Whole-body computed tomographic scanning leads to better survival as opposed to selective scanning in trauma patients: A systematic review and meta-analysis

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BACKGROUND: Traumatic injury in the United States is the Number 1 cause of mortality for patients 1 year to 44 years of age. Studies suggest that early identification of major injury leads to better outcomes for patients. Imaging, such as computed tomography (CT), is routinely used to help determine the presence of major underlying injuries. We review the literature to determine whether whole-body CT (WBCT), a protocol including a noncontrast scan of the brain and neck and a contrast-enhanced scan of the chest, abdomen, and pelvis, detects more clinically significant injuries as opposed to selective scanning as determined by mortality rates.

METHODS: Scientific publications from 1980 to 2013 involving the study of the difference between pan scan and selective scan after trauma were identified. The Preferred Reporting Items for Systematic Reviews and Meta-analyses was used. Publications were categorized by level of evidence. Injury Severity Score (ISS) and pooled odds for mortality rate of patients who received WBCT scan versus those who received selective scans were compared.

RESULTS: Of the 465 publications identified, 7 were included, composing of 25,782 trauma patients who received CT scan following trauma. Of the patients, 52% (n = 13,477) received pan scan and 48% (n = 12,305) received selective scanning. Overall ISS was significantly higher for patients receiving WBCT versus those receiving selective scan (29.7 vs. 26.4, $p < 0.001$, respectively). Overall mortality rate was significantly lower for WBCT versus selective scanning (16.9; 95% confidence interval [CI], 16.3–17.6 vs. 20.3; 95% CI, 19.6–21.1, $p < 0.0002$, respectively). Pooled odds ratio for mortality rate was 0.75 (95% CI, 0.7–0.79), favoring WBCT.

CONCLUSION: Despite the WBCT group having significantly higher ISS at baseline compared with the group who received selective scanning, the WBCT group had a lower overall mortality rate and a more favorable pooled odds ratio for trauma patients. This suggests that in terms of overall mortality, WBCT scan is preferable to selective scanning in trauma patients. (*J Trauma Acute Care Surg*. 2014;77: 534–539. Copyright © 2014 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Systematic review and meta-analysis, level III.

KEY WORDS: Whole-body CT; selective scan; trauma; mortality.

Traumatic injury in the United States is the Number 1 cause of mortality for patients 1 year to 44 years of age.[1–3] The Centers for Disease Control estimates that the cost in medical care and lost productivity from traumatic injury in the United States is more than $514 billion. One pilot study showed the average cost to a patient is in excess of $500,000, with other consequential, nonmedical costs that may burden the patient.[4] To help improve patient outcome, the physician must determine the presence of major injury and treat within the "golden hour."[5,6]

Cardiovascular compensation in younger patients often leads to occult hypoperfusion and can leave the health care provider with a false sense of security.[7–10] Research in the areas of biomarkers such as serum lactate and diagnostic tools such as the computed tomography (CT) have been shown to help the physician determine the presence of major injury in occult shock.[11–15] Exposure to radiation from CT scan is thought to increase one's lifetime risk for cancer (i.e., leukemia, thyroid cancer, brain tumors).[16–18] A lifetime excess cancer mortality risk of 0.08% is estimated in patients younger than 45 years who undergo whole-body CT (WBCT).[19] Controversy now exists over the use or overuse of the CT scan, known as the "traumagram" or WBCT, in trauma to detect major injury.[20–23] The standard WBCT protocol includes a noncontrast scan of the brain and neck and a contrast-enhanced scan of the chest, abdomen, and pelvis.[24]

This review seeks to evaluate the literature to determine whether there is a difference in outcome for trauma patients who have undergone WBCT scan versus a more focused selective CT scan method. The question being asked is, in patients presenting for trauma, are the odds of a fatal outcome greater if WBCT scan is performed over a more focused imaging examination? The main outcome measured was overall mortality for the use of WBCT versus selective CT scan.

PATIENTS AND METHODS

Scientific publications investigating the use of WBCT after trauma were identified using MEDLINE, the Cochrane Review, PubMed, and EMBASE. Search terms included ("Whole

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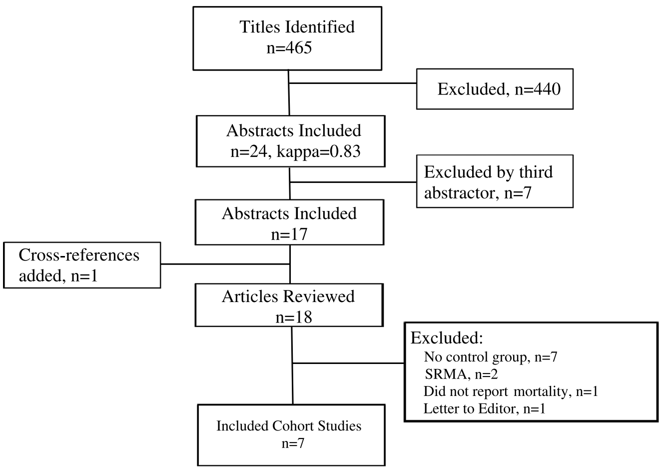

Figure 1. Flow diagram of included studies.

Body Imaging" OR "Whole body imaging" OR "pan scan" OR "whole body ct") AND ("Tomography, X-Ray Computed" OR "ct scan" OR "computed tomography") AND ("Wounds and Injuries" OR "Trauma Centers" OR "Multiple Trauma" OR "Emergency Service, Hospital" OR "emergency department" OR "wounds and injuries" OR "trauma centers" OR "multiple trauma" OR "emergency service"). A systematic review of the literature was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA, see Checklist, Supplemental Digital Content 1, http://links.lww.com/TA/A469) statement.[25] The search strategy was restricted to studies published in English and after the year 1980 to present.

Inclusion Criteria

All English-language publications in peer-reviewed journals from 1980 to 2013 were considered, including human retrospective studies, prospective studies, and randomized controlled trials. The primary study population must have received a WBCT scan and compared with a control group receiving a selective scan for any trauma (blunt, penetrating, or blast).

Exclusion Criteria

Case reports, studies only describing one population (WBCT or selective scanning only), non-English publications, and/or those that otherwise did not meet inclusion criteria were excluded from the review.

The titles and/or abstracts for each citation were examined, and all potentially relevant articles were retrieved and assessed. The final set of articles to be included in the review was determined by consensus by two abstractors (C.S. and G.L.). A predesigned form was used by the two reviewers, independently, to assess study eligibility, critical appraisal, and data collection. The following variables were collected: type of study, population, outcomes reported, and statistical method used. Microsoft Excel was used in the tabulation and analysis of the studies. In the event that the abstractors did not agree on whether an article should be included, a third investigator used the same eligibility criteria to determine inclusion. Articles were then categorized according to the levels of evidence identified in Wright's evidentiary table by the reviewers.[26] Data were tabulated in Microsoft Excel version 2007 (Microsoft Inc., Redmond, WA).

Statistical Analysis

Patient characteristics (ISS) and mortality rates for each included study were summarized and compared using descriptive statistics. For mortality, data were extracted to calculate the odds ratio (OR) and its 95% confidence interval (CI) for each study. Random-effects meta-analysis model for mortality was performed for pooled OR with selectively scanned patients being the control. Cochran's Q statistic was calculated to determine heterogeneity. Funnel plot was generated to determine publication bias. Analysis for descriptive statistics was performed using Excel version 2007, and analysis for random-effects model and test of heterogeneity were performed using MedCalc version 13.

RESULTS

A total of 465 citations were identified by the electronic search. Twenty-five studies in total were considered to meet initial requirements for this review by either of the two abstractors ($\kappa = 0.83$; 95% CI, 0.7–0.95). The decision of the third abstractor was made in seven in which all seven were excluded. After the review of each of the final 18 articles remaining, 7 were included in the final analysis (Fig. 1).

All of the studies reviewed the use of WBCT scanning as compared with selective scanning. Study characteristics and level of evidence are outlined in Table 1.[22,24,27–31] Sample sizes ranged from 318 to 16,719 patients. All studies reported differences in ISS and mortality rates. One study[24] reported differences in ISS between the use WBCT and selective scanning as median as well as percentage of patients with ISS greater than 35. One study[28] reported differences in ISS between the use of WBCT and selective scanning as percentage of patients with ISS greater than 35. All studies reported differences in mortality rate.

Four of the five studies that reported mean ISS demonstrated significantly higher scores in the WBCT group versus the selective scan group (Table 2). This held true when these five studies were pooled (WBCT ISS, 29.72 vs. selective ISS, 26.46; $p < 0.001$; n = 23,172).

TABLE 1. Study Demographics

Authors	Year	Total Patients	Type	n	Wright's Level
Huber-Wagner et al.[27]	2013	16,719	Retrospective, multicenter cohort	16,719	III
Hsiao et al.[24]	2013	660	Prospective, single center	660	II
Yeguiayan et al.[28]	2012	1,950	Prospective, multicenter cohort	1,950	II
Hutter et al.[22]	2011	1,144	Retrospective, single cohort	1,144	III
Wurmb et al.[29]	2011	318	Retrospective, single-center cohort	318	III
Huber-Wagner et al.[30]	2009	4,621	Retrospective, single-center cohort	4,621	III
Weninger et al.[31]	2007	370	Retrospective, single-center cohort	370	III

TABLE 2. Individual and Total ISS

	Year	Total Patients	WBCT	Selective	*p*
Huber-Wagner et al.	2013	16,719	29.7	27.7	0.001
Hsiao et al.*	2013	660	17	5	0.001
Yeguiayan et al.**	2012	1,950	N/A	N/A	N/A
Hutter et al.	2011	1,144	28.3	24.3	0.01
Wurmb et al.	2011	318	31.6	24.3	0.001
Huber-Wagner et al.	2009	4,621	32.4	28.4	0.001
Weninger et al.	2007	370	26.6	27.6	0.1
Total†		23,172	29.72	26.46	0.001

*Reports significantly higher median ISS for patients who received WBCT versus those who received selective scan and also reports a significantly higher percentage of patients with ISS greater than 35 who received WBCT versus selective scan (51 vs. 16).

**Reports significantly higher percentages of patients with ISS greater than 35 who received WBCT versus those who did not.

†Total mean for the five studies reporting mean ISS.

N/A, not applicable.

Differences in mortality rates for each study are listed in Table 3. Overall mortality was significantly higher in the selective scan group versus the WBCT group (16.9; 95% CI, 16.3–17.6 vs. 20.3; 95% CI, 19.6–21.1, $p < 0.0002$, respectively). This equates to approximately a 20% mortality reduction for patients receiving WBCT. There was evidence of heterogeneity among the studies (Cochran's statistic, 17.40; $df = 6$; $p = 0.01$). Figure 2 demonstrates the funnel plot, which was minimally skewed, indicating minimal bias. Table 4 lists OR for each study and 95% CIs. Pooled OR for mortality by random-effects model favored WBCT (OR, 0.75; 95% CI, 0.7–0.79).

DISCUSSION

Trauma is recognized as the leading cause of mortality in young and healthy patients.[32–34] Organized trauma systems have been developed and help reduce the risk of fatal outcomes in traumatically injured patients.[35–37] Part of these systems include the organized and algorhithmic approach to the trauma patient as offered by advanced trauma life support to reduce the likelihood of missing injuries, which can impact on patient outcome.[6,38]Part of this approach has been the use of adjunctive studies such as CT to detect injury not obvious on physical examination.[39] The application of CT imaging in trauma is a topic of much debate, with some advocating WBCT scanning or pan scan and others advocating judicious use or selective scanning based on physical examination findings.

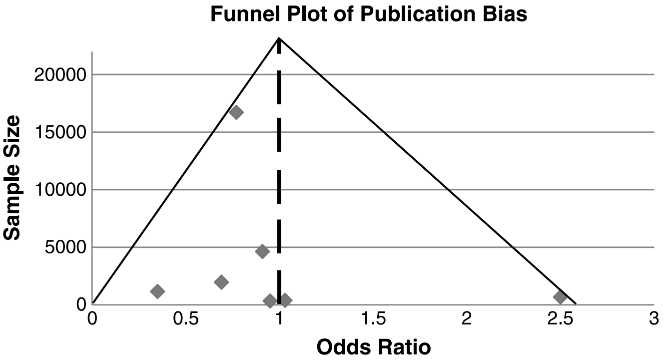

Figure 2. The funnel plot for the detection of bias.

The former is based on evidence that pan scanning detects major injuries that may be missed by selective scaning.[40,41] However, one study found that pan scanning has a high false-negative rate, which affects its accuracy,[20] and others suggest that these missed injuries are not clinically significant.[42,43] There is also concern about radiation and its risk of causing cancer as outlined by a review of Walsh et al.[44]

Although no large-scale epidemiologic studies of cancer risk have been reported in association with CT scans, experts state that up to 2% of cancers in the United States may be attributed to radiation exposure from CT scans.[45] The stochastic or risk of chance mutations of carcinogenesis is suggested to be a linear relation between dose and biologic effect with no safe threshold.[46] Much of what we know about radiation exposure is derived from the 1945 atomic bomb survivors in Japan who experienced a mean effective dose of 40 mSv. These survivors are known to have an increased cancer risk, and a similar exposure can be reached in five to six CT scans.[45] In a study by Tien et al.,[47] dosimeters were used on 172 injured patients (mean ISS, 22.7) to capture overall radiation exposure from imaging. In this cohort, the mean effective dose was 22.7 mSv, which is associated with an estimated 190 additional cancer deaths for every 100,000 patients sustaining this exposure.

This argument aside, as trauma deals with immediate life-threatening events, two systematic reviews and analyses have examined the base of evidence. Healy et al.[48] found no difference in mortality when comparing WBCT versus selective scanning (n = 8,180; pooled OR; 0.68; 95% CI, 0.43–1.09;

TABLE 3. Individual and Total Mortality

Author	Year	Total Patients	WBCT % (95% CI)	Selective % (95% CI)	*p*
Huber-Wagner et al.	2013	16,719	17.4 (16.6–18.2)	21.4 (20.5–22.3)	0.0002
Hsiao et al.	2013	660	3 (1–8.6)	1.25 (0.6–2.5)	0.17
Yeguiayan et al.	2012	1,950	16.3 (14.6–18.1)	22 (17.3–27.5)	0.024
Hutter et al.	2011	1,144	7.8 (6–10.3)	19.7 (16.6–23.3)	0.0002
Wurmb et al.	2011	318	8.5 (5.1–13.9)	9 (5.4–14.5)	0.88
Huber-Wagner et al.	2009	4,621	20.4 (18.5–22.6)	22.1 (20.6–23.5)	0.21
Weninger et al.	2007	370	17.3 (12.5–23.4)	16.7 (12–22.8)	0.89
Total		25,782	16.9 (16.3–17.6)	20.3 (19.6–21.1)	0.0002

TABLE 4. Individual and Pooled OR

Author	Year	Total Patients	OR	95%CI
Huber-Wagner et al.	2013	16,719	0.77	0.71–0.83
Hsiao et al.	2013	660	2.5	0.63–9.8
Yeguiayan et al.	2012	1,950	0.69	0.49–0.95
Hutter et al.	2011	1,144	0.35	0.24–0.5
Wurmb et al.	2011	318	0.95	0.43–2
Huber-Wagner et al.	2009	4,621	0.91	0.78–1.05
Weninger et al.	2007	370	1.03	0.6–1.7
Total		25,782	0.75	0.7–0.79

p = 0.11), and Sierink et al. also found no difference in mortality (n = 5,470; pooled OR, 0.91; 95% CI, 0.79–1.05; p = 0.21).[49] Both analyses failed to include the studies by Huber-Wagner et al. in 2013 (n = 16,719) and Hsiao et al. in 2013 (n = 660), and the analysis of Sierink et al. also did not include the study of Yeguiayan et al. in 2012 (n = 1,950). These studies greatly increased the number of patients included in our systematic review and meta-analysis. To date, we were unable to find another systematic review and meta-analysis examining this question with a large pooled sample size (n = 25,782). These studies exhibited heterogeneity as demonstrated by the Cochran's Q statistic. We included two prospective cohort studies and five retrospective cohort studies (Table 1).

When comparing the severity of injury of the patients studied, we found that those undergoing WBCT had significantly higher ISS compared with those receiving selective scanning (29.72 vs. 26.46, $p < 0.001$, n = 23172). This may be misconstrued that patients appearing to have more significant injuries may have received WBCT scan, suggesting a selection bias, but both groups had ISS greater than 15 and so were comparable in that both were severely injured.

When comparing mortality as our main outcome, we found that mortality was lower in five of the seven studies for the group receiving WBCT scan versus those receiving selective scans, with three of those five studies being significantly lower (Table 3). Finally, a comparison random-effects model of pooled OR favored WBCT scanning when mortality is considered versus selective scanning (OR, 0.75; 95% CI, 0.7–0.79; $p < 0.001$) as demonstrated in Figure 3 and further demonstrates a mortality reduction of 20% for those receiving WBCT. A systematic review by Surendren et al. in 2014 also found that mortality may be decreased in patients with WBCT, although the main aim of that review was to determine time to injury detection.[50] This review covered the studies in the current meta-analysis. Two studies this review looked at did not meet criteria to be included in this meta-analysis because they did not report on mortality for outcomes.

Although these results may be interpreted as more severely injured patients receiving WBCT scans and those considered not as badly injured being selectively scanned, leading to better outcomes for the WBCT, the possible selection bias (i.e., patients who underwent WBCT scans having higher ISSs compared with patients undergoing selective CT scans) should have had an effect increasing mortality among the WBCT scan patients. The finding of lower mortality among the WBCT scan group could be interpreted as an underestimation of the overall benefit associated with the WBCT scan.

Limitations

The greatest limitation to this analysis is that it is vastly an examination of retrospective data as only two of the studies included were prospective. These studies cumulatively account for only 11.4% (n = 2610) of the patients included. However, the REACT-2 trial, which is currently underway, will add a prospective, randomized controlled trial to the body of evidence to help better define the answer to this dilemma in the

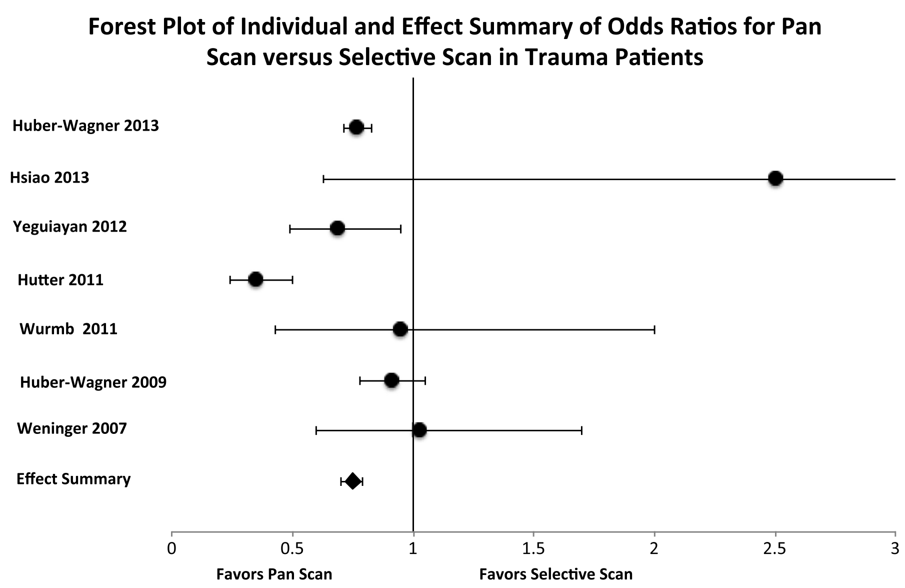

Figure 3. Forest plot of random-effects model, pooled ORs for mortality in trauma patients receiving WBCT versus those receiving selective scanning.

evaluation of the acutely injured trauma patients.[51] The Q statistic indicates the possibility of heterogeneity; however, it must be noted that the statistical power of the Q test may be affected by the small number of studies included in the meta-analysis.

CONCLUSION

We present the largest systematic review and meta-analysis determining the odds of mortality in trauma patients when comparing the use of WBCT scan versus selective scanning. Our analysis suggests that in severely injured trauma patients, those who receive WBCT scan are less likely to have a fatal outcome. We therefore recommend its use until further randomized controlled trials currently being investigated are reported.

AUTHORSHIP

N.D.C., C.S., G.L., and K.S. contributed to the conception and design of this study. N.D.C., C.S., G.L., and K.S. performed the data acquisition, analysis, and interpretation. N.D.C., C.S., G.L., and K.S. drafted the article, revised it critically for important intellectual content, and gave final approval of the submitted version.

DISCLOSURE

The authors declare no conflicts of interest.

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