

# Clinical Judgment Is Not Reliable for Reducing Whole-body Computed Tomography Scanning after Isolated High-energy Blunt Trauma

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## ABSTRACT

**Background:** The purpose of this study was to test the diagnostic performance of clinical judgment for the prediction of a significant injury with whole-body computed tomography scanning after high-energy trauma.

**Methods:** The authors conducted an observational prospective study in a single level-I trauma center. Adult patients were included if they had an isolated high-energy injury. Senior trauma leaders were asked to make a clinical judgment regarding the likelihood of a significant injury before performance of a whole-body computed tomography scan. Clinical judgments were recorded using a probability diagnosis scale. The primary endpoint was the diagnosis of a serious-to-critical lesion on the whole-body computed tomography scan. Diagnostic performance was assessed using receiver operating characteristic analysis.

**Results:** Of the 354 included patients, 127 patients (36%) had at least one injury classified as abbreviated injury score greater than or equal to 3. The area under the receiver operating characteristic curve of the clinical judgment to predict a serious-to-critical lesion was 0.70 (95% CI, 0.64 to 0.75%). The sensitivity of the clinical judgment was 82% (95% CI, 74 to 88%), and the specificity was 49% (95% CI, 42 to 55%). No patient with a strict negative clinical examination had a severe lesion (n = 19 patients). The sensitivity of the clinical examination was 100% (95% CI, 97 to 100%) and its specificity was 8% (95% CI, 5 to 13%).

**Conclusions:** Clinical judgment alone is not sufficient to reduce whole-body computed tomography scan use. In patients with a strictly normal physical examination, whole-body computed tomography scanning might be avoided, but this result deserves additional study in larger and more diverse populations of trauma patients. (**ANESTHESIOLOGY 2017; 126:1116-24**)

WHOLE-BODY computed tomography (CT) scanning is the imaging modality of choice for the diagnosis of injuries after severe trauma.<sup>1</sup> It provides an exhaustive assessment of posttraumatic lesions and prevents missing occult lesions<sup>2</sup> with a beneficial effect on mortality.<sup>3,4</sup> In stable patients with suspected severe injury because of high-energy trauma, a whole-body CT scan is increasingly performed to diagnose occult lesions. However, occult injuries are not always clinically relevant,<sup>5-7</sup> and the benefits of whole-body CT scanning on mortality have been shown in physiologically unstable trauma patients.<sup>8</sup> Recently, a systematic review failed to identify any randomized controlled trials that studied whole-body CT scanning in stable patients with high-energy trauma.<sup>9</sup> Moreover, x-ray exposes patients to the risk of radiation-induced cancer,<sup>10</sup> and the infusion of an iodine agent is associated with contrast-induced nephropathy.<sup>11</sup>

### What We Already Know about This Topic

- Whole-body computed tomography (CT) scanning is performed to evaluate the extent of injury in patients who have sustained high-energy trauma. In such patients, the use of clinical judgment by expert physicians in reducing the need for CT scans was determined.

### What This Article Tells Us That Is New

- The diagnostic performance of clinical judgment in the prediction of the presence of significant lesions on computed tomography (CT) scan was modest and was considered to be insufficient. However, in patients with a completely normal physician examination, clinical judgment predicted the lack of a lesion on CT scan.
- The data suggest that clinical judgment is not sufficient to reduce the need for whole-body CT scans in patients with high-energy trauma.

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Hence, the possible beneficial effects of a whole-body CT scan in stable, high-energy trauma patients may be balanced by long-term safety issues. To avoid futile radiation, the clinical judgment of the physician may screen patients at risk for relevant posttraumatic lesions.<sup>12,13</sup> This judgment combines the circumstances of the trauma with clinical examination and bedside ultrasonography. However, the predictive value of this clinical judgment remains unknown for the detection of serious, severe, or critical injuries. The aim of our study was to estimate the diagnostic accuracy of clinical judgment for the prediction of a significant injury on the whole-body CT scan. We hypothesized that clinical judgment alone can obviate the need for whole-body CT scanning.

## Materials and Methods

### Study Design and Patients

We conducted a prospective observational study in a level-I trauma center (Grenoble University Hospital, Grenoble, France) from June 2014 to June 2015. The Regional Institutional Ethics Committee (Comité d'Éthique des Centres d'Investigation Clinique de l'Inter-Région Rhône-Alpes-Auvergne, institutional review board No. 5708) approved the study design and, given its observational nature, waived the requirements for written informed consent from each patient.

Inclusion criteria were patients older than 15 yr, stable from the prehospital field to the hospital admission, and admitted in the trauma center for suspected severe blunt trauma because of a high-energy mechanism. Stability was defined by a Glasgow Coma Scale (GCS) score strictly greater than 13, an oxygen saturation measured by pulse oximetry ( $\text{SpO}_2$ ) strictly greater than 92% without oxygen supply or mechanical ventilation, and a systolic blood pressure (SBP) strictly more than 90 mmHg without fluid resuscitation or vasopressor. A high-energy trauma was defined according to the Vittel criteria<sup>14</sup>: fall more than 6 m, ejection, projection, blast, crushed injuries, the presence of a deceased or severe trauma patient in the same accident, or an accident with an estimated high velocity.<sup>15,16</sup> All of the patients had a whole-body CT scan within 6 h of their initial injury according to our institutional protocol.<sup>17</sup> Noninclusion criteria were unstable patients defined as having the following: (1) an SBP less than 90 mmHg and/or the need for more than 20 ml/kg intravenous fluid therapy and/or vasopressor; (2) an  $\text{SpO}_2$  less than 92% without oxygen supply; (3) the use of mechanical ventilation; or (4) a GCS less than or equal to 13.

### Study Protocol and Data Collection

Consecutive patients were included at their admission to the emergency department based on their trauma history and physiologic stability. The following clinical data were prospectively collected: age; sex; mechanism of injury; vital variables (heart rate, SBP,  $\text{SpO}_2$ , and GCS) on admission; the Mechanism, Glasgow, Age, and Arterial Pressure

score<sup>18</sup>; the new injury severity score with detailed abbreviated injury score (AIS)<sup>19,20</sup>; the need for surgery, disposition of the patient after the emergency department (home, standard surgical ward, or intensive care unit [ICU]); length of hospital stay; in-hospital mortality; and mortality predicted by the Trauma Injury Severity Score.<sup>21</sup> The physical examination was performed by the attending physician and was detailed for each body area (head, neck, face, thorax, abdomen, spine, and limbs). The result of the bedside ultrasonography was also reported. Ultrasonography consisted of a focused assessment with sonography for trauma on admission.<sup>22</sup> According to the trauma history, clinical examination, and bedside ultrasonography, the physician was asked to report in a dedicated patient file his/her judgment for a significant posttraumatic lesion according to a probability diagnosis scale: 0 = sure of the absence of a lesion; 1 = suspect the absence of a lesion; 2 = suspect the presence of a lesion; and 3 = sure of the presence of a lesion.<sup>23</sup> Before whole-body CT scan completion, the attending physician was also asked to predict the disposition of the patient after the emergency department, including home, standard surgical ward, or ICU. The attending physician was the senior trauma leader (anesthesiologist or emergency physician) in charge of the trauma bay.

### Whole-body CT Scan

Each patient was transported to the radiology department to undergo a whole-body CT scan. CT scans were conducted using Philips Brilliance 40, Philips Brilliance 64 (Philips Medical Systems, The Netherlands), or Siemens Sensation 16 (Siemens Healthcare, Germany). Whole-body CT protocol consisted of the following acquisitions: (1) a nonenhanced encephalic CT scan; (2) a nonenhanced CT scan of the neck, from the base of the skull to the level of the second thoracic vertebra; (3) a contrast-enhanced CT scan of the thorax, abdomen, and pelvic regions from the level of the sixth cervical vertebra to the lesser trochanter; and (4) a contrast-enhanced scan of the abdomen from the diaphragmatic dome to the lesser trochanter. Arms were placed above the head after the CT scan of the head and neck. Optionally, mainly when a severe cervical trauma was suspected, a CT angiography of arterial supraaortic vessels was added. Regarding contrast-medium injection, a 120-ml bolus of iso-osmolar, nonionic iodinated contrast material (350 mg of iodine per milliliter, Iohexol [Omnipaque 350; GE Healthcare, United Kingdom]), followed by a saline flush of 40 ml, was injected into an antecubital vein at a flow rate of 4 ml/s. The data acquisition was initiated 6 s after 100-Hounsfield unit (HU) attenuation in the descending thoracic aorta. After an additional delay of 45 s, the abdominal portal venous-enhanced phase was acquired. For supra-aortic vessel acquisition, an additional injection of 120 ml of the same contrast medium was performed, and acquisition was triggered at 75-HU attenuation in the ascending aorta. Image reconstruction included systematically

1-mm-thick axial CT images for all of the body parts in appropriate windows and level settings, 1-mm contiguous reconstructed images in axial and sagittal plane and bone settings (window, 2500 HU; level, 500 HU) of the cervical, thoracic, and lumbar spines and the pelvis. Whole-body CT scans were immediately evaluated and documented by a radiologic resident, supervised by a trauma-dedicated senior radiologist.

### Endpoints

The primary outcome was the diagnosis of a serious, severe, and/or critical lesion using whole-body CT scan. Injury severity was defined by at least one injury classified as AIS greater than or equal to 3, because a score greater than or equal to 3 is regarded as a serious injury. All of the lesions were classified by two trained physicians (T.M. and V.B.) using the AIS 2005 catalog (<https://www.aaam.org/>) and the final report of the senior radiologist. In case of disagreement regarding the classification of a lesion, an expert in trauma care (P.B.) was responsible for final classification. Secondary outcomes were characteristics of the population with a serious-to-critical lesion after high-energy trauma and disposition after the emergency department to home, standard surgical ward, or ICU.

### Study Size

To have a good diagnostic accuracy, we expected an area under the receiver operating characteristic curve equal to 0.8 for the clinical judgment to predict a significant post-traumatic injury. The number of patients to be included was set at 350 patients to obtain an acceptable 95% CI between 0.75 and 0.84.

### Statistical Analysis

Descriptive statistics included frequencies and percentages for categorical variables and mean  $\pm$  SD or median values (25th to 75th percentiles) for continuous variables according to their distribution. The diagnostic performance of physician judgment to predict a clinically relevant lesion on whole-body CT scan was evaluated using receiver operating characteristic (ROC) analysis. The ROC curve was analyzed using both nonparametric and parametric methods. The nonparametric analysis was conducted using the method of DeLong *et al.*,<sup>24</sup> and 95% CIs were calculated using both asymptotic normal approximation and bootstrap resampling from 1,000 replicates. The parametric analysis was conducted by fitting a binomial model by maximum likelihood.

The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and positive and negative likelihood ratios (LR+ and LR-) were also reported for the clinical judgment considering two categories of patients, those with a high suspicion of severe lesion (probability diagnosis scale 2 and 3) and those with a low suspicion (probability diagnosis scale 0 and 1). The same parameters were calculated for the physical examination alone.

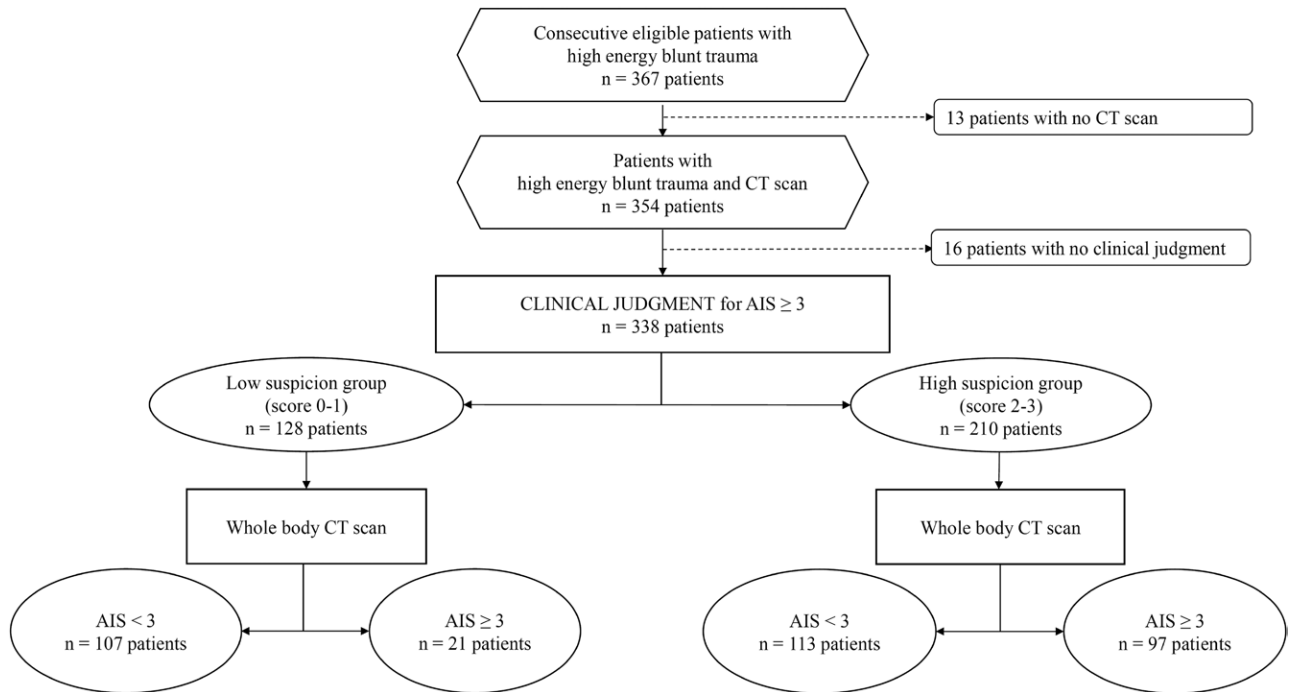
To offer insight into clinical consequences, decision curve analysis was also performed for the clinical judgment and the physical examination.<sup>25</sup> These curves determine the relationship between a chosen predicted probability threshold and the relative value of false-positive and false-negative results to obtain a value of net benefit using the test at that threshold. Comparisons between the group of patients with AIS greater than or equal to 3 lesions and the group of patients with no significant lesion were performed using a chi-square test (or Fisher exact test, where appropriate) for categorical variables and a Student's *t* test for continuous variables (or a nonparametric Mann-Whitney U test, where appropriate). Statistical analysis was performed with the software STATA 13.0 (Stata Corp, USA). All of the tests were two tailed, and a *P* value of 0.05 or less was considered statistically significant.

### Results

Within the study period, 367 consecutive patients with a suspicion of severe blunt trauma after a high-energy mechanism according to the Vittel criteria were eligible. Flowchart of the study population is presented in figure 1, and 354 patients with high-energy trauma were finally included. Patient characteristics are presented in table 1. Whole-body CT scan revealed 127 patients (36%) with at least one injury classified as AIS greater than or equal to 3. Overall, 171 severe lesions were identified, and 36 patients (28%) had more than one severe injury. Lesions were more frequently located in the thorax (40%), head (16%), limbs (15%), and spinal (13%) areas and were less frequently located in the abdomen (7%), pelvic bone (5%), neck (2%), and facial (2%) areas. We found three patients with a critical lesion (AIS = 5), including two patients with a severe traumatic brain injury and one patient with a thoracic injury. Findings for the physical examination are detailed in table 2. On admission, 19 patients (5%) had a normal physical examination. After the emergency department, 126 patients (47%) were discharged to home within 24 h. Fifty-seven patients (16%) were admitted to the ICU, and 167 patients (36%) were admitted to the standard surgical ward with a median length of stay in the hospital of 6 days (range, 2 to 12 days). Seventy-one patients required surgery within 24 posttraumatic hours, including orthopedic surgery for 51 patients, spinal surgery for 14 patients, maxillofacial surgery for four patients, laparoscopy for one patient, and neurosurgery for one patient. One patient required a splenic embolization.

### Primary Outcome

Of the 354 patients, clinical judgment was reported for 338 patients. Sixteen patients with missing data were excluded from the analysis (complete case analysis). The area under the curve (AUC) for clinical judgment to predict a significant lesion on the whole-body CT scan was 0.70 (95% CI, 0.64 to 0.75; fig. 2). Using a bootstrap technique, AUC was 0.70 (95% CI, 0.64 to 0.75). The ROC curve fitted to the



**Fig. 1.** Flowchart of the study population. AIS = abbreviated injury score; CT = computed tomography.

binomial model with its 95% CI is presented in figure 3 (AUC = 0.73 [95% CI, 0.67 to 0.79]). A total of 210 patients had a high suspicion for a severe lesion (probability diagnosis scale 2 and 3), and 128 patients had a low suspicion (probability diagnosis scale 0 and 1). In the low-suspicion group, 21 patients had at least one lesion classified as AIS greater than or equal to 3. Four patients had a severe lesion in the limbs area only. Eighteen severe occult lesions were found in 17 patients (13%), because one patient had two AISs at greater than or equal to 3 lesions. In the high-suspicion group, only 97 of 210 patients had severe lesions. Hence, the sensitivity of the clinical judgment was 82% (95% CI, 74 to 88%) and the specificity was 49% (95% CI, 42 to 55%). The NPV of the clinical judgment was 84% (95% CI, 76 to 90%), and the PPV was 46% (95% CI, 39 to 53%). LR+ was 1.6 (95% CI, 1.4 to 1.9), and LR- was 0.4 (95% CI, 0.2 to 0.6). Regarding the performance of the physical examination, no patient with a strict negative clinical examination had a severe lesion (n = 19 patients), whereas 127 of 334 patients with a positive clinical examination had a severe injury. Hence, the sensitivity of the clinical examination was 100% (95% CI, 97 to 100%). However, its specificity was only 8% (95% CI, 5 to 13%). The NPV was 100% (95% CI, 83 to 100%), and the PPV was 15% (95% CI, 10 to 20%). LR+ was 1.1 (95% CI, 1.05 to 1.14), and LR- was 0.

Decision curves are presented in figure 4. At the acceptable probability threshold of 10% (one patient with a positive CT scan for every 10 patients), physical examination is more beneficial than clinical judgment: patients with abnormal physical examination benefit from systematic whole-body CT scanning at this threshold. With this strategy, 5

of 100 CT scans are avoided without increasing the number of missing injuries. On the other hand, a strategy based on clinical judgment leads to 30 futile CT scans in a population of 100 patients. For a probability threshold at 20% (one patient with a significant lesion for every five patients), a strategy based on a high suspicion after clinical judgment is more beneficial than a strategy based on physical examination. With this strategy, 1 of 100 CT scans are avoided without increasing the number of missing injuries.

### Secondary Outcomes

Using univariate analysis, age, GCS, and the presence of an abnormal physical sign on admission were variables associated with the presence of a significant lesion on a whole-body CT scan (table 3). The predicted disposition before whole-body imaging was available for 300 patients. Fifty-eight of 100 patients with a prediction of home were finally discharged to the home, 29 of 52 patients with a prediction of ICU were admitted to the ICU, and 121 of 148 patients with a prediction of standard ward were finally admitted to a standard surgical ward. Hence, sensitivities for the clinical judgment were 58% (95% CI, 48 to 68%), 56% (95% CI, 41 to 70%), and 82% (95% CI, 75 to 88%) to predict final disposition at home, in the ICU, and in the surgical ward, respectively. Specificities were 95% (95% CI, 90 to 97%), 92% (95% CI, 88 to 95%), and 59% (95% CI, 51 to 67%), respectively.

### Discussion

In a cohort of stable patients with a suspicion of severe injury after high-energy blunt trauma, we observed a poor

**Table 1.** Patient Characteristics (n = 354 Patients)

Variable	Value
Age, mean $\pm$ SD, yr	39 $\pm$ 17
Male/female, n (%)	261 (74)/93 (26)
Mechanism of injury, n (%)	
Road traffic accident	208 (59)
Outdoor activities	114 (32)
Home accident	19 (5)
Work injury	13 (4)
Vital variables on admission	
Heart rate, mean $\pm$ SD, beats/min	82 $\pm$ 16
Systolic arterial blood pressure, mean $\pm$ SD, mmHg	128 $\pm$ 21
Pulse oximetry, median (25th–75th percentiles), %	98 (97–100)
GCS	
14, n (%)	37 (11)
15, n (%)	317 (89)
FAST, n (%)	119 (34)
Positive FAST on admission, n (%)	13 (4)
ISS, median (25th–75th percentiles)	4 (0–10)
NISS, median (25th–75th percentiles)	4 (0–16)
AIS maximum $\geq$ 3, n (%)	127 (36)
Head AIS $\geq$ 3, n (%)	27 (8)
Neck AIS $\geq$ 3, n (%)	4 (1)
Face AIS $\geq$ 3, n (%)	4 (1)
Spine AIS $\geq$ 3, n (%)	22 (6)
Thorax AIS $\geq$ 3, n (%)	68 (19)
Abdomen AIS $\geq$ 3, n (%)	13 (4)
Pelvis AIS $\geq$ 3, n (%)	8 (2)
Limb AIS $\geq$ 3, n (%)	25 (7)
MGAP score, median (25th–75th percentiles)	29 (27–29)
Emergency surgery (24 h), n (%)	74 (20)
TRISS, median (25th–75th percentiles)	0.99 (0.98–1.00)
Disposition after the emergency department	
Discharged to home, n (%)	126 (36)
Standard unit, n (%)	167 (47)
Intensive care unit, n (%)	57 (16)
Missing data, n	4
Length of stay in hospital, median (25th–75th percentiles), d	3 (0–9)
Predicted mortality by the Trauma Injury Severity Score, %	1
Mortality at day 28, n (%)	1 (0.03)

Values are mean  $\pm$  SD or median (25th–75th percentiles) according to their distribution.

AIS = abbreviated injury score; FAST = focused assessment with sonography for trauma; GCS = Glasgow Coma Scale; ISS = injury severity score; MGAP = Mechanism, Glasgow, Age, and Arterial Pressure; NISS = new injury severity score; TRISS = trauma score–injury severity score.

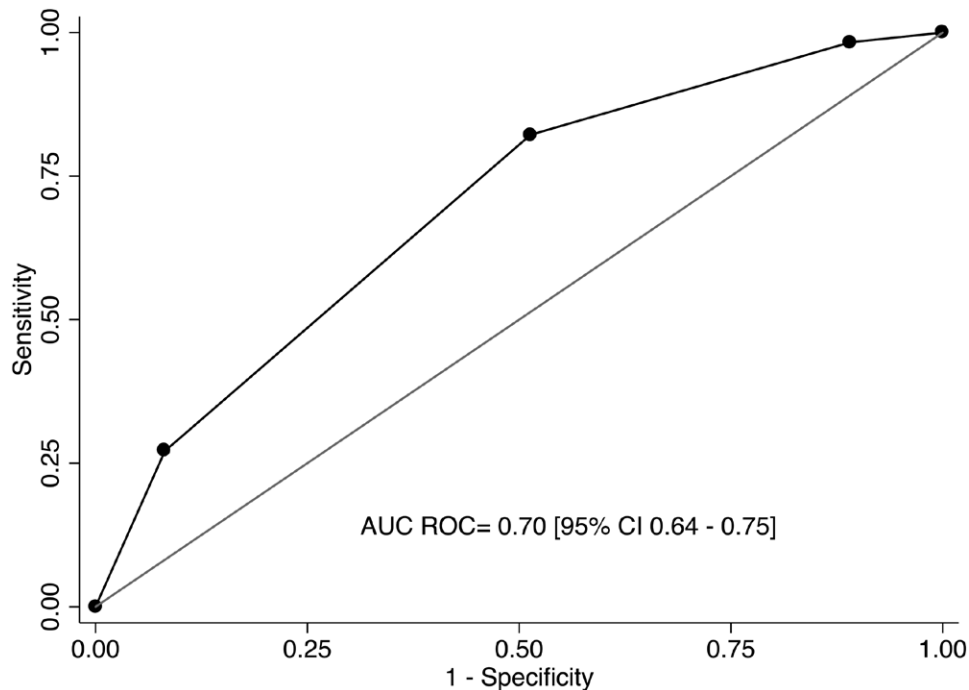
diagnostic performance of clinical judgment to predict a significant lesion on whole-body CT scan. Interestingly, the physical examination had excellent sensitivity, and 0 of the 19 patients with a normal examination on admission had a clinically relevant lesion after whole-body imaging. These results suggest that whole-body CT scan remains mandatory to assess occult injuries after high-energy trauma, except in cases of a strictly normal physical examination.

**Table 2.** Results of Physical Examination

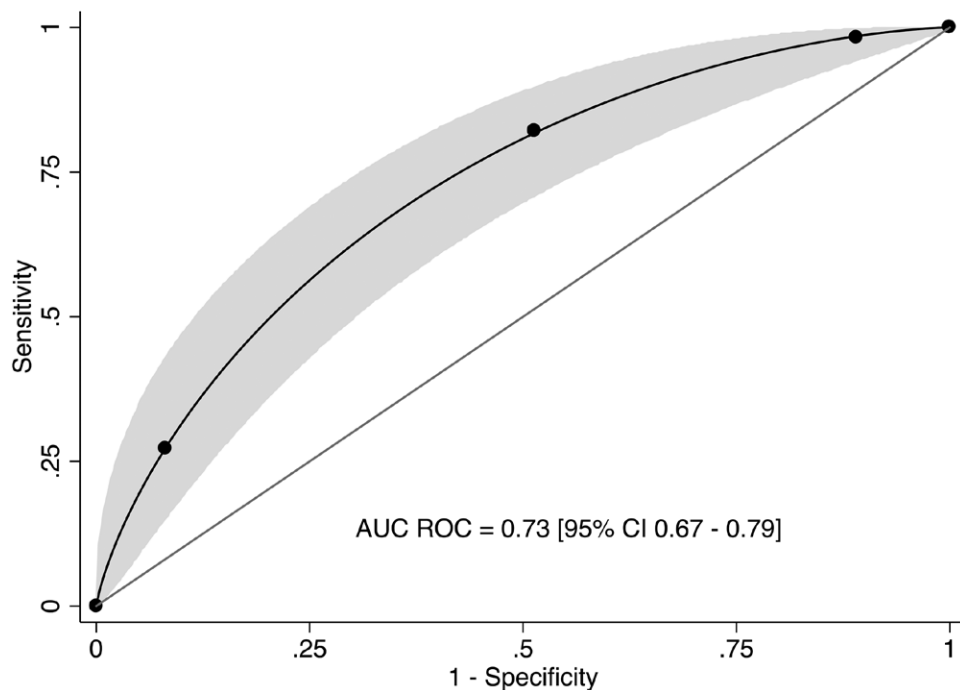
Physical Sign	No. of Patients (%)
Head	197 (55)
Traumatic brain injury	162 (46)
Temporary loss of consciousness (< 30 min)	88 (25)
Neck	64 (18)
Face	42 (12)
Spine	113 (32)
Thorax	112 (32)
Abdomen	90 (25)
Pelvic ring	61 (17)
Limbs	198 (56)
Patient with at least one physical sign	335 (94)

In our population, the incidence of severe lesions was high, because one third of patients presented with at least one lesion classified as AIS greater than or equal to 3. Conversely, the median new-injury severity score was low, demonstrating a large variability among injury severity in our cohort. Hence, accurate and early detection of these lesions is the main goal of the attending physician and argues for systematic indication of whole-body CT scan on admission. This imaging technique is increasingly used by trauma teams across the world despite well-known long-term issues and no strong scientific evidence.<sup>26</sup> Although the true incidence is unknown, the risk of radiation-induced cancer is well established. All of the authors agree with it even if they fail to objectively quantify its incidence.<sup>10,27</sup> Another concern is the occurrence of contrast-induced nephropathy. Although this problem is rare and usually reversible, it is an avoidable complication of whole-body CT scanning nonetheless.<sup>11</sup> As a result, physicians in the trauma bay face a dilemma between the need for diagnosing all possible lesions and reducing the radiation dose.

The clinical judgment of the physician on admission was not accurate to predict severe lesions, as shown by the AUC with a lower limit of its 95% CI equal to 0.64. Intuition integrates a subjective and individual assessment of trauma history with clinical findings to build clinical judgment. This concept is described as a gut feeling,<sup>12</sup> and its role was demonstrated for the in-hospital triage of trauma patients.<sup>13</sup> In our study, clinical judgment missed 13% of severe lesions and had poor sensitivity (82%). Indeed, clinical judgment regarding severe injuries and the need for lifesaving interventions is fraught with difficulty. In a recent study comparing clinical judgment with an automated analysis of photoplethysmograph waveforms from pulse oximetry, pulse oximeter algorithms consistently outperformed provider assessments.<sup>28</sup> Clinical judgment can lead to errors in decision-making; such errors have been associated with up to two thirds of preventable hemorrhagic deaths after injury.<sup>29</sup> Interestingly, clinical variables including heart rate, systolic arterial pressure, and GCS also had poor performance to predict the need of initial imaging assessment in 400 consecutive patients



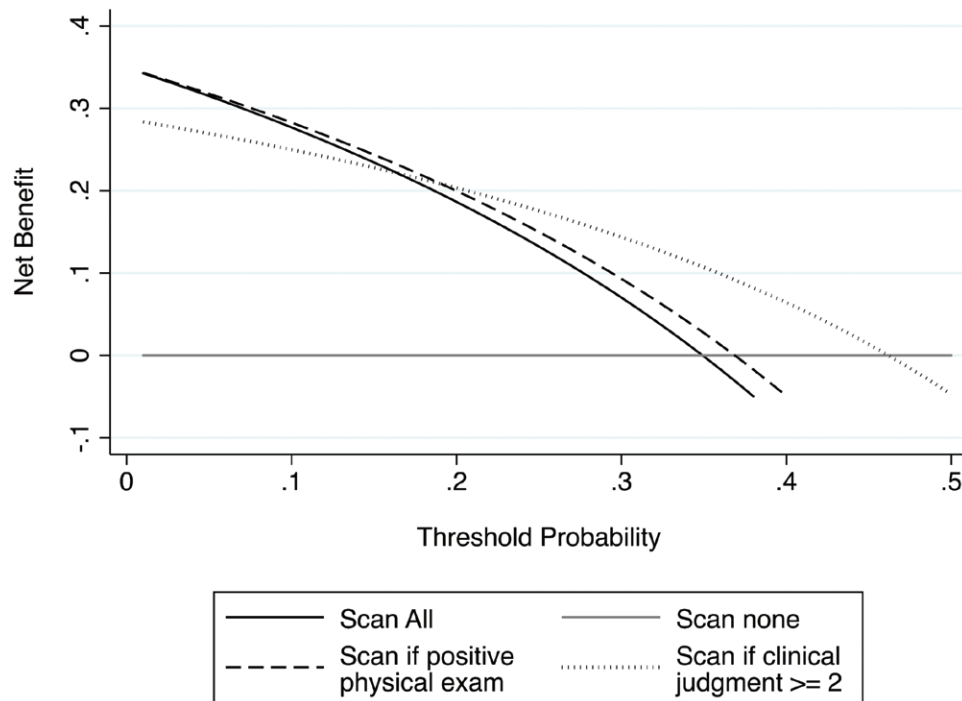
**Fig. 2.** Empirical receiver operating characteristic (ROC) curve of the clinical judgment to predict a serious-to-severe lesion on whole-body computed tomography scanning after high-energy trauma. The area under the ROC curve (AUC ROC) was 0.70 (95% CI, 0.64 to 0.75).



**Fig. 3.** Smooth receiver operating characteristics (ROC) curve of the clinical judgment to predict a serious-to-severe lesion on whole-body computed tomography scanning after high-energy trauma. This curve was generated by fitting the binomial distribution. The gray area represents the 95% CI of the ROC curve. The area under the ROC curve (AUC ROC) was 0.73 (95% CI, 0.67 to 0.79).

with severe trauma.<sup>30</sup> This indicates that adding physiologic variables does not improve the performance of clinical judgment. Occult lesions were mostly located in the thorax and

head areas. In the existing literature, the incidence of occult lesions is variable, from 3 to 14%, depending on the type of trauma patients, the definition of lesion severity, and the type



**Fig. 4.** Net benefit curves for the clinical judgment and the physical examination. These curves determine the relationship between a chosen predicted probability threshold (*x-axis*) and the relative value of false-positive and false-negative results to obtain a value of net benefit (*y-axis*) using the test at that threshold. At the acceptable threshold of 10%, there is no net benefit for the clinical judgment as compared with the physical examination.

of suspected lesion.<sup>2,5,6,31</sup> Our findings were similar to those of Shannon *et al.*,<sup>31</sup> who found that the clinical suspicion of injury was poorly associated with imaging findings. In other studies, the high incidence of occult severe lesions might be explained by pulmonary contusions, which might be asymptomatic.<sup>7</sup> Accordingly, these lesions were considered to be minor if not associated with mechanical ventilation.<sup>32</sup>

In the case of an absolutely normal physical examination, we did not find severe lesions in our population (NPV = 100%). This indicates that a CT scan would not be indicated in this category of trauma patients. This result was additionally confirmed by a decision curve showing net benefit of a strategy based on physical examination at a threshold probability of 10%. In our study, a normal physical examination was defined as the absence of any sign of trauma, including pain or hematomas. For instance, these trauma patients belong to the category of patients admitted for a suspicion of severe trauma after a road traffic accident with one deceased patient in the same accident. Despite the absence of posttraumatic symptoms, these patients are considered at risk for having a potentially lethal lesion according to trauma history.<sup>33</sup> We suggest that these patients could be safely monitored without total body imaging thanks to physical examination and bedside ultrasonography. As a result, this approach allows for a limitation of the radiation dose and the avoidance of an iodine agent. Conversely, the specificity of the physical examination was poor, demonstrating that a positive physical examination did not predict severe posttraumatic lesions.

For instance, acute pain after limb fractures may mask another vital lesion, which was described as the concept of distracting injuries.<sup>34</sup> Nevertheless, distracting injuries were not associated with increased occult abdominal lesions and did not challenge the relevancy of a clinical examination for the diagnosis of significant abdominal injury.<sup>35</sup> In this study, we found few occult severe abdominal injuries ( $n = 2$  of 354 patients).

Another role of the whole-body CT scan is to help the decision for final disposition. In our study, 11 patients (3%) estimated to be discharged to the home before CT scan were finally directed to the standard ward, and 23 patients (6%) initially directed to the standard ward required an admission to the ICU. These results also confirmed the prominent role of a whole-body CT scan for the medical management of trauma patients. According to the clinical judgment for the occurrence of a severe lesion, the attending physician also failed to accurately predict final disposition after admission to the emergency department. Innovative CT technology, based on adaptive statistical iterative reconstruction, is developed for dose reduction without loss of image quality. In trauma patients, application of iterative reconstruction allowed for a 23% reduction of the radiation dose.<sup>36</sup>

We acknowledge several limits of our study. First, a limited proportion of patients had a strictly normal physical examination (5%). The generalization of our results on a larger population deserves additional studies focusing on patients with a normal physical examination. Second, we

**Table 3.** Comparison between the Group of Patients with a Lesion Classified as AIS  $\geq 3$  and the Group of Patients with a Lesion Classified as AIS  $< 3$ 

Variable	AIS $< 3$ Group (n = 227 Patients)	AIS $\geq 3$ Group (n = 127 Patients)	P Value
Age, y	34 (22–50)	41 (25–54)	0.04
Sex, n (%)			0.06
Male	160 (70)	101 (80)	
Female	67 (30)	26 (20)	
Mechanism of injury, n (%)			0.17
Road traffic accident	141 (62)	67 (53)	
Outdoor activities	71 (31)	43 (34)	
Home accident	8 (4)	10 (8)	
Work injury	7 (3)	6 (5)	
Vital variables on admission			
Heart rate, beats/min	82 $\pm$ 16	80 $\pm$ 15	0.33
Systolic arterial blood pressure, mmHg	128 $\pm$ 21	127 $\pm$ 20	0.57
Pulse oximetry, %	98 (97–100)	98 (97–100)	0.57
GCS, n (%)			$< 0.01$
14	13 (6)	24 (20)	
15	199 (94)	97 (80)	
Positive FAST on admission, n (%)	6 (3)	7 (6)	0.56
Positive physical examination, n (%)	208 (92)	127 (100)	$< 0.01$

Values are mean  $\pm$  SD or median (25th–75th percentiles) according to their distribution.

AIS = abbreviated injury score; FAST = focused assessment with sonography for trauma; GCS = Glasgow Coma Scale.

only conducted an observational study. However, we performed a diagnosis study following the standard international recommendation to assess the diagnosis performance of clinical judgment.<sup>37</sup> Third, 13 patients were excluded because of the absence of a whole-body CT scan. These patients had no CT scan and could not be analyzed for the primary and secondary outcomes. However, we considered our recruitment to be exhaustive, because approximately 500 patients are admitted each year in the trauma system of the Northern French Alps, which includes 17 trauma centers.<sup>38</sup> Fourth, we focused on the prediction of serious-to-critical posttraumatic lesions. However, minor injuries could also be responsible for late morbidity, and our study is limited to the exploration of immediate consequences of major lesions. Finally, the study population was adult trauma patients, and our results cannot be extrapolated to a pediatric population.

### Conclusions

The clinical judgment of an attending physician is not sufficiently accurate to reduce the use of routine whole-body CT scanning after high-energy traumatic injuries. In patients with a physical examination completely devoid of any signs of traumatic injury, whole-body CT scanning might be avoided, but the results from this investigation deserve additional study in larger and more diverse populations of trauma patients.

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### Competing Interests

The authors declare no competing interests.

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