized controlled trials, would further support our findings. Multiple included studies were considered as high risk for bias; however, the effect of risk of bias was controlled for with meta-regression. Assessment of bias in patient selection was limited given that clinical judgment often played a role in determining which patients underwent CT. However, we assessed sampling methods only in patients deemed eligible for CT according to clinical assessment. Although we used meta-regression models to assess the impact of multiple covariates, we were unable to assess other potentially important covariates because of limitations in sample size and reporting, including CT technique (slice thickness and number of detectors) and enteric contrast material details. A gray literature search was not performed, although studies published after the search was conducted were included in the analysis, and non-English full-text studies were excluded [31]. Furthermore, our results do not adequately assess imaging of penetrating trauma in pediatric patients, given that our search did not include this population, and additional study is warranted.

In summary, this systematic review and meta-analysis assessed the utility of enteric contrast administration for CT in the detection of penetrating traumatic abdominopelvic injuries in 1287 adults and found no additional diagnostic benefit of enteric contrast material compared with use of IV contrast material alone. Given the scarcity of comparative evidence on this topic, the findings may influence guideline recommendations on the use of enteric contrast material in penetrating trauma.

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Editorial Comment: Forgoing Enteric Contrast Use for CT in Penetrating Abdominal Trauma

This is potentially a landmark article in the arena of CT for penetrating abdominal trauma. Does the diagnostic value of enteric contrast administration justify the costs? The most important cost is the time required for contrast administration in a field in which time is of the essence.

CT is a cornerstone in the evaluation of blunt trauma. Use of enteric contrast material has long been abandoned. The selective use of CT for penetrating trauma has lagged but steadily grown for several decades. Enteric contrast administration was integral in early studies, but its value has been questioned. We are seeing the same evolution with penetrating trauma CT as we did with blunt trauma.

Extravasation of enteric contrast material occurs in a minority (15–29%) of patients with bowel injury from penetrating trauma and much less commonly (2–6%) in all patients scanned [1, 2]. It is speculative but likely that most of these injuries would be identified because of secondary signs.

Despite a dearth of high-quality comparative studies, there has been a shift away from the use of enteric contrast administration for penetrating trauma CT. This article is a timely evaluation of the available literature. In the absence of large controlled trials, meta-analysis such as this can serve as a proxy to drive practice standards.

We have successfully managed without enteric contrast material use in blunt trauma CT. It is time to consider the same paradigm shift for CT for penetrating trauma. There is no loss of sensitivity or specificity, or, most importantly, false-negative rates with single-contrast CT. The main concern is the inherent limitations (biases) of the individual studies evaluated.

I find the conclusions of this study compelling. I believe we can forgo routine use of enteric contrast material in patients with penetrating trauma, Selective use of enteric contrast material and follow-up scanning remain viable options in equivocal cases.

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