



## Review Article

## Whole body computed tomography in multi trauma patients: Review of the current literature

Şeref Kerem Çorbacıoğlu<sup>a,\*</sup>, Gökhan Aksel<sup>b</sup><sup>a</sup> Kecioren Training and Research Hospital, Department of Emergency Medicine, Ankara, Turkey<sup>b</sup> Ümraniye Training and Research Hospital, Department of Emergency Medicine, Istanbul, Turkey

## ARTICLE INFO

## Keywords:

Whole body computed tomography  
Pan-ct  
Multitrauma  
Selective CT  
Atls  
Radiation exposure

## ABSTRACT

Many authors adopt the Selected Computed Tomography (SCT) approach of the Advanced Trauma Life Support (ATLS) for the management of multiple trauma patients. In the SCT approach, the initial physical examination is followed by conventional radiography (cervical X-ray, chest X-ray, pelvic X-ray and Focused Abdominal Sonography in Trauma (FAST)), and the computed tomography (CT) of the specific body regions if indicated. An alternative to this traditional approach is the Whole-body Computed Tomography (WBCT) protocol, which became widespread all over the world in the last two decades to minimize the rate of missed injuries and decrease the mortality rate.

According to the literature, the WBCT approach is superior to the traditional SCT approach in the time of imaging, diagnostic accuracy, and mortality rates. Conversely, WBCT increases the cancer risk due to additional irradiation. Therefore, it is recommended that the WBCT protocol should be reserved for only severe multi-trauma patients. However, further studies to define severe patients, and clinical decision criteria for WBCT are needed.

Trauma is one of the most important causes of death in especially young population around the world.<sup>1–3</sup> Despite recent medical improvements, the mortality rate of multi-trauma patients is varied between 10% and 20%.<sup>4,5</sup> As described initially in 1982, traumatic deaths show a trimodal distribution pattern: immediate, early, and late phases.<sup>6</sup> The early phase is known as golden hours, and fatalities occur within minutes to several hours following trauma. Today, we know that the initial assessment and diagnostic efforts have to be as rapid and accurate as possible to reduce mortality during the golden hours. Although many authors adopt the traditional selected CT (SCT) approach of the ATLS in multi-trauma patients, an alternative, the whole-body computed tomography (WBCT) became widespread all over the world in the last two decades to minimize the rate of missed injuries and decrease the mortality rate.

According to the SCT approach, after the initial physical examination, conventional radiography (cervical X-ray, chest X-ray (CXR), and pelvic X-ray) and focused abdominal sonography in trauma (FAST) should be obtained. Then, computed tomography (CT) of the specific regions were ordered if indicated. However, the SCT approach of the ATLS is thought to be a time-consuming and subjective method according to some physicians. They argue that the WBCT approach

decreases the mortality and morbidity with a quicker and more accurate diagnosis, and is superior to the SCT approach. The WBCT approach consists of unenhanced head and cervical, and contrast-enhanced chest, abdomen, and pelvis CTs.

On the contrary, supporters of the SCT approach claim that the evidence for the mortality and morbidity benefit of the WBCT approach is insufficient, and patients are exposed to unnecessary and excess radiation. Recently, the first randomized controlled study (REACT-2 trial) has been published and it reported that no significant difference on mortality between both approaches.<sup>7</sup> However, the outcome of this debate is still unclear with opposing arguments put forward about the advantages and the disadvantages of the WBCT. Therefore, we aimed to appraise the answers to some of the clinical questions mentioned above in the light of the current evidence.

### 1. Are the physicians reliable in selecting regions to scan in SCT approach?

It is argued that the rate of missed injuries is higher in SCT approach compared to the WBCT approach since the SCT approach is based on the subjective decisions of the physicians. Is it true? In 2015, Shannon

Peer review under responsibility of The Emergency Medicine Association of Turkey.

\* Corresponding author. Kecioren Training and Research Hospital, Emergency Medicine Department, Ankara, Turkey.

E-mail addresses: [serefkeremcorbacioglu@gmail.com](mailto:serefkeremcorbacioglu@gmail.com) (Ş.K. Çorbacıoğlu), [gokhanaksel@gmail.com](mailto:gokhanaksel@gmail.com) (G. Aksel).

<https://doi.org/10.1016/j.tjem.2018.09.003>

Received 2 September 2018; Received in revised form 26 September 2018; Accepted 26 September 2018

Available online 03 October 2018

2452-2473/2018 Emergency Medicine Association of Turkey. Production and hosting by Elsevier B. V. on behalf of the Owner. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

et al. assessed the compatibility of the final WBCT diagnosis with the clinical suspicions of trauma team leaders in 588 suspected polytrauma patients.<sup>8</sup> Suspected injuries were asked to the trauma team leaders before evaluating the results of the WBCT. They found that twenty-four of the 588 patients (4%) had injuries at WBCT that were not clinically suspected by the trauma leader. Besides, unsuspected injuries were severe (such as cervical injury, bilateral lung contusion, occult pneumothorax, brain contusion) in eighteen of those 24 patients (75%), which could cause failure of treatment and increase the morbidity. Similarly, in another study with 329 patients, Smith et al. assessed the ability of emergency physicians (EPs) to determine predefined clinically significant injuries by traditional SCT approach.<sup>9</sup> A pretest was performed to EPs after their initial trauma evaluation before the WBCT, and they were asked to stratify the injury risk in each body region of the patient for a clinically significant injury as very low, low, intermediate, high, or very high. Eight and sixty-four clinically significant injuries were identified respectively in very low and low-risk groups. In another study with a different methodology from previous studies, Salim et al. preferred WBCT in the patients with no expected significant abnormalities such that all of the patients were neurologically intact, hemodynamically stable and had a normal abdominal examination with no visible evidence of chest or abdominal injury. The only indication for WBCT was defined as having a severe trauma mechanism. Eventually, even these patients seemed to be mildly injured according to the initial evaluation, treatments of 18.9% of these patients were changed based on the abnormal WBCT findings.<sup>10</sup> In two different prospective studies which evaluated the significance of routine thorax CT in multi-trauma patients with normal physical examination and normal chest X-ray, SCT approach was reported to miss 16% and 52% of the clinical significant injuries, which were entirely different.<sup>11,12</sup>

Overall, considering the limited evidence in the current literature, management of multi-trauma patients with the traditional SCT approach seems to be based on physicians' unreliable judgments.

## 2. Is the traditional SCT approach a time-consuming method?

Time is one of the critical components in of trauma management. Therefore, WBCT supporters argue that the time spent during the SCT protocol is higher, which may delay the diagnosis and definitive treatment, and contribute to the emergency department (ED) overcrowding. Evidence in the current literature seems to support this claim. For instance, Huber-Wagner et al., in their two different studies in 2009 and 2013, reported that the WBCT protocol shortened the time from admission to CT by 10 min.<sup>13,14</sup> In another study in 2007, Weninger et al. reported that total ED time was significantly lower in the WBCT group (Mean  $\pm$  SD: 70  $\pm$  17 min) compared to the SCT group (104  $\pm$  21 min).<sup>15</sup> Hutter et al. reported the total ED time of 95.7  $\pm$  63.0 min in the SCT, and 83.5  $\pm$  49.2 min in the WBCT group in 2011.<sup>16</sup>

Finally, the first randomized controlled trial (RCT) on this topic (REACT-2 trial) was published. In this study, aimed to assess the effect of WBCT scanning compared with a SCT on mortality in patients with multi-trauma. After sample size calculation for detection of a difference in mortality of 5%, 540 patients with trauma were included and randomized to each arm, and the primary outcome was determined as in-hospital mortality rate. Secondary outcomes were defined as varied clinically relevant time intervals during the trauma management and these parameters were compared for each group. Finally, in the REACT-2 trial, all durations, including the time from admission to the diagnosis of a life-threatening injury, were found to be lower in the WBCT group compared to the SCT group.<sup>7</sup> Different studies reported similar results except for the study by Mao et al. and their findings are presented in Table 1.<sup>7,13–20</sup>

The WBCT approach does not include conventional X-rays, and re-evaluation/re-examination procedures, which probably may be the primary reason for shorter ED times. Besides, improvements in the CT

technologies increased the speed of the CT procedure. According to Gordic et al. the mean time for the completion of trauma-related imaging was 12 min if the WBCT protocol is used. This time was reported as 75 min in the SCT group.<sup>20</sup> Ptak et al. reported the total scanning time in WBCT with the single body protocol as 3 min.<sup>21</sup>

Current evidence shows that time to imaging is significantly shorter with WBCT compared to SCT approach, which was reported no more than a few minutes with WBCT, while it was at least an hour even more with SCT approach.

## 3. Does the WBCT approach reduce mortality?

The most crucial question is whether WBCT decreases the mortality rate or not. Evidence of mortality benefit may nullify the effect of factors such as radiation exposure, cost, and time. Hugner-Wagner et al. published the first and the largest retrospective cohort in 2009 which investigated the effect of WBCT approach on mortality.<sup>13</sup> Authors calculated the expected mortality rates in both groups (WBCT and SCT groups) by using trauma and injury severity score (TRISS) and compared predicted mortality rates (PMR) with recorded real mortality rates (RRMR). PMR was 23.2%, and RRMR was 17.3% ( $p < 0.001$ ) in the WBCT group and PMR was 17.1%, and RRMR was 17.5% ( $p = 0.66$ ) in the SCT group. The RRMR was reported to be significantly lower in the WBCT group. Hugner-Wagner et al. expanded their retrospective cohort in 2013 and published a lower absolute mortality rate in the WBCT group (17.4%) compared to the SCT group (21.4%).<sup>14</sup> Kimura et al. conducted another study with a similar methodology in 5208 patients, and the difference between the real and estimated mortality rates was shown to be higher in WBCT group (0.24 and 0.29, respectively) compared to the SCT group (0.28 and 0.29, respectively).<sup>22</sup> In 2011, Hutter et al. in their retrospective cohort with 1144 patients, it was reported the mortality rates of the WBCT and SCT groups as 15% and 8%, respectively ( $p < 0.001$ ).<sup>16</sup> On the contrary, there are also several studies to report no difference in the mortality rates of both approaches.<sup>15,17,18,23</sup> Therefore, we think that the current evidence from the retrospective studies is insufficient to conclude whether there is a mortality benefit with the WBCT or not.

Nonetheless, several meta-analyses based on results of these studies before the REACT-2 trial have supported that WBCT approach reduced mortality of patients with multi-trauma. For example, in a meta-analysis was done by Caputo et al. with 25,782 patients, mortality rates of WBCT and SCT approaches were found as 16.9% and 20.3% ( $p:0.0002$ ), respectively and it was found that pooled odds ratio for mortality rate of 0.75 (95% CI, 0.7–0.9), favoring WBCT.<sup>24</sup> Similarly, in different meta-analyses were conducted by Jiang et al. with 26371 patients and Chidambaram et al. with 32207 patients, pooled odds ratios were found as 0.66 (95% CI, 0.52–0.85) and 0.79 (95% CI, 0.74–0.83).<sup>25,26</sup> However, it is hard to say that this evidence is reliable as they were all based on retrospective studies because of lacking RCT. Thus, in a Cochrane meta-analysis was conducted in 2013, the authors stated that zero studies with high-quality evidence included in quantitative synthesis.<sup>27</sup>

Eventually, Sierink et al. published the first well-designed randomized controlled trial (REACT-2 trial) in 2016. In this study, after sample size calculation for detection of a difference in mortality of 5%, 540 patients with trauma were included and randomized to each arm, and the primary outcome was determined as in-hospital mortality rate.<sup>7</sup> In-hospital mortality rates were similar in the WBCT and the SCT groups (16% vs. 16%,  $p = 0.92$ , respectively). The subgroup analysis of multi-trauma patients revealed a statistically insignificant 3% difference between the groups (22% vs. 25%,  $p = 0.46$ , respectively). At this point, we should thoroughly understand what results of REACT-2 trial exactly say. When we considered the target sample size of this study, we can only assume that there is no difference of 5% between both groups instead of there is no difference between both groups. Because the target sample size of this study was calculated for the reduction of in-hospital mortality of 5%. However, several meta-analyses reported that

**Table 1**  
Comparing several time outcomes (minutes) between the WBCT and selective CT approaches.

Study	Study Design	Subjects number	Time definition	WBCT	Selective CT	P value
- Sierink et al., in 2016 <sup>7</sup>	RCT	540 patients for each groups	- Time to diagnosis of life-threatening injuries (min)	50 (38–68) <sup>a</sup>	58 (42–78) <sup>a</sup>	0.001
			- Time to end of imaging (min)	30(24–40) <sup>a</sup>	37 (28–52) <sup>a</sup>	< 0.0001
			-Time in trauma room (min)	63(47–102) <sup>a</sup>	72 (50–109) <sup>a</sup>	0.067
- Huber-Wagner et al., in 2009 <sup>13</sup>	Retrospective study	4621 patients	- Time from trauma-room admission to CT (min)	35.5 (26.5) <sup>b</sup>	46.6 (37.5) <sup>b</sup>	< 0.001
- Huber-Wagner et al., in 2013 <sup>14</sup>	Retrospective study	16719	- Time from hospital admission to CT (min)	24.6 (18) <sup>b</sup>	35.2 (25.6) <sup>b</sup>	< 0.001
- Weninger et al., in 2007 <sup>15</sup>	Retrospective study	185 patients for each groups	- ED time (min)	70 (17) <sup>b</sup>	104 (21) <sup>b</sup>	0.025
- Hutter et al., in 2011 <sup>16</sup>	Retrospective study	1134 patients	- ED time (min)	83.5 (49.2) <sup>b</sup>	95.7 (63.1) <sup>b</sup>	< 0.001
- Wurmb et al., in 2015 <sup>17</sup>	Retrospective study	318 patients	- Time from ED to operation room	105 (85–133) <sup>a</sup>	120 (90–150) <sup>a</sup>	< 0.05
- Mao et al., in 2012 <sup>18</sup>	Retrospective study	123 patients	- ED time	124 (60) <sup>b</sup>	112 (72) <sup>b</sup>	0.359
- Hong et al., in 2016 <sup>19</sup>	Retrospective study	144 unconscious patients	- ED time	108 (80) <sup>b</sup>	186 (168) <sup>b</sup>	0.020
- Gordic et al., in 2015 <sup>20</sup>	Retrospective study	120 patients for each groups	- Time to complete trauma related imaging (min)	12 (9) <sup>b</sup>	75 (232) <sup>b</sup>	< 0.001

**RCT:** Randomized controlled study, **ED:** Emergency Department, **CT:** Computed tomography, **WBCT:** Whole body computed tomography.

<sup>a</sup> Median (IQR25%-75%).

<sup>b</sup> Mean (standard deviation).

mortality differences between both groups as nearly 3%. If sample size was calculated for reduction of 3% instead of 5%, it was calculated as almost 1600 patients for each arm. Therefore, though the REACT-2 trial has a well-designed methodology, to clarify on differences in mortality rate between both approaches, we still need new RCTs with larger sample size.

In conclusion, even though the majority of retrospective studies reported that WBCT decreases the mortality rate, it is still a matter of debate in the current literature. There is only one high-quality RCT regarding this debate, to date, and it reported a statistically insignificant difference between WBCT and SCT groups regarding in-hospital mortality.

#### 4. Is it contraindicated to use WBCT approach for unstable multi-trauma patients?

Even if the WBCT is the primary approach in the management of trauma patients, it would be contraindicated in unstable patients according to most of the physicians due to several reasons, such as the need to move patients from the ED to the radiology, which is probably far from trauma resuscitation room, or due to the precious time lost during the work-up delaying the move to the operating room. Therefore, the majority of retrospective cohort studies did not include unstable trauma patients. Luckily, a few studies, including unstable trauma patients, were published in recent years. In 2013, Huber-Wagner et al. performed a subgroup analysis of unstable trauma patients in their retrospective study.<sup>14</sup> They grouped unstable patients into moderate (systolic blood pressure [SBP] on admission was between 90 and 110 mmHg) and severe shock subgroups (SBP < 90 mmHg). The respective overall mortality rates in WBCT and SCT groups were 42.1% and 54.9% in severe shock (n = 1821, p < 0.001), 18.1% and 22.6% in moderate shock subgroups (n = 4280, p < 0.001). There was statistically significant mortality benefit with the WBCT approach in both patient subgroups. In the same year, Wada et al. compared the mortality rates of both approaches in trauma patients with an intervention for emergency bleeding control, and they found a lower mortality rate in the WBCT group (26.3% and 18.1%, p < 0.001).<sup>28</sup> Finally, in retrospective study was conducted by Tsutsumi et al. with unstable trauma patients, it was reported similar findings with the results of previous studies.<sup>29</sup>

The opposing argument for performing WBCT in unstable trauma patients would be the long distance of the trauma bay to the CT scanner. In 2014, Huber-Wagner et al. aimed to evaluate the impact of

the distance of the CT scanner from the trauma bay and found that closer (< 50 m) placement had a statistically significant positive effect on the probability of survival of severely injured patients.<sup>30</sup>

To summarize, the evidence base for this question is weak, and there are only a few WBCT studies including unstable multi-trauma patients. Even though these studies reported a lower mortality rate with WBCT, they are still inadequate to support the WBCT approach in unstable trauma patients.

#### 5. Does the WBCT approach expose patients to more radiation?

One of the most critical opposing arguments against the WBCT protocol is the increased cancer risk due to excess radiation exposure. The radiation dose exposed by the patients depends on the type of the CT scanner (single vs. multiple detectors), operator and the protocol used for WBCT screening. In a prospective study, in which patients were managed according to the ATLS guideline, trauma patients received a mean effective dose of 22.7 millisieverts (mSv). This study did not compare WBCT with SCT, but regardless of the scanning protocol, they aimed to draw attention to the increased risk of cancer and suggested avoiding unnecessary CT scans.<sup>31</sup> Despite the claims that the newer 64, 128 and 256-row multidetector computed tomography (MDCT) devices expose patients to lower doses of radiation compared to single or 4-row devices, Harrieder et al. demonstrated that the radiation exposure with MDCTs was similar to the older generation of CTs because of the increased duration of scans.<sup>32</sup> In a multicenter study, it was found that the actual radiation exposure was different at each medical center with the same patient.<sup>33</sup> They reported the mean effective dose of WBCT as 16.3 mSv (range: 8.9–26.0 mSv). In the literature, average radiation doses with WBCT are reported between 10 and 31.8 mSv.<sup>33–35</sup> Multi-trauma patients are typically younger; therefore, they have a higher risk of CT-induced cancer. Even though the exact cancer risk is unknown, the estimated cancer risks are less than 1/100,000, 1/10,000, 1/1,000 and greater than 1/1,000 for the doses < 0.2 mSv, 0.2–2 mSv, 2–20 mSv, and > 20 mSv, respectively.<sup>36</sup> Brenner et al. examined the radiation-related cancer mortality risk with single or WBCT, and found an estimated lifetime attributable cancer mortality risk of 1/1250 (0.08%) for radiation doses of 10–20 mSv if a single WBCT is performed in a 45-year-old adult.<sup>34</sup>

To the best of our knowledge, there are only three studies comparing radiation doses of the WBCT and SCT approaches (Table 2). In their retrospective before-after type cohort studies in multiple trauma patients, Gordic et al. and Asha et al. compared the radiation doses of

**Table 2**  
Studies comparing radiation doses produced by whole body computed tomography and selected tomography approaches.

Study	Study Design	Subjects number	Radiation dose		P value	Results and comments
			WBCT <sup>a</sup>	SCT <sup>b</sup>		
Asha et al., 2012 <sup>37</sup>	Retrospective, before/after cohort study. Patients were included 6 months before and after implementation of WBCT protocol.	Totally 1280 patients; 656 patients before and 624 after the introduction of WBCT protocol	76 <sup>c</sup> (11.6%) (9.1–14.1)	122 <sup>c</sup> (19.6%) (16.6–22.7)	< 0.001	Absolute risk (20%, 95% confidence interval [CI] 17–23) for WBCT of receiving a higher radiation dose (dose $\geq$ 20 mSv) was higher when compared with SCT (12%, 95% CI 9–14).
Gordic et al., 2015 <sup>20</sup>	Retrospective, before/after cohort study. 120 consecutive patients before and 120 patients after implementation WBCT protocol were included	240 patients, 120 patients in each protocol group.	29.5 mSv <sup>d</sup>	15.9 mSv <sup>d</sup>	< 0.001	In the SCT group, additional CT imaging was needed more frequently than in WBCT group with a cumulative dose of 13.0 mSv/patient (p < 0.001).
Sierink et al., 2016 <sup>7</sup>	Multi-center, randomized controlled trial.	Totally 1083 patients were included; 541inWBCT, 542in SCT group.	21 mSv <sup>d</sup> (20.9–25.2)	20.6 mSv <sup>d</sup> (11.8–27.6)	< 0.001	Not only the total radiation exposure was lower in SCT group, but also more patients in this group were exposed to a radiation dose < 20 mSv.

<sup>a</sup> WBCT: whole body computed tomography.

<sup>b</sup> SCT: Selected CT.

<sup>c</sup> number of patients (given as median (%-IQR)) who were exposed radiation dose  $\geq$  20 mSv.

<sup>d</sup> The radiation results included all diagnosing tests during hospital admission.

trauma-related imaging with the WBCT, and SCT approaches using the data before and after the introduction of WBCT in their hospitals. In both studies, the cumulative total effective radiation doses were significantly lower in the non-WBCT group, which was reported by Gordic et al. as 15.9 vs. 29.5 mSv (p < 0.001). Asha et al. provided the rate of patients who were exposed to a radiation dose of greater than 20 mSv, which was 76 patients (11.6%) in the WBCT, and 122 (19.6%) in the SCT group.<sup>20,37</sup> The last study is the REACT-2 trial, which reported a lower median radiation exposure in the SCT group (20.6 mSv, IQR: 9.9–22.1 vs. 20.9 mSv, IQR: 20.6–20.9; p < 0.001). Although the median radiation dose for the SCT group was higher than those reported in the previous studies, it seems that WBCT increases the radiation exposure significantly. Since the median radiation doses are almost similar, trying to decrease the radiation exposure by WBCT with newer protocols is reasonable.<sup>7</sup>

### 5.1. Is it possible to reduce the radiation dose of WBCT?

Fanucci et al. and Ptak et al. compared two WBCT protocols according to the radiation dose emitted. They both found the mean dose length product (DLP), which is a measure of CT tube radiation output/exposure, to be lower than the sum of the DLPs of each of the individual body segment scans with the single-pass protocol of the same scanner.<sup>38,39</sup>

Geyer et al. measured the emitted radiation doses in 152 WBCT scans performed by two separate 64-row MDCT scanners with different brands, and found a statistically significant effective radiation dose difference between the two devices (Mean  $\pm$  SD: 24.4  $\pm$  6.0 mSv, vs. 17.2  $\pm$  5.8 mSv; p < 0.001).<sup>40</sup>

In summary, according to the evidence from the current literature, the exposed radiation dose is increased significantly with the WBCT approach compared to the SCT approach. The average radiation exposure with WBCT is between 10 and 31.8 mSv, and in most cases, the critical threshold of 20 mSv for cancer risk is surpassed. The evidence discussed in this review is based on studies performed with at least 64-row MDCT scanners. Therefore, the emitted radiation doses would be much higher if single-detector CTs were used. We can conclude that the radiation dose emitted with the WBCT approach is highly variable and depends on the scanning protocol, CT specifications (mono-/multi-detector), brand and operator.

On the other hand, it is still unknown if this difference in the radiation doses exposed is turned into a mortality risk by cancer in real-life. The advancement in technology and adjustments in the current scanning protocols promising a lowered overall exposed radiation according to the existing literature. However, further studies are needed to explore the best WBCT scanning protocol balancing image quality with radiation exposure. WBCT is associated with higher radiation exposure and may increase the cancer risk; therefore, clinicians should be aware that routine use of WBCT in all multi-trauma patients is not reasonable. Unfortunately, it is unclear in whom to prefer WBCT over SCT regardless of the concerns for increased cancer risk.

### 6. Is there any decision criteria present for the WBCT approach?

Even though limited, there are efforts to develop WBCT decision rules in multi-trauma patients. Davies et al. suggested a model in order to detect significant injuries as a decision rule for WBCT. This model included the following criteria: clinical signs in more than one body region, Glasgow Coma Score (GCS) < 14, presence of hemodynamic abnormality (SBP < 100 mmHg, or heart rate > 100 bpm), presence of respiratory abnormality (respiratory rate > 24 breaths/min, or pSO2 < 93%), and mechanism of the injury. The accuracy or the area under the curve (AUC) of the receiver operating characteristic (ROC) of this model was reported as 0.82, with the sensitivity and specificity values of 79% and 71%, respectively.<sup>35</sup> Similarly, Hsiao et al. conducted a retrospective diagnostic decision rule study in 660 trauma

patients to detect multi-region injury with WBCT. The independent predictors of a multi-region injury determined by the multivariable logistic regression analysis were as follows: male sex, GCS < 9, mechanism of the injury (fall > 5 m, and being a cyclist). The accuracy (AUC) of this model was reported as 0.74 (95% CI: 0.67–0.80) to predict multi-region injury.<sup>23</sup> In another study, Babaud et al. evaluated the utility of Vittel criteria to detect the need for a WBCT, which was used to define a patient with severe trauma. The independent factors they reported were GCS > 13, the presence of penetrating trauma, and resuscitation with more than 1000 mL of colloids.<sup>41</sup>

Overall, despite all the above evidence, there is still no robust decision criteria to prefer WBCT in the management of multi-trauma patients.

## 7. Summary key comments

*Do physicians miss clinically significant injuries when SCT approach was preferred?*

Although evidence in the current literature is limited, it seems that misdiagnosis rate is higher when multi-trauma patients were managed with traditional SCT approach.

*Is traditional SCT approach really a time consuming method?*

Current evidences robustly tell us that time of trauma related imaging in WBCT is significantly less when compared with SCT protocol such that this time was reported as a few minutes in WBCT protocol, while it was around a hour or more in SCT protocol.

*Does WBCT approach reduce mortality?*

Although majority of previous retrospective studies' results showed that WBCT reduces mortality, there is no clear consensus on mortality data based on contradictory results in the current literature. There is only one high quality RCT answering this question that there was non-statistically significant difference between WBCT and SCT groups terms of in-hospital mortality. We believe that it is still needed further RCTs with larger sample sizes.

*Is WBCT contraindicate in unstable multi-trauma patients?*

There are only a few studies included unstable trauma patients scanned with WBCT. Although these studies reported that WBCT reduces mortality of these patients, it is hard for now to defend suggesting CT scan for unstable trauma patients with these weak evidences.

*Does WBCT expose more radiation?*

Current literature tells us that WBCT increases radiation dose significantly when compared with SCT approach so that this significant additional radiation caused by WBCT seems to be related with increased cancer risk. This clear data warns us about not performing WBCT routinely.

*Do we have decision criteria on using WBCT approach?*

We still don't have strong rule-out criteria for decision of WBCT. Current literature suggests WBCT for seriously injured multi trauma patients but describing seriously injured patient is hard with previous studies.

*Key conclusion*

WBCT approach seems superior to traditional SCT approach in subjects of time of trauma related imaging, diagnosis accuracy and mortality rates. But we believe that performing WBCT for all multi trauma patients is not favorable because of having serious additional radiation dose. It is sensible to prefer WBCT in seriously injured multi trauma patients but we need further studies defining seriously injured patients and strong rule-out criteria for decision of WBCT.

## Conflict of interest

None.

## Financial disclosure

None and no funding was obtained.

## Acknowledgements

None.

## References

- Lozano R, Naghavi M, Foreman K, et al. Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet*. 2012;380(9859):2095–2128.
- Heron M. Deaths: leading causes for 2008. *Natl Vital Stat Rep*. 2012;60(6):1–94.
- Patton GC, Coffey C, Sawyer SM, et al. Global patterns of mortality in young people: a systematic analysis of population health data. *Lancet*. 2009;374:881–892.
- Hilbert P, Lefering R, Stuttmann R. Trauma care in Germany: major differences in case fatality rates between centers. *Dtsch Arztebl Int*. 2010;107:463–469.
- Schoeneberg C, Schilling M, Burggraf M, et al. Reduction in mortality in severely injured patients following the introduction of the "Treatment of patients with severe and multiple injuries" guideline of the German society of trauma surgery—a retrospective analysis of a level 1 trauma center (2010–2012). *Injury*. 2014;45(3):635–638.
- ATLS Subcommittee. the ninth ed. *American College of Surgeons' Committee on Trauma*. vol. 74. International ATLS working group Advanced trauma life support (ATLS®); 2013:1363–1366 J Trauma Acute Care Surg.
- Sierink JC, Treskes K, Edwards MJ, et al. REACT-2 study group. Immediate total-body CT scanning versus conventional imaging and selective CT scanning in patients with severe trauma (REACT-2): a randomised controlled trial. *Lancet*. 2016;388:673–683.
- Shannon L, Peachey T, Skipper N, et al. Comparison of clinically suspected injuries with injuries detected at whole-body CT in suspected multi-trauma victims. *Clin Radiol*. 2015;70:1205–1211.
- Smith CB, Barrett TW, Berger CL, et al. Prediction of blunt traumatic injury in high-acuity patients: bedside examination vs computed tomography. *Am J Emerg Med*. 2011;29:1–10.
- Salim A, Sangthong B, Martin M, et al. Whole body imaging in blunt multisystem trauma patients without obvious signs of injury: results of a prospective study. *Arch Surg*. 2006;141:468–473.
- Çorbacıoğlu SK, Er E, Aslan S, et al. The significance of routine thoracic computed tomography in patients with blunt chest trauma. *Injury*. 2015;46(5):849–853.
- Exadaktylos AK, Sclabas G, Schmid SW, et al. Do we really need routine computed tomographic scanning in the primary evaluation of blunt chest trauma in patients with "normal" chest radiograph? *J Trauma*. 2001;51(6):1173–1176.
- Huber-Wagner S, Lefering R, Qvick LM, et al. Working Group on Polytrauma of the German Trauma Society. Effect of whole-body CT during trauma resuscitation on survival: a retrospective, multicentre study. *Lancet*. 2009;373:1455–1461.
- Huber-Wagner S, Biberthaler P, Häberle S, et al. TraumaRegister DGU, Whole-body CT in haemodynamically unstable severely injured patients—a retrospective, multicentre study. *PLoS One*. 2013;8:e68880.
- Weninger P, Mauritz W, Fridrich P, et al. Emergency room management of patients with blunt major trauma: evaluation of the multislice computed tomography protocol exemplified by an urban trauma center. *J Trauma*. 2007;62:584–591.
- Hutter M, Woltmann A, Hierholzer C, et al. Association between a single-pass whole-body computed tomography policy and survival after blunt major trauma: a retrospective cohort study. *Scand J Trauma Resuscitation Emerg Med*. 2011;19:73.
- Wurmb TE, Fruhwald P, Hopfner W, et al. Whole-body multislice computed tomography as the first line diagnostic tool in patients with multiple injuries: the focus on time. *J Trauma*. 2009;66:658–665.
- Mao Shanlin X, Xinfu XY, Hongfei W, et al. The value of whole-body CT in severe traffic trauma patients during the early resuscitation phase. *Chin J Traumatol*. 2012;28(3):269–271.
- Hong ZJ, Chen CJ, Yu JC, et al. The evolution of computed tomography from organ-selective to whole-body scanning in managing unconscious patients with multiple trauma: a retrospective cohort study. *Medicine (Baltimore)*. 2016;95:e4653.
- Gordic S, Alkadhi H, Hodel S, et al. Whole-body CT-based imaging algorithm for multiple trauma patients: radiation dose and time to diagnosis. *Br J Radiol*. 2015;88:20140616.
- Ptak T, Rhea JT, Novelline RA. Experience with a continuous, single-pass whole-body multidetector CT protocol for trauma: the three-minute multiple trauma CT scan. *Emerg Radiol*. 2001;8:250–256.
- Kimura A, Tanaka N. Whole-body computed tomography is associated with decreased mortality in blunt trauma patients with moderate-to-severe consciousness disturbance: a multicenter, retrospective study. *J Trauma Acute Care Surg*. 2013;75:202–206.
- Hsiao KH, Dinh MM, McNamara KP, et al. Whole-body computed tomography in the initial assessment of trauma patients: is there optimal criteria for patient selection? *Emerg Med Australasia*. 2013;25:182–191.
- Caputo ND, Stahmer C, Lim G, et al. 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;77:534–539.
- Jiang L, Ma Y, Jiang S, et al. Comparison of whole-body computed tomography vs selective radiological imaging on outcomes in major trauma patients: a meta-analysis. *Scand J Trauma Resuscitat Emerg Med*. 2014;22:54.
- Chidambaram S, Goh EL, Khan MA. A meta-analysis of the efficacy of whole-body computed tomography imaging in the management of trauma and injury. *Injury*. 2017;48:1784–1793.
- Van Vugt R, Keus F, Kool D, Deunk J, et al. Selective computed tomography (CT) versus routine thoracoabdominal CT for high-energy blunt-trauma patients. *Cochrane Database Syst Rev*. 2013(12):CD009743<https://doi.org/10.1002/14651858>.

- CD009743.pub2.
28. Wada D, Nakamori Y, Yamakawa K, et al. Impact on survival of whole-body computed tomography before emergency bleeding control in patients with severe blunt trauma. *Crit Care*. 2013;17:R178.
  29. Tsutsumi Y, Fukuma S, Tsuchiya A, et al. Computed tomography during initial management and mortality among hemodynamically unstable blunt trauma patients: a nationwide retrospective cohort study. *Scand J Trauma Resuscitat Emerg Med*. 2017;25:74.
  30. Huber-Wagner S, Mand C, Ruchholtz S, et al. TraumaRegister DGU, Effect of the localisation of the CT scanner during trauma resuscitation on survival – a retrospective, multicentre study. *Injury*. 2014;45(Suppl 3):S76–S82.
  31. Tien HC, Tremblay LN, Rizoli SB, et al. Radiation exposure from diagnostic imaging in severely injured trauma patients. *J Trauma*. 2007;62:151–156.
  32. Harrieder A, Geyer LL, Korner M, et al. Evaluation of radiation dose in 64-row whole-body CT of multiple injured patients compared to 4-row CT. *Röfo*. 2012;184:443–449.
  33. Sato T, Saito Y, Saito N, et al. Multicenter investigation of the effective dose for whole-body CT scanning. *Nippon Hoshasen Gijutsu Gakkai Zasshi*. 2017;73(4):258–266.
  34. Brenner DJ, Elliston CD. Estimated radiation risks potentially associated with full-body CT screening. *Radiology*. 2004 Sep;232(3):735–738 Epub 2004 Jul 23.
  35. Davies RM, Scrimshire AB, Sweetman L, 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. *Injury*. 2016 Jan;47(1):43–49. <https://doi.org/10.1016/j.injury.2015.08.036> Epub 2015 Sep. 1.
  36. Radiation Protection Series Publication No 8. *Exposure of Humans to Ionizing Radiation for Research Purposes*. Australian Radiation Protection and Nuclear Safety Agency; 2005:13–14.
  37. Asha S, Curtis KA, Grant N, et al. Comparison of radiation exposure of trauma patients from diagnostic radiology procedures before and after the introduction of a panscan protocol. *Emerg Med Australasia*. 2012 Feb;24(1):43–51.
  38. Fanucci E, Fiaschetti V, Rotili A, et al. Whole body 16-row multislice CT in emergency room: effects of different protocols on scanning time, image quality and radiation exposure. *Emerg Radiol*. 2007;13:251–257.
  39. Ptak T, Rhea JT, Novelline RA. Radiation dose is reduced with a single-pass whole-body multi-detector row CT trauma protocol compared with a conventional segmented method: initial experience. *Radiology*. 2003;229:902–905.
  40. Geyer LL, Körner M, Harrieder A, et al. Dose reduction in 64-row whole-body CT in multiple trauma: an optimized CT protocol with iterative image reconstruction on a gemstone-based scintillator. *Br J Radiol*. 2016;89(1061):20160003. <https://doi.org/10.1259/bjr.20160003> Epub 2016 Feb 8.
  41. Babaud J, Ridereau-Zins C, Bouhours G, et al. Benefit of the Vittel criteria to determine the need for whole body scanning in a severe trauma patient. *Diagn Interv Imaging*. 2012;93:371–379.