

Effectiveness of CT Scans in Trauma Patient at the Emergency Room, Bangkok Hospital Pattaya, Chonburi Province

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Abstract

OBJECTIVES: To study the safety of radiation doses, comparing radiation exposure between whole body and divided into sections of computed tomography (CT) scan performed. Assess the safety of the amount of radiopaque contrast received and the effect on kidney function, Creatinine Glomerular Filtration Rate (GFR), in each type of CT scan. The under-covered diagnosis among trauma patients who were not sent for CT Trauma Body examination from the first time at the emergency room in order to find the cost-effectiveness of CT scans.

MATERIALS AND METHODS: Retrospective descriptive research study to answer research questions and study trauma patients who received whole-body scan and divided into sections, such as CT Brain, CT Cervical Spine (C-Spine), CT Chest, CT Abdomen. Between 1 January 2018 - 30 September 2023 records sourced from the X-ray department Bangkok Hospital Pattaya (BHP), Chonburi Province. The number of trauma patients: 5,507 cases from 5,833 records.

RESULTS: 1) Safety of radiation dose received from whole body and segmental CT scans. It can be concluded that, 1) segmental CT scans receive less radiation than whole body CT scans. While the in-patient department (IPD) examination results of trauma patients who underwent whole body CT scans had radiation doses that trauma patients received equal to 124.53 milligray (mGy), and segmental examinations received less radiation than whole body examinations, namely, brain CT equal to 62 mGy, total abdominal CT equal to 20 mGy, chest CT equal to 18 mGy, and spine CT equal to 24.53 mGy. 2) Safety of radiation doses affects the GFR of kidney creatinine from each type of CT scan. It was found that most trauma patients who were referred for examination received 370 nanometers of ultraviolet radiation. 3) Safety from incomplete diagnosis in patients who did not receive the first CT Trauma Body examination in the emergency room. It was found that injured patients were at risk from incomplete diagnosis from the first examination in the emergency room. leading to a repeat referral from the IPD and 4) the cost-effectiveness in terms of the cost of sending a CT Trauma Body examination. It was found that injured patients who underwent a CT Trauma Body examination had an average total cost of 28,640.26 baht (842.36 United States dollar (USD)), while the cost of sending a separate examination averaged 51,727.63 baht (1,521.40 USD). When considering the cost-effectiveness of a CT scan, it was found that a whole-body examination was more worthwhile than a separate examination because these were expensive (when all the costs were added together).

CONCLUSION: Therefore, trauma patients who undergo a CT Trauma Body scan from the emergency room will benefit from comprehensive diagnostics, the absence of complications, rapid and complete recovery, and the avoidance of repeat scans. Additionally, the cost is lower compared to multiple, separate CT scans. However, the assessment for each type of radiological examination depends on the severity of the injury, the patient's vital signs, level of consciousness, medical history, physical examination, physician's judgment, and other precautions taken into consideration before ordering the scan.

Keywords: effectiveness, sending for CT scan, trauma patient, emergency room, Bangkok Hospital Pattaya, BHP

Injuries among trauma patients are common in emergency rooms. This is because trauma patients experience injuries to various parts of the body. According to the latest data from the World Health Organization (WHO) and the Centers for Disease Control (CDC), there are more than 9 deaths per minute from injuries or violence and 5.8 million people of all ages die every year from unintentional injury and violence. The injury burden is even more significant, accounting for 18 percent of all illnesses in automobile accidents. This alone causes more than 1 million deaths per year and approximately 20 to 50 million serious injuries, making it the leading cause of injury-related death worldwide. However, injury control efforts are having an impact in developed countries. Injuries remain the leading cause of death in people aged 1-44 years. It is worth noting that more than 90 percent of car accidents occur in developing countries. Injury-related deaths are expected to increase significantly by 2020, and deaths from automobile accidents are expected to increase by 80 percent from current rates in low- and middle-income countries.¹

From a study by Amnard Chitvoranand,² it was found that accident patients with severe injuries often have multiple system injuries and life-threatening emergencies. Many will die before reaching the hospital, up to 60 percent of accident victims. From a study in Korea by Kim et al.,³ it was found that 35.2% of deaths of injured people at emergency rooms were preventable deaths and 48.4% were due to wrong decisions in assessment and management. For this reason, care and assistance for trauma patients will differ according to the condition of the trauma patient and the situation. It is therefore necessary to send for a CT scan. When sending for CT scan, the trauma patient will receive a radiographic examination in order to diagnose the injury. It can be divided into 2 main parts: fractional irradiation and whole-body irradiation. Therefore, sending for a CT scan is important to assess the extent of a patient's injury in order to provide urgent treatment to save the trauma patient's life by making a diagnosis in a timely and efficient manner.

A CT scan is vital to help doctors understand the injuries of trauma patients and how to treat trauma patients. For this reason, CT scan is an appropriate and important tool and is certified for the evaluation of trauma patients who suspect that the trauma patient has injuries to multiple systems within the body. X-ray examination takes a short time and is highly accurate. However, sending CT scans in sections is more expensive and may result in misdiagnosis if more tests are sent than necessary, which in addition will cost the hospital money that could have been saved.⁴ In addition, CT scans have a disadvantage in that trauma patients are exposed to increased radiation, although there is no research that definitively indicates that they can cause cancer. However, sending for CT scans should be done as a necessary step. If necessary, trauma patients should be exposed to radiation only once by undergoing a whole-body examination to reduce misdiagnosis and reduce the number of times they are exposed to radiation. Reducing radiation exposure is beneficial to trauma patients and makes it cost-effective to send trauma patients for whole-body CT scans.

From a review of the literature, it was found that there are many studies that study how CT scans can help doctors diagnose abnormalities in trauma patients. Sending for a CT scan improves accuracy and includes etiology and complications, which are important for trauma patient treatment. Research by the International Atomic Energy Agency⁵ states that the diagnostic reference level (DRLs) is the radiation dose value that is the reference value for diagnostic radiographs for each type of radiological procedure. The International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurement (NCRP) recommend that national radiation protection agencies set DRLs as reference dose levels. It is determined from the 75th percentile of the median amount of radiological indications from each radiographic procedure from each regional or local radiation agency (LDR). In cases where the radiation doses the trauma patient receives is lower than or equal to this reference value, it means that the trauma patient receives a radiation dose within the general range for the majority of the population. But if the radiation doses the trauma patient receives is higher than this value, it means that the trauma patient has received a radiation dose higher than the general limit.⁶

A study of data from Kidney Disease Improving Global Outcome (KDIGO) found that acute kidney failure from contrast injection has an incidence of 1-2% in trauma patients with normal kidney function and increases as high as 22-25 percent in trauma patients with existing chronic kidney failure. It is the third most common cause of acute kidney failure in hospitalized trauma patients. And the risk increases even more if the trauma patient has risk factors such as diabetes, heart failure, low blood pressure, anemia, receiving drugs that are toxic to the kidneys, and sepsis, etc.⁷⁻⁹

From the statistics of trauma patients who received CT scan services at BHP between 1 January 2018 - 30 September 2023,¹⁰ it was found that there were 5,507 cases of trauma patients who received a CT scan, including whole-body and sectional examinations, out of 5,833 examination items. The total cost of sending for a CT scan was 72,427,239 baht (2,130,212.91 USD). Therefore, the average cost of sending for CT scan per time is 12,416.81 baht (365.20 USD).

For this reason, the researchers studied the effectiveness of CT scan in a group of trauma patients to determine its cost-effectiveness, safety from reducing misdiagnosis, and safety of trauma patients who receive X-ray radiation doses and the safety of trauma patients in receiving less radiopaque contrast material.

Material and Methods

In this research, the researcher used a retrospective descriptive study to answer the research questions and to study trauma patients who received CT scans. The injured people studied were trauma patients who received CT scans of the whole body and sectional examinations such as Brain, C-Spine, Chest, Abdomen, etc. Then, the incidence of CT scans of

trauma patients and the effectiveness of CT scans was analyzed to determine: its cost-effectiveness and; safety in the amount of radiation received and; safety in the amount of contrast media received (affecting kidney function) and; safety from further non-comprehensive diagnosis.

Data collection

The researcher collected Secondary Source data from the database of the X-ray department, which is the CT scan data of trauma patients at the emergency room, Bangkok Hospital Pattaya, Chonburi Province, between 1 January 2018 - 30 September 2023. Total data amount: 5,507 cases from 5,833 records by classifying CT scans from the number of cases used in this study, the researcher analyzed to find Trauma ER Visit cases that received CT scans, divided into 2 parts: the first part was CT Trauma Body examination, and the second part is the non-extensive examination from the emergency department. In terms of sending for CT Trauma Body, data is classified into 2 parts: 1) Data from Emergency room (ER) and data from IPD or inpatients (Information of trauma patients who have been hospitalized for at least 6 consecutive hours).

Data analysis and data processing

The researcher analyzed the data using descriptive statistics. Quantitative research was analyzed and the data interpreted using averages and percentages, and the qualitative research was analyzed and the data interpreted data to determine the value of CT scans for trauma patients who are sent for CT scans. From this information, the researcher analyzed according to the research objectives as follows:

1. Analyzed from the amount of radiation that trauma patients receive from one whole-body CT scan and the amount of radiation received from a sectional CT scan (number of times).
2. Analyzed from the amount of contrast material and the name of the contrast material that trauma patients receive when having radiological examinations. Then consider the safety value of the amount of contrast agent that the trauma patient receives with the value of Creatinine. (Information may be obtained only for trauma patients who submit a repeat Creatinine test). Each individual person must be analyzed for confounding factors such as congenital disease, medications taken or kidney injury, etc.
3. Analyzed the number of cases of trauma patients with non-comprehensive diagnosis, in the group of trauma patients who did not receive CT Trauma Body examination from their first arrival in the emergency room. Then consider by repeating the CT scan of the case in question whether there are test results indicating injuries that were not diagnosed in the emergency room or not. Following up on cases where CT Trauma body/CT investigations are sent, and other CT investigations related to accidents that have treatment orders from IPD/Critical Care.
4. Find the cost-effectiveness of CT scan by analyzing the Incremental Cost Effect Ratio (ICER) and considering the cost-effectiveness plane. This research was approved by

the Human Research Ethics Committee on November 21, 2023.

Results

Analyze the effectiveness of trauma patients' CT scans. The researcher will present research results on 4 issues as follows:

1. The safety of the amount of radiopaque contrast received and the effect on kidney function.

It was found that in the cases of trauma patients who received CT Trauma Body examinations, there were a total of 394 cases and in the cases of trauma patients who received CT Trauma in separate sections, there were a total of 2,068 cases. From this number of cases, the researchers synthesized sample cases for an in-depth study to analyze the safety of the trauma patient's radiation dose between whole-body and sectional CT. The researcher analyzed cases of Trauma ER Visit that had CT scans divided into 2 parts: the first part was CT Trauma Body, and the second part was non-comprehensive diagnosis from the emergency department or sectional examinations. As for the CT Trauma Body examination, the researcher used data from the IPD or inpatients in 29 cases. Of these cases, there were tests that were non-comprehensive diagnosis by the emergency department, the number of cases where Injury was found/the number of CT Trauma Body sent to the Ward/IPD was 18 cases. The types of contrast agents administered to the patient include Ultravist-370 (100 ml, 150 ml), a solution for injection/infusion into the blood vessels, and Optiray-350 (100 ml), a non-ionic, water-soluble contrast agent with low osmolality, suitable for intravenous administration.

From a study of 18 cases of trauma patients who received CT scans, we studied the safety of the amount of radiation received from trauma patients who had CT scans from the emergency room and IPD. They can be classified according to the items sent for examination as follows:

- 1) **Examination from the emergency room and IPD**, it was found that there were 6 trauma patients who were examined from the emergency room and IPD, with sectioned examination and whole-body examinations, from consideration of the safety of the amount of radiation received. In conclusion, trauma patients who received sectioned CT scans from the emergency room and IPD received less radiation than a single whole-body CT trauma examination. This is because the radiation dose that the trauma patient receives from each examination will not be the same depending on the examination item. Therefore, it results in lower radiation values than the whole-body examination.
- 2) **Single whole-body examination from IPD**, it was found that there were 9 trauma patients who received a single whole-body examination from the IPD. When considering the safety of the radiation dose received by the trauma patients from the IPD examination, it was concluded that in trauma patients who received a whole-body CT scan, the radiation dose received was 124.53 mGy.

3) **Sectional IPD examination**, it was found that there were 4 trauma patients who received separate examinations from IPD. When comparing trauma patients who received a sectional examination with a single whole-body examination, it was found that trauma patients who received a sectional examination would receive less radiation than in the case of a single whole-body examination. CT brain received a dose of 62 mGy, CT Whole abdomen received 20 mGy, CT Chest received 18 mGy, and CT C-spine received 24.53 mGy, respectively.

In the case of trauma patients diagnosed at the emergency room, it is considered that there must be a separate examination, so it is brought to the IPD examination, which is a CT Trauma Body examination. The results showed that the trauma patients received a higher radiation dose than a single CT Trauma Body. This is in addition to the initial radiological diagnosis performed in the ER examination from the emergency room because they received the radiation dose according to the number of CT scans.

From the above data, a single CT Trauma Body examination of a trauma patient was found to reduce the Volumetric Radiation Index (mGy) in trauma patients requiring repeated scans. It was found that the Volumetric Computed Tomography Dose Index (CTDIvol) value for the CT Trauma Body examination of the trauma patient was 124.53. During the process of measuring the radiation dose of the CT scanner, known as nCTDIw (normalize weighted computed tomography dose index; mGy/mAs), measurements were taken using a pencil-type ion chamber with a phantom representing an average-sized patient. Two types of phantoms were used: a head phantom with a diameter of 16 centimeters and a body phantom with a diameter of 32 centimeters. The nCTDIw value represents the output that indicates the radiation dose of the CT scanner. This value is used to calculate the radiation dose during patient diagnosis. In this study, the calculated radiation dose per unit volume was determined using the Computed Tomography Dose Index (CTDI volume; CTDIvol). In this case, the radiation dose for the trauma patient under examination was assessed. (higher than normal) When the trauma patient's CT scan was examined in sections, it was found that the CTDIvol value of the trauma patient's CT brain examination was 62 mGy, which is within the normal range of the reference radiation dose value. In the case of trauma patients undergoing CT whole abdomen examination, the CTDIvol value was equal to 20 mGy, which is within the normal range of the reference radiation dose value. Similar to the trauma patient who had a CT Chest + Whole abdomen examination, the CTDIvol value was 18 mGy, which is within the normal range of the reference radiation dose value.

This study has not yet collected data and determined the exact trauma patient radiation dose for CT C-spine examinations. Because it is a high frequency examination in cervical spine examinations, the researcher used CTDIvol values equal to 24.53 mGy and DLP equal to 560.50 mGy.cm from the CT C-spine examination.¹¹

Substitute values from the formula:

- Safety Radiation Dose CTDIvol of CT Trauma Body Examination = 124.53 mGy
- Safety Radiation Dose CTDIvol of CT brain Examination = 124.53 mGy – 62 = 62.53 mGy
- Safety Radiation Dose CTDIvol of CT Whole Abdomen Examination = 124.53 mGy – 20 = 104.53 mGy
- Safety Radiation Dose CTDIvol of CT Chest Examination = 124.53 mGy – 18 = 106.53 mGy
- Safety Radiation Dose CTDIvol of CT C-spine Examination = 124.53 mGy – 24.53 = 100 mGy

The results of the study found that the radiation dose values from CT brain without contrast, CT chest, CT whole abdomen, and CT C-spine and normal scans were all within acceptable limits of the reference radiation dose values. But when the scan was repeated, most trauma patients received a radiation dose that exceeded the standard. And the main cause for this is that the trauma patient is in a state of confusion and unconsciousness. However, comparing the radiation doses of different contrast agents may not be directly related to the actual risk to the patient. In cases where the patient has contraindications or adverse reactions to iodine-based contrast agents, the CTDIvol does not represent the patient's radiation dose but rather indicates the amount of contrast agent the patient received during the CT scan. Additionally, the reference radiation dose in this study is based on the CTDIvol per scan for each examination area, serving as a reference value from the technical settings during each patient's examination. It is not the total radiation dose for the entire examination. Since the details of the examination are determined by the radiologist or physician, the number of scans for each patient may vary, resulting in different total radiation doses depending on the diagnostic purpose.

2. The safety of the amount of radiopaque contrast received and the effect on kidney function, Creatinine GFR, in each type of CT scan.

It was found that in the case of trauma patients who received a whole-body CT Trauma Body examination, there were a total of 394 cases and in the case of trauma patients who received a sectioned examination, there were a total of 2,068 cases from the number of cases record. Trauma patients who received CT Trauma Body examinations of the whole body and trauma patients who received sectional examinations, it was found that in both cases most trauma patients received a dose of 100 milliliters of Ultravist-370 radiation. But there are some people who receive 100 ml of Optiray-350 contrast media (this may depend on the diagnosis of the doctor and the symptoms of each trauma patient).

Therefore, it is possible that the trauma patient's safety in the amount of contrast received from whole-body examinations will be lower than in sectioned examinations. This is because the number of times the examination is performed in sections affects the injection of contrast material into the trauma patient's body and may affect the trauma patient's kidney

function. (For example, in the case of a trauma patient who receives more than 2 injections of contrast material into the body, it may indicate that that trauma patient receives more contrast material than a trauma patient who receives contrast material only once). In some trauma patients, the renal function markers such as Creatinine and GFR are directly affected by the injection of contrast agents into the body, along with the risks associated with the patient's physical condition and individual symptoms.

3. Risk from non-comprehensive diagnosis among trauma patients who do not undergo CT Trauma Body examination from the first time in the emergency room.

It was found that there was a risk from a non-comprehensive diagnosis by collecting statistical data retrospectively on a group of trauma patients who had an incidence of non-comprehensive diagnosis by not having a CT Trauma Body examination from the first time at the emergency room. Out of 29 cases, there were incomplete examinations requested from the emergency department. Specifically, the number of cases with injuries/number of CT Trauma Body scans sent from the Ward/IPD was 18 cases, accounting for 62.06%.

4. Cost-effectiveness in the examination (CT Trauma Body). Results of the study are detailed in the following order.

It was found that trauma patients who received a CT scan examination between this study were considered to interpret the results for cost-effectiveness. (During the years 2018 to 2023, the exchange rate was 1 US dollar equal to 34 Thai baht.) The results of the study found that the cost of a whole-body computerized tomography examination was approximately 28,640.26 baht (842.36 USD). In terms of the cost of computerized tomography examinations, these include brain examination (CT Brain), cervical spine examination (CT C-Spine), chest/lung/heart examination (CT Chest) and abdominal and pelvic examination (CT Abdomen) totaling 51,727.63 baht (1,521.40 USD).

In order to estimate the cost of computerized tomography examinations of trauma patients from 2018-2023, classified by specific CT examination items, we totaled the costs of trauma patients who received CT Trauma body examination

(whole body examination), namely 394 cases. The total expense amounted to 11,284,263.31 baht (331,890.10 USD). The average cost per case for whole body examination is 28,640.26 baht (842.36 USD). In the case of sending a CT Trauma body examination in sections, it consists of:

1. CT Brain: there were 1,313 cases of trauma patients who received CT Brain examination. Total expenses 10,400,124.52 baht (305,886.02 USD). The average cost per case for CT Brain examination is 7,920.89 baht (232.97 USD).
2. CT C-Spine: there were 88 cases of trauma patients who received CT C-Spine examination. Total expenses 1,197,238.64 baht (35,212.90 USD). The average cost per case for CT C-Spine examination is 13,604.98 baht (400.15 USD).
3. CT Chest: there were 59 cases of trauma patients who received CT Chest examination. Total expenses 742,376.90 baht (21,834.61 USD). The average cost per case for CT Chest examination is 12,582.66 baht (370.08 USD).
4. CT Abdomen: there were 608 cases of trauma patients who received CT Abdomen examinations. Total expenses 10,712,412.15 baht (315,070.95 USD). The average cost per case for CT Abdomen examination is 17,619.10 baht (518.21 USD).

The total cost of sectional CT Trauma examination is 23,052,152.21 baht (678,004.48 USD), with 2,068 cases. The total cost per case of sectional CT Trauma examination is 51,727.63 baht (1,521.40 USD).

From the above information, when considering the cost-effectiveness of the CT scan examination, it was found that the whole-body CT trauma examination has an average cost of 28,640.26 baht (842.36 USD). When considering comparing the cost of CT Trauma sectional examinations, the total is 51,727.63 baht (1,521.40 USD), so it can be seen that CT Trauma examination of the whole body is more cost-effective than CT Trauma examination in sections at 23,087.37 baht (679.04 USD). This is because sectional examinations are expensive, including causing trauma patients to receive increased amounts of radiation as the number of examinations takes place and to inject more contrast material into the body. This affects the amount of kidney function in trauma patients, which may cause side effects to trauma patients.

$$\text{ICER} = \frac{\text{Cost of whole-body examination} - \text{Cost of sectioned examinations}}{\text{Comprehensive examination and no repeated examinations} - \text{The examination was not comprehensive or repeated examinations}}$$

$$\text{ICER} = \frac{28,640.26 - (7,920.89 + 13,604.98 + 12,582.66 + 17,619.10 = 51,727.63)}{\text{no repeated examinations (one examinations)} - \text{repeated examinations (2-3) times}}$$

Based on the above data, the researcher aims to explain the cost-effectiveness of conducting CT scans by analyzing the Incremental Cost-Effectiveness Ratio (ICER). The analysis will then consider the cost-effectiveness plane, meaning the cost of conducting a full-body CT scan for trauma patients will be compared to the cost of conducting separate CT scans for

different body parts. Once the actual costs are determined, they will be divided by the outcomes of the diagnostic results, comparing comprehensive and incomplete examinations. This will help assess the ICER value for each patient's CT scan to determine cost-effectiveness.

In addition, the researcher has also applied the concept of Value-based Health Care: VBHC to analyze the cost-effectiveness of the trauma patient's CT scan under the equation $\text{Value} = \text{Results} \div \text{Expenses}$. The health outcomes cover prevention, diagnosis, complications, fast and complete recovery, and recurrence.

Substitute the value from the formula:

Value = non-comprehensive diagnosis, complications, Slow and incomplete recovery *and repeated examinations* $\div$ 51,727.63 (old)

Value = comprehensive diagnosis, no complications, fast and complete recovery *and no repeated examinations* $\div$ 28,640.26 (new)

Discussion

1. Safety in terms of the amount of radiation received for CT scans of the whole body and divided into sections examinations.

In conclusion, sending CT scans from the emergency room and IPD in sections the patient receives less radiation than sending a single CT trauma body scan. This is because the radiation dose that the trauma patient receives from each section of the examinations will not be the same depending on the type of test sent. Therefore, it results in a lower radiation dose than a single whole-body CT scan for trauma patients from IPD. The radiation dose received by trauma patients is 124.53 mGy.

When comparing trauma patients who underwent CT Trauma Body scans in both single whole-body and sectioned examinations, it was found that trauma patients who were examined in sections received less radiation than in the case of a single whole-body examination. This observation aligns with the research conducted by Sarusupa Limcharoen,¹² who studied the reduction of radiation dose in trauma patients who had repeated CT scan at Burapha University Hospital. The study focused on reducing radiation exposure for follow-up trauma patients using the CT scanner. Data was collected from 2014-2016 by comparing the amount of radiation that trauma patients received between using standard parameters and adjusting the parameters in the case of follow-up on treatment. The reduced radiation dose data was obtained from repeated scans of the same trauma patients, averaging the values. Similarly, Phanphat Inprom¹³ studied the development of a technique for reducing radiation exposure in trauma patients who required repeated brain CT scans. The results of the study found that the median DLP value of CT brain without contrast trauma patients with normal scans was 636.07 (minimum 523.52, maximum 831.47 mGy.cm), which is within the acceptable range of the reference radiation dose, which is not more than 1,028.00 mGy.cm. However, when unnecessary repeat scans were performed due to non-diagnostic images, the DLP had a median value of 1,217.66 (minimum 992.82, maximum 3,062.45 mGy.cm), exceeding the reference radiation dose by 63.94% (39 cases). The main cause of

unnecessary rescans was due to the trauma patient being in a confused and unconscious state (93.44%, 57 cases) and when testing the parameters by scanning the head model and evaluating the quality of the radiograph with physical characteristics to make them of sufficient quality for diagnosis, allowing for a 21.69% reduction in radiation dose, which was within an acceptable range of reference radiation dose for diagnostic radiography.

Therefore, the conclusion from this research is that the radiation dose values from sectioned CT scans when all normal scans are within the acceptable limits of the reference radiation dose. But when the scan was repeated, most trauma patients received radiation doses that exceeded the reference radiation dose. To prevent trauma patients from receiving increased amounts of radiation, it is necessary to have a comprehensive diagnosis starting at the emergency room, which is the best method of prevention.

2. Safety in the amount of radiopaque contrast received affects kidney function values, Creatinine GFR, in each type of CT scan.

It can be concluded that trauma patients who received whole body CT Trauma Body examinations and trauma patients who received sectional examinations, it was found that in both cases most trauma patients received a dose of 100 milliliters of Ultravist injection-370 radiation. But there are some people who received 100 ml of Optiray injection-350 contrast media.

Therefore, the trauma patient's safety in the amount of contrast received from whole-body examinations will be lower than in sectioned examinations. This is because the number of times the examination is performed in sections affects the injection of contrast material into the trauma patient's body and may affect the trauma patient's kidney function.

3. Risk from non-comprehensive diagnosis among trauma patients who do not undergo CT Trauma Body examination from the first time in the emergency room.

It can be concluded that trauma patients are at risk from non-comprehensive diagnosis in when they arrive in the emergency room for the first time, until they receive a repeat CT scan examination. This puts trauma patients at risk from diagnostic tests that are not covered by the emergency room. These results are consistent with Yeguiayan JM, et al.,¹⁴ study on the impact of whole-body CT on mortality and surgical management of severe injuries. To evaluate the impact of whole-body CT versus segmental CT on mortality and management of trauma patients with severe injuries, the results of the study found that in trauma patients who received whole-body CT examination, the 30-day mortality rate was 16% in whole-body CT trauma patients and 22% in segmental CT trauma patients ($p = 0.02$). This resulted in a significant reduction in the risk of death in trauma patients undergoing whole-body CT, regardless of the modification method. Self ML, et al.,¹⁵ also

studied the utility of chest, abdominal, and pelvic computed tomography in evaluating trauma patients with non-invasive head injuries. The study found that additional body CT examinations resulted in minimal trauma patient care costs. A faster and comprehensive diagnosis from the emergency room can lead to receiving surgery promptly, covering all injury systems, reduced number of hospital stays, and increased quality of life after receiving treatment.

4. Cost-effectiveness of CT examination in the trauma patient group.

In terms of expenses for CT scan examinations of trauma patients between 2018-2023 from sectional examinations of 5,507 cases or 5,833 items, it was found that there was a total examination cost of 72,427,239 baht (2,130,212.91 USD). When considering the cost-effectiveness analysis in terms of price, considering the Incremental Cost Effect Effectiveness Ratio (ICER) and considering the cost-effectiveness plane, it was found that the overall cost of a single whole-body CT scan averaged 28,640.26 baht (842.36 USD).

In the overview of the cost of sectional computed tomography based on brain examination (CT Brain), Cervical spine examination (CT C-Spine), chest/lung/heart examination (CT Chest) and abdominal and pelvic examination (CT Abdomen), the total average was 51,727.63 baht (1,521.40 USD).

For estimating the cost of computed tomography examinations of trauma patients from 2018-2023, classified by specific CT examination record. It was found that there were 394 cases of CT Trauma body examination with a total cost of 11,284,263.31 baht (331,890.10 USD). The average cost per case of whole-body examination was 28,640.26 baht (842.36 USD). In the case of sectional CT Trauma examinations, there were 2,068 cases, with a total cost of 23,052,152.21 baht (678,004.48 USD). The average cost per case of sectional examination is 51,727.63 baht (1,521.40 USD).

When considering the cost-effectiveness of the CT scan examination, it was found that the whole-body CT trauma examination has an average cost of 28,640.26 baht (842.36 USD) per case. And the cost of CT Trauma sectional examinations, the total is 51,727.63 baht (1,521.40 USD), so it can be seen that CT Trauma examination of the whole body is more cost-effective than CT Trauma examination in sections at 23,087.37 baht (679.04 USD). This is because sectional examinations are expensive, including causing trauma patients to receive increased amounts of radiation as the number of examinations takes place and to inject more contrast material into the body. This affects the amount of kidney function in trauma patients, which may cause side effects to trauma patients.

When applying the concept of Value-based Health Care (VBHC) to analyze the cost-effectiveness of CT scans for trauma patients, the value is determined by the equation:

Value = Outcomes ÷ Costs. Therefore, health outcomes encompass prevention, diagnosis, the occurrence of complications, rapid and complete recovery, recurrence, and cost-effectiveness for trauma patients.

Conclusion

It can be concluded that trauma patients who undergo a CT Trauma Body scan from the emergency room will benefit from comprehensive diagnostics, the absence of complications, rapid and complete recovery, and the avoidance of repeat scans. Additionally, the cost is lower compared to multiple, separate CT scans. However, the assessment for each type of radiological examination depends on the severity of the injury, the patient's vital signs, level of consciousness, medical history, physical examination, physician's judgment, and other precautions taken into consideration before ordering the scan.

Therefore, from summarizing and discussing the preliminary results of this research, to conclude, a comprehensive CT scan of the trauma patient is recommended in the emergency room. It is suggested that these findings can be developed to create guidelines for evaluating trauma patients for CT scans in groups of severe multi-organ trauma patients in hospitals in order to further increase excellence in trauma patient care.

Recommendation

Increased effectiveness is needed of CT scans of trauma patients at the emergency room at BHP, where non-comprehensive diagnosis by the emergency room affects whole body and section CT scans from IPD, as appropriate. This will increase the efficiency of re-evaluating trauma patients in each case to cover in a complete and systematic manner to reduce delays or erroneous diagnosis, before the trauma patient is discharged from the hospital.

In terms of safety regarding the amount of radiation received during a whole-body CT scan and sectional scans, the safety in terms of the amount of radiopaque substance received affects the kidney function values, Creatinine GFR, in each type of CT scan. The safety from a non-comprehensive diagnosis in the group of trauma patients who did not have a CT Trauma Body scan from the first time at the emergency room is extremely necessary for trauma patients, because the trauma patients receive an appropriate amount of radiation and radiopaque substance, which benefits the kidney function values of each trauma patient. Similarly, a non-comprehensive diagnosis in the group of trauma patients who did not have a CT Trauma Body scan from the first time at the emergency room tends to put trauma patients at risk of receiving increased radiation and radiopaque substance. Further, there is an increased risk of incorrect or delayed diagnoses, which may result in delayed surgical intervention.

In terms of the value for trauma patients in receiving radiological diagnosis by CT Trauma Body examination, using

the concept of Value-based Health Care: VBHC analyzed the cost-effectiveness of the trauma patient's CT scan under the equation $\text{Value} = \text{Results} \div \text{Expenses}$. Namely, the health outcomes cover prevention, diagnosis, complications, fast and complete recovery, and recurrence.

References

1. Global Burden of Disease 2004. Injuries and Violence: The Facts. Geneva: World Health Organization Department of Injuries and Violence Prevention; 2010.
2. Chitvoranand A. Guidelines for the care of patients with multiple injuries. [in Thai] *JCP* 2010;6:50-60.
3. Kim H, Jung KY, Kim SP, et al. Changes in preventable death rates and traumatic care systems in Korea. *J Korean Soc Emerg Med* 2012;23(2):189-97.
4. Piphattanyaukul A. Cost-effectiveness of assessing patients suspected of cervical spine injuries using computed tomography in Sisaket Hospital. (In Thai). *J Med Assoc Sisaket Surin Buriram*. 2019;34:427-38.
5. International Atomic Energy Agency. Dosimetry in diagnostic radiology: an international code of practice. Technical Reports Series No.457. Vienna, Austria: IAEA; 2007.
6. Khwaja A. KDIGO clinical practice guideline for acute kidney injury. *Nephron Clin Pract* 2012;120(4):c179-84. doi: 10.1159/000339789.
7. Hossain MA, Costanzo E, Cosentino J, et al. Contrast-induced nephropathy: pathophysiology, risk factors, and prevention. *Saudi J Kidney Dis Transpl*. 2018;29:1-9. doi: 10.4103/1319-2442.225199.
8. Rear R, Bell RM, Hausenloy DJ. Contrast-induced nephropathy following angiography and cardiac interventions. *Heart* 2016;102:638-648. doi: 10.1136/heartjnl-2014-306962.
9. Ozkok S, Ozkok A. Contrast-induced acute kidney injury: A review of practical points. *World J Nephrol* 2017;6(3):86-99. doi: 10.5527/wjn.v6.i3.86.
10. Statistical data of patients injured and examined by computer X-ray in the emergency room at Bangkok Hospital Pattaya, Chonburi from January 1, 2018, to September 30, 2023. (In Thai)
11. Wonglao S. Evaluation of the patient radiation doses from computed tomography (CT) in neurological institute of Thailand. [in Thai]. *J Med Dep*. 2022;47:51-9.
12. Limcharoen S, Kongpromboon S, Khawiwiset K, et al. Reducing radiation dose in patients with repeated computer X-ray examinations. Burapha University Hospital. 2022. (In Thai)
13. Inprom P. Development of CT brain scanning techniques to reduce radiation dose in patients requiring repeated scans. Radiol Dep, Chiang Mai Neurological Hospital. 2018. (In Thai)
14. Yeguiayan JM, Yap A, Freysz M, et al. Impact of whole-body computed tomography on mortality and surgical management of severe blunt trauma. *Crit Care* 2012;16(3):R01. doi: 10.1186/cc11375.
15. Self ML, Blake AM, Whitley M, et al. The benefit of routine thoracic, abdominal, and pelvic computed tomography to evaluate trauma patients with closed head injuries. *Am J Surg* 2003;186:609-13. doi: 10.1016/j.amjsurg.2003.08.003.

Conflict of interest

The authors declare no conflict of interest.