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Composition and Associated Factors of Radiological Examination in Major Trauma Patients

A Prospective Observational Study

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Abstract: The care of major trauma patients continues to be a challenge for emergency physicians and trauma surgeons. We found that the total number of radiological examinations for major trauma patients in this study was high and mainly comprised radiography and computed tomography (CT), with CT being more commonly adopted. The number of CT scans was positively correlated with severity of injury and intensive care unit length of stay. Further study is warranted to optimize radiological examinations involving major trauma patients.

Key Words: major trauma, prospective observational study, radiological examination

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The care of major trauma patients continues to be a challenge for emergency physicians and trauma surgeons. New approaches to the treatment of major trauma now may require repeated imaging for diagnosis and/or assessment of response to the therapy.[1] Injured patients often receive a large number of radiological examinations during their hospitalization, including multiple computed tomography (CT) scans and radiography. Computed tomography scanning has increased rapidly over the last 20 years and is associated with exposure to high-radiation doses. It is estimated that more than 62 million CT scans are currently performed each year in the United States, as compared with approximately 3 million in 1980. Recent studies have demonstrated that the cumulative effective dose of radiation from CT scans has the potential to increase radiation-induced mortality from cancer.[2] It has been reported that approximately 1.5% to 2.0% of all cancers in the United States may be attributed to radiation exposure during CT studies.[3] Now some studies have focused on radiation exposure in trauma patients,[4,5] but few is known about the temporal distribution of radiological examination in trauma care or about factors associated the number of examination.

The present study was undertaken to explore composition and associated factors in the radiological examination of major trauma patients during their hospitalization, with the objective of providing a scientific basis for an optimized strategy for radiological examination.

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METHODS

Study Design

This prospective observational study was carried out in a Chinese tertiary general hospital with 2000 inpatient beds, which works as a level I trauma center. Ethical approval was not required. All adult trauma patients with an Injury Severity Score (ISS) of 16 or greater, who were admitted to a 16-bed emergency intensive care unit (ICU) within 48 hours after injury from April to July 2010, were enrolled. The exclusion criteria included patients with malignant tumors, death within 72 hours after admission, and withdrawal of therapy by the family because of medical expenses and other reasons.

Data Collection

The type, number, and site of radiological examination of the patients were registered. The time after injury and stages of treatment at which radiological examination was carried out were also recorded. The composition of type, number, and site of radiological examination was described. The number and proportion of radiological examinations at different stages of treatment (emergency room [ER], ICU, general ward) were also compared. The correlation between the number of radiological examinations and age, number of injured sites, ISS, Glasgow Coma Scale (GCS), ICU length of stay (LOS), and overall hospital LOS was analyzed.

Statistical Analysis

Statistical analyses were performed using SPSS 13.0 software (SPSS, Chicago, Ill). Quantitative data were expressed as the mean ± SD or median (P_{25}–P_{75}, interquartile range [IQR]) and then analyzed using the Wilcoxon rank sum test. Data for categorical variables were described by frequencies and proportions and then analyzed using the χ^2 test. Pearson correlation analysis and multiple linear regression analysis were used to describe the correlation between number of radiological examinations and age, number of injured sites, ISS, GCS, ICU LOS, and overall hospital LOS. A 2-tailed $P < 0.05$ was considered as statistically significant.

RESULTS

Patients

A total of 60 major trauma patients, consisting of 43 males and 17 females, were enrolled. The mean age of patients was 50 ± 14 years, with an ISS of 28.5 ± 8.3. Thirty-six of the patients (60%) were injured in traffic accidents, 16 (27%) from falling, and 8 from interpersonal assault or other reasons. The number of injured sites was 3.7 ± 0.9, varying from 2 to 6. The mean time between injury and arrival at this hospital was 11.0 hours. The mean period in the ICU and the overall hospital LOS per patient were 7.0 and 27.0 days, respectively. Fifty-three patients (88.3%) recovered and were discharged from hospital. Seven of the patients died.

The Composition of Radiological Examination

Most radiological examinations in these 60 trauma patients involved radiography and CT. A few examinations involving CT angiography (14 site·times), CT urography (1 site time), and digital subtraction angiography (1 site·time) were performed. None of the 60 patients received fluoroscopy or nuclear medical imaging.

Radiographic plain film. Of the 60 patients, 55 (91.7%) were evaluated using 456 radiographic plain films. The median number of examinations was 6.0 (IQR, 3.0–11.0) per patient. One patient received 24 radiographic plain films within 53 days. Approximately half of the examinations (227 [49.8%]) involved the extremities. There were 8 patients who received 10 or more radiographic plain films involving the extremities, of whom 1 received 17 examinations. The numbers of chest, pelvis, and spinal examinations using radiographic plain films were 83 (18.2%), 47 (10.3%), and 96 (21.1%), respectively. Two patients received 3 abdominal examinations using radiographic plain films (Fig. 1).

Computed tomography examination. Fifty-eight patients (96.7%) received 636 CT examinations. The median number of examinations was 10.0 (IQR, 8.0–13.8) per patient. One patient underwent 21 CT scans within 35 days. The most common CT scans involved the head (179 scans [28.1%]), followed by the chest (142 scans [22.3%]), the spine (104 scans [16.4%]), and the abdomen CT (84 scans [13.2%]). There were also 63 CT scans involving the extremities, 24 involving the maxillofacial region, and 22 involving the pelvis (Fig. 2). The proportion of patients who received more than 1 head CT scan was 68.3%, with the highest number of head scans being 9. Repeat chest CT scans were carried out in 70% of patients, and the maximum number of scans was 8.

The Temporal Distribution of Radiological Examination

In the first 24 hours after injury, 27.4% of radiographs and 40.4% of CT scans were carried out. The number of radiographs and CT scans had increased to 52.9% and 68.1%, respectively, in the first 7 days after injury (Table 1). Statistical analysis showed that the percentage of CT scans that were performed during the first 24 hours, first 3 days, and first 7 days after injury was significantly higher than that of radiography (χ^2 = 19.73, 24.16, and 21.79, respectively; all $P < 0.001$).

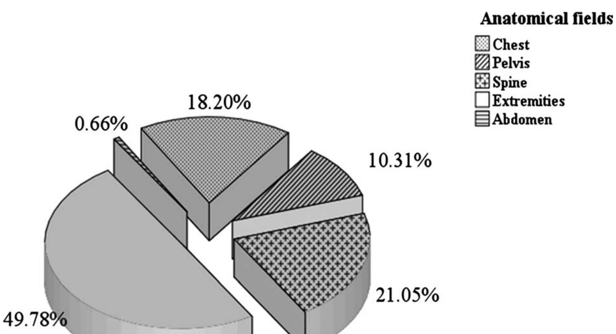

FIGURE 1. The composition of sites involving 456 radiographs that were obtained in 60 major trauma patients.

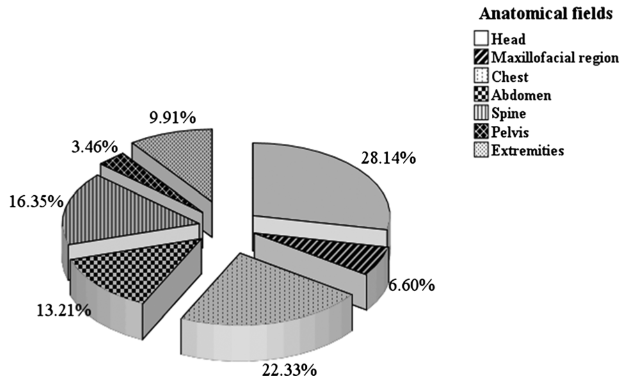

FIGURE 2. The composition of sites involving 636 CT scans that were obtained in 60 major trauma patients.

During the above 3 time periods, there were more CT scans carried out than plain film radiography ($Z = -3.64$, -4.01, and -3.87, respectively; all $P < 0.001$).

The Number and Proportion of Sites of Radiological Examination at the 3 Stages of Treatment

There was a significant difference between the proportion of radiography examinations and CT scans performed at the 3 stages of treatment (χ^2 = 46.548, $P < 0.001$). Radiography was uniformly performed in an ER, emergency ICU, and general ward (χ^2 = 4.043, $P = 0.132$), whereas CT was mainly performed in the earlier 2 stages of treatment (χ^2 = 20.274, $P < 0.001$) (Table 2). Further statistical analysis showed that trauma patients received more CT scans than radiographic plain film examinations when they were in the ER and ICU (ER: $Z = -3.673$, $P < 0.001$; ICU: $Z = -3.763$, $P = 0.0017$). However, there was no difference in the number of CT scans and radiographic plain film examinations undertaken in the general ward ($Z = -1.215$, $P = 0.224$).

The composition of sites for radiography was significantly different at different stages of treatment (χ^2 = 114.609, $P < 0.001$). Plain film radiography involving the pelvis was mainly performed in an ER, whereas radiography involving the spine and extremities was usually performed in a general ward (Table 3). The composition of sites for CT also differed during the 3 stages of treatment (χ^2 = 75.932, $P < 0.001$). Higher proportions of CT scans took place in the ER and were 65.5% for the cervical spine, 67.3% for the abdomen, and 54.5% for the pelvis CT. In contrast, head CT was mainly performed in the ER and ICU (Table 4).

Correlation Analysis of the Number of Radiological Examinations and Associated Factors

No association could be detected between the number of radiography examinations and age, number of injured sites, ISS, GCS, ICU LOS, and overall hospital LOS (r = 0.104, 0.18, 0.015, 0.104, 0.125, and 0.187, respectively; all $P > 0.05$). It was also found that there was no connection between the number of CT scans and age and GCS (r = 0.145 and 0.05, respectively; both $P > 0.05$). The number of CT scans was positively correlated with the number of injured sites, ISS, ICU LOS, and overall hospital LOS (r = 0.273, 0.369, 0.523, and 0.417, respectively; all $P < 0.05$). Multivariate linear regression analysis was used for stepwise evaluation of the association between CT scans and the

TABLE 1. Number and Percentage of Radiological Examinations at Different Times After Injury in 60 Patients

		First 24 h			3 d After Injury			7 d After Injury		
	Sum	n	%	Median (IQR)	n	%	Median (IQR)	n	%	Median (IQR)
Plain film	456	125	27.4	0 (0–4)	209	45.8	1.0 (0–5)	241	52.9	3.0 (1–6)
CT	636	257	40.4	4.0 (3–6)	387	60.8	6.5 (4–8)	425	68.1	7.0 (5–9)

The χ^2 test was used for statistical comparisons of the different percentages of radiological examinations that were undertaken. Statistical comparisons of the number of radiological examination per patient were carried out using the Wilcoxon rank sum test.

TABLE 2. Number and Proportion of Radiological Examination at Different Stages of Treatment in 60 Patients

		ER			ICU			General Ward		
	Sum	n	%	Median (IQR)	n	%	Median (IQR)	n	%	Median (IQR)
Plain film	456	155	34.0	0 (0–5)	95	20.8	1.0 (0–3)	206	45.2	3.0 (0–6)
CT	636	282	44.3	5.0 (4–7)	192	30.2	3.0 (2–6)	162	25.5	3.0 (1–4)

The χ^2 test was used for statistical comparisons of the different proportions of radiological examinations that were undertaken. Statistical comparisons of the number of radiological examination per trauma patient were carried out using the Wilcoxon rank sum test.

above 4 factors (Table 5). The linear regression equation relating to the number of CT scans and ISS and ICU LOS is established.

Number of CT scans = 4.386 + 0.123 × ISS + 0.268 × ICU LOS (days).

DISCUSSION

Radiological studies are integral in the evaluation of major trauma patients. Radiographs, CT scans, and interventional radiology studies frequently reveal life-threatening injuries that require immediate intervention.[6] It has been reported that integration of whole-body CT into early trauma care has significantly increased the probability of survival in patients with polytrauma.[7,8] Increasing numbers of imaging studies have been performed over recent years because of technological progress in creating faster and more sensitive scanners and improved worldwide access to these scanners.[9] The use of CT scans in the United States has increased more than 3-fold since 1993 to approximately 70 million scans annually.[9]

The majority of the radiation dose received during medical imaging can be attributed to the increasing number of CT procedures performed every year.[10] The American National Council on Radiation Protection and Measurements found that the per-capita dose from medical radiation exposure in the United States has increased nearly 6-fold since previous estimates were made in 1980. It was estimated that approximately 29,000 future cancers could be related to the 72 million CT scans performed in the United States in 2007.[9] Winslow et al[11] carried out a study to determine the amount of ionizing radiation received by adult blunt trauma patients at a level I trauma center during the first 24 hours of their care. The median effective total radiation dose received by these trauma patients in their study was 40.2 mSv, which would contribute to an additional 322 cancer cases per 100,000 subjects exposed.[11] Thankfully, Hadley et al[12] have found that application of the American College of Radiology criteria has the potential to reduce imaging costs by 39% and estimated radiation dose exposure by 44%. Therefore, it is necessary to study the composition and associated factors related to radiological examination in trauma patients and to try to optimize the strategy for radiological examination.

In our study, radiography and CT composed the majority of radiological examinations in trauma patients. The latter modality was more commonly adopted. The mean number of studies per patient involved 6.0 plain film radiographs and 10 CT scans. Tien et al[4] calculated the radiological studies received by trauma patients with LOSs in surgical ICUs of more than 30 days.[4] The 46 patients in their study (ISS = 32.2) underwent 70.1 plain film radiographs and 7.8 CT scans per patient. In our trauma center, doctors seemingly preferred using CT scans to evaluate major trauma patients. What is more, Chwals et al[13]

TABLE 3. Number and Proportion of Radiography Sites at Different Stages of Treatment in 60 Patients

Site	n	ER	ICU	General Ward
Chest	83	19 (22.9%)	51 (61.4%)	13 (15.7%)
Pelvis	47	24 (51.1%)	8 (17.0%)	15 (31.9%)
Spine	96	32 (33.3%)	5 (5.2%)	59 (61.5%)
Extremities	227	80 (35.2%)	30 (13.2%)	117 (51.5%)
Others	3	0 (0)	1 (33.3%)	2 (66.7%)
Sum	456	155 (34.0%)	95 (20.8%)	206 (45.2%)

TABLE 4. Number and Proportion of CT Sites at Different Stages of Treatment in 60 Patients

Site	n	ER	ICU	General Ward
Head	179	60 (33.5%)	80 (44.7%)	39 (21.8%)
Maxillofacial region	42	16 (38.1%)	10 (23.8%)	16 (38.1%)
Cervical spine	55	36 (65.5%)	10 (18.2%)	9 (16.3%)
Chest	171	66 (38.6%)	40 (23.4%)	65 (38.0%)
Abdomen	104	70 (67.3%)	11 (10.6%)	23 (22.1%)
Pelvis	22	12 (54.5%)	4 (18.2%)	6 (27.3%)
Others	63	22 (34.9%)	37 (58.7%)	4 (6.4%)
Sum	636	282 (44.3%)	192 (30.2%)	162 (25.5%)

TABLE 5. Results of Multivariate Linear Regression Analysis of Factors Associated With the Number of CT Scans

						95% CI	
	Unstandardized Coefficients	SE	Standardized Coefficients	t	P	Lower Bound	Upper Bound
Constant	4.386	1.710	—	2.565	0.013	0.960	7.811
ICU LOS (d)	0.268	0.069	0.450	3.895	0.000	0.130	0.405
ISS	0.123	0.060	0.235	2.035	0.047	0.002	0.244

95% CI indicates 95% confidence interval.

reported that after transferring to a level I pediatric trauma center from the referring hospitals, a duplicate CT scan of the same anatomical field (within 4 hours of transfer) was required in 91% (30/33) of pediatric trauma patients. Thus, it can be concluded that our 60 patients received even more radiological examinations.

Figures 1 and 2 reveal the composition of sites for radiography and CT scans in 60 major trauma patients enrolled in the present study. Nearly half of the radiography examinations (49.8%) involved the extremities. The proportions of radiographic plain film examinations of the spine and chest were 21.1% and 18.2%, respectively. However, the head received the greatest number of CT scans (28.1%), followed by the chest and spine. Perhaps this was due to the fact that different kinds of radiological examination have their own advantage in different anatomical fields. It should be noted that as compared with radiographic plain film CT scans involve exposure to much higher radiation doses. Marissa et al[14] examined the amount of radiation exposure that 716 pediatric trauma patients received during a single hospital visit. They found that while CT accounted for only 31.7% of the radiological studies performed, it accounted for 91% of the total radiation dose.[14]

Our data suggest that CT was mainly performed in the first week after injury, which reflects the fact that CT has gained importance in the early diagnostic phase of trauma care.[15] The distribution of the proportion of radiological examinations in different anatomical fields was also not balanced. One explanation for this is that radiography and CT scans have their own advantages in different anatomical fields. In addition, trauma doctors apply radiological examinations at different sites to estimate the patient's condition at different stages in treatment. For example, more than half of the CT scans involving the cervical spine, abdomen, and pelvis were carried out in the ER. As injuries in these fields must be assessed and treated immediately, repeated CT scanning is seldom needed after the diagnosis is confirmed. Head CT was mainly undertaken in the ICU. Traumatic brain injury is usually more serious, and the patient's condition can change rapidly. Scheduled head CT scans are used to monitor the progression of traumatic brain injury.[16] A simple external fixation technique is used to treat the fracture of extremities in the ER. Then an internal fixation operation is carried out after the patient's condition has stabilized. Thus, examination of the extremities using plain film is mainly performed in the general ward.

Single factor correlation analysis showed that the number of CT examinations was related to the number of injured sites, ISS, ICU LOS, and total hospital LOS. The fact that the number of injured sites and the ISS were associated with the number of CT scans can be easily understood. In the present study, the number of CT scans was also positively correlated with the patient's ICU and overall hospital LOS. Maybe this was due to the severity of illness resulting in prolonged hospitalization. However, we cannot eliminate the possibility that the prolonged hospital LOS itself increased the frequency of repeated examination.

The study had several limitations. It was a single-center experience in a level I trauma center of a tertiary general hospital. The number of major trauma patients enrolled in this prospective observational study was 60, which may increase the probability of statistical error. There was no attempt made to directly measure the effective radiation dose that patients were exposed to at the time that radiological studies were performed, so we could not assess the associated cancer risks.

CONCLUSIONS

In conclusion, the total number of radiological examinations undergone by major trauma patients in our study was high and mainly comprised radiography and CT, with CT being more commonly adopted. The number of CT scans was positively correlated with the severity of injury and ICU LOS. Further study is warranted to enable optimization of radiological examinations in major trauma patients.

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