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Single Pass Whole-Body versus Organ-Selective Computed Tomography for Trauma: Timely diagnosis versus radiation exposure? – An observational Study

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Abstract

Background

Single Pass Whole-Body Computed Tomography (WBCT) has been used as a high yield diagnostic tool in trauma. However, increased exposure to radiation and delay in treatment, have been cited as challenges to its widespread use. We hypothesized that WBCT has at least the same radiation exposure compared to Organ-Selective CT and it does not inflict further delays in treatment.

Methods

We retrospectively review all trauma patients in whom CT-scans were performed on arrival at a Level I Trauma Center from January, 2016 to December, 2017.

Results

123 patients were included: 53 in the OSCT group and 70 in the WBCT group. In the OSCT group, 64.1% of the patients had penetrating trauma and chest injuries were the most common injured body cavity (79.3%). In the WBCT group, 65.7% had blunt trauma and head injuries were the most common (71.9%) injured organ. The OSCT group required subsequent trips to the scanner suite for follow-up studies to rule out other potential injuries which in turn did not occur in the WBCT group (47.2% vs 0%, p< 0.001). The total radiation exposure dose was higher in the OSCT group compared to the WBCT group [22 mSv (IQR 6-31) vs 15.1 mSv (IQR 9.9-24.8) p<0.001].

Conclusion

OSCT has the potential of missing potentially life threatening injuries that require subsequent follow-up scans. This, in turn, would increase the patient's overall radiation exposure and potentially delay definitive surgical treatment. Trauma patients undergoing WBCT had lower total radiation exposure with no delay in treatment.

Background

Despite advances in acute trauma care, hemorrhage remains the leading cause of preventable death. Control of the bleeding during the first hour after injury is essential to increase the overall survival in these patients. With this purpose in mind, the American College of Surgeons has developed the Advanced Trauma Life Support (ATLS) Course as a guide in the initial management of trauma patients, which includes ultrasound, x-rays and computed tomography (CT) as adjunts in the workup of a trauma patient, but limits specifically the use of CT-scan in hemodynamic unstable trauma patients.

For many years the use of CT-scan in trauma has been considered part of the secondary evaluation of a stable trauma patient. Many leading national and international academic trauma surgeons have even gone to name its use in hemodynamic unstable patients as "The Tunnel or Doughnut of Death", suggesting that the transfer of critically ill patients from the trauma bay to the CT suite interrupts the ongoing resuscitation of the patient, delays the definitive treatment and increases the risk of death in patients with active bleeding. Currently, multi-slice computed tomography allows for a fast total body evaluation, an excellent image quality and a significant reduction in total scan time. For these reasons the CT-scan has been integrated into the initial management of trauma patients and approximately 60% of all European trauma centers include Whole Body Computed Tomography (WBCT) as part of their initial workup algorithm (1, 2).

Since there are still gaps in the knowledge about the risks or potencial benefits of WBCT, we hypothesized that WBCT is safe to performe in patients with blunt and penetrating trauma, has the same radiation exposure as compared to Organ-Selective CT scan (OSCT) and it does not necessarily inflict further delays in the definitive treatment of trauma patients. The main objective of our study was to prove that WBCT is a useful diagnostic tool that can be used safely and timely in all trauma patients, independently of their hemodynamic status.

Methods

Study design

We conducted an observational, case-control study. We retrospectively included trauma patients admitted at a Level I Trauma Center - Fundacion Valle del Lili (FVL), Cali, Colombia, in whom a CT-scan was performed upon arrival from January, 2016 to December, 2017. The study included all adult patients (>16 years-old) that suffered penetrating and/or blunt trauma who received a CT-scan upon arrival. Patients who didn't meet the inclusion criteria, patients who underwent CT-scans without recorded DLP (Dose Length Product), those that had received CT scans at outside institutions prior to arrival to our Trauma Center, and patients with missing data were excluded (74 patients).

The DLP is a measure of CT radiation output/exposure. DLP accounts for the length of radiation output along the patient's z-axis and its unit of measurement is the miliGrey (mGy). DLP does not take the size of the patient into account and does not represent the patient's effective dose. The effective dose depends on others factors incluiding the scanned body zone, and is the product of DLP and K conversion coefficient. The values for K are specific to each part of the body. The unit of measurement for the effective radiation dose to which the patient is exposed to is the miliSievert (mSv) (3, 4).

Patients were divided in two groups: those who underwent Organ-Selective CT scan (OSCT Group), and those who had Single-Pass Whole Body CT-scans (WBCT Group). WBCT was defined as an intravenous (IV) contrast CT-scan that included the brain all the way through to the pelvis. The OSCT was defined as an IV contrast CT-scan limited to a single body cavity.

Upon arrival, all patients were evaluated by the Trauma Team and managed according to ATLS guidelines. Focused Assessment with Sonography for Trauma (FAST), chest and pelvic X-rays were performed in all patients as initial screening tools. The decision to perform OSCT or WBCT depended on the trauma surgeon on call, and was based on the institutional WBCT guidelines, patients who didn't meet the criteria to perform WBCT, underwent OSCT (*Table 1).*

Patients in hemorrhagic shock were initially managed in the trauma bay with endovenous (EV) fluid restriction and blood product transfusion. Hemorrhagic shock was defined as a mean systolic blood pressure (SBP) lower than 90 mmHg and a pulse rate higher than 100 beats per minute on arrival to the Trauma Center. If patients responded by means of sustaining their SBP between 80 and 90 mmHg during their initial resuscitation then the patient was taken to the CT suite for a WBCT or OSCT scan. The CT suite is located adjacent to the trauma bay (less than 100 feet), and there are three CT Scanners available at all times in the institution.

WBCT technique

Data was adquired using a multi-slice IVR-CT system (Aquilion ONE 320 Slice CT scanner, software version 7.0, Toshiba Medical Systems Corp., Tochigi, Japan). Each patient was accompanied by the trauma team (trauma surgeon, general surgeon, fellow, general surgery resident, ER physician and trauma nurses). A radiologist read each study in real time. Resuscitation which was initiated in the trauma bay was continued in the scanner. WBCT protocol consists on injection of low osmolar, non ionic contrast medium (Iopromide Ultravist R.Whippany, NJ:Bayer HealthCare Pharmaceuticals) with 18-gauge peripheral IV catheters. A simple acquisition phase is performed for the head and a phase of acquisition with contrast is performed for the neck, thorax, abdomen and pelvis through high-volume injectors. Overall, we used 130 ml of contrast with biphasic injection technique with an inter-bolus delay of 45 seconds. The first phase: 60 ml bolus of iopramide IV, at a rate of 2.0 ml/sec in 30 seconds. An iopromide administration pause for 45 seconds followed by the second phase: 70 ml bolus of iopramide IV, at rate of 4.0 ml/sec in 17 seconds. Finally, 40 ml of normal saline solution IV was administered at a rate of 4.0 ml/sec in 10 seconds. The sequential contrast bolus results in a single acquisition reflecting the combination of arterial and portal venous phases, with excelent image quality and fast reconstruct image acquisition. The slices of the CT scanner are 1 mm and the total number of slices depended on the height of the patient.

Data Collection and Statistical methods

Data was extracted from the clinical records. Patients demographics, clinical variables and injury related characteristics were obtained. The DLP values were obtained from each CT- scan performed, and the effective radiation dose was estimed using the product of DLP and *K* conversion coefficient specific to each body region. The results were exported to a database from BD Clinic® to be analyzed in Stata 12.1®, College Station Tx. Initially, a descriptive analysis was performed. The continuous variables were summarized as averages ± standard deviation or median and interquartile ranges, depending on their normality analysis and they were compared with T Student or Wilcoxon-Mann–Whitney U Test, according to whether normality assumptions were accomplished or not, respectively. The categorical variables were presented in proportions, and the comparison between them were made with Chi-square or Fisher's exact test accordingly. A value of $p < 0.05$ was considered statistically significant.

Results

A total of 123 patients were included during the study period, 53 were in the OSCT group and 70 in the WBCT group and the presence or absence of shock was noted (*Figure 1).* In the OSCT group, 77.4% were male, with a median age of 28 (IQR 22–39). The median Injury Severity Score (ISS) was 10 (IQR 9–17) and RTS 7.9 (IQR 5.9–7.8). In the WBCT group, 92.8% were male, with a median age of 29 years old (IQR 23–50). The ISS was 16 (IQR 11–25) and RTS was 6,9 (IQR 5.9–7.8). ISS and RTS were significantly higher in the WBCT group ($p<0.001$ and $p = 0.01$, respectively).

In the OSCT group, the most common trauma mechanism was penetrating in 64.1% (34 cases), of these, 54.7% had injuries by gunshot wounds. The thoracic cavity was the most common injured body zone (79.3%), followed by the extremities in 39.6% and head in 17% of the cases. Thirty-one cases had 2 or more body zones injured (58.5%) and of these, 10 patients (18.1%) arrived in shock. The most common trauma mechanism in the WBCT group was blunt (85.7% vs 35.9%; $p<0.001$), of which 65.7% were secondary to traffic accidents and 21.4% were falls from hights. The head was the most common (71.9%) injured organ,70% of the patients had thoracic trauma, and 57 patients (81%) had two or more body zones injured, of these, 8 (11.4%) patients arrived in shock.

None of the patients of either group presented cardiac arrest or died in the CT-scanner. The median ER to CT-scan time was lower in the WBCT group compared to the OSCT group (28 min [13–50] vs 41 min [21–60]) ($p = 0.01$). The median CT-scan to diagnosis time was also lower in the WBCT group (22 min [14–32] vs 32 min [21–65]; $p<0.001$).

In the OSCT group, 17 patients (47.2%) required a follow up CT-scan for definitive diagnosis. A total of 25 extra CT-scans were performed. The most frequent extra CT-scans were in brain and chest. In all patients with extra CT-scans, a second transfer to the CT suite was necessary. In one case, 3 transfers were necessary. This did not occur in the WBCT group, since none of the patients requiered a follow up CT-scan (47.2% vs 0%, $p< 0.001$) (*Table 2).*

The median total radiation dose in the OSCT group was 22 (IQR 6–31) mSv, which was higher than the total radiation dose in the WBCT group (22 mSv [IQR 6–31] vs 15.1 mSv [IQR 9.9–24.8]; $p<0.001$) (*Table 3).*

Discussion

In the past decade, the use of CT-scan for the evaluation of the trauma patient has increased significantly. It is much more specific and sensitive for injury detection than conventional imaging strategies (5). Thanks to its own technological advances, the multi-slice computed tomography has improved the speed, image quality and accuracy, allowing the integration of WBCT into the early trauma care algorithm.

Currently, WBCT is widely used in trauma centers worldwide as the standard workup of severely injured patients (6,7,8).

The specific imaging protocol varies between institutions around the world (9). Usually, WBCT is performed as a multipass CT acquisition technique with different helical CT phases of specific body zones (10–15). The contrast medium is used for the chest, abdomen and pelvis. Nguyen, et al. showed that the use of single-pass WBCT decreased the acquition time in 42.5% compared to conventional WBCT (16, 17, 18). In our institution, the single-pass continuos WBCT protocol allows the biphasic application of the contrast medium in 1 minute 27 seconds, with the adquisition of an image in a single-pass with a high resolution imaging of both the arterial and venous phases.

The benefits of Whole-Body CT-scan are multiple: it decreases the time to definitive diagnosis and/or treatment and it shortens the overall emergency department length of stay (22–24). However, it is still considered that "*WBCT can potentially delay critical interventions".* To this point we found that WBCT decreased by 68% the time between ED arrival and transfer to the CT suite as compared to patients that had selective CT-scans. This is partly due to the delay in decision making on behalf of the treating trauma surgeon in the OSCT cases who must decide which diagnostic /treatment algorithm he or she must take for each case according to the clinical information obtained on primary survey and initial screening adjuncts in the trauma bay. This phenomenon does not occur in the WBCT group because the patient is automatically processed via a pre-established institutional diagnostic/treatment algorithm that guarantees the expeditious flow of the definitive workup of the patient. This time reduction allowed for a faster triage of the most serious injuries and an expeditious onset.

Numerous retrospective studies have shown that the use of WBCT in severe trauma patients increases their survival rates (25–28). Huber and Collegues showed a decrease in absolute mortality in patients with polytrauma who received WBCT when compared to those who received OSCT scans (29, 30). However, such results should be evaluated with caution considering that the inclusion of a substancial number of patients with an ISS higher than 16 (36%) could have affected these results (31, 32).

Opponents of WBCT argue that a major potential disadvantage is the increased exposure to radiation and potential longterm risk of developing a malignancy (9). WBCT was performed using a single-pass and the patient's position with the arms above the head decreased the effective radiation dose by 16 to 22% (34–37). The effective radiation dose in the WBCT group was between 10–20 mSv compared to 5–16 mSv in the OSCT group but the net total radiation exposure was higher in the OSCT group because they required in many cases follow up scans to rule out potential missed injuries.

We believe that time is of escense for a favorable outcome in critically ill trauma patients and this time includes that spent in the prehospital arena and in the trauma bay. To this end, the single-pass WBCT scan allows for an overall reduction in radiation exposure when compared to OSCT and provides timely diagnosis of the multi-injured trauma patient.

Limitations

Our study was an observational study which inherently carries limitations and selection bias. First, we did not perform a power analysis based on the primary outcome, the sample was a convenience sample, based on the hospital capacity. The decision to performe WBCT or OSCT depended on the treating physician, and even there is a workflow to guide this decision, there wasn't a randomization of the patients to assure the homogeneity of the patient's characteristics. The differences in trauma mechanisms and severity scores between the two groups make the patients non-comparable, but is useful to evaluate characteristics and outcomes of patients receiving WBCT or OSCT, and to stablish the potential uses of WBCT.

Conclusion

Our results suggest that trauma patients undergoing single-pass WBCT seem to have overall lower total radiation exposure, lower ED to CT-scan time and lower CT-scan to diagnosis time, with no delay in definitive treatment when compared to patients that underwent OSCT scans. These findings reiterate our hypothesis that WBCT scans are a safe and efficient tool to diagnose trauma patients. However, this is a single-center study, results should be interpreted with caution as they cannot be generalized to all trauma centers, more studies are needed to assess the usefulness, efficacy and effectiveness of WBCT in severe trauma patients.

Declarations

List of abbreviations

ATLS: Advanced Trauma Life Support

CT: Computed Tomography

DLP: Dose Length Product

ED: Emergency Department

EV: Endovenous

FAST: Focused Assessment with Sonography for Trauma

FVL: Fundación Valle del Lili

IQR: Interquartile Range

ISS: Injury Severity Score

OSCT: Organ Selective Computed Tomography

RTS: Revised Trauma Score

SBP: Systolic Blood Pressure

WBCT: Whole Body Computed Tomography

Ethics approval

Ethics approval was granted by the Institutional Review Board from Fundacion Valle del Lili under the number 554 in 2014, and has been updated annually since its approval.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

CAO, MWP, AMdV, MGR, HM, CNV, CG, PF, RFD, JPH, AO, AD, LI, JCP and AG contributed equally to this work. AMdV, HM, AD and LI collected the data. All authors participated in the writing and editing of the manuscript, and the decisión to submit for publication.

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Tables

Due to technical limitations, all tables are only available for download from the Supplementary Files section.

Figures

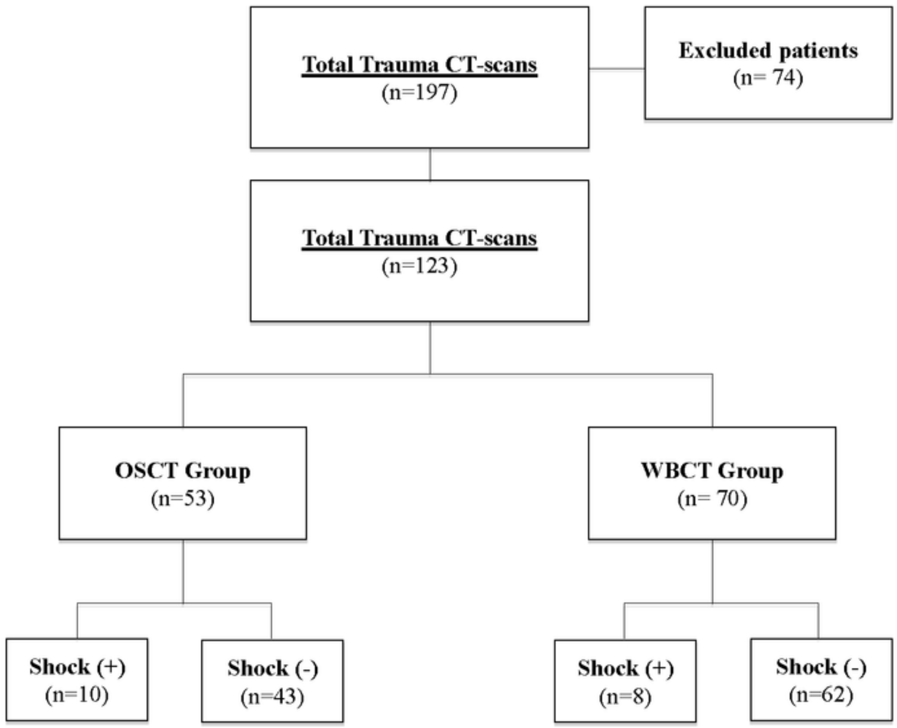

Figure 1

Trauma Computed Tomography. Scheme summarizing Total Trauma CT-scans and patients included in each group.

Supplementary Files

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