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TITLE PAGE

The value of precontrast thoraco-abdominopelvic CT in polytrauma patients.

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ABSTRACT

PURPOSE: to evaluate the utility and radiation dose of thoraco-abdominopelvic precontrast CT in polytrauma patients.

MATERIALS AND METHODS: we examined retrospectively 125 patients who underwent a thoraco-abdominopelvic CT for trauma.Two radiologists, indipendentely, evaluated precontrast CT acquisition and two other radiologists examined the contrast-enhanced scans. A further two radiologists assessed both the acquisitions. Mean value of sensitivity (SE), specificity (SP), positive predictive value (PPV) and negative predictive value (NPV) were calculated by each group of radiologists. For 104 patients, CTDIvol, DLP data and individual mean size were collected to calculate effective dose.

RESULTS: mean values of SE, SP, PPV and NPV of findings of radiologists who assessed contrast-enhanced acquisitions were respectively: SE=85%, SP= 98%, PPV=86%, NPV=88% versus: SE=43%, SP=95%, PPV=69%, NPV=88% of radiologists who examined non-contrast-enhanced scans.Mean values of radiologists who analyzed both acquisitions were: SE=80%, SP=97%, PPV=80%, NPV=88%. Neither the precontrast scans nor the precontrast and postcontrast scans together provided additional useful information compared to the single contrast-enhanced acquisition.Patients received a mean dose of 12 mSv for the precontrast CT.

CONCLUSIONS: precontrast CT acquisition did not provide significant information in trauma patients, exposing them to an unjustified radiation dose.

INTRODUCTION

Despite the improvement in road traffic and occupational safety, as well as the advances in patient management, non intentional traumatic wounds represent the most frequent cause of death among people under 40 years. Immediate and early death as a result of trauma are determined by severe brain injuries or important bleeding; delayed causes of death are secondary brain lesions and failure of the immune defences of the host [1].

A fast and accurate diagnosis is important, but the diagnostic value of clinical evaluation is limited.

Thanks to the upgrade in the last decade of CT technology, which allows the study of the main anatomical regions, the so called "whole-body CT", this is now being considered the gold standard in emergency to provide a fast and accurate diagnosis in the narrow management window of trauma victims with multiple significant injuries [2]. CT has become an essential element in early evaluation and in decision algorithm for hemodynamically stable polytrauma patients and, for some authors, also for hemodynamically unstable patients, if emergency room is close to CT equipment [3].The term polytrauma has been used for decades in scientific literature and generally describes trauma patients with injuries involving multiple organs or parts of the body, which compromise patient physiology and virtually cause failure of undamaged organs [4]. Patients are at a higher risk of morbidity and mortality than the sum of morbidity and mortality of their single injuries [5]. However there is not a universal definition of the term polytrauma. As in most European literature [4], in our Hospital, we use this term to indicate a patient at risk of death because of his injuries or the mechanism of the accident.

Multiple attempts have been made over the years to develop guidelines for trauma imaging that provide adequate sensitivity for injury detection, dose reduction and adequate cost-effectiveness, such as the referral guidelines for imaging of European Commission [6,7] or the American College of Radiology appropriateness criteria [8]. ATLS guidelines provide some indications regarding execution of exams of conventional radiology, as, for example, chest x-ray and ultrasound, while for CT, the decision of execution and the region of body to examine is left to the leader of trauma team [9]. Literature suggests some CT protocols in polytrauma patients but there is not a unanimous consensus for the study of thorax, abdomen and pelvis: some trauma centers do not perform non-contrast-enhanced acquisition [10,11,12,13], while others do perform it.

According to some authors, precontrast CT scans are important for the abdomen and pelvis, to detect hyperdensity that suggests presence of blood [14,15,16], in particular these scans help to detect small mesenteric, hepatic, splenic, renal hematomas and the presence of hemoperitoneum [17,18].

The aim of this paper was to evaluate the additional value of precontrast phase in the CT of chest, abdomen and pelvis with polytrauma patients and to calculate the radiation dose that patients received for precontrast thoraco-abdominopelvic acquisition.

MATERIALS AND METHODS

Population studied: this is a retrospective study performed in the Radiology Emergency Department of Foundation IRCCS Ca' Granda Maggiore Policlinico Hospital of Milan, a second level Emergency Department.

The study protocol was approved by the institutional review board of our Hospital.

We researched adult patients who received a CT for trauma between June 17th 2012 and March 10th 2014 (21 months) and who underwent chest, abdomen and pelvis scans before and after contrast injection. Note that not all colleagues of our Hospital perform both acquisitions in trauma patients.

Patients who did not receive both scan phases were excluded from evaluation.

We included and evaluated 125 patients (96 men and 29 women), aged between 16 years and 89 years (mean age 43 years).

Before the beginning of the study, we prepared a list where we reported the most frequent pathological findings that can be found in a CT of a polytrauma patient (TAB.1).

In this list we separated active bleeding from other vascular lesions, understood as: pseudo-aneurysm/arterio-venous fistula, irregularity of the vessel contour, intimal tear/flap, dissection, intramural hematoma.

Two radiologists (respectively with five and ten years experience in trauma radiology), independently, evaluated non-contrast-enhanced scans of the 125 patients and, at the same time, two other radiologists (respectively with five and ten years experience in trauma radiology), independently, evaluated those with contrast injection of the same patients, reporting pathological findings in the list.

Another two colleagues (respectively with five and ten years experience in trauma radiology) evaluated both precontrast and contrast-enhanced scans and reported the pathological findings in the list.

After two months, the six radiologists reviewed together both precontrast and postcontrast images, considering previous results reported by all of them.

This allowed us to reach a consensus on all findings and to prepare a table called "consensus table", to use as a "gold standard" for the subsequent evaluation of the results and for the calculation of sensitivity and specificity of the radiologists who respectively analyzed precontrast scans, contrast-enhanced scans and both scans.

Computed Tomography acquisition technique: all exams were performed using a 128-row detector CT scanner (Somatom Definition Flash, Siemens Healthcare, Germany, Forcheim) with the following parameters: reconstruction, 3 mm thick at 3-mm intervals (acquisition: 128 x 0.6 mm); pitch, 1.2 mm/2.1 mm; speed of the system, 0.28/0.33 mm/sec; 120/140 kVp, with a current intensity (mA) automatically modulated (care dose 4D), based on patient dimension.

After non-contrast-enhanced acquisition, with a single pass, from the base of the neck to the symphysis pubis we administered contrast medium by intravenous injection, with an automatic injector with double syringe (Stellant, Medrad, Bayer Healthcare), with a flow of 3.5/4 mL/sec, with an amount of contrast medium depending on iodine concentration and patient weight, followed by 50 mL of normal saline flush, with the second syringe, with the same flow.

For the study, we used Visipaque 320 mgI/mL (GE Healthcare, United States), Iopamiro 370 mgI/mL (Bracco, Italy), Iomeron 400 mgI/mL (Bracco, Italy).

The contrast-enhanced acquisitions included an arterial phase from the base of the neck to the symphysis pubis with bolus tracking, after 15/20 seconds by the recognition of a density of 100 HU, in a region of interest (ROI), usually localized in the descending thoracic aorta and a portal phase, about 30 seconds after the end of the arterial phase, on abdomen and pelvis. Some colleagues also included the thorax in the portal phase.

In case of kidneys or urinary tract injuries or inconclusive findings, a delayed phase was performed on the abdomen and pelvis, 2-3 minutes after the venous phase.The images were stored in PACS (Synapse, Fujifilm, Japan) and available for visualization on high resolution screens (Barco, Belgium), with a thickness of 3 mm and 1 mm, with the possibility of MPR and 3D reconstructions.

Statistical analysis

Comparison of findings of the six evaluators with those of the "consensus table" allowed to calculate SE, SP, PPV and NPV for each evaluator. Then the averages of results from each group of radiologists were calculated (those expressed by the two evaluators of non-contrast-enhanced scans, those indicated by the two radiologists who examined the contrast-enhanced scans and those obtained by evaluators of unenhanced and contrast-enhanced scans).

Dosimetry aspects

$CTDI_{vol}$ (computed tomography dose index) and DLP (dose-length product) were collected for 104 patients out of 125 (83%). In the remaining 21 patients data was not complete.
Mathematical formula used to calculate the effective dose is:

DE *(mSv)* = DLP *(mGy x cm)* x *f (mSv/mGy x cm)*

The f factor depends on the age of patient, the peak energy of X-ray beam and body part considered.
In particular, as our patients were adults (aged between 16 and 89 years), we considered an average f factor (from the f value of chest, abdomen and pelvis) of about 0.0142 mSv/mGy x cm for the exams at 120 kVp and about 0.0144 mSv/mGy x cm for the single exam at 140 kVp [19].
Data collected was then corrected by a factor, f204, obtained from the measurement of the mean thickness of the patient in the A-P and L-L projections of the scout images. As dosimetric data

provided by CT is referred to a cylindrical phantom with a diameter of 32 x 32 cm, this data was then scaled to the actual size of patients [20]. In our case the average correction factor, f204, was about 1,33, so both DLP and effective dose were both increased with 33%.

RESULTS

To obtain statistically significant samples, we considered, for the evaluation of the averages of SE, SP, PPV, NPV, only pathological findings observed in the "consensus table", in two or more patients.

As you can observe in TAB. 2 and 3, the averages of SE and SP of the radiologists who evaluated only non-contrast scans were always lower in the pathological findings than the average value of findings of the evaluators who examined only the scans with contrast. The average values of findings of radiologists who assessed both non-contrast scans and those with contrast were comparable to those of the radiologists who evaluated only the postcontrast acquisitions. Reevaluating images, where average values of the findings of the radiologists who evaluated both acquisitions were superior to those of evaluators who assessed postcontrast scans, it has been observed that radiologists did not obtain additional information from the precontrast scans; the better evaluation was due only to a more accurate identification of findings documented in the postcontrast acquisitions.

In none of the patients we examined did the precontrast scans change the management of the trauma patients.

In TAB. 4 are listed the average doses received by the majority of patients we examined in the precontrast thoraco-abdominopelvic acquisition.

Note that patients received a corrected average dose of 12 mSV, a high dose. We also verified that in all patients the diagnostic reference levels for chest, abdomen and pelvis were normal.

DISCUSSION

An estimated 39 million people suffer traumatic injuries each year in the United States [21]. CT has an established role in the evaluation of trauma patients for the diagnosis of many traumatic injuries, such as solid organ and vascular lesions and spine fractures. There has been a 20-fold increase in the use of CT scans in the United States over the past two decades [22,23]. This increase entailed a significant overall rise in ionizing radiation exposure and its associated risks, particularly carcinogenesis. According to Song et al.[24], severely injured patients were exposed to extremely high (73.8 mSv) cumulative effective doses from CT scans in the emergency department.

In 2006, Ott et al. [25] examined the radiation doses of patients at a level 1 trauma center through the use of dosimeter badges attached to the wrist. They found that many patients received > 10 mSv of radiation, which is the limit set by the US Nuclear Regulatory Commission for the public.

With the increasing concerns about radiation exposure, several groups have proposed that guidelines should be established for a more selective and appropriate use of CT. Hadley et al. [26] reported that CT examinations for trauma performed according to the American College of Radiology (ACR) guidelines would reduce radiation doses by 44% and imaging costs by 39%. These guidelines in stable trauma patients give a superior score of appropriateness for contrast-enhanced CT examination compared with CT examination before and after contrast injection [8]. As there is not a unanimous consensus for standardized protocols between radiological societies, that define the phases to be used in polytrauma, especially when performing scans without contrast injection, the use of unenhanced CT scans depends on individual judgement, national guidelines or local protocols [27].

The referral guidelines for imaging of European Commision [6] in trauma imaging do not solve the question. Recent UK radiological guidelines (2011) [12] say that non-contrast scans in a trauma patient are unnecessary. On the contrary, French radiological guidelines (2009) [28] suggest the usefulness of the precontrast scans in these patients: so there is a discrepancy of opinions even in European literature.

Nor is there a unanimous agreement among the radiologists of our Hospital on this question.

The idea of this study originated from the experience of two authors of this article (A.E. and M.Z.), who attended two American Trauma Centers, the Adams Cowley Shock Trauma Center of Baltimore, Maryland, and the Memorial Hermann Hospital of Houston, Texas, for a period of two weeks, between 2009 and 2011. There they observed that it is not the practice of American radiologists to use non-contrast enhanced scans for the thoraco-abdominopelvic CT of a trauma patient, as they consider them unnecessary.

Evaluating the literature, as of the early 80s, Federle P et al. [29] in San Francisco, among the first to use CT in trauma patients, stopped using the acquisitions without contrast in trauma patients, as they did not consider them essential.

In their preliminary, but already acquired experience, the majority of hematomas, after contrast, appear hypodense compared to surrounding contrasted parenchyma and are therefore recognizable.

In 1988 Kelly J et al. [15] and in 1992 Miyakawa K et al. [30], evaluating trauma patients with precontrast and postcontrast acquisitions, obtained an increase of SE by the use of both. In the second study, patients were evaluated for lesions of the intestinal tract, in which the precontrast hyperdensity of the bowel wall, indicating hematoma, was lost by the radiologists who assessed only the contrast-enhanced scans.

According to these conflicting opinions, in 1999, Katz et al. [31], in a review on the use of CT in polytrauma patients, say that the utility of non-contrast scans is not clear.

According to the literature, there are cases in which precontrast scans may be useful in the evaluation of thorax, abdomen and pelvis: 1) to better identify small parenchymal or gastrointestinal hematomas, if hyperdense in the precontrast scans; 2) to characterize thickening of the vessels wall; 3) to better differentiate acute from chronic pseudo-aneurysms; 4) to better characterize incidental lesions, such as lesions of the adrenal glands; 5) to differentiate small bone fragments of fractures or soft tissue calcifications from active bleeding; 6) to correctly interpret the presence of medical devices/outcomes of previous surgery unknown in the patient's history; 7) to increase the confidence of radiologists, particularly those unskilled in emergency CT.

However, we believe that, for the points 3, 5 and 6, delayed scans are sufficient to clarify any doubts (Fig.1, 2 and 3). The points 1 and 2 are rare occurrences: in the first case hematomas are usually small and they do not change the management of the patients, while for the second point, some authors, including Boscak AR et al. [32], have demonstrated that significant alterations, warranting surgery, do not occur in isolation, but in association with other findings, such as stranding of adjacent adipose tissue or the presence of fluid.

In addition, studies in which radiologists observed the usefulness of non-contrast scans are old; meanwhile CT scanners have evolved, the thicknesses of reconstruction have been reduced, high-definition monitors have improved, leading to a more accurate diagnosis [15,30].

Point 4 does not result in a change in the management of trauma patients. Regarding point 7, we cannot force anyone to change their practice nor can we make them overcome their misgivings. Our experience reflects that of Naulet P et al. [28], who also have ascertained that there is therefore no advantage to performing non-contrast-enhanced acquisition in addition to contrast-enhanced scans in trauma patients. Our results are in accordance with the recommendations of the Royal College of Radiologists and the practice of many other teams who do not undertake scans without contrast injection [5,10,12,33,34,35,36,37,38,39].

In our study, the average values of SE and SP of findings of radiologists who assessed both non-contrast scans and those with contrast were comparable to those of the radiologists who evaluated only the post-contrast acquisitions, even regarding certain lesions such as vascular injuries and parenchymal hematomas where the utility of precontrast scans is discussed.

The major limitations of this study are its retrospective nature and the use of data from a single trauma center. In the future, additional prospective investigations, involving multiple centers, with different degrees of experience in trauma CT between radiologists is suggested to confirm our data.

CONCLUSIONS

In our experience precontrast scans did not provide additional insight in the principal lesions of trauma patients.

It should be stressed, as it is very likely (as happened in the 104 patients assessed by us), that an undue and high dose is administered to the patient studied, in our study a dose of 12 mSV. Trauma centers perform more than 100 CTs per year for thoraco-abdominopelvic trauma. So it is crucial to use protocols providing exclusively contrast-enhanced scans in trauma patients, to avoid unnecessary ionizing radiation, particularly bearing in mind the young age of these patients.

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FIGURE LEGENDS

Fig. 1. A) Arterial CT phase. False positive dissection of ascending aorta (white arrow) and true dissection (black arrow) of descending aorta in a trauma patient with previous surgery for a non-traumatic aortic dissection. B) In the delayed phase in the site of the suspected intimal flap of ascending aorta there is a linear hyperdensity, corresponding to a felt pledget of a previous surgery.

Fig. 2. A) Arterial CT phase shows some hyperdensities in a hematoma in posterior soft tissues of right dorsal region, impossible to differentiate from an active bleeding even with a bone window. B) Delayed phase demonstrates that the hyperdensities are unchanged, because they represent bone fragments (white arrows).

Fig. 3 A) Arterial CT phase shows a pseudo-aneurysm of aortic isthmus (white arrows); in this phase wall calcifications are difficult to recognize. B) In the delayed phase the better identification of wall calcifications helps to diagnose correctly a chronic pseudo-aneurysm.

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HIGHLIGHTS

- We evaluated the additional value of precontrast CT in polytrauma patient.
- We evaluated the radiation dose CT in polytrauma patient.
- Precontrast CT scan does not have an additional value in polytrauma patient.
- Precontrast CT expose patient to an unjustified radiation dose.

TAB. 1. Evaluation list for the alterations observed in chest, abdomen, pelvis, soft tissues and vessels.

CHEST INJURY			**SOFT TISSUE INJURY**			**ABDOMINOPELVIC INJURY**		
Hemothorax/Pleural effusion	Y	N	Active bleeding	Y	N	Hematoma/Effusion	Y	N
Pneumothorax	Y	N	Vascular injury	Y	N	Spleen lesion	Y	N
Heart/Pericardial lesion	Y	N				Liver lesion	Y	N
Pneumomediastinum	Y	N				Gallbladder and biliary tract lesions	Y	N
Lung laceration	Y	N				Renal lesion	Y	N
Mediastinal hematoma	Y	N				Pancreatic lesion	Y	N
Tracheobronchial lesion	Y	N				Adrenal gland lesion	Y	N
Esophageal lesion	Y	N				Gastro-intestinal lesion	Y	N
Lung contusion/hematoma	Y	N				Pneumoperitoneum	Y	N
Active bleeding	Y	N				Active bleeding	Y	N
Diaphragmatic lesion	Y	N				Bladder lesion	Y	N
Vascular injury	Y	N				Genital organ lesions	Y	N
						Vascular injury	Y	N

TAB. 2. Mean sensitvity (SE), specificity (SP), positive predictive value (PPV) and negative predictive value (NPV) of findings observed by radiologists who evaluated respectively non-enhanced CT (NECT) scans, contrast-enhanced scans (CECT) and both scans for thorax and vessels.

Injuries	**Number of cases**	**NECT**	**CECT**	**NECT + CECT**
Hemothorax/ Pleural effusion	28			
SE		71%	82%	71%
SP		92%	95%	92%
PPV		80%	90%	100%
NPV		77%	77%	78%
Pneumothorax	33			
SE		86%	97%	96%
SP		95%	99%	99%
PPV		100%	98%	100%
NPV		74%	73%	74%
Pneumomediastinum	5			
SE		60%	70%	76%
SP		98%	99%	99%
PPV		92%	100%	100%
NPV		96%	96%	96%
Chest active bleeding	4			

SE		0%	40%	92%
SP		96%	98%	100%
PPV		0%	80%	100%
NPV		96%	96%	96%
Lung laceration	17			
SE		57%	76%	69%
SP		94%	96%	95%
PPV		75%	87%	84%
NPV		86%	86%	86%
Lung contusion/hematoma	46			
SE		92%	92%	91%
SP		95%	96%	95%
PPV		85%	92%	94%
NPV		61%	62%	62%
Vascular injuries	6			
SE		13%	67%	73%
SP		96%	98%	99%
PPV		100%	67%	52%
NPV		95%	95%	95%
Mediastinal hematoma	12			
SE		13%	71%	62%
SP		91%	97%	96%
PPV		100%	89%	82%
NPV		90%	90%	90%

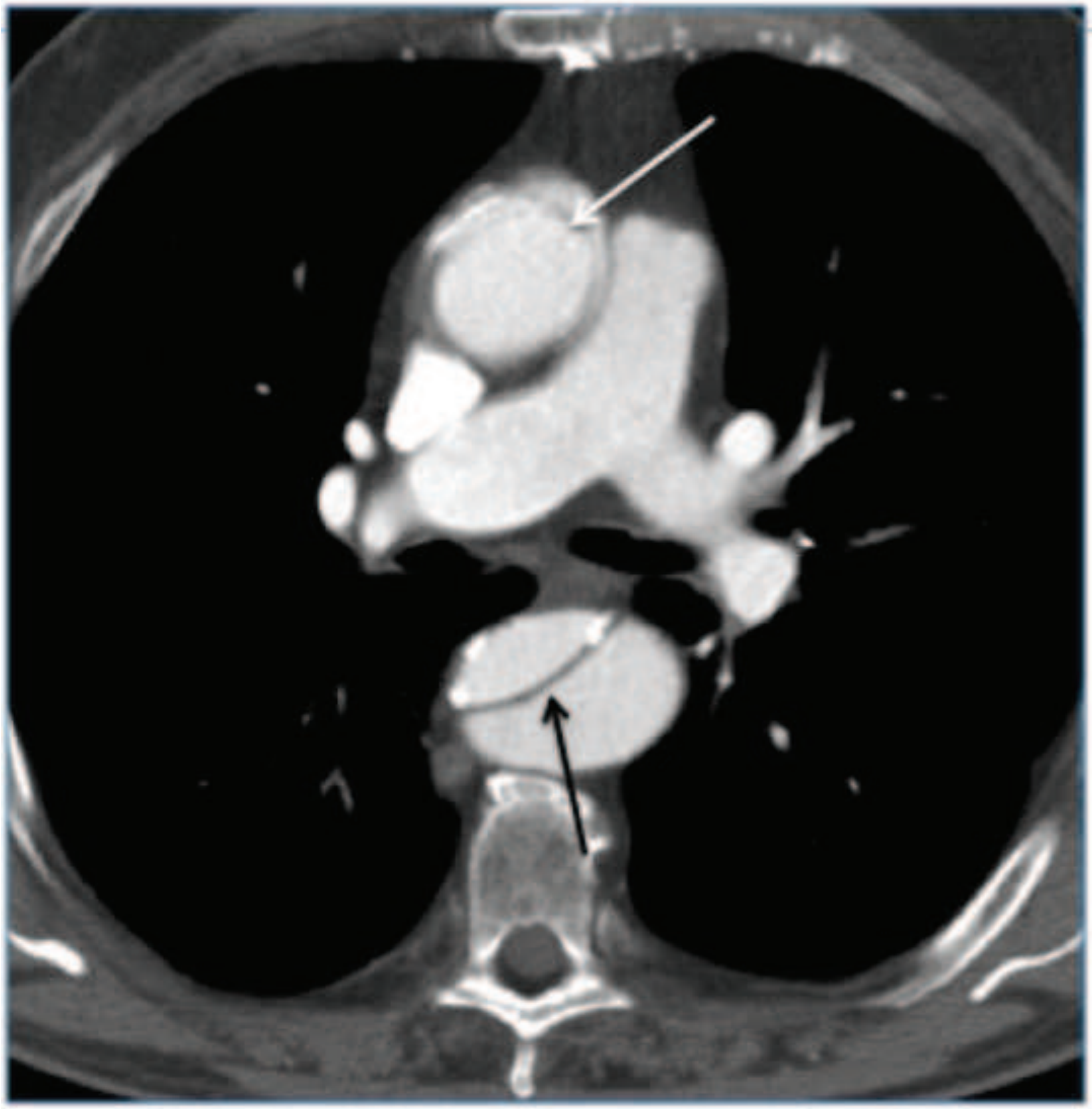
TAB.3: Mean sensitvity (SE), specificity (SP), positive predictive value (PPV) and negative predictive value (NPV) of findings observed by radiologists who evaluated respectively non-enhanced CT (NECT) scans, contrast-enhanced scans (CECT) and both scans for abdomen, pelvis and soft tissues.

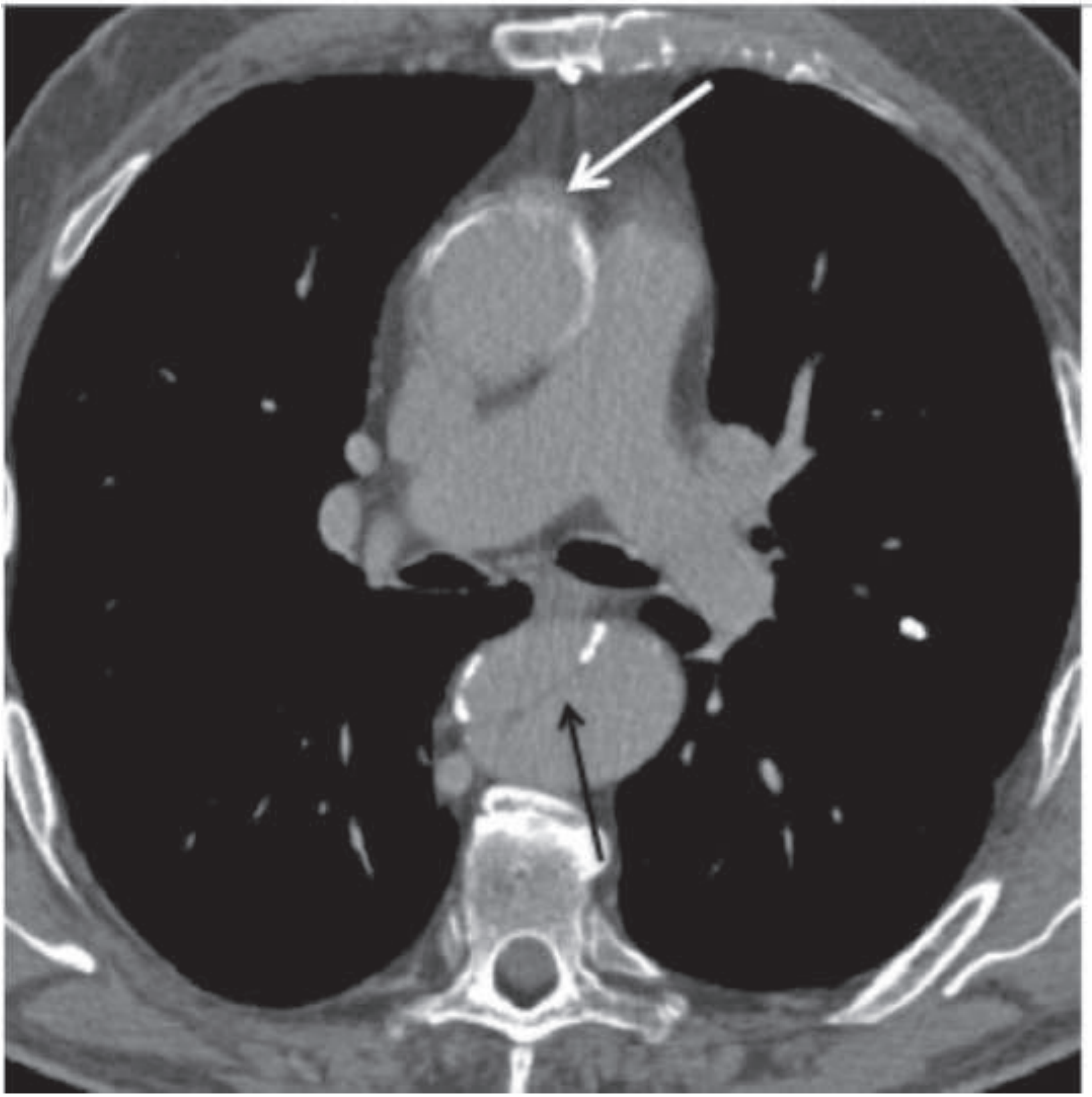
Injuries	**Number of cases**	**NECT**	**CECT**	**NECT + CECT**
Hematoma/ Effusion	35			
SE		53%	80%	78%
SP		85%	93%	92%
PPV		100%	98%	96%
NPV		72%	62%	72%
Abdominal bleeding	9			
SE		0%	100%	91%
SP		93%	100%	99%
PPV		0%	95%	93%
NPV		93%	93%	93%
Spleen lesion	10			
SE		55%	95%	96%
SP		96%	100%	100%
PPV		100%	86%	83%
NPV		92%	92%	92%

Renal lesion	2			
SE		100%	100%	80%
SP		100%	100%	100%
PPV		100%	67%	53%
NPV		98%	98%	98%
Adrenal gland lesion	2			
SE		0%	100%	60%
SP		98%	100%	99%
PPV		0%	44%	43%
NPV		98%	98%	98%
Liver lesion	9			
SE		44%	83%	80%
SP		96%	99%	98%
PPV		100%	100%	90%
NPV		93%	93%	93%
Soft tissue bleeding	6			
SE		0%	83%	80%
SP		95%	99%	99%
PPV		0%	100%	32%
NPV		95%	95%	95%

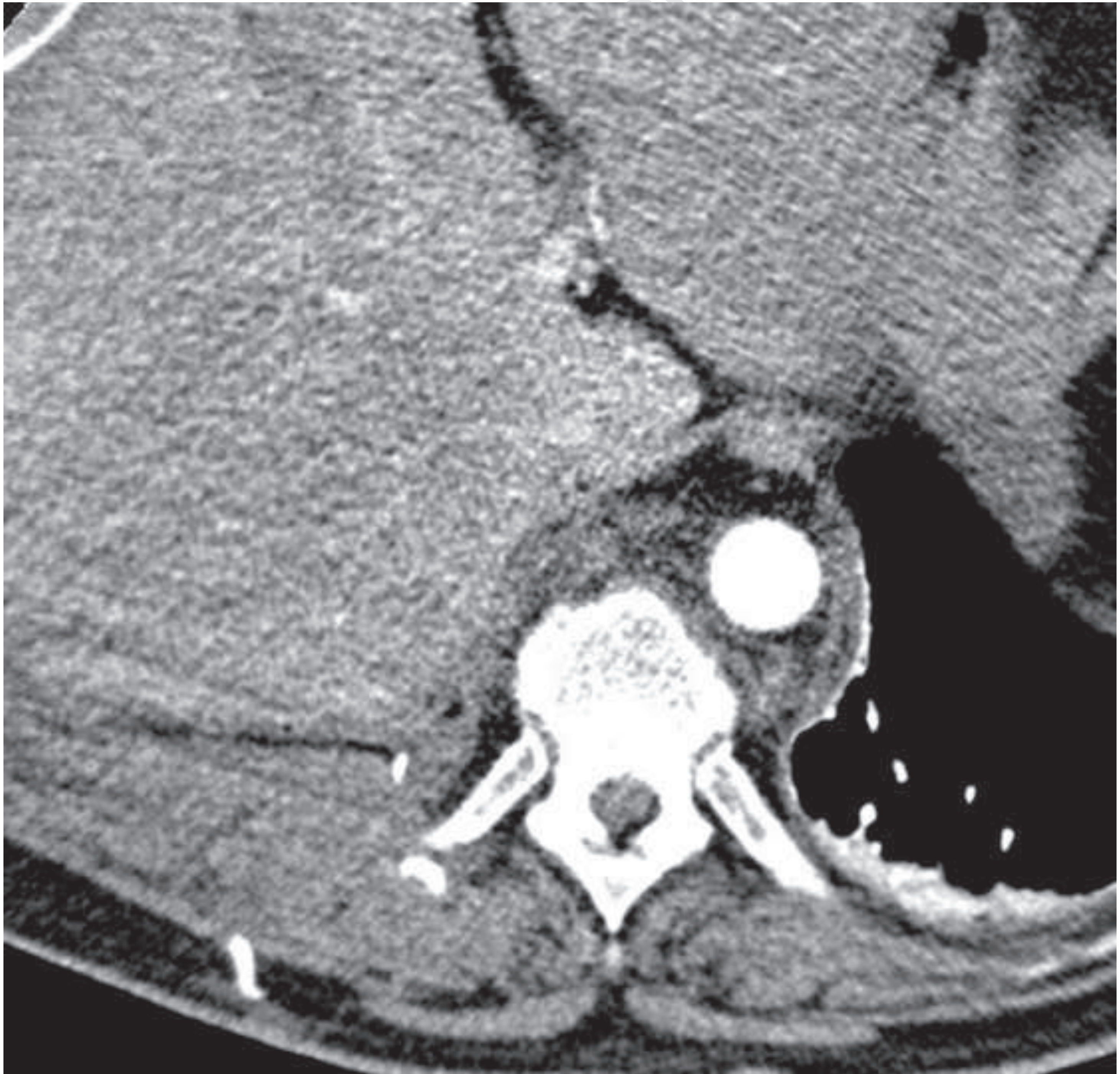
TAB.4: Average values of patients scan length, CTDIvol, DLP, DE, corrected DE, with respective ranges, in 104 out of 125 patients, for non-contrast-enhanced thoraco-abdomino-pelvic CT scans.

	Average	Range	M	**F**
Scan Lenght	**67 cm**	45.7-86 cm	67.5 cm	65.6 cm
$CTDI_{VOL}$	9.8 mGy	5.1 - 21.9 mGy	10.2	8.6
DLP	**661.4 mGyxcm**	330-1675 **mGyxcm**	691.3	567.1
DE	**9.4 mSv**	4.7 - 23.8 **mSv**	9.8	8.0
Corrected DE	**12 mSv**	6.0 - 25.2 mSv	12.1	11.8





Figure(s)



Figure(s)