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ORIGINAL ARTICLE

Influence of routine computed tomography on predicted survival from blunt thoracoabdominal trauma

R. van Vugt · J. Deunk · M. Brink · H. M. Dekker · D. R. Kool · A. B. van Vugt · M. J. Edwards

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Abstract

Introduction Many scoring systems have been proposed to predict the survival of trauma patients. This study was performed to evaluate the influence of routine thoracoabdominal computed tomography (CT) on the predicted survival according to the trauma injury severity score (TRISS).

Patients and methods 1,047 patients who had sustained a high-energy blunt trauma over a 3-year period were prospectively included in the study. All patients underwent physical examination, conventional radiography of the chest, thoracolumbar spine and pelvis, abdominal sonography, and routine thoracoabdominal CT. From this group with routine CT, we prospectively defined a selective CT (sub)group for cases with abnormal physical examination and/or conventional radiography and/or sonography. Type and extent of injuries were recorded for both the selective and the routine CT groups. Based on the injuries found by the two different CT algorithms, we calculated the injury severity scores (ISS) and predicted survivals according to the TRISS methodology for the routine and the selective CT algorithms.

Results Based on injuries detected by the selective CT algorithm, the mean ISS was 14.6, resulting in a predicted mortality of 12.5%. Because additional injuries were found by the routine CT algorithm, the mean ISS increased to 16.9, resulting in a predicted mortality of 13.7%. The actual observed mortality was 5.4%.

Conclusion Routine thoracoabdominal CT in high-energy blunt trauma patients reveals more injuries than a selective CT algorithm, resulting in a higher ISS. According to the TRISS, this results in higher predicted mortalities. Observed mortality, however, was significantly lower than predicted. The predicted survival according to MTOS seems to underestimate the actual survival when routine CT is used.

Keywords Trauma care · Trauma scoring · TRISS

R. van Vugt (✉) · J. Deunk · M. J. Edwards
Departments of Surgery and Trauma, Radboud University Nijmegen Medical Center, Internal Postal Code 690, Geert Groote Plein 10, 6500 HB Nijmegen, The Netherlands
e-mail: raoul.vanvugt@gmail.com; r.vanvugt@chir.umcn.nl

J. Deunk
e-mail: j.deunk@mmc.nl

M. J. Edwards
e-mail: m.edwards@chir.umcn.nl

M. Brink · H. M. Dekker · D. R. Kool
Department of Radiology, Radboud University Nijmegen Medical Center, Nijmegen, The Netherlands
e-mail: m.brink@rad.umcn.nl

H. M. Dekker
e-mail: h.dekker@rad.umcn.nl

D. R. Kool
e-mail: d.kool@rad.umcn.nl

A. B. van Vugt
Department of Emergency Medicine, Radboud University Nijmegen Medical Center, Nijmegen, The Netherlands
e-mail: a.vanvugt@mst.nl

Introduction

Trauma remains a major cause of death and disability, especially in persons younger than 45 years [1–3]. In the past 30 years, several scoring systems have been proposed for assessing trauma patients' initial status, describing injuries, and eventually predicting outcome [4–9]. These scoring systems, like the trauma injury severity score

(TRISS), can be used to develop models for predicting the probability of survival in a population base [10]. Despite advances in trauma care and the identification of numerous limitations of TRISS, this method continues to be the most commonly used tool for monitoring trauma outcomes and assessing trauma unit performance [11, 12]. The TRISS method has led to the major trauma outcome score (MTOS), which allows comparative evaluation of the hospital care of the injured patient [10, 13]. The TRISS method was developed in 1987 and revised a couple of years later [10, 14]. However, computed tomography (CT) was not used extensively in emergency departments at that time, whereas it has found increasing use ever since. Moreover, due to technological advances, the sensitivity of CT has increased considerably, which has led to improved injury detection. As a consequence of these and other factors, CT has been increasingly used in the initial evaluation of blunt trauma patients during the last few decades [15]. While many institutions still prefer to use thoracoabdominal CT only in selected situations, others prefer to use CT routinely in every patient after high-energy blunt trauma. We hypothesized that the use of routine thoracoabdominal CT will interfere with injury-based survival analyses such as the TRISS method, since routine CT will result in an improved injury detection and therefore in higher injury severity scores, which in turn will lead to higher predicted mortality rates. Although this seems logical, to the best of our knowledge, no study has demonstrated and quantified this before. However, when interpreting survival results of individual institutions and comparing several clinics, it is crucial to comprehend the influence of routine CT on the survival analyses. Moreover, knowledge of this mathematical influence is essential when interpreting studies about the effect of routine CT on outcome parameters such as survival [16]. Therefore, the purpose of this study was to evaluate the influence of routine thoracoabdominal CT scanning on predicted survival calculations according to the TRISS method.

Patients and methods

Subjects

A prospective observational cohort study was performed in a 953-bed teaching hospital with a full 24-h surgical capability that serves as a level 1 trauma center for an area with a population of 1.6 million. Patients with a high index of suspicion for serious injuries after trauma are directly transported to our hospital. In the period of May 2005 until June 2008, all patients who sustained high-energy blunt trauma were prospectively registered and included in a trauma CT database that was originally designed to evaluate the additional value of routine versus selective CT of the cervical spine, chest, abdomen and pelvis in blunt trauma patients.

High-energy trauma was defined as a fall from a height of ≥3 m, a car collision at ≥50 km/h (or at ≥30 km/h when a seatbelt was not worn), collisions between bicyclists or moped drivers and motor vehicles at a speed of ≥30 km/h, or being jammed, stuck, buried or crushed between heavy objects.

The results from studies of the additional value of CT have been described in previous publications [17, 18]. In this trauma CT database, radiological and clinical data were collected from all blunt trauma patients of 16 years and older. Patients who had been transferred from another hospital and patients who had sustained penetrating trauma were excluded. We also excluded patients with class III or IV shock requiring immediate surgical intervention, cases with neurological conditions or deterioration requiring immediate neurosurgical intervention without any further diagnostic delay, and patients with a suspected or known pregnancy. At admission, a multidisciplinary trauma team examined each patient according to the hospital's protocol based on the guidelines for Advanced Trauma Life Support (ATLS®) [19].

Data collection

Data were prospectively collected in a standardized database using Microsoft Access version 2000 (Microsoft Inc., Redmond, WA, USA). All patients underwent primary and secondary surveys according to the ATLS® guidelines and conventional radiography, consisting of radiography of the chest, pelvis and spine, and a focused abdominal sonography. After this, the trauma team prospectively established whether there was an indication to perform an additional (selective) CT of the chest, abdomen, pelvis or thoracolumbar spine (Table 1) [17, 18]. Subsequently, instead of a selective MDCT, all patients underwent a routine thoracoabdominal CT. After this, it was determined whether the final diagnoses should be made based on selective CT that was performed on indication or by routine CT. For all patients, we processed the data using two different algorithms: "CT on indication" and "Routine CT" (Fig. 1), and calculated the RTS, ISS, and predicted survival for both algorithms using published methods [10, 14]. For the calculations of the ISS and the predicted survival in the "CT on indication" algorithm, we only used the injuries found by physical examination, conventional radiography, and selectively performed CT. In the "Routine CT" algorithm, we used all injuries found on physical examination and total radiological workup, including routine thoracoabdominal CT.

The RTS was derived from the respiratory rate, the systolic blood pressure, and the (on-scene) Glasgow Coma Score [14]. The ISS was calculated using the square of the

Table 1 Indications for selective CT of specific body regions

Region	Indication
Thorax	>3 rib fractures on conventional radiography
	Suspicion of hemothorax on conventional radiography
	Suspicion of lung contusion on conventional radiography
	Suspicion of pneumothorax on conventional radiography
	Abnormal mediastinum/suspicion of aortic lesion on conventional radiography
Abdomen	Abdominal tenderness
	Free fluid on sonography
	Parenchymal injuries on sonography
	Macroscopic hematuria
Pelvis	Pelvic fracture on conventional radiography
	Inadequate quality of conventional radiography
Thoracolumbar spine	Spinal cord injury
	Osseous pain
	Vertebral fracture on conventional radiography
	Inadequate quality of conventional radiography

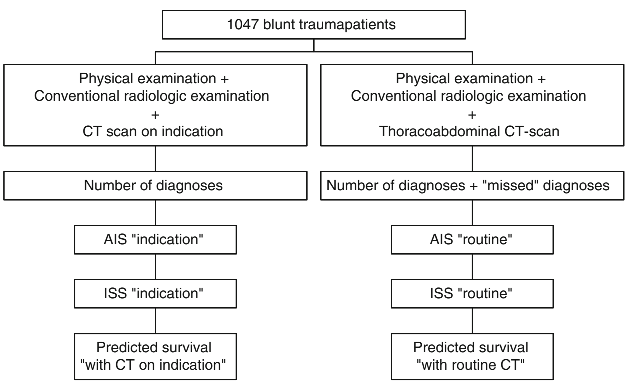

Fig. 1 Two algorithms were compared in this study: “CT scan on indication” and “Routine CT scan.” All 1,047 blunt trauma patients underwent thoracoabdominal CT. However, patients who met criteria for the “CT on indication” algorithm were also prospectively defined. This resulted in a number of diagnoses, AIS, ISS, and a predicted survival based on physical examination, conventional radiologic examination, ultrasound, and CT for patients who met these criteria for “CT on indication.” In the right arm, the total number of diagnoses was based solely on routine CT in all patients

three highest scores on the AIS, following the six body regions of: face; head and neck; chest and thoracic spine; abdomen, lumbar spine and pelvic contents; bony pelvis and limb and body surface [5]. The TRISS was calculated from the RTS, ISS, the age of the patient and the nature of the injury (blunt or penetrating), and this subsequently provided a probability of survival (P_s). The TRISS was calculated using the formula presented in the original publication from Boyd et al. [10].

Statistical analysis

Statistical analysis was performed with SPSS version 16.0 for Windows (SPSS Inc., Chicago, IL, USA). *M*, *Z* and *W* statistics were calculated. The *M* statistic is a measure of how closely the injury severities of the study subset and the MTOS match. It is defined by adding the lowest of all fractions of patients falling into each of six predicted survival ranges (Ps) of the study subset and the baseline subset (MTOS) together. A value of 1 represents an excellent match between the study group and the baseline patient group (MTOS). Lower values indicate a disparity in the injury severity between groups. The *Z* score is a statistic that compares the outcomes of two subsets of a population [20]. It quantifies the difference between the actual number of deaths in the test (e.g., our hospital) and the predicted number of deaths based on the MTOS norm.

The statistic *W* describes the clinical and practical significance of the difference between the actual and expected survivors. The *Z* and *W* scores were calculated as presented in the publication from Flora et al. [20].

Results

Characteristics of subjects

From May 2005 to June 2008, a total of 1,199 patients who had sustained a high-energy blunt trauma were admitted to our emergency department. A total of 1,047 of these patients met the inclusion criteria. The predominant mechanism of trauma was traffic incidents. In this study, 569 patients were admitted after being involved in a motor vehicle accident, 217 were bicyclist or moped drivers, and 37 were pedestrians. Sixty-six patients fell from a height of ≥3 m. Other high-energy mechanisms ($n = 158$) were being jammed, stuck, buried or crushed between heavy objects. The population consisted of 731 men (69.8%) and

316 women. Mean age was 39.5 (range 16–95, SD 17.8), mean RTS was 11.3, and mean GCS was 12.7. Four hundred seventy-eight patients had an ISS of $\geq$16. Of the 265 patients who presented with an RTS of $\leq$11, 231 had a decreased Glasgow Coma Score of 12 or less. Fifty-seven patients died during their hospital stay, most of them ($n = 46$) due to associated neurologic injury (81.0%).

Of the 1,047 patients included, 115 (11.0%) were indicated for complete thoracoabdominal CT based on abnormalities during physical examination, conventional radiography, and abdominal sonography. For 205 patients there was an indication to perform solely CT of the thorax, and 211 patients had an indication to perform CT of the abdomen and pelvis. For 516 patients (49.3%) there was no indication to perform an additional CT. These patients received thoracoabdominal CT based solely on their high-energy trauma mechanism.

Analysis predicted survival

In the algorithm based on the injuries detected solely by CT scan on indication, the mean injury severity score was 14.6 (SD 13.9). Calculations according to the TRISS methodology gave a mean predicted survival of 87.5%, representing a predicted mortality of 12.5%. In the routine CT algorithm, based on all injuries detected by routine thoracoabdominal CT, the mean injury severity score was 17.0 (SD 13.1). Using the TRISS methodology, the predicted survival in the routine CT algorithm was 86.3%. This implies that the predicted mortality rates according to the TRISS methodology were 13.7% using CT routinely and 12.5% using CT on indication (Table 2). This is a significant difference ($p = 0.016$). In our study population, the W score was 13, implying a difference in the predicted number of deaths between the two algorithms of 13 patients. The most important reasons for an increase in the ISS due to routine thoracoabdominal CT as compared CT on indication were diagnoses of (bilateral) lung contusion, multiple rib fractures with or without pneumothorax, or laceration of the abdominal organs which were not detected by physical examination, conventional radiography, sonography, and indicated radiological work-up.

Table 2 Differences in ISS and probable survival between two different algorithms

	CT on indication	Routine CT
Injury severity score*	14.6	16.9
Range	0–75	0–75
SD	13.9	13.1
Predicted survival (MTOS)	87.5%	86.3%

* Significant difference between "Routine CT" and "CT on indication" ($p < 0.05$)

Evaluation of survival with routine CT versus MTOS

The actually observed mortality was 5.4%. This was significantly lower than predicted for both the routine CT group and the CT on indication group according to the TRISS methodology. In our study, the M score was 0.866 (Table 3). After applying the values derived from our study data ($D = 57$; $\sum Q_i = 143.7$; $\sum Q_i P_s = 54.9$) to the formula used to establish the Z score, the overall Z statistic for our hospital was -11.7. Applying our values ($A = 990$, $E = 903$, $N = 1{,}047$) to the previously mentioned formula for the W statistic of Flora et al., a W value of 8.3 was calculated. This means that, in our hospital, per hundred patients treated, 8.3 more adults with blunt trauma injuries survive than would be expected from the MTOS norm. Table 4 outlines the number of patients with additional injuries found through routine CT as compared to the injuries found on CT by indication.

Discussion

Despite its widespread use, the TRISS methodology for calculating the predicted survival has many limitations and is criticized widely in the literature [4, 7–9, 21–23]. It has been found to have high misclassification rates in severely traumatized patients [4]. In many studies, attempts have been made to improve either physiologically or anatomically based outcome estimates in trauma

Table 3 *M*-score definition

Range of predicted survival	No. of patients	Fraction of patients within range	
		Study subset	Baseline subset (MTOS)
0.96–1.00	728	*0.695*	0.828
0.91–0.95	60	0.057	*0.045*
0.76–0.90	58	0.055	*0.044*
0.51–0.75	77	0.074	*0.029*
0.26–0.50	55	0.053	*0.017*
0.00–0.25	69	0.066	*0.036*

The M score was defined by summing the smaller of the two fractions (in italics), resulting in an M score of 0.866

Table 4 The number of patients (study group $n = 1{,}047$) and percentages with additional injuries found through routine CT as compared to the injuries found on CT by indication

	CT on indication	Routine CT	Absolute difference
Thorax	198 (18.9%)	409 (39.1%)	211 (20.2%)
Abdomen	116 (11.1%)	362 (34.6%)	245 (23.4%)

[7, 9]. Nevertheless, it is still the most commonly used method for predicting outcomes in trauma populations. In this study we evaluated the influence of improved injury detection by routine thoracoabdominal CT on the TRISS survival analysis.

We found a significant difference for both the injury severity scores and the predicted survival rates within the same group of patients when comparing the two different diagnostic algorithms "CT on indication" and "Routine CT." Predicted mortality in the two algorithms was 12.5 and 13.7% ($p = 0.016$), respectively. Performing a routine thoracoabdominal CT resulted in the detection of an increased number of diagnoses, resulting in higher injury severity scores and consequently in a significant decrease in predicted survival. Based on the results of this study, it is demonstrated that the interpretation of outcome data in blunt trauma patients is highly dependent on the diagnostic modalities used. This is not only important when comparing the outcomes of different institutions, but also when comparing historical cohorts and drawing conclusions from them.

Another finding of our study is the disparity between the observed and predicted outcomes using the TRISS methodology. The predicted mortality based on the TRISS and MTOS data was 13.7%, while the actually observed mortality was only 5.4%. This is a significant difference. Although mathematical calculations using *M* statistics showed that the case mix of our study was slightly different from that of the MTOS database, the distribution of the *M* statistics showed that our study population was more severely injured than the TRISS population. Nevertheless, we still found a significantly better observed survival than predicted according to the TRISS methodology. This significant difference between the predicted and observed survival may be explained by several arguments. First, this might be explained by the fact that the predicted (reference) survival rates according to the MTOS seem to be too pessimistic when CT is performed routinely. Although it is unclear which diagnostic tools were used in the MTOS population, it is unlikely that each patient received routine CT at that time. Without the use of routine CT, it is likely that some injuries in the original MTOS population remained undetected, resulting in an underestimation of the actual injury severity in some cases, thus leading to an deceivingly low ISS for the MTOS population, while the population was actually more injured than assumed. On the other hand, routine CT scanning leads to the detection of many additional injuries (for example small and clinically irrelevant pulmonary contusions) that can consequently lead to a higher ISS, thus leading to a higher predicted mortality. Moreover, the missing/underestimated injuries due to incomprehensive diagnostics in the MTOS population may have had a negative result on the actual outcome of the MTOS population, thereby leading to worse reference mortality rates. Taken together, this implies that the MTOS data are outdated and need adjustments, or that new (CT-based) scoring systems should be created in the future. The mortality rate in the excluded patients with class III or IV shock requiring immediate surgical intervention, cases of neurological condition or deterioration needing immediate neurosurgical intervention without any further diagnostic delay, and patients with suspected or known pregnancy should also be noted. The mortality rate in this group of patients was 28%. If we add these numbers to the dataset, the overall mortality rate may become closer to the MTOS.

Besides the overly pessimistic predicted survival rates, the significant difference in the predicted and observed survival rates can also be explained by improved care in our population as compared to the care of patients described in the MTOS [10]. This in turn may be explained by our use of better diagnostic tools, like routine thoracoabdominal CT, resulting in more specific diagnoses and thereby enabling better-tailored care. Recently, Huber-Wagner et al. [16] tried to demonstrate improved outcome due to routine CT in a large retrospective study. They concluded that the use of whole-body CT increases the probability of survival in polytrauma patients. However, it could be argued that the discrepancy between the predicted and the actual survival rates in their study was not caused by an improved diagnostic algorithm (i.e., routine CT), but rather by the fact that the use of routine CT resulted in an increase in ISS due to the diagnosis of more injuries, which will consequently result in an underestimation of the predicted survival rates. This is backed up by the results of our present study. To demonstrate the influence of routine CT on the outcome of blunt trauma patients definitively, large prospective randomized trials are also needed in the future.

Finally, the improved outcome of our populations as compared to the MTOS might be explained by the ongoing evaluation of damage control surgery and the improved care of current intensive care units, as well as the logistical procedure and improved prehospital care [24]. For instance, in the Netherlands, distances to well-equipped level II hospitals or level I trauma centers are relatively short, and 24/7 helicopter emergency medical services are provided in cases where patients require special assistance, for instance full anesthesia and intubation.

Although the results of our study seem to be important for interpreting outcome data concerning blunt trauma patients, some limitations of our study should be addressed. First of all, estimations of the performances of conventional radiography and CT were not done independently of clinical information. Radiologists were not blinded to this information. In our clinic, surgeons and radiologists work in close cooperation; the radiologist is present in the trauma bay during resuscitation. However, because of the purpose and design of our study, this was not considered a major problem. Secondly, we eliminated hindsight bias as much as possible by insisting that clinicians and radiologists thoroughly assess conventional radiography before CT was performed. However, in the middle of the night, no investigator was present to protect and ensure the prospective nature of selective CT classification, and clinicians and radiologists were trusted with respect to their reports. This may have induced hindsight bias in the interpretation of radiography and clinical evaluations. In a minority of the cases, this may have resulted in misjudgments of physical examination and conventional radiography performance and in the misclassification of an indicated or routine CT. Thirdly, although CT was indicated prospectively, trauma scores of the indication algorithm were calculated retrospectively. This may have led to a certain bias.

Conclusions

Routine thoracoabdominal CT in patients after high-energy blunt trauma leads to the detection of more injuries, thus resulting in higher injury severity scores and a lower predicted probability of survival as compared to a diagnostic work-up with the selective use of CT on indication. Calculated predicted survival by the TRISS methodology does not seem to be representative of the observed survival if thoracoabdominal CT is used routinely. Re-evaluations of current trauma scores and survival prediction methods appear mandatory if these are to be applied to blunt trauma populations who undergo routine CT in a standard fashion.

Conflict of interest No conflict of interest or financial support exists.

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