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Do Clinical Guidelines for Whole Body Computerised Tomography in Trauma Improve Diagnostic Accuracy and Reduce Unnecessary Investigations? A Systematic Review and Narrative Synthesis.

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Abstract:

Introduction
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Materials and Methods
A systematic review of Medline, Cinhal and the Cochrane database, supplemented by a manual search of relevant papers was undertaken, with narrative synthesis. Studies comparing clinical guidelines to physician gestalt for the use of WBCT in adult trauma were included.
Results
887 papers were identified from the electronic databases, and 1 from manual searches. Of these, 7 papers fulfilled the inclusion criteria. Two (2) papers compared clinical guidelines with routine practice: one found increased diagnostic accuracy while the other did not. Two papers investigated the performance of established clinical guidelines and demonstrated moderate sensitivity and low specificity. Two papers compared different components of established triage tools in trauma. One paper devised a de novo clinical decision rule, and demonstrated good diagnostic accuracy with the tool. The outcome criteria used to define a 'positive' scan varied widely, making direct comparisons between studies impossible.
Conclusions
Current clinical guidelines for WBCT in trauma may increase the sensitivity of the investigation, but the evidence to support this is limited. There is a need to standardise the definition of a 'clinically significant' finding on CT to allow better comparison of diagnostic studies.

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Conflicts of Interest and Sources of Funding

None declared

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Introduction

While whole body computerised tomography (WBCT) has become a common investigative modality in major trauma patients, the evidence for its efficacy and diagnostic accuracy are limited at best. WBCT involves the use of CT scanning with and without the injection of contrast to image the head, neck and torso, whether or not the patient demonstrates clinical signs of injury in all these body areas (1). Its use as an imaging technique during the early resuscitation and treatment phase of trauma management has increased over the past two decades. WBCT is now seen as a standard of care for selected trauma patients in many trauma systems around the world (2, 3).

Several studies suggest benefits to the use of WBCT in trauma, including shorter time to definitive care, identification of injuries that would have potentially been missed and even improved survival of patients (4-6). However, the majority of studies to date have used an observational methodology, and the only randomised trial of WBCT in trauma did not show any survival benefit to the technique (7). In addition, there is no clear consensus as to the indications for its use, or its accuracy as a diagnostic tool (7-10).

There are potential risks to the investigation, such as radiation exposure and contrast induced nephropathy, which warrant a considered approach to the widespread use of WBCT in trauma. While these are common to all patients undergoing CT scanning, some studies have highlighted the likelihood of adverse events in seriously injured patients, particularly those of advanced age (11-13).

There are no universally accepted guidelines for the use of WBCT in trauma, and previous research suggests that there is wide variation in its use, between hospitals and across different countries (14-17). In these circumstances, it is likely that the use of specified guidelines would improve the diagnostic accuracy of WBCT in trauma. We therefore conducted a systematic review of the existing scientific literature to determine whether clinical decision rules increase the sensitivity of WBCT in trauma and reduce the number of unnecessary negative investigations.

Materials and Methods

The methodology of this study is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta- Analyses (PRISMA) Statement for systematic reviews (18). The aim of this review was to determine whether the use of guidelines for WBCT in adult major trauma patients increases the diagnostic accuracy of the investigation.

A systematic review of the literature was conducted through the Medline (via OvidSP), Cochrane Library and Cinahl (via EBSCO) electronic databases. The electronic search was supplemented by a manual search of reference lists of relevant papers. All relevant papers up to September 2016 were included in the review. All searches were conducted independently by the four primary researchers (NH, AM, JM and MY), and checked by the two research supervisors (IS and HC). Any discrepancies were discussed between the reviewers and supervisors, and a consensus decision made regarding the inclusion of these papers.

A – Research Question

The PICOS research question used for this review was:

'In adult major trauma patients (<u>population</u>), does the use of clinical guidelines for ordering whole body computerised tomography (<u>intervention</u>) improve the sensitivity and specificity of the investigation to detect clinically relevant injuries (<u>outcome</u>), when compared to the use of physicians' clinical judgement to determine when to order a WBCT (<u>comparator</u>)?'

Table 1 shows the search terms used when interrogating the individual databases.

	Relevant Section of PICO Question	Search Terms Used
Population	*adult major trauma patients*	trauma/ wounds and injuries/ severe trauma/multiple trauma /wounds, nonpenetrating / trauma centres/ injury severity score / trauma patients/ major trauma/emergency medical services / blunt trauma patients/ blunt trauma/ blunt multisystem trauma/Trauma severity indices/ poly-trauma/ trauma CT
Intervention	*clinical guidelines for ordering whole body computerised*	(clinical factors/ decision making/ decision process/ decision rules/ scanning criteria/experience/ decision tool/ decision support techniques/ decision support systems, clinical/ prediction score/ clinical-decision making/ screening tools/ clinical protocols) AND

	tomography	(Whole body computerised tomography/whole body imaging/ whole body scan/ multisystem scan/ Pan-scan/ total body scan/ whole body scanning/ CT scanning/ Tomography X-ray computed/ tomography emission-computed/ whole body computed tomography/ whole body multislice computed tomography/ total body CT/ whole body CT)
Comparator	*physicians' clinical judgement to determine when to order a WBCT*	(No terms included)
Outcome	*the sensitivity and specificity of the investigation to detect clinically relevant injuries*	(injur* AND severity)/ injur*/ sensitivity/ specificity/ diagnostic accuracy

Table 1: Search terms used to develop the search strategies for each of the electronic databases used in the review.

A – Search Strategy

The search strategy used for Medline is shown below:

*[(multiple trauma.mp. or *Multiple Trauma/) or (*Trauma Centers/ or trauma centres.mp.) or (wounds, non penetrating.mp. or *Wounds, Nonpenetrating/) or trauma CT.mp.] and [(injury severity score.mp. or *Injury Severity Score/) or (*Trauma Severity Indices/ or trauma severity indices.mp.) or primary survey.mp. or indications.mp. or*

*decision tool.mp.] and [(whole body imaging.mp. or *Whole Body Imaging/) or (tomography x-ray computed.mp. or *Tomography, X-Ray Computed/) or (whole body CT.mp.)]*

The search was limited to studies published in or translated to English (including conference proceedings and abstracts). This search strategy was modified for use in Cinahl and the Cochrane Library.

Studies of the diagnostic accuracy of WBCT in adult major trauma patients were included in the review, if they investigated the use of clinical guidelines in determining the need for WBCT in trauma. Studies using specified clinical outcomes to define a 'positive' scan were included in the review. Exclusion criteria included studies with only paediatric patients, those investigating focused CT scanning alone, those assessing WBCT in non-trauma patients and studies using outcomes other than a 'positive' scan (for example, studies investigating the impact of WBCT on mortality).

A – Data Extraction, Reporting of Outcome and Critical Appraisal of Papers

For each eligible study, data were extracted using a standardised data extraction form (Appendix 1). For each study, data extraction was performed independently by two of the four primary researchers (NH, AM, JM and MY), and checked by the two research supervisors (IS and HC). Where possible, the sensitivity and specificity of WBCT was extracted from the study data, or calculated from data provided in the study results. Other measures of diagnostic importance (including the number of 'unsuspected' or 'clinically occult' injuries identified using WBCT) were also reported, where relevant to the study being reviewed.

Each of the studies included in the final review were critically appraised using the CASP checklist for assessing cohort studies (19). Due to the methodological heterogeneity between studies, narrative synthesis was employed to describe the overall findings of the review. Meta-analysis of the results was not attempted.

Results

888 studies were identified: 887 through the electronic databases and 1 through manual searching of reference lists of previously identified studies. Of these, 871 were excluded on title and abstract. Of the remaining 17 studies, 10 were excluded as they did not fulfil our inclusion criteria. Three (3) of these studies did not investigate clinical guidelines for WBCT in trauma (20-22). Five (5) used outcomes other than a positive scan as their primary outcome, including time to definitive surgery (1 study); time spent in the ED (1 study); dose of contrast media (1 study) and mortality (2 studies) (1, 4-7). One survey of Swiss Trauma Centres investigated if hospitals had protocols for the use of WBCT, but did not assess their diagnostic accuracy (14). One systematic review of WBCT in trauma was found, looking broadly at the indications for WBCT in trauma (10). Appendix 2 shows the PRISMA flow diagram for our systematic review.

Table 2 provides a summary of the papers included in the systematic review. All 7 studies were single centre, observational studies (3 retrospective and 4 prospective designs). There were no randomised controlled trials and no diagnostic studies. Two studies explicitly compared the accuracy of imaging protocols with routine clinical decision making (23, 24). Two studies investigated the utility of using currently existing triage criteria for trauma patients to determine which needed WBCT (8, 25). Two studies assessed triage systems for trauma patients, investigating the diagnostic accuracy of different components of each system in determining the need for WBCT (26, 27). The final study used logistic regression analysis to develop a clinical decision rule for WBCT from prospectively collected data, and assessed the diagnostic accuracy of this derived tool in identifying suitable patients for WBCT (28).

A – Studies comparing routine practice to clinical decision rules

Hsiao K.H. et al (2013) studied the sensitivity and specificity of WBCT versus targeted CT in detecting multi-region trauma, and the impact of a clinical decision rule (compared to physician judgement) for ordering WBCT. The primary outcome was the identification of multi-region trauma, defined as one or more injuries (AIS > 1), in ≥ 2 body regions. External superficial soft tissue injuries or injuries located in the extremities were excluded. Body regions were defined as head or face, vertebral column, chest, abdomen or pelvis. All adult patients (age >15 years) whose initial assessment involved either a focused CT scan or a WBCT were included. Anyone who had been transferred from another department was excluded. 660 patients were enrolled in the study (562 had focused CT, while 98 had WBCT). The percentage of patients with multi-region injuries was significantly higher ($p < 0.001$) in patients who underwent WBCT (32%; 31/98), than in those who received targeted CT scanning (5.5%; 31/562). The sensitivity of WBCT was 50% (31/62) with a specificity of 89% (531/597). Statistically significant predictors of multi-region injury were identified, and these used to formulate a clinical decision rule. This rule mandated WBCT in all patients meeting full trauma activation criteria, or those with a GCS <9 (independent of whether there was a full trauma activation), or with an injury mechanism involving fall >5m, or if the patient was a pedal cyclist. Using this rule, the sensitivity of WBCT increased to 73% (45/62), but specificity was reduced to 57% (342/597). The difference between routine clinical practice and the decision rule was not statistically significant. Routine clinical practice was concluded to be the most accurate determinant for the use of WBCT. The majority of patients who had WBCT did not suffer multi-region injury (68%; 66/97 patients), and 5.5% of patients with multi-region injury did not receive a WBCT. The authors noted that the implementation of their derived clinical decision rule would increase the number of WBCT scans performed three-fold (from 15% to 46% of study patients) and increase the proportion of 'unjustified' scans (scans that ultimately did not identify multi-region trauma) from 68% to 85%.

Smith C.M. et al (2009) conducted an observational study to examine how the implementation of a WBCT protocol affected the detection of clinically significant injury. All patients that were suspected of having serious poly-trauma or serious injuries and had full medical records available were included in the study. Pre-protocol, the decision to perform a WBCT scan was made by the senior ED doctor and the duty radiologist that attended the patient. A protocol was then introduced, based on mechanism of injury (MOI) only (for patients with penetrating trauma this included gunshot wounds [including air rifle] and blast injuries, and for blunt trauma a motor vehicle crash with a combined velocity ≥ 50 km/h or with ejection, motorcyclist or pedestrian hit by vehicle >30 km/h, fall > 3 metres, fatality in the same vehicle, entrapment > 30 minutes or a crush injury to the thorax or abdomen). The authors identified all patients with 'significant' injuries on imaging as positive outcomes. The definition of 'significant' injuries was not clearly stated in the paper. The records of 254 patients were analysed: 116 pre-protocol and

138 post-protocol. The percentage of patients with an appropriate MOI that received WBCT increased from 47% (44/94) to 76% (87/114) with the introduction of the protocol. In the pre-protocol phase of the study, 7 of 116 patients (including 3/94 patients who had WBCT) had no identifiable injury on imaging while in the post-protocol phase, 32 of 138 patients (including 14/44 patients who had WBCT) had no injury. While sensitivity and specificity of WBCT pre- and post-protocol were not reported in the paper, these could be calculated from the data provided. Pre-protocol, the sensitivity of WBCT was 47.1%, with a specificity of 57.1%, while post-protocol the sensitivity of WBCT was 89.0% and the specificity was 56.2%. It should be noted, however these values refer to the sensitivity and specificity of WBCT in detecting of any injury (AIS >1). However, the authors also noted that, post-protocol, 17 injuries were diagnosed that would not have been suspected on clinical assessment alone. Of these, 3 led to a change in clinical management of the patient.

A – Studies that assessed the diagnostic accuracy of established trauma triage protocols

Salim A. et al (2006) conducted a prospective observational study over an 18-month period, which reviewed the clinical details of 1,000 consecutive trauma patients in whom WBCT was performed (8). Patients were included if they had a significant mechanism of injury, no visible evidence of chest or abdominal injury, were hemodynamically stable and had normal abdominal examination results in neurologically intact patients (or if abdominal examination was unevaluable secondary to a depressed level of consciousness). The main outcome was any change in the treatment of patients directly due to the findings of the WBCT. Of these patients, 592 were fully awake and had a normal abdominal examination (that is, they were scanned on mechanism of injury only) while the remaining 408 patients had altered conscious level and their abdominal examination was ‘unevaluable’. Of the 1000 patients included in the study, 189 (18.9%) patients had their treatment plan changed due to the results of the scan. In the 592 who received a WBCT scan due to their mechanism of injury only, 120 (20.3%) had their treatment plan changed due to the scan results. Of note, 138 of the 189 patients recorded as having a ‘change of treatment’ due to their WBCT scan had a normal scan (that is, the normal scan was determined to have contributed to a different treatment plan). There are a few inconsistencies in this study: while the authors listed ‘no visible signs of chest or abdominal injuries’ as an inclusion criterion, 323 participants were noted to have ‘visible signs of chest trauma’. In addition, the study only included patients who had a WBCT, so true sensitivity and specificity of the test cannot be determined (as patients who did not have a WBCT but turned out to have injuries would have been excluded from the analysis).

Wurmb T.E. et al (2007) conducted a retrospective single centre study assessing the accuracy of their trauma triage criteria (which included mechanism of injury, vital signs and clinically apparent injuries) in deciding the need for Whole Body CT Scan (25). The study population included trauma patients admitted to their trauma centre during the study period who were sedated and endotracheally intubated. A clinically significant outcome was defined as an ISS of ≥ 16. There were 120 patients in this study. Of the 85 triage positive patients, 70% (59/85) had an ISS of 16 or over, while 5.7% (2/35) patients had an ISS of ≥ 16. The authors calculated the sensitivity of the triage rule to be 96.7% (59/61), with a specificity of 55.9% (33/59). The positive predictive value was

69.4% (59/85) with a negative predictive value of 94.3% (33/35). The triage rule was not compared to routine clinical practice. A significant limitation of this study was the very strict inclusion criteria for this study. Only sedated, ventilated major trauma patients were included, introducing an element of selection bias and making the results not generalizable.

A – Studies investigating the diagnostic accuracy of different components of trauma triage systems in determining the need for WBCT

Babaud J. et al (2012) conducted a prospective, single centre observational study of 339 patients who had WBCT following major trauma, assessing the accuracy of different aspects of the Vittel criteria in identifying patients for WBCT (26). The Vittel criteria are a set of triage criteria used in the prehospital setting in France to characterise severity of trauma. The 339 patients were divided into 172 who would have had a WBCT on the physician's 'prescribing intent' (clinical judgement) and 164 who would have had one solely on the basis of the Vittel Criteria ('prescribing intent' was not recorded in 3 patients). Of the patients in whom the prescribing intent of the physician was to order a WBCT, 73.3% (126/164) were abnormal, compared to 32.3% 53/172) whose scans were ordered solely on the basis of the Vittel criteria. However, the overall sensitivity and specificity of the Vittel criteria could not be assessed, as all patients included in the study were Vittel criteria positive and all had a WBCT. The study also looked at the number of injuries identified outside of the area that would have been scanned on the basis of the physician's prescribing intent ('unsuspected injuries'). In total, 21.3% (35/164) of patients whose WBCT was ordered solely on the basis of the Vittel criteria had unsuspected injuries. There were a total of 49 unsuspected injuries and of these, 29 were classified as severe. Finally, the diagnostic accuracy of various components of the Vittel criteria was assessed. The commonest criteria in study subjects were 'global assessment of vehicle condition', 'thrown/run over' and 'ejected from vehicle'. Apart from 'global assessment of vehicle condition (sensitivity 76.2%), all other individual criteria had a sensitivity for identifying abnormal WBCT of <50%. Multivariate analysis of all Vittel criteria, 'Glasgow coma score <13'; 'fluid resuscitation of >1000ml' and 'penetrating trauma' were found to be independent predictors of an abnormal WBCT. However the authors noted that the results of the multivariate analysis should be interpreted with caution, as these criteria were seen in only a small number of subjects.

Sloan R. (2012) retrospectively reviewed the notes of 33 patients who had WBCT following major trauma, to assess the impact of mechanism of injury, clinical findings and vital signs on the probability of having a clinically occult injury. Mechanism of injury (MOI) was classified as 'minor', 'moderate' or 'severe' based on a modification of the findings of Lerner et al (29). Clinical findings and vital signs were classified using the revised trauma score and probability of survival for patients based on data from the Trauma Audt and Research Network. The authors found that 27.75% had a severe MOI, 48% had abnormal physiology and 55% had severe clinical assessment. Clinically occult injuries were found in 55% of study subjects. No statistically significant relationship was found between these variables and the diagnosis of clinically occult injuries. The study could not investigate the diagnostic accuracy of these clinical criteria, as it only included major trauma patients who had a WBCT, thus making the identification of 'false negative' patients (those with clinically occult injuries who did not have a WBCT) impossible. The major limitations of this study were its small sample size and retrospective design.

A – Studies that developed a de novo clinical decision rule based on the association between clinical characteristics of trauma patients and positive WBCT

Davies R.M. et al. (2016) used multivariate logistic regression modelling in their prospective observational study to identify the association between various clinical factors and the presence of polytrauma on WBCT. The authors defined polytrauma as the presence of any injuries of AIS >1 in more than one body region, but qualified this by defining 'significant' injuries as those with an AIS of >2. All patients who underwent WBCT for trauma during the study period were included. Of the 255 patients recruited, 16.5% (42/255) were positive. Five (5) significant predictors from the multivariate analysis were included in the final clinical decision model: clinical signs in more than one body region; Glasgow Coma Score; haemodynamic abnormality (systolic blood pressure below 100 mmHg or heart rate above 100); respiratory abnormality (respiratory rate over 24 breaths/minute or saturations below 93%) and mechanism of injury. The clinical decision rule devised by the authors had a sensitivity of 79% (95% CI 63–89%) and specificity of 71% (95% CI 66–78%) for detecting patients with polytrauma. However, the authors then added a second clinical decision rule to identify patients with 'significant' injuries in one body region (those in whom a focused CT would have identified their injuries). When combined (to select patient needing either a WBCT or a focused CT), the rules had a sensitivity of 95% (95% CI 86-99%) and a specificity of 59% (95% CI 52-66%). Only patients who had a WBCT were included in the study, so the true sensitivity of the rule could not be ascertained, as 'false negative' patients (those who had significant injuries, but did not have a WBCT) would not have been included. In addition, the second clinical decision rule was developed as a post-hoc analysis following the failure of the study to identify a decision rule that could identify patients with polytrauma with acceptable sensitivity. Finally, the authors' definition of 'polytrauma' is not widely accepted, as many researchers would not consider injuries of AIS = 2 to be clinical important in the context of major trauma.

A – Inclusion criteria for studies in this review

Table 2 summarises the inclusion criteria and outcome measures used in each of the studies included in this systematic review. There was significant variation in the inclusion criteria for different studies. The studies by Babaud, Davies, Salim and Sloan restricted their sample to patients who had a WBCT as part of their initial management (8, 26-28). Of the 3 remaining studies, Hsiao et al included all trauma activations that had a CT (either WBCT or focused CT); Smith included all patients fulfilling the criteria for WBCT (whether or not a WBCT was performed) and Wurmb included all sedated and intubated trauma patients admitted to the trauma centre (whether or not a WBCT was done) (23-25).

A – Outcome measures used in different studies

The studies also used different criteria to define a 'positive' WBCT after trauma (Table 2). Babaud et al defined a positive outcome as all patients with any injury on WBCT. However, when analysing patients in whom the original intent of the treating physician was not to have a WBCT, they also identified the looked at the number of 'unsuspected injuries' picked up by WBCT (that is, the number of injuries found that were outside of the region that would have been scanned on the basis of the clinical judgement of the treating physician) (26). Davies et al defined a positive WBCT as one that identified multi-region trauma (injuries with an AIS of >1 in more than one body region). They also defined 'significant' injuries as those with an AIS of >2. This latter definition was used to select patients needing focused CT scanning (28). Like Davies, Hsiao et al used multi-region trauma (injuries in more than one body region, with an AIS of >1) as their man outcome (23). Salim et al identified any change in management plan directly attributable to the results of the WBCT as a 'positive' outcome. This included negative scans (for example negative finding on WBCT that allowed early discharge of patients) (8). In Sloan's review, the identification of any clinically occult injuries was a positive outcome (27). Smith et al reported the number of patients with any 'significant' injury found on WBCT (the authors did not define a 'significant' injury). This study also reported the number of injuries identified on WBCT that would have been missed if the scan was not done, and the number of patients in whom the identification of these 'missed' injuries led to a change in immediate management (24). Wurmb et al defined any patient with an ISS of ≥16 as a positive outcome (25).

Discussion

This review identified a small number of observational studies that investigated the utility of clinical decision rules for WBCT in trauma, but there were no prospective randomised trials or diagnostic studies. While most studies in the review found some benefit to the use of standardised protocols for WBCT in trauma, there is insufficient high-quality evidence to definitively confirm this benefit.

There is even less research comparing clinical decision rules with standard practice: only two studies in our review directly compared routine clinical practice to the use of clinical decision rules. Of these, Hsiao's study from Australia demonstrated no benefit to the use of a standardised protocol compared to routine clinical practice, while Smith's study from the United Kingdom suggested that the use of a protocol improved sensitivity of WBCT without adversely affecting specificity. However, both studies were relatively small, with significant differences in study design and outcome measures (23, 24).

The wide methodological variation between studies makes it impossible to compare the results of different studies with each other. Of the seven studies included in our review, some were prospective while others were retrospective; some included only patients who had undergone a WBCT, while in others, all trauma patients were included; the outcome measured varied widely and the clinical decision rules used in each study were unique to that study (8, 23-28). With this degree of variation, comparison of different studies would be inappropriate. They therefore do not help the reader to decide which particular rule is best for identifying patients who would benefit most from WBCT.

The significant variation in the inclusion criteria for each study is partly explained by a lack of standardisation of definitions of major trauma patients globally. Different inclusion criteria are used by different trauma registries across the world (30-33). Similarly, inclusion criteria for the studies in this review varied from all trauma patients through only those in whom a WBCT was obtained to only those patients who were sedated and intubated (8, 23-28). As with other methodological differences between studies, this variation in inclusion criteria made it difficult to meaningfully compare results across studies. This variation in inclusion criteria has been a feature of research into the use of WBCT in trauma for some time. For example, the landmark study by Huber-Wagner et al into the impact of WBCT on mortality only included patients with blunt trauma and an ISS of >15 (34). While this study provided good evidence of a survival benefit of WBCT in severely injured patients, it did not address the issue of its use in the less severely injured.

The wide variation in outcomes used in each study demonstrates a lack of consensus in the research community regarding the clinical significance of CT scan findings in trauma. Other authors have questioned the significance of some radiological findings in trauma patients. For example, some studies have questioned the clinical importance of cerebral contusions, subarachnoid haemorrhages, rib fractures and pneumothoraces in the setting of major trauma (35-37). In this context, it is no surprise that studies into the utility of WBCT do not agree on the most appropriate outcome measure to use.

The wide variation in definitions and methodology of the studies in this systematic review parallels variations in the use of WBCT in major trauma generally. Previous studies in the UK and Europe have documented broad differences in the use of clinical guidelines for WBCT in trauma between individual hospitals (9, 14). In addition a review of data from the Trauma Audit and Research Network found a significant and largely unexplained variation in the use of WBCT in trauma between individual hospitals in the United Kingdom (17). The lack of good quality evidence supporting any guidelines has meant that none of the current guidelines are widely accepted or implemented (9, 14).

There were a few limitations of this study. Only English language publications were included, and the ‘grey’ literature was not included in the review: thus, there is a chance that studies from non-English speaking countries were missed. In addition there may have been publication bias in study selection, although conference proceedings and abstracts of papers were also searched in this review.

Conclusion

While our systematic review identified a number of observational studies that investigated the impact of clinical decision rules on the diagnostic accuracy of WBCT, there was significant methodological variation, limiting the usefulness of comparison. We would recommend the design and conduct of a large multicentre trial specifically designed to identify the most appropriate clinical decision rule for WBCT in trauma, that would maximise the sensitivity of the test while minimising the number of unnecessary investigations. While there is good evidence that WBCT confers a survival benefit in patients with serious injuries (ISS >15), the need for WBCT in less severely injured patients is less clear, and more research into this group of patients is required.

Table and Figure Legends

Table 1: Search terms used to develop the search strategies for each of the electronic databases used in the review.

Table 2: Summary of studies included in the systematic review

Appendix 1: Data extraction tool used in the systematic review

Appendix 2: PRISMA flow diagram for the systematic review

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Table 1: Summary of all studies included in the systematic review

Paper	***Country***	***Year of Publication***	***Database***	***Type of Study***	***Main Aim***	***Patient Group and Sample Size***	***Main Outcome Measure***	***Main Findings***
Studies comparing routine practice to clinical decision rules								
Hsiao et al. *Whole-body computed tomography in the initial assessment of trauma patients: is there optimal criteria for patient selection?*	Australia	2013	Medline Via Ovid	Single centre, prospective cohort study.	To compare the accuracy of clinical judgement to a clinical decision rule when ordering WBCT in trauma	All patients aged >15 years admitted as major trauma to a level 1 trauma centre in Australia, who had a CT scan (either focused CT or WBCT) as part of their initial management. *(n=660)* *562 had focused CT and 98 had WBCT.*	Percentage of patients with multi-region trauma (one or more injuries [AIS > 1], in ≥ 2 body regions).	Using clinical judgement, the sensitivity and specificity of WBCT were 50% and 89% respectively. Using the protocol, the sensitivity and specificity of WBCT were 73% and 57%. The protocol increased the percentage of 'unnecessary' scans from 68% to 85%. The differences in sensitivity and specificity were not significant.
Smith et al. *Major trauma CT scanning: the experience of a regional trauma centre in the UK*	United Kingdom	2011	Medline Via Ovid	Single centre observational study	To assess the effect of a WBCT Protocol on detection of clinically significant results	All major trauma patients admitted to a UK major trauma centre, who were suspected of having major trauma or severe injury. *(n = 254)* *116 presented in a 3-month period before and 138 presented after the introduction of a WBCT Protocol.*	Percentage of eligible patients (according to the triage protocol) who had a WBCT; Number of patients fulfilling criteria for WBCT who had significant injuries. Sensitivity and Specificity of WBCT were calculated from the data provided in the study.	Percentage of eligible patients (according to the triage protocol) who had a WBCT increased from 47% (44/94) pre-protocol to 76% (87/114) post-protocol Pre-protocol, 7 of 116 patients (including 3/94 patients who had WBCT) had no identifiable injury while in the post-protocol phase, 32 of 138 patients (including 14/44 patients who had WBCT) had no injury. Sensitivity and specificity of WBCT prior to protocol were 47.1% and 57.1% respectively, while post-protocol they were 89.0% and 56.2%.

Studies that assessed the diagnostic accuracy of established trauma triage protocols								
Salim et al *Whole Body Imaging in Blunt Multisystem Trauma Patients Without Obvious Signs of Injury*	United States	2006	Medline Via Ovid	Single centre prospective observational study	To determine the accuracy of WBCT to detect injuries in trauma patients with no obvious signs of chest or abdominal injury	Consecutive patients admitted to a level 1 trauma centre with a significant mechanism of injury, no visible evidence of chest or abdominal injury, were hemodynamically stable and had normal abdominal examination results in neurologically intact patients (or unevaluable abdominal examination results secondary to a depressed level of consciousness). *(n=1,000)*	Findings on CT scan that changed the immediate management of patients (including normal scans that allowed, for example, early discharge)	592 patients were awake and had a normal abdominal examination; 408 had altered consciousness and their abdominal examination was 'unevaluable'. 189 (18.9%) of all patients had their treatment plan changed due to the WBCT; including 120 (20.3%) of the awake patients with a normal abdominal examination. 138 of the 189 patients who had their treatment plans changed had a normal WBCT (treatment changed due to no detected injuries).
Wurmb et al. *Whole-body multislice computed tomography as the primary and sole diagnostic tool in patients with blunt trauma: searching for its appropriate indication.*	Germany	2007	Medline Via Ovid	Single centre retrospective study	To assess if the Triage Rule in ordering WBCT helped to identify patients with Major Trauma	Trauma Patients that were sedated, endotrachealy incubated and ventilated *(n=160)*	Injury Severity Score >15	85 patients required WBCT as a result of Triage Rule: 70% (n=59) had ISS > 15 30% (n=26) had ISS <16 9 of those with ISS below 16 did have significant injuries Triage Rule: Sensitivity = 96.7%, Specificity = 55.9% NPV = 94.3% PPV = 69.4%

Studies investigating the diagnostic accuracy of different components of trauma triage systems in determining the need for WBCT								
Babaud et al. *Benefit of the Vittel criteria to determine the need for whole body scanning in a severe trauma patient.*	France	2012	Medline via Ovid	Single centre prospective study	To investigate the effectiveness of Vittel Criteria in determining need for Whole Body CT Scan	Trauma Patients who had a WBCT after referral from the ED or Surgical Resuscitation Room between December 2008 and November 2009, *(n=339)*	Injuries that would not have been identified if the patient had only been investigated according to the intent of the treating physician (either WBCT, focused CT or no CT).	Out of all WBCT ordered 44.2% were normal (n=150) 164 were prescribed solely on Vittel Criteria of which 67.7% were normal and 32.3% abnormal. 15% of patients that had a WBCT due to Vittel Criteria had unsuspected severe injuries.
Sloan *A retrospective review of influences on clinicians to order whole body CT scans in trauma and its effectiveness in this regard.* Abstract only	United Kingdom	2013	Manual search of reference lists	Single centre retrospective observational study	To identify the association between different trauma triage parameters (mechanism of injury, vital signs and clinical findings) and the presence of clinically occult injuries on WBCT	Trauma patients admitted to a UK regional trauma centre, who had a WBCT as part of their initial management. (n=33)	Clinically occult injuries (the term was not defined in the abstract)	No statistically significant relationship was found between any of these variables and the diagnosis of clinically occult injuries. Moderate or severe MOI increased probability of COI being diagnosed by 1.368 and 4.965 respectively. Moderate and severe physiology increased the probability of diagnosing a COI by 1.368 and 8.682 respectively. Moderate clinical assessment increased the probability of diagnosing a COI by 3.526 while severe clinical assessment decreased it by 69%, but none of these associations was statistically significant. The study sample size was very small.

Studies that developed a de novo clinical decision rule based on the association between clinical characteristics of trauma patients and positive WBCT								
Davies et al. *A decision tool for whole-body CT in major trauma that safely reduces unnecessary scanning and associated radiation risks: An initial exploratory analysis.*	United Kingdom	2016	Medline via Ovid	Single centre prospective observational study	To identify the association between various clinical factors and the presence of polytrauma on WBCT, using multivariate logistic regression modelling. A clinical decision rule was then created and its accuracy in selecting patients for WBCT was assessed.	Trauma patients admitted to a UK regional trauma centre, who had a WBCT as part of their initial management. *(n = 255)*	Polytrauma, defined as the presence of any injuries of AIS >1 in more than one body region. A secondary outcome of 'significant' injuries was defined as injuries with an AIS of >2.	16% of scans were positive for polytrauma. 42% demonstrated some injury and 42% showed no injury. Sensitivity and specificity of clinical decision rule for detecting polytrauma on WBCT were 79% (95% CI 63–89%) and 71% (95% CI 66–78%)respectively. When a second rule for detecting significant injury was added, the sensitivity and specificity of the combined rules were 95% (95% CI 86-99%) and 59% (95% CI 52-66%). The study did not include patients who did not have WBCT, so true sensitivity could not be determined.

Appendix 1: Data extraction tool used in the systematic review

General information	**Date of data extraction** **14/10/16**
Identification features of the study	
Author	
Article Title	
Source (eg Journal, Conference) Year / Volume / Pages / Country of Origin	
Institutional Affiliation (first author) and/or contact address	
Identification of the reviewer	
Notes	
Specific information	
Study characteristics	
Verification of study eligibility	
Population characteristics and setting	
1 Target population (describe)	
2 Inclusion criteria	
3 Exclusion criteria	
4 Recruitment procedures used (participation rates if available)	
5 Characteristics of participants at intervention commencement	

• age
• ethnicity
• class
• sex
• other information
• geographical region
6 Number of participants
7 Were intervention and control groups comparable?
Methodological quality of the study
Interventions
1 Focus of intervention
2 Intervention site
3 Delivery mode of intervention
4 What mediating variables were investigated (if any)
5 Staff types
Outcomes, outcome measures
1 What was measured at baseline?
2 What was measured after the intervention?

3 Who carried out the measurement?
4 What was the measurement tool?
5 Was/were the tool(s) validated and how?
Analysis
1 Statistical techniques used
2 Does technique adjust for confounding?
3 Unit of analysis
4 Attrition rate (overall rates)
5 Was attrition adequately dealt with?
6 Number (or %) followed-up from each condition
Results
Quantitative results (e.g. estimates of effect size)
Effect of the intervention on other mediating variables
Qualitative results
Cost of intervention
Cost-effectiveness
Notes

4

Appendix 2 - PRISMA Flow Diagram for the systematic review