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A decision tool for whole-body CT in major trauma that safely reduces unnecessary scanning and associated radiation risks: An initial exploratory analysis

Ronnie M. Davies [a,*], Ashley B. Scrimshire [a], Lorna Sweetman [b], Michael J. Anderton [a], E. Martin Holt [a]

[a] Department of Orthopaedics, University Hospital of South Manchester, Southmoor Road, Wythenshawe M239LT, United Kingdom
[b] Christie NHS Foundation Trust, 550 Wilmslow Road, Manchester M20 4BX, United Kingdom

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ABSTRACT

Background: Whole-body CT (WBCT) has become routine practice in the assessment of major trauma patients. Whilst this may be associated with increased survival, several studies report high rates of negative scans. As no national guideline exists, selection criteria for WBCT vary widely. This study aims to (1) produce a scoring system that improves patient selection for WBCT (2) quantify patient radiation doses and their concomitant risk of malignancy.

Methods: Clinical notes were reviewed for all patients undergoing a WBCT for trauma over a 21-month period at a UK major trauma centre. Clinical and radiological findings were categorised according to body region. Univariate analysis was performed using Chi-squared testing, followed by multivariable logistic regression. Secondary regression analysis of patients with significant injuries that the model did not identify was performed. The model was optimised and used to develop a scoring system. Sensitivity and specificity were calculated using the same dataset as was used to derive the models. Radiation exposure was determined and the excess lifetime risk of malignancy calculated.

Results: 255 patients were included, with a mean age of 45 years. 16% of scans were positive for polytrauma, 42% demonstrated some injury and 42% showed no injury. The regression model identified independent predictors of polytrauma to be (1) clinical signs in more than one body region, (2) reduced Glasgow Coma Score, (3) haemodynamic abnormality, (4) respiratory abnormality, (5) mechanism of injury. The final model had a sensitivity of 95% (95% CI 86–99%) and specificity of 59% (95% CI 52–66%) for significant CT findings. Mean radiation exposure was 31.8 mSv, conferring a median excess malignancy risk of 1 in 474.

Conclusion: After including neurological deficit, our scoring system had a sensitivity of 97% (95% CI 88–99%) and specificity of 56% (95% CI 49–64%) for significant injury. We propose this is used to stratify the use of trauma radiographs, focused CT and WBCT for major trauma patients. Although not intended to replace clinical judgement, our scoring system adds an objective component to decision-making. We believe this will safely reduce the number of unnecessary CT scans performed on a relatively young cohort of patients.

Introduction

Optimal care of the polytraumatised patient requires rapid identification and treatment of immediately life-threatening injuries. Subsequently, additional injuries must be identified and their treatment prioritised. This approach has been encapsulated by the Advanced Trauma Life Support (ATLS®) protocol [1], and is practised across the United Kingdom in its major trauma centres. Although this protocol emphasises detailed clinical examination and basic radiographic imaging, advances in computed tomography have seen a shift towards early whole-body imaging, with a de-emphasis of the clinical examination.

* Corresponding author. Tel.: +44 0161 998 7070.
E-mail address: ronnie@etailers.co.uk (R.M. Davies).

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Whole-body computed tomography (WBCT) scanning of polytrauma patients has been reported since 1997 [2], Such scans are typically contrast-enhanced helical CT scans from vertex to upper thigh and are intended to identify traumatic injuries early and avoid missing injuries. Several studies have demonstrated a survival benefit for patients undergoing early WBCT scans [3,4]. Contrary to the historical view that the CT scanner is the 'doughnut of death' [5] for trauma patients, multidetector CT scanners acquire up to 128 slices at a time, with acquisition times of three minutes or less [6]. This has made WBCT possible for haemodynamically-unstable patients [7]. One advantage of WBCT over standard diagnostic approaches is a reduction in time taken to obtain a final diagnosis (33 min vs. 70 min) [8] and management plan (47 min vs. 83 min). Further justification for the routine use of WBCT in polytrauma cites the identification of clinically-occult injuries (COIs), which may not otherwise be apparent [9,10], although their clinical relevance in changing management is subject to debate [11,12]. It is estimated that between 1 and 6% of patients may have their management changed if a WBCT is performed [13,14].

WBCT is of benefit if used judiciously in the care of trauma patients but it exposes a relatively young cohort of patients to high-doses of ionising radiation of approximately 20 mSv [15,16], equivalent to approximately 1000 chest radiographs [17]. It is a doctor's duty to minimise radiation exposure to as low as reasonably practicable [18]. Several studies have reported high rates of unnecessary or negative scans, ranging from 14 to 30% [13,19,20]. In our institution, the rate of negative WBCT scan was 42%.

The decision to perform a WBCT is heavily influenced by the mechanism of injury [21], physiologic parameters [20] and clinical suspicion of major injuries. Currently, the evidence for selecting which patients require a WBCT is at the level of expert opinion [22], based on a Delphi study and the need for higher-level evidence has been recognised [23], 22% of hospitals have developed a local policy for which patients should have a WBCT [24] although these policies vary as no national guidelines for selection criteria exist.

The aim of our study was to determine clinical features that most reliably predict positive findings on a WBCT. These can be used to produce an evidence-based guideline for selecting which patients require a WBCT, and thereby reduce negative scans. Our secondary aim was to quantify the radiation dose that each patient received, and their concomitant risk of malignancy.

Patients and methods

Study design

This was a single-centre cohort study, undertaken at a Major Trauma Centre in the United Kingdom. The study took place over a 21-month period, between April 2012 and January 2014. Data collection occurred prospectively using a standardised trauma proforma, and was analysed retrospectively following anonymisation.

Inclusion and exclusion criteria

All patients who underwent a whole-body CT scan for trauma during the study period were included. Those who were intubated prior to arrival were excluded as clinical examination would be limited, necessitating a WBCT to diagnose their injuries. As with previous studies [3,9], we excluded patients with isolated penetrating trauma because occult injuries are unlikely remote from the penetration track. Drownings, those with delayed presentation greater than 24 h and patients with incomplete case notes were excluded. Of 281 patients identified, 255 were included in the analysis (Fig. 1).

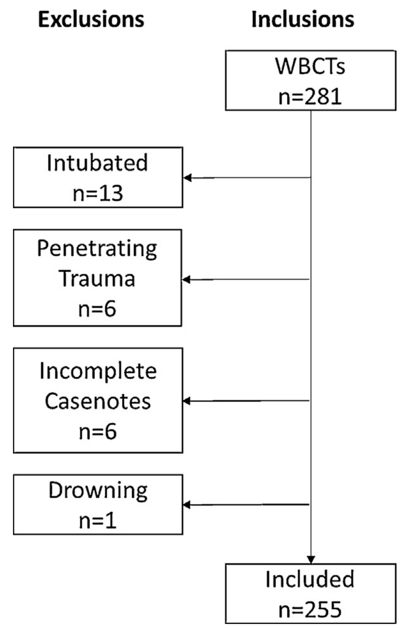

Fig. 1. Inclusion and exclusion criteria.

Emergency management

Polytrauma patients were managed in line with the ATLS® protocol. A trauma team attended to each patient. It was led by an emergency department consultant or registrar and comprised an anaesthetist, a general surgeon, an orthopaedic surgeon, a cardiothoracic surgeon and nursing staff. The decision to proceed to a WBCT scan was at the discretion of the trauma team leader. A plain chest radiograph was performed prior to transfer to CT if there were concerns about untreated thoracic injuries. Plain radiographic evaluation following clinical examination of the pelvis or cervical spine prior to the WBCT was performed for selected patients.

Our institution's standard CT protocol was a non-contrast scan of the head and neck, with a contrast-enhanced arterial scan of the chest, abdomen and pelvis followed by a venous phase scan of the abdomen and pelvis. Scans were initially performed using a Siemens SOMATOM Sensation 16-slice CT scanner (61% of scans), until it was replaced by a Siemens SOMATOM Perspective 128-slice scanner (37% of scans). When the primary scanner was unavailable, a Siemens SOMATOM Emotion scanner was used (2% of scans). All patients were scanned from vertex to lesser trochanters. All scan reports were verified by a consultant radiologist.

Data collection

Data collected from emergency department notes included patient demographics, basic observations and haemodynamic parameters (Table 1). Where recorded, the mechanism of injury was classified using a system similar to that adopted by a previous study [25], including height of fall or vehicle types involved. Clinical examination was divided into five separate body regions: head and face, vertebral column, chest, abdomen and bony pelvis. The presence of clinical findings defined as tenderness, bruising and swelling, along with localised signs, such as abnormal breath sounds or crepitus in each of these body regions was recorded. Isolated grazes and superficial abrasions were not counted as significant.

The WBCT scan findings for each patient were divided into the same five body regions and abnormalities within each region recorded. The maximum abbreviated injury score (AIS) [26] for each of these body regions was then determined. Radiation exposure data from the CT scans was also recorded.

Table 1
Criteria for whole-body CT. Positive scan is defined as an AIS > 1 in 2 or more body regions. $n = 255$.

Criterion	Positive scan ($n = 42$), n (%)	Negative scan ($n = 213$), n (%)	Odds ratio (95% CI)	p-Value
Clinical evidence of injury to >1 body region**	30 (71)	92 (43)	3.01 (1.5–6.1)	0.002*
Arrival by helicopter ambulance	14 (33)	60 (28)	1.22 (0.6–2.5)	0.575
Glasgow Coma Score < 14**	11 (26)	14 (7)	4.9 (2.0–11.6)	<0.001*
Haemodynamic abnormality**	27 (64)	68 (32)	3.6 (1.8–7.1)	<0.001*
Systolic blood pressure <100 mmHg or Heart rate >100				
Respiratory abnormality**	22 (52)	34 (16)	5.6 (2.7–11.1)	<0.001*
Respiratory rate >24 breaths/minute or Saturations <93%				
Age > 64	9 (21)	37 (17)	1.5 (0.7–3.3)	0.331
Male sex	31 (74)	145 (68)	1.2 (0.6–2.5)	0.633
Mechanism**				0.006*
RTA (driver/passenger)	11 (26)	64 (30)	1.0	
Pedestrian or pushbike	9 (21)	29 (14)	1.6 (0.6–4.3)	0.324
Fall ≤ 5 m	6 (14)	71 (33)	0.4 (0.2–1.3)	0.125
Fall > 5 m	10 (24)	12 (6)	4.4 (1.5–12.4)	0.005
Motorcyclist	4 (10)	25 (12)	0.8 (0.2–2.7)	0.732
Other	2 (5)	12 (6)	1.0 (0.2–4.9)	0.955

* Statistically significant ($p < 0.05$).
** Independent predictor of polytrauma, identified on multivariable analysis.

Outcomes

The primary outcome for comparison was presence of polytrauma on WBCT. We defined polytrauma as a CT scan demonstrating an AIS > 1 in at least two body regions. For secondary analysis, a significant injury was defined as an AIS > 2 in any body region.

Data analysis

Data analysis used SPSS (version 22). We performed univariate analysis of dichotomous variables using chi-squared or Fisher's Exact tests. Odds ratios and their 95% confidence intervals for each parameter were calculated for each variable. A multivariable logistic regression model was then obtained. Parameters with $p < 0.1$ in the univariate analysis were entered into a backward stepwise elimination model with likelihood-ratio testing, stopping when all p-values were less than 0.05. The regression model was then used to develop a scoring system and a receiver operating characteristic curve was produced to determine the appropriate cut-off value for performing WBCT.

Radiation exposure data, dose-length product (DLP), were recorded separately for three scan regions: head, cervical spine, and thorax, abdomen and pelvis. Conversion coefficients from DLP to effective dose were calculated for each region using the ImPACT CT patient dosimetry calculator version 1.0.4 (ImPACT, London, UK) with ICRP103 weighting factors [27]. The total effective dose for each examination was determined by summing the products of the relevant conversion coefficients and DLPs. Using risk tables produced by Public Health England [17], the excess lifetime risk of new malignancy attributable to the radiation dose was determined.

Results

Of the 255 scans included in the analysis, 16% were positive for polytrauma and 42% demonstrated some injury and 42% showed no injury. The mean age was 45 years (range 2–100). The mean Injury Severity Score (ISS) was 16 for the 124 patients scored. Official scores were available only for patients whose ISS exceeded 8 and were submitted to the regional Trauma Network. The results of univariate analysis are summarised in Table 1. The multivariable regression model identified five independent predictors of polytrauma (Table 2):

- having 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%),
- mechanism of injury.

Table 2
Results of multivariable analysis indicating the final fitted model.

Criterion	Positive scan ($n = 42$), n (%)	Negative scan ($n = 213$), n (%)	Odds ratio (95% CI)	p-Value
Clinical evidence of injury to >1 body region	30 (71)	92 (43)	2.8 (1.2–6.3)	0.013
Glasgow Coma Score < 14	11 (26)	14 (7)	4.2 (1.4–12.4)	0.009
Haemodynamic abnormality	27 (64)	68 (32)	2.2 (1.0–4.8)	0.047
Systolic blood pressure <100 mmHg or Heart rate >100				
Respiratory abnormality	22 (52)	34 (16)	4.4 (1.9–10.2)	<0.001
Respiratory rate >24 breaths/minute or Saturations <93%				
Mechanism				0.033
RTA (driver/passenger)	11 (26)	64 (30)	1.0	
Pedestrian or pushbike	9 (21)	29 (14)	2.2 (0.7–6.5)	0.164
Fall ≤ 5 m	6 (14)	71 (33)	0.4 (0.1–1.3)	0.142
Fall > 5 m	10 (24)	12 (6)	2.9 (0.9–9.8)	0.076
Motorcyclist	4 (10)	25 (12)	0.6 (0.1–2.4)	0.458
Other	2 (5)	12 (6)	0.6 (0.1–4.2)	0.614

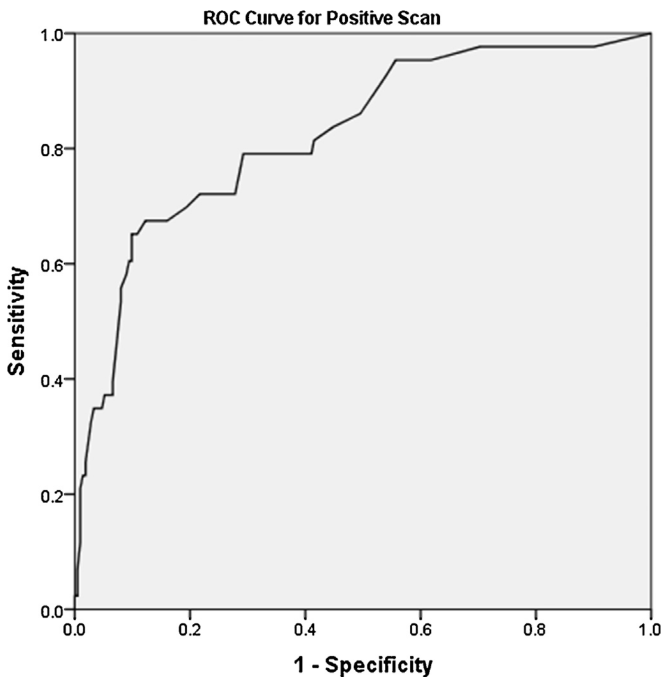

Fig. 2. Receiver operating characteristic for the multivariable model. The area under curve is 0.82 (95% CI 0.75–0.90).

The area under curve of the receiver operating characteristic for this model, is 0.82 (95% CI 0.75–0.90) (Fig. 2). The best cut-off produces a sensitivity of 79% (95% CI 63–89%) and specificity of 71% (95% CI 66–78%).

Since the regression model misses 21% of patients with multiple injuries, data for all patients excluded from a WBCT were reanalysed to determine whether a secondary set of criteria could be produced to pick up these injuries on a region-specific CT. For this phase of analysis, scans were also classified as positive if a single body region had an AIS of 3 or above. Using the additional criteria of (a) the presence of clinical signs in a single body region, (b) positive findings on a radiographic trauma series of the cervical spine (AP, lateral and peg view), chest and pelvis, and (c) positive findings on log rolling the patient, multivariable analysis found respiratory abnormality and trauma series abnormalities to be independent predictors of positive findings on a region-specific CT scan. If body regions identified clinically or on trauma series have a region-specific CT, the sensitivity of this secondary model for focused scanning is 89% (95% CI 71–97%) and specificity 88% (95% CI 80–93%). Scanning only areas of clinical suspicion would not have missed any injuries with an AIS of 2 or greater.

If the two predictive models are used in combination, with patients excluded from WBCT having focused scans if they have a positive trauma series, the sensitivity is 95% (95% CI 86–99%) and specificity is 59% (95% CI 52–66%) for detecting patients with multiple injuries of AIS > 1 or single injuries of AIS > 2. Applied retrospectively to our dataset, 114 patients would not have required any scan. 96 would have had a WBCT and 41 would have had a focused CT. Four patients would have had the following injuries missed:

1. Maxillary and skull fractures.
2. Nasal and scapular fractures.
3. Stable L1 vertebral wedge fracture with no neurological deficit.
4. T8/9 fracture-dislocation, with neurological deficit.

Radiation doses

The mean effective radiation dose was 31.8 mSv (SD 9.1). No significant differences in dose were found by age or sex of patients aged 15 years or older, or by CT scanner used. Therefore variations in the excess lifetime risk of malignancy are primarily due to age and sex. The median excess risk of lifetime malignancy was 1 in 683. The highest risk patient was a 19-year-old female, with an estimated increased risk of malignancy of 1 in 194 (0.5%). Four scans were performed on paediatric patients with an average dose of 16.1 mSv and median excess risk of lifetime malignancy of 1 in 474. A steady decline in malignancy risk was found with advancing age (Fig. 3). Over the period of the study, the collective radiation dose was 8.1manSv, representing 1.9% of the dose from all CT examinations performed at our institution, but only 0.7% of the number of examinations.

Discussion

This study evaluates comprehensively Whole-body CT scans for polytrauma, with radiation doses and attributable risks. Through regression analysis, we have derived a model that predicts which patients have significant findings on CT scanning. This model has a high sensitivity, missing only four injuries when applied to our data. The most serious of these injuries was a fracture-dislocation of the thoracic spine with a documented neurological deficit. However the predictive model could be further optimised by including significant neurological findings as an indication to perform a CT scan. We reviewed the other patients' injuries that our model missed. For each of these patients, there was no documentation of a log roll, facial bruising or tenderness, or shoulder pain. If these had been documented, their scores would have triggered a WBCT on the basis of our scoring system. We believe that these omissions relate to inadequate documentation, rather than the absence of clinical signs.

Our results extend the findings of a previous study that investigated prediction criteria to select patients who would benefit from a WBCT [25]. They compared 562 patients who underwent a focused CT scan with 98 patients who underwent a WBCT and found independent predictors of polytrauma to be male gender, falls > 5 m, cyclists, SBP < 90 mmHg and GCS < 9. They produced a predictive model with 73% sensitivity and 57% specificity, inferior to our results. Methodologically, we were at an advantage because Hsiao et al. performed WBCT in only 15% of their subjects. In contrast, the practice in our institution was to perform a WBCT for all polytrauma patients, making it possible to more accurately determine the existence of all CT-diagnosable injuries.

We propose a decision-making tool for clinical practice based on our analysis that can be used to decide whether a patient requires a WBCT or focused CT imaging (Fig. 4). The scoring system was produced by rescaling and rounding the regression coefficients obtained from the final, selected regression model. The possible score ranges from -1 to 13, with a cut-off value of 4 for WBCT. Patients who are unconscious or have signs of spinal cord injury bypass the scoring and proceed directly to WBCT since their condition makes clinical examination unreliable. Patients with low scores following clinical examination have a radiographic trauma series, following which those with positive findings on the trauma radiographs, and those with respiratory abnormality should be considered for focused CT scanning of areas of clinical interest.

Retrospective application of our composite decision tool, the Manchester Trauma Imaging Score (ManTIS) results in a sensitivity of 97% (95% CI 88–99%) and specificity of 56% (95% CI 49–64%). These values compare favourably with other widely-used decision criteria for diagnostic imaging in trauma, such as the Canadian

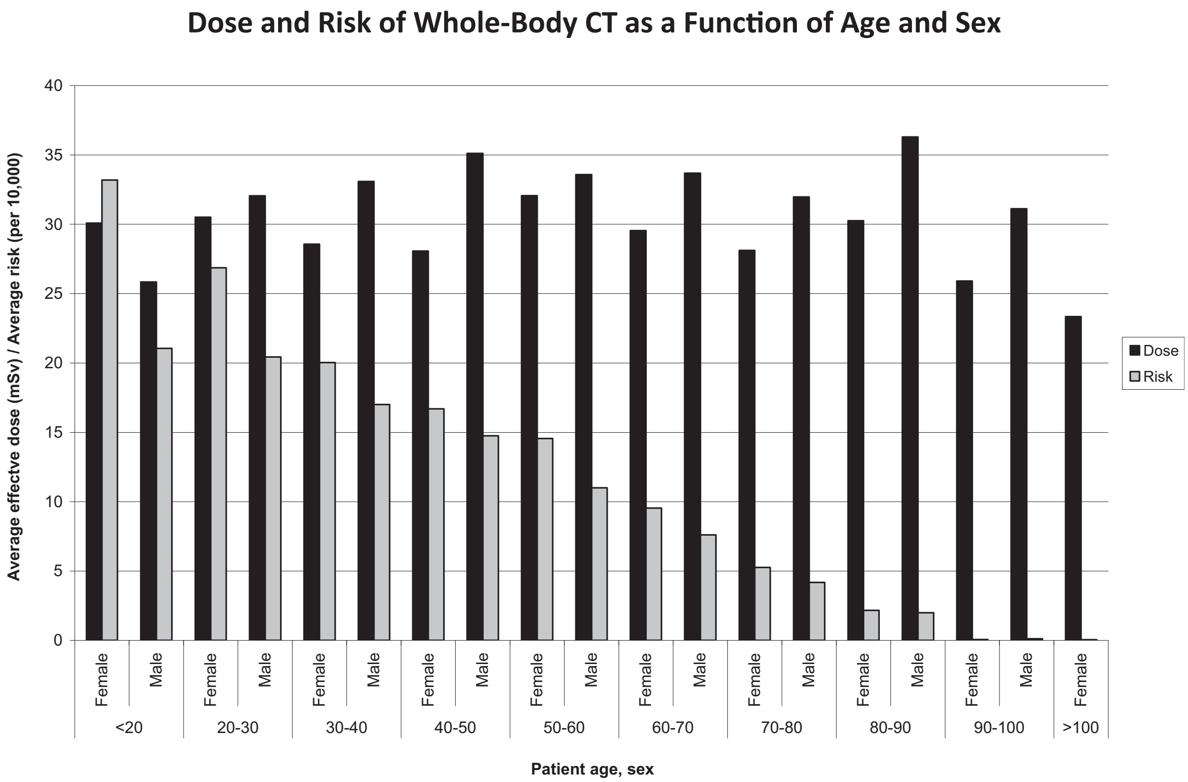

Fig. 3. Radiation dose and associated risk of malignancy for whole-body CT scans as a function of age and sex.

C-Spine Rule [28], which has a sensitivity of 95% and specificity of 51%. Our system would have missed two patients whose cases have been described above: one had a stable L1 vertebral wedge fracture and another had maxillary and scapular fractures. As with any decision-aid, it is impossible to account for every eventuality and we recommend that the ManTIS is used as a guide, and should be overridden by clinical suspicion in all cases.

Some studies advocate selective scanning [29,30], while others [4,31] have demonstrated a survival benefit of WBCT over focused scanning. These studies are limited to patients with severe injuries, having excluded patients who had negative scans. One systematic review and meta-analysis did demonstrate a survival benefit of 83% vs. 80% for patients undergoing a WBCT versus focused scanning respectively [32]. Another meta-analysis [33] was unable

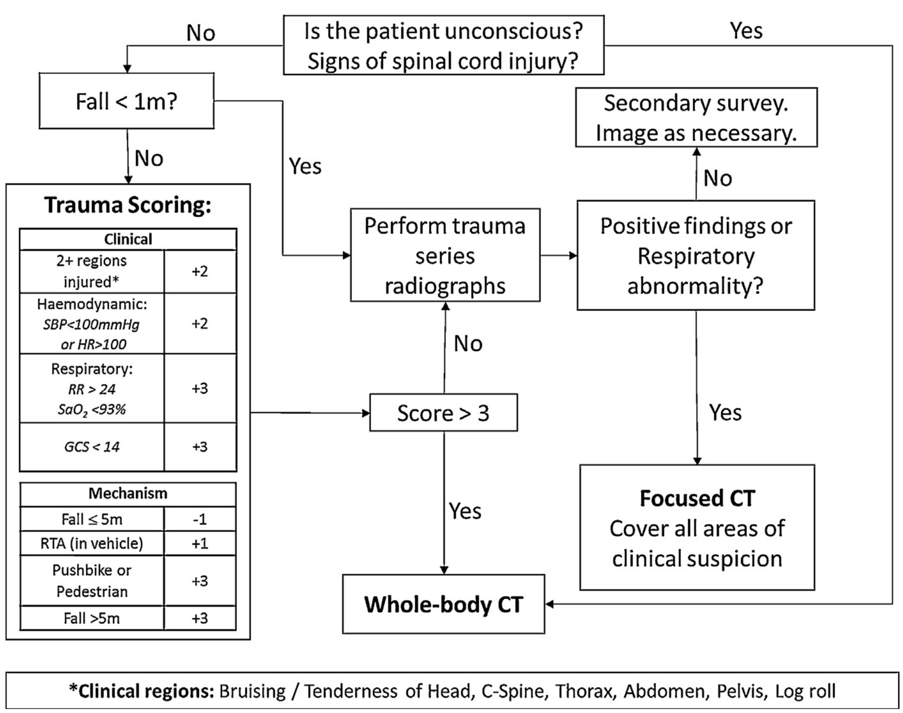

Fig. 4. The Manchester Trauma Imaging Protocol, a decision tool for imaging in polytrauma.

to demonstrate a survival advantage of WBCT versus focused scanning. In previous studies, the study populations had a mean ISS of over 25, suggesting that they included patients with more severe injuries, and excluded patients with negative scans. Our series included all patients with suspected polytrauma, rather than those retrospectively identified as such. We believe that this approach is more pragmatic because the true ISS is unknown when a patient presents in an emergency department.

A radiographic trauma series subject patients to a radiation dose of 0.87 mSv [34], considerably less than the dose of a WBCT. One may argue that clinical examination and a radiographic trauma series is of insufficient diagnostic sensitivity to exclude serious injuries. The sensitivity and specificity of clinical examination for cervical spine fractures is 80% and 74%, respectively [35]. Trauma radiographic evaluation of the cervical spine has a documented sensitivity of between 93% and 100% and a specificity of 95% [36] and combined clinical and radiographic examination has a sensitivity of 97% [1]. These figures compare favourably to the 98% sensitivity of CT scans [36] for picking up cervical spine fractures. Clinical examination of the chest has a negative predictive value of over 99% [37], meaning that it is highly reliable in excluding chest injuries and may preclude the need to perform any imaging of the chest. The sensitivity of a CT thorax is considerably higher that chest radiographs (CXR) in detecting thoracic injuries [38] however this is explained by some minor injuries such as undisplaced rib fractures, early pulmonary contusions and tiny pneumothoraces not visualised on CXR. Evidence that diagnosing these subtle injuries affects management is very limited [39,40], with most treated by simple observation. The negative predictive values for clinical examination and pelvic radiograph for diagnosing pelvic fractures are 99% and 98%, respectively [41], making these modalities appropriate first-line investigations for trauma patients.

It has been suggested that WBCT can be used in polytrauma as a screening test, rather than a diagnostic test, to identify clinically-occult injuries for all polytrauma patients [42]. If used liberally in this way, it must be conform to the standards of screening tools described by Wilson and Jungner [43]. One consideration is whether it causes harm to the patients. A WBCT scan confers an appreciable risk of malignancy to patients, 42% of whom required no scan at all in our series, with only 16% demonstrating radiological evidence of polytrauma. Our study suggests that large numbers of patients in the UK are being subjected to unnecessary radiation with its longer-term risk of future life-threatening consequences of malignancy.

Although associated with a high diagnostic accuracy for clinically-occult injuries, little is known about whether WBCT confers a survival advantage which outweighs the risk of radiation. Diagnosing additional injuries will produce an inflation of the ISS. Consequently, patients will appear to survive with a higher ISS, adding strength to the argument that WBCT is associated with reduced mortality (the Will Rogers phenomenon) [33]. This is exemplified by a large retrospective study which found a higher ISS in patients who underwent a WBCT, with no difference in unadjusted mortality [12]. The prognostic value of the ISS may therefore change as a result of such studies.

Only four paediatric patients were scanned and their radiation doses were approximately half that of adults. While the numbers are small, this suggests good practice in the use of "child-sized" protocols [44]. We have observed that the mean radiation dose calculated in our study was over 30 mSv, rather than the previously-quoted 20 mSv for a WBCT. While no national reference doses exist specifically for CT in polytrauma, the average DLPs for CT scans of the head and cervical spine were in line with the national references doses [45] for those examinations. We used up-to-date tissue weighting factors and validated methods for determining effective dose and therefore conclude that the lower value underestimates the actual dose to which patients are subjected thus increasing the concerns relating to the risk of WBCT scanning.

This study uses the definition of polytrauma being an AIS > 1 in 2 or more body regions, or an AIS > 2 in any single body region, based on the mortality risks published by the Association for the Advancement of Automotive Medicine [26]. The chance of survival for AIS scores of 1 or 2 is 99.3% and 99.2%, respectively. Only when AIS increases to 3 do survival rates drop to 96.5% for isolated injuries. We therefore believe that our definition of polytrauma is conservative, with a minimum ISS of 8. This approach increases the sensitivity of our scoring system, minimising the risk of missed injuries, although it may result in a higher number of unnecessary scans than if the definition of polytrauma were more stringent.

Limitations

Our dataset was limited by the variability in completion of trauma proformas. Some forms had been incompletely-filled, meaning that there was no documentation of clinical signs which may have influenced the quality of our data. If clinical signs were not documented, such as any findings when log rolling, we adopted a policy of assuming that they were not present. If anything, this would have reduced the sensitivity of our scoring system. Although proformas can improve the quality of documentation [46], in the busy emergency room, notes can be frequently incomplete.

In producing the model and scoring system, the same dataset was used to select the regression model as was used to look at the area under the curve, sensitivities and specificities. This produces a favourable bias of unknown magnitude for all of these measures. As this is an initial exploratory analysis, it will be important to validate our proposed model against an external dataset to confirm that the results are not exclusive to our data. External validation via a larger multi-centre study will permit our findings to be confirmed and allow the model to be optimised further to improve its accuracy.

Conclusions

Our study demonstrates that with proper evaluation, a large proportion of WBCT scans for trauma patients is unnecessary. Emergency physicians should resist the temptation to resort to a WBCT and instead rely on their clinical evaluation in choosing the most appropriate imaging modalities for their patients. WBCT scans undoubtedly identify more injuries, although their clinical relevance requires further study. WBCT scans expose patients to excessive future risk of malignancy, and place additional demands on radiology departments. Although our decision tool is not intended to replace clinical judgement, it can add a more objective component to decision-making. We believe that this will safely reduce the number of unnecessary scans performed on a relatively young cohort of patients. The ManTIS should be evaluated in a prospective validation study to confirm its wider applicability. Whole-body CT is a very useful diagnostic instrument but should be used as a necessary supplement not as an alternative to clinical history and examination. A doctor should remember first do no harm [47] and this should include the longer as well as the short term for a patient; use of the ManTIS may assist Emergency Doctors in their decision making at a time of intense activity.

Conflict of interest

The authors have no conflicts of interest to declare.

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References

[1] American College of Surgeons, editor. Advanced trauma life support student course manual. 9th ed., American College of Surgeons; 2012.
[2] Low R, Duber C, Schweden F, Lehmann L, Blum J, Thelen M. Whole body spiral CT in primary diagnosis of patients with multiple trauma in emergency situations. RoFo: Fortschritte auf dem Gebiete der Rontgenstrahlen und der Nuklearmedizin 1997;166(5):382–8.
[3] Huber-Wagner S, Lefering R, Qvick LM, Korner M, Kay MV, Pfeifer KJ, et al. Effect of whole-body CT during trauma resuscitation on survival: a retrospective, multicentre study. Lancet 2009;373(9673):1455–61.
[4] Yeguiayan JM, Yap A, Freysz M, Garrigue D, Jacquot C, Martin C, et al. Impact of whole-body computed tomography on mortality and surgical management of severe blunt trauma. Crit Care 2012;16(3):R101.
[5] Davis JW, Hoyt DB, Mackersie RC, McArdle MS. Complications in evaluating abdominal trauma: diagnostic peritoneal lavage versus computerized axial tomography. J Trauma 1990;30(12):1506–9.
[6] Ptak T, Rhea J, Novelline R. Experience with a continuous, single-pass whole-body multidetector CT protocol for trauma: the three-minute multiple trauma CT scan. Emerg Radiol 2001;8(5):250–6.
[7] Huber-Wagner S, Biberthaler P, Haberle S, Wierer M, Dobritz M, Rummeny E, et al. Whole-body CT in haemodynamically unstable severely injured patients – a retrospective, multicentre study. PLOS ONE 2013;8(7):e68880.
[8] Wurmb TE, Frühwald P, Hopfner W, Keil T, Kredel M, Brederlau J, et al. Whole-body multislice computed tomography as the first line diagnostic tool in patients with multiple injuries: the focus on time. J Trauma Acute Care Surg 2009;66(3):658–65.
[9] Salim A, Sangthong B, Martin M, Brown C, Plurad D, Demetriades D. Whole body imaging in blunt multisystem trauma patients without obvious signs of injury: results of a prospective study. Arch Surg 2006;141(5):468–75.
[10] Bardon M, Young N, Sindhusake P, Lee T, Le K. Correlation of CT findings remote from prime area of interest: a multitrauma study. Open Access Emerg Med 2012;4:75–83.
[11] Fried AM, Humphries R, Schofield CN. Abdominal CT scans in patients with blunt trauma: low yield in the absence of clinical findings. J Comput Assist Tomogr 1992;16(5):717–21.
[12] Plurad D, Green D, Demetriades D, Rhee P. The increasing use of chest computed tomography for trauma: is it being overutilized? J Trauma Inj Infect Crit Care 2007;62(3):631–5.
[13] Smith CM, Woolrich-Burt L, Wellings R, Costa ML. Major trauma CT scanning: the experience of a regional trauma centre in the UK. Emerg Med J 2010. emj.2009.076414.
[14] Deunk J, Brink M, Dekker HM, Kool DR, van Kuijk C, Blickman JG, et al. Routine versus selective computed tomography of the abdomen, pelvis, and lumbar spine in blunt trauma: a prospective evaluation. J Trauma Acute Care Surg 2009;66(4):1108–17.
[15] Brenner DJ, Elliston CD. Estimated radiation risks potentially associated with full-body CT screening 1. Radiology 2004;232(3):735–8.
[16] Wedegartner U, Lorenzen M, Nagel HD, Weber C, Adam G. Diagnostic imaging in polytrauma: comparison of radiation exposure from whole-body MSCT and conventional radiography with organ-specific CT. RoFo: Fortschritte auf dem Gebiete der Rontgenstrahlen und der Nuklearmedizin 2004;176(7):1039–44.
[17] Wall B, Haylock R, Jansen J, Hillier M, Hart D, Shrimpton P. Radiation risks from medical X-ray examinations as a function of the age and sex of the patient: Centre for Radiation, Chemical and Environmental Hazards. Health Prot Agency 2011.
[18] Webb GAM. The requirement to keep radiation exposures as low as reasonably practicable (ALARP). HMSO 1984.
[19] Sampson M, Colquhoun K, Hennessy N. Computed tomography whole body imaging in multi-trauma: 7 years experience. Clin Radiol 2006;61(4):365–9.
[20] Wurmb TE, Frühwald P, Hopfner W, Roewer N, Brederlau J. Whole-body multislice computed tomography as the primary and sole diagnostic tool in patients with blunt trauma: searching for its appropriate indication. Am J Emerg Med 2007;25(9):1057–62.
[21] Sloan R. A retrospective review of influences on clinicians to order whole body CT scans in trauma and its effectiveness in this regard. Scand J Trauma Resusc Emerg Med 2013;21(Suppl. 1):S16.
[22] Hunt P. Whole bodyCT scanning following blunt multitrauma: a Delphi study. Emerg Med J 2010;27(Suppl. 1):A7-A.
[23] Hunt P, Smith C, Oliver A. Early computed tomography scanning in multisystem trauma: the evidence. Trauma 2012;14(4):287–300.
[24] Smith CM, Mason S. The use of whole-body CT for trauma patients: survey of UK emergency departments. Emerg Med J 2011. emj.2011.111708.
[25] Hsiao KH, Dinh MM, McNamara KP, Bein KJ, Roncal S, Saade C, et al. Whole-body computed tomography in the initial assessment of trauma patients: is there optimal criteria for patient selection? Emerg Med Australasia: EMA 2013;25(2):182–91.
[26] AAAM. Abbreviated injury scale. Barrington, IL: Association for the Advancement of Automotive Medicine; 2005 (Update 2008).
[27] Valentin J. The 2007 recommendations of the international commission on radiological protection. Oxford: Elsevier; 2007.
[28] Stiell IG, Clement CM, McKnight RD, Brison R, Schull MJ, Rowe BH, et al. The Canadian C-spine rule versus the NEXUS low-risk criteria in patients with trauma. N Engl J Med 2003;349(26):2510–8.
[29] Gupta M, Schriger DL, Hiatt JR, Cryer HG, Tillou A, Hoffman JR, et al. Selective use of computed tomography compared with routine whole body imaging in patients with blunt trauma. Ann Emerg Med 2011;58(5):407–16. e15.
[30] Cowan I, Cresswell C, Liu H, Siew T, Ardagh M, Than M. Selective versus mandatory whole-body computed tomography scanning in the multiply injured F patient. Emerg Med Australasia: EMA 2012;24(1):115–6.
[31] Sierink JC, Saltzherr TP, Beenen LF, Russchen MJ, Luitse JS, Dijkgraaf MG, et al. A case-matched series of immediate total-body CT scanning versus the standard radiological work-up in trauma patients. World J Surg 2014;38(4):795–802.
[32] Caputo ND, Stahmer C, Lim G, Shah K. Whole-body computed tomographic scanning leads to better survival as opposed to selective scanning in trauma patients: A systematic review and meta-analysis. J Trauma Acute Care Surg 2014;77(4):534–9. http://dx.doi.org/10.1097/TA.0000000000000414.
[33] Stengel D, Frank M, Matthes G, Schmucker U, Seifert J, Mutze S, et al. Primary pan-computed tomography for blunt multiple trauma: can the whole be better than its parts? Injury 2009;40(Suppl. 4):S36–46.
[34] Wall BF, Hart D. Revised radiation doses for typical X-ray examinations. Report on a recent review of doses to patients from medical X-ray examinations in the UK by NRPB, National Radiological Protection Board. Br J Radiol 1997;70(833):437–9.
[35] Hussain M, Javed G. Diagnostic accuracy of clinical examination in cervical spine injuries in awake and alert blunt trauma patients. Asian Spine J 2011;5(1):10–4.
[36] Nguyen GK, Clark R. Adequacy of plain radiography in the diagnosis of cervical spine injuries. Emerg Radiol 2005;11(3):158–61.
[37] Bokhari F, Brakenridge S, Nagy K, Roberts R, Smith R, Joseph K, et al. Prospective evaluation of the sensitivity of physical examination in chest trauma. J Trauma 2002;53(6):1135–8.
[38] Traub M, Stevenson M, McEvoy S, Briggs G, Lo SK, Leibman S, et al. The use of chest computed tomography versus chest X-ray in patients with major blunt trauma. Injury 2007;38(1):43–7.
[39] Poole GV, Morgan DB, Cranston PE, Muakkassa FF, Griswold JA. Computed tomography in the management of blunt thoracic trauma. J Trauma Inj Inf Crit Care 1993;35(2):296–302.
[40] Marts B, Durham R, Shapiro M, Mazuski JE, Zuckerman D, Sundaram M, et al. Computed tomography in the diagnosis of blunt thoracic injury. Am J Surg 1994;168(6):688–92.
[41] den Boer TA, Geurts M, van Hulsteijn LT, Mubarak A, Slingerland J, Zwart B, et al. The value of clinical examination in diagnosing pelvic fractures in blunt trauma patients: a brief review. Eur J Trauma Emerg Surg 2011;37(4):373–7.
[42] Leidner B, Beckman M. Standardized whole-body computed tomography as a screening tool in blunt multitrauma patients. Emerg Radiol 2001;8(1):20–8.
[43] Wilson J, Jungner G. Principles and practice of screening. Geneva: WHO; 1968.
[44] Goske MJ, Applegate KE, Boylan J, Butler PF, Callahan MJ, Coley BD, et al. The Image Gently campaign: working together to change practice. AJR: Am J Roentgenol 2008;190(2):273–4.
[45] Shrimpton P, Britain G. Doses from computed tomography (CT) examinations in the UK-2003 review. UK: National Radiological Protection Board Chilton; 2005.
[46] Humphreys T, Shofer FS, Jacobson S, Coutifaris C, Stemhagen A. Preformatted charts improve documentation in the emergency department. Ann Emerg Med 1992;21(5):534–40.
[47] Sokol DK. "First do no harm" revisited. BMJ 2013;347:f6426.