Whole-body computed tomography is associated with decreased mortality in blunt trauma patients with moderate-to-severe consciousness disturbance: A multicenter, retrospective study

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BACKGROUND: Whole-body computed tomography (WBCT) has become commonly used in the management of blunt trauma (BT) in high-income countries, but its indications are controversial. Advanced trauma life support recommends conducting head CT for traumatized patients with a Glasgow Coma Scale (GCS) score of 3 to 12. This nationwide study was conducted to verify that WBCT is also beneficial for these patients.

METHODS: The Japan Trauma Data Bank (2007–2010) was used to identify BT patients with systolic blood pressure of greater than 75 mm Hg having a GCS score of 3 to 12. Because the probability of survival (Ps) by the Trauma and Injury Severity Score (TRISS) method was used for severity adjustment, 5,208 patients not lacking variables necessary for TRISS Ps calculation were analyzed. WBCT was defined as CT including all of the head, neck, chest, abdomen, and pelvis during initial trauma management, and the WBCT group was compared with patients who did not undergo CT of one or more of the body regions (non-WBCT).

RESULTS: No significant difference in TRISS Ps was observed between the groups. However, the recorded mortality proportion was significantly lower ($p = 0.0002$) in the WBCT group (0.24; 95% confidence interval, 0.22–0.26) than in the non-WBCT group (0.28; 95% confidence interval, 0.27–0.30).

CONCLUSION: In Japan, integration of WBCT into initial trauma management may decrease mortality in BT patients with a GCS score of 3 to 12 for whom head CT is indicated. (*J Trauma Acute Care Surg*. 2013;75: 202–206. Copyright © 2013 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Epidemiologic study, level III.

KEY WORDS: Pan-scan; pan–computed tomography; multidetector (MD) CT; multisystem injury; standardized mortality ratio (SMR).

Whole-body computed tomography (WBCT) has become commonly used in the management of high-energy, blunt trauma (BT) in developed nations such as European countries,[1–5] the United States,[6,7] and Japan.[8] However, its indications[6,9,10] and effects on mortality[5,11] are still controversial.

According to the advanced trauma life support,[12] a CT of the head should be obtained for all patients with moderate-to-severe brain injuries, namely a Glasgow Coma Scale (GCS) score of 3 to 12. It may be beneficial for such patients to also undergo WBCT because the symptoms and physical findings related to the torso are not reliable in patients with consciousness disturbance. Salim et al.[6] pointed out that WBCT may be indicated if "normal abdominal examination results in a neurologically intact patient or unevaluable abdominal examination results secondary to a depressed level of consciousness." However, they did not stratify the level of consciousness disturbance based on the GCS.

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In Japan, a primary survey with chest and pelvic plain radiographs plus focused assessment with sonography has been well standardized nationwide for several years with expansion both of the use of the Japanese guidelines for initial trauma management and of off-the-job training courses for doctors, called the Japan Advanced Trauma Evaluation and Care (JATEC), such as the advanced trauma life support courses. The latest JATEC guidelines weakly recommended that WBCT scanning should be conducted, only for comatose BT patients.[13] For such patients, WBCT can be conducted at the beginning of the secondary survey.

Within the Organization of Economic Cooperation Development (OECD) countries, Japan has the largest number of CT scanners per million people.[14] Most Japanese emergency and critical care centers (ECCCs) at tertiary hospitals authorized by the Ministry of Health, Labor and Welfare have 16- to 64-row multidetector CTs within or are closely located to them. Time for transportation and scan do not seem to be major concerns in Japan. Thus, using our own nationwide data, this multicenter, observational study was conducted to demonstrate the benefit of WBCT for patients with a GCS score of 3 to 12.

PATIENTS AND METHODS

We used data from the Japan Trauma Data Bank (JTDB),[15,16] in which more than 196 hospitals of all over Japan have been involved since 2004, and most of them are well-staffed ECCCs where major trauma victims are transported

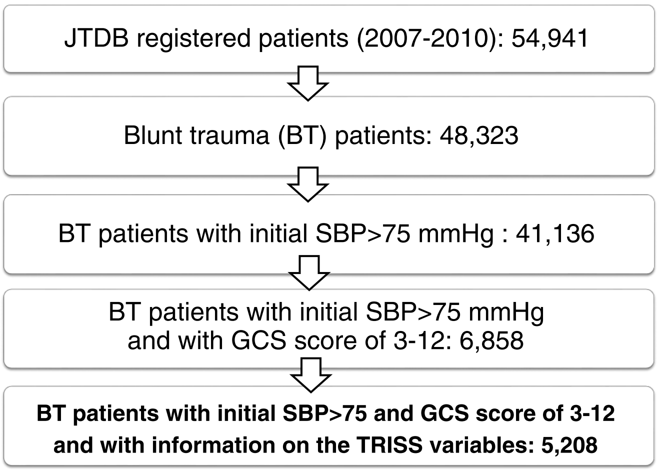

Figure 1. Flow to the analyzed 5,208 patients.

by the well-equipped, Japanese ambulance transfer system, which is handled by either the fire departments of municipal governments or transferred by the hospital-based helicopter/car transfer system with a doctor on board for long distances. Thus, we consider that the JTDB data, especially after 2007, are representative of the data of severe trauma in Japan. A total of 48,232 BT patients' data were gathered from the JTDB from 2007 to 2010 for this study.

Most Japanese emergency physicians or surgeons think that it is possible to safely perform WBCT in BT patients with preresuscitation systolic blood pressure (SBP) greater than 75 mm Hg if they are promptly given the appropriate amount of fluid just after arrival at the well-equipped ECCCs, and they show some response. Thus, 6,858 BT patients with SBP greater than 75 mm Hg and a GCS score between 3 and 12 were selected. In addition to the other vital signs, the GCS scores were obtained just after arrival at the emergency departments at the hospitals.

Because patients' records without any one of the predictors of the Trauma and Injury Severity Score (TRISS)[17] or outcomes were excluded, the data on 5,208 patients in whom the probability of survival (Ps) could be calculated using the TRISS method, which is the most widely used method for measurement of expected outcome in trauma patients, were analyzed; Ps was calculated with age, the Revised Trauma Score (RTS),[18] and the Injury Severity Score (ISS)[19,20] using the Abbreviated Injury Scale (AIS) 90[21] (Fig. 1). In Japanese BT patients, the TRISS Ps has been shown to have enough discriminant ability for survival prediction, with a derived area under the receiver operating characteristic curve of greater than 0.95.[22,23]

Estimated mortality was defined as 1-Ps as a percentage. The standardized mortality ratio (SMR) was defined as the ratio of recorded mortality at discharge from hospitals to estimated mortality. Approximate 95% confidence intervals (CIs) for the SMRs were calculated assuming a Poisson distribution.[24]

WBCT was defined as a CT scan including the head, neck, chest, abdomen, and pelvis during initial trauma management at emergency centers. Non-WBCT was defined as CT scanning without including one or more of the previously mentioned body regions.

Student's or Welch's *t* test and Pearson's χ^2 test were used for univariate comparisons between the groups as appropriate to the type of variable. To determine whether WBCT is an independent predictor for mortality reduction, logistic regression analysis was performed, using maximum likelihood estimation as the method of coefficient estimation with Wald's χ_2 test. The JMP 10 (SAS Institute Inc.) software package was used for statistical analyses.

The protocol of this study was approved by the ethics committee of the National Center for Global Health and Medicine.

RESULTS

Table 1 shows the mortality proportions and percentages of patients who underwent WBCT by GCS score in BT patients with SBP greater than 75 mm Hg. About 10% more WBCTs were conducted in patients with a GCS score of 3 to 12, who were included in the analysis, than in patients with higher GCS scores (13–15).

Injury mechanisms of the total eligible 6,858 patients (Fig. 1) included pedestrian accidents (15.4%), motor cycle accidents (15.0%), fall from a height (13.9%), bicycle accidents (13.6%), fall on the ground (12.9%), fall from stairs (11.5%), motor vehicle accidents (10.6%), and others (7.1%). Overall, 80.3% was brought by ambulances, and 14.7% was brought by helicopters or cars with a doctor. The absence or presence of alcohol drinking was recorded in 58.1% of the eligible patients; 25.9% of cases with this information was alcohol drinkers.

Of the 5,208 analyzed patients, 82.6% (Fig. 1) were brought by ambulances, and 14.3% were brought by doctor-helicopters or doctor-cars. The distribution of injury mechanisms included pedestrian accidents (15.2%), motorcycle accidents (15.2%), fall from a height (14.0%), bicycle accidents (14.0%), fall on the ground (12.9%), fall from stairs (11.9%), motor vehicle accidents (10.7%), and others (6.1%). Absence or presence of alcohol drinking was recorded in 58.7% of the analyzed patients, of whom 26.4% were intoxicated.

As shown in Table 2, WBCTs were performed in 1,858 patients. The remaining 3,350 patients belonged to the non-WBCT group, less than half of which had no CT scans of at least one torso region.

Table 3 shows univariate comparisons of the patients' characteristics between the WBCT and non-WBCT groups. Although significant because of the large numbers, only slight differences were found in age, body temperature, SBP, and the

TABLE 1. Mortality Proportions and WBCT by GCS Score in Patients With Initial SBP of Greater Than 75 mm Hg

GCS Score	Patients	Mortality Proportion (95% CI)	WBCT, %
13–15	23,583	0.024 (0.022–0.026)	25
9–12	2,235	0.11 (0.096–0.12)	34
6–8	1,565	0.22 (0.20–0.24)	38
4–5	495	0.51 (0.46–0.55)	35
3	913	0.61 (0.58–0.64)	36

TABLE 2. Initial CT Scans Conducted

Body Part	Total (n = 5,208)	WBCT (n = 1,858)	Non-WBCT (n = 3,350)
Head	4,890 (94%)	1,858 (100%)	3,032 (91%)
Neck	2,796 (54%)	1,858 (100%)	938 (29%)
Chest	3,440 (66%)	1,858 (100%)	1,582 (47%)
Abdomen	3,308 (64%)	1,858 (100%)	1,450 (43%)
Pelvis	2,662 (51%)	1,858 (100%)	804 (24%)

ISS, and no significant difference was found in the distribution of TRISS Ps, which contains age, ISS, and RTS including SBP as predictor variables, between the WBCT group and the non-WBCT group, with the same average of 0.71. Thus, the mortality risks of both groups were almost equal.

As shown in Table 4, the recorded mortality proportion was significantly lower (p = 0.0002) in the WBCT group (mean, 0.24; 95% CI, 0.22–0.26) than in the non-WBCT group (0.28; 95% CI, 0.27–0.30), whereas estimated mortalities were almost identical in the two groups. Moreover, the SMR was 0.83 (95% CI, 0.75–0.91) in the WBCT group, which meant that the recorded mortality proportion was significantly lower than the predicted mortality. The SMR was 0.97 (95% CI, 0.91–1.03), which was not significantly different from the predicted mortality, in the non-WBCT group.

Table 5 shows the percentage of maximum AIS score equal to or greater than 3 for each body region. Only the percentage for the head region was significantly lower in the WBCT group, which was one of the independent predictors for trauma death (Table 6). However, WBCT was another independent predictor for trauma death, with an odds ratio of 0.83 (95% CI, 0.72–0.95), quite similar to the previously mentioned SMR (Table 6). WBCT seems to be associated with more major injuries (AIS score Q3) of the chest and/or pelvic bony ring (Table 5).

DISCUSSION

Japan has 97.3 CT scanners per million people, the largest ratio among the 38 OECD countries (2008).[15] The average numbers of CT scanners per million people in these countries were 34.0 in 2007 and 40.7 in 2011. Most ECCCs that are authorized by the Japanese Ministry of Health, Labor and Welfare have 16- to 64-row multidetector CTs within or very close to them. Thus, in Japan, WBCT can be liberally used for patients with suspected multisystem injuries during the anatomic, secondary survey of initial trauma management without putting a strain on resources. However, little scientific evidence regarding the indications for WBCT has been collected in Japan before this study.

The present study successfully demonstrated that WBCT scanning was associated with an unexpected mortality proportion of 0.24 among BT patients in Japan with an estimated mortality of 0.29 based on the TRISS method and an SMR of 0.83. Thus, WBCT may be indicated for BT patients with a GCS score of 3 to 12 because it seems to reduce mortality. Some authors have questioned the validity of the TRISS method in contemporary trauma care.[25] We have also pointed out that its minor modification would provide better survival prediction in Japan.[23] However, the TRISS showed enough discriminating ability with an area under the receiver operating characteristic curve of more than 0.95 in 2004 to 2008 in Japan,[22,23] and it has been widely used outside Japan. Therefore, its use for standardization seemed appropriate. The reason why WBCT reduces mortality is probably caused by increased detection of occult, major injuries of the chest or pelvic ring (Table 5).

Salim et al.[6] proposed one of the indications of WBCT, namely "normal abdominal examination results in a neurologically intact patient or unevaluable abdominal examination results secondary to a depressed level of consciousness." This definition agrees with our proposal that WBCT is indicated for BT patients with moderate-to-severe consciousness disturbance. They also suggested hemodynamic stability as a condition. In Japan, fluid resuscitation is not allowed in the prehospital setting without a doctor. Thus, SBP on arrival seems to be lower than in other countries where prehospital fluid resuscitation is allowed without a doctor. If a BT patient with an initial SBP of greater than 75 mm Hg is quickly given the appropriate amount of fluid just after arrival at a well-equipped ECCC and shows some response, most Japanese emergency physicians or surgeons think that it is possible for such patients to safely undergo WBCT.

TABLE 3. Characteristics of Both Patient Groups

Factors	WBCT (n = 1,858)	Non-WBCT (n = 3,350)	p
Men	71% (69–73)	70% (68–71)	*0.38*
Age, y	48 (47–49)	53 (52–53)	*<0.0001*
HR, beats per minute	94 (93–95)	93 (92–94)	*0.15*
Temperature, °C	36.0 (35.9–36.0)	36.1 (36.0–36.1)	*0.0075*
RTS	5.80 (6.75–5.85)	5.84 (5.80–5.88)	*0.24*
SBP, mm Hg	134 (132–135)	141 (140–142)	*<0.0001*
RR, breaths per minute	22 (22–23)	22 (22–23)	*0.47*
GCS score	7.6 (7.4–7.7)	7.6 (7.5–7.8)	*0.31*
ISS	26 (25–26)	23 (23–24)	*<0.0001*
Ps	0.71 (0.69–0.72)	0.71 (0.71–0.72)	*0.23*

Data are presented as mean (95% CI).
HR, heart rate; RR, respiratory rate.

TABLE 4. Estimated and Recorded Mortality and SMR by Group

	WBCT (n = 1,858)	Non-WBCT (n = 3,350)	p
Recorded mortality proportion	**0.24** (0.22–0.26)	**0.28** (0.27–0.30)	0.0002
Estimated mortality (=1 j estimated Ps)	0.29 (0.28–0.31)	0.29 (0.28–0.29)	*0.23*
SMR	**0.83 (0.75–0.91)**	0.97 (0.91–1.03)	

Data are presented as mean (95% CI).
SMR = recorded mortality/estimated mortality.

Our recent study[13] demonstrated that integration of WBCT into initial trauma management also decreased mortality in comatose BT patients with an initial SBP of greater than 75 mm Hg and that the SMR of the WBCT group was 0.84 (95% CI, 0.74–0.95) and that of the non-WBCT group was 1.01 (95% CI, 0.93–1.10). The results were quite similar to those of the present study. Thus, unexpectedly, a group of BT patients with a more severe degree of neurologic insult seemed to receive little added benefit from WBCT scanning with respect to preventing mortality.

Even if WBCT provides reduced mortality, the disadvantages of radiation exposure[26–29] must be considered. WBCT is associated with greater radiation exposure than CT targeted to a particular anatomic area and potentially increases an individual's risk of cancer. Some studies[28,30] demonstrated that WBCT or torso CT increased radiation exposure without a decrease in mortality. The number needed to scan demonstrating a survival advantage was 13 to 33 in the present study. Therefore, to justify WBCT despite the increased radiation exposure, overtriage and unnecessary WBCT scanning should be minimized. The total cost of a trauma WBCT scan is about US $1,000 in Japan, and for Japanese citizens, most of that is covered by the national health insurance. Thus, to reduce not only individual radiation exposure but also national health insurance fees, WBCT should be limited to fluid responders with moderate-to-severe consciousness disturbance. For BT patients with clear consciousness or with mild consciousness disturbance, for whom WBCTs were actually conducted less often in Japan (Table 2), clinical decision rules for patient selection, similar to indications for head CT in minor traumatic brain injuries,[31–34] are expected.

TABLE 5. Percentages of Both Groups with Maximum AIS Score of 3 or Greater

Injured Body Region	WBCT	Non-WBCT	p
Head	92% (1,431/1,555)	94% (2,665/2,846)	*0.044*
Face	8.3% (43/521)	5.8% (47/806)	*0.087*
Neck	29% (6/21)	16% (5/31)	*0.28*
Chest	90% (720/799)	86% (843/984)	*0.046*
Abdomen and pelvic contents	48% (138/286)	52% (176/340)	*0.38*
Spine	46% (173/376)	42% (175/413)	*0.30*
Upper extremities	13% (56/447)	13% (90/673)	*0.68*
Lower extremities and pelvic ring	53% (360/679)	48% (455/952)	*0.038*

TABLE 6. Multivariate Adjustment

Variables	Coefficient	p	Odds Ratio
Head injury of AIS Q3	0.967	<0.0001	6.92 (4.41–11.6)
WBCT	j 0.093	<0.0092	0.83 (0.72–0.95)
Constant	j 1.823	<0.0001	—

Finally, several limitations of the present study must be mentioned. Since this was a retrospective, observational study, a causal relationship between WBCT and decreased mortality cannot be proven.[2,5] Scanning methods and indications for WBCT depended on the protocol of each emergency center, about which no information was available. Because data of TRISS predictors or outcomes were missing in the JTDB, the Ps values could only be calculated for 5,208 patients, 75.9% of the eligible 6,858 patients. However, the distribution of injury mechanisms, the percentage of patients transported by each transportation method, and the percentage of alcohol drinkers of the analyzed patients were almost the same as those of the total eligible patients. Thus, the differences in characteristics between the eligible patients and the analyzed patients seem to have been quite small.

Despite these limitations, the present study used nationwide data of a relatively high patient volume as compared with previous studies,[5,11] and the results suggested a simple indication for WBCT. Thus, the results of the Japanese experience seem to be worth reporting to an international audience.

CONCLUSION

As compared with the selective use of WBCT, integration of WBCT into initial trauma management may decrease mortality in BT patients with a GCS score of 3 to 12, for whom head CT is absolutely indicated.

AUTHORSHIP

A.K. conceived of the idea for this work, analyzed the data, and wrote the article. N.T. contributed to the statistical assurance.

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DISCLOSURE

The authors declare no conflicts of interest.

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