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GACETA MÉDICA DE MÉXICO **REVIEW ARTICLE**

The radiologist physician in major trauma evaluation

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Abstract

Background: *Trauma is the most common cause of death in young adults. A multidisciplinary trauma team consists of at least a surgical team, an anesthesiology team, radiologic team, and an emergency department team.* **Objective:** *Recognize the integration of multidisciplinary medical team in managing the trauma patient and which must include the radiologist physician responsible for the institutional approach to the systematization of the trauma patient regarding any radiological and imaging study with emphasis on the FAST (del inglés, Focused Assessment with Sonography in Trauma)/USTA, Whole body computed tomography.* **Methods:** *Ultrasound is a cross-sectional method available for use in patients with major trauma. Whole-body multidetector computed tomography became the imaging modality of choice in the late 1990s.* **Results:** *In patients with major trauma, examination FAST often is the initial imaging examination, extended to extraabdominal regions. Patients who have multitrauma from blunt mechanisms often require multiple diagnostic examinations, including Computed Tomography imaging of the torso as well as abdominopelvic Computed Tomography angiography.* **Conclusions:** *Multiphasic Whole-body trauma imaging is feasible, helps detect clinically relevant vascular injuries, and results in diagnostic image quality in the majority of patients. Computed Tomography has gained importance in the early diagnostic phase of trauma care in the emergency room. With a single continuous acquisition, whole-body computed tomography angiography is able to demonstrate all potentially injured organs, as well as vascular and bone structures, from the circle of Willis to the symphysis pubis.* (Gac Med Mex. 2016;152:480-91)

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"Medicine is the science of temporary truths."
Naim Sauaia, MD, PhD, 1928-2001.

Better been slapped with the truth,
than kissed with a lie.

Introduction

Deaths and injuries caused by accidents and acts of violence are of grave concern for current society and are among the main causes of morbidity and mortality in the world, affecting both developed and developing countries alike. The mortality rate is elevated, and the population suffering such accidents is part of the economically active population that would otherwise be healthy and productive were they not affected by these problems.

In Mexico, accidents are the first cause of death among the population aged 15 to 64 years, out of which 40% correspond to car accidents.

The practice of medicine in the 21st century implies a multidisciplinary approach[1]. Trauma represents an urgent clinical-surgical condition that is difficult to

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assess because of the different possibilities of injury that deserve specialized multidisciplinary treatment[2].

Management of the polytrauma patient is a race against time. The clock starts ticking at the moment of the incident. The golden hour is the first one after the injury, during which the patient has to be systematically evaluated and all life-threatening injuries have to be identified[3]. Appropriate triage, quick transportation and efficient establishment of an airway, breathing and circulation are essential to increase survival to the maximum.

Blunt thoraco-abdominopelvic trauma represents an urgent clinical-surgical situation that is difficult to assess owing to the different possibilities of injury both on the thoracic and the abdominopelvic cavity, which require specialized multidisciplinary treatment. In addition, decisions have to be made promptly, since injuries can be life-threatening for the patient.

A common and many times serious mistake is to postpone surgical intervention when clearly indicated, and this delay is mainly due to an attempt to establish an accurate diagnosis on the type and nature of the injury. This is why establishing a management protocol that enables adequate management of such patients adequately using all available resources is essential.

The effects of blunt thoraco-abdominopelvic trauma are frequently masked by other more evident, but clinically unimportant, trauma injuries; in addition, blunt trauma symptoms are often so unspecific that can be ignored and go unnoticed during the first minutes or hours after the traumatic event.

In our country, there is a need to establish an energetic, quick and effective treatment plan for polytrauma patients, and especially for those who sustain blunt trauma, with the minimum use of resources and ensuring effectiveness of the procedure. This is why, on August 6, 2008, the Mexican Army directive for the trauma system[4] was established for immediate implementation and application, which currently is still ongoing, with achievements and modifications made with the experience acquired with its application.

In patients with blunt thoraco-abdominopelvic trauma and hemodynamic instability, performing an exploratory laparotomy was common and, in some cases, diagnostic peritoneal lavage, which had an important role in intra-abdominal injury assessment, was carried out. However, this procedure does not detect retroperitoneal lesions, it is invasive and modifies computed tomography (CT) or ultrasound (US) findings. CT enables accurately demonstrating and stratifying retroperitoneal injuries; it is recommended in patients with suspected thoraco-abdominopelvic injury that remain hemodynamically stable and have no evident clinical data of complication.

Additionally, those patients with hypotension or any other sign of physiological instability, who should not suffer any delay in the definitive management decision, were initially not subjected to prolonged radiology or imaging studies outside the resuscitation station at the Emergency Department. It is in these patients that a focused scan has to be conducted by means of focused assessment with sonography in trauma (FAST) US with the sole purpose to identify or not free intra-abdominal fluid, which would indicate the presence or not of hemiperitoneum.

In world medical literature there are multiple reports pointing out at the usefulness of imaging methods such as CT and US in the assessment of blunt thoraco-abdominopelvic trauma. CT allows for all intra-abdominal structures to be evaluated, with high sensitivity to detect trauma-originated injuries and display them in cross-sectional anatomic slices, and with current multi-detector computed tomography (MDCT) technology, the time required to conduct a scan encompassing the thoraco-abdominopelvic region is 1 minute.

Imaging diagnosis has surpassed plain film radiology traditional concepts and it is now a multimodal discipline. Images have become important not only for diagnosis but also for treatment.

According to the recommendations of the Advanced Trauma Life Support (ATLS), an advanced trauma life support program for doctors, in most trauma centers, radiology studies are systematically performed in the resuscitation area for initial assessment of any trauma patient involved in a high-impact trauma accident with loss of consciousness.

Available resources to support the decision to operate a patient with blunt thoraco-abdominopelvic trauma have significantly increased over the past 15 years. Diagnostic peritoneal lavage remains a tool that today still provides with great sensitivity to detect hemoperitoneum.

FAST has substituted peritoneal lavage in most centers dedicated to assess trauma patients[5].

In many countries, ATLS[6], Prehospital Trauma Life Support (PHTLS) and Advanced Cardiac Life Support (ACLS) represent the initial approach in trauma situations, pre-hospital care and in medical conditions requiring emergency vital care. Originally, these approach systems were designed for expedite decision-making in settings where there was only one nurse and one doctor available. Based on our daily hospital practice

in a setting with multiple health institutions in Mexico City, there is no reason for not including the physician radiologist in the trauma work group.

Current challenges faced by new millennium physician radiologists are the consequence of technology's constant progress, as well as clinical medicine field adaptation to science advances and globalization, which have modified their function and day-to-day tasks in the medical team. With the development of more sophisticated technologies, the growing role of radiology and imaging studies in the direction of trauma victims increases the workload and responsibility of the radiology team in the emergency room, by identifying life-threatening diagnoses and enabling immediate use of life-saving procedures. Current physician radiologist is faced not only with hundreds of images, but also with a considerable number of study protocols for each patient, with the inherent and immediate need of the required skills for the management of digital networks and connections, having accurate and non-invasive tools at hand for diagnostic support, thus becoming the clinician's, and especially the patient's, most powerful ally.

Objective

To recognize the integration of the physician radiologist to the multidisciplinary medical team in the management of the polytrauma patient, responsible for the polytrauma patient approach institutional systematization regarding any radiology and imaging study, with an emphasis on FAST/abdominal trauma US (ATUS) and on whole-body thoraco-abdominopelvic CT.

Which is the role of the physician radiologist in blunt thoraco-abdominopelvic assessment?

- To treat the patient, NOT the images.
- To review the images in their entirety, each one as a whole.
- To examine and reexamine the patient if there is inconsistency between findings and clinical data.
- To establish communication with his/her physician surgeon colleagues. Let radiologists do radiology. CT images interpretation is dependent on the operator who performs it. This subjectivity element places the experience of the interpreter as a vital situation.
- Hemorrhage is the common denominator of all causes of death. In the Emergency Department, immediate diagnosis and management of this condition should be favored[7].

The presence of certified physician radiologists all the time is essential in the assessment, subsequent management and error reduction in trauma patients.

FAST and ATUS[8-10]

FAST US refers to the US that is carried out by the surgeon, originally restricted to intra-abdominal free fluid identification. In our institution, US is performed by physician radiologists, technicians and medical residents of the specialty, and it is not only restricted to intra-abdominal free fluid identification, but also to try to identify visceral and/or vascular injuries. This is why we coined the term ATUS, to differentiate and broaden the term, and for this reason, we will refer to it indistinctively as FAST/ATUS in the present manuscript.

In experienced hands, US has comparable sensitivity, specificity and safety to diagnostic peritoneal lavage and CT in the assessment of blunt thoraco-abdominopelvic trauma. US provides a quick, non-invasive and safe means in the diagnosis of intra-abdominal injuries (secondary to blunt thoraco-abdominopelvic trauma) and can be frequently repeated. Exploration with FAST/ATUS can be carried out at the reanimation room when other diagnostic or therapeutic procedures are simultaneously performed. Indications for this procedure are the same than for diagnostic peritoneal lavage. The only factors that compromise its usefulness are obesity, presence of subcutaneous air and prior history of abdominal surgery procedures.

FAST/ATUS exploration to detect hemoperitoneum can be quickly performed, and pericardial sac, hepatorenal fossa, splenorenal fossa and pelvic images should be obtained. After initial examination, a second "control" exam is performed with a 30-minute interval to detect progressive hemoperitoneum in those patients with slow bleeding and a short interval between the injury and initial examination.

Patient sudden blood pressure decrease and persisting metabolic acidosis in spite of sustained reanimation are common indications of the need to examine the peritoneal cavity as the source of hemorrhage. If required, FAST/ATUS exploration can be performed at bedside to exclude hemiperitoneum as hypotension potential source. FAST/ATUS can be applied to patients with multiple system traumas or to those on anticoagulation treatment. In these cases, more extensive US can promptly identify hemoperitoneum and, sometimes, retroperitoneal hemorrhage.

The study that is used to identify or exclude hemoperitoneum is FAST/ATUS. Peritoneal cavity should be systematically explored in search for any fluid accumulation.

FAST/ATUS in blunt thoraco-abdominopelvic trauma

- Documents the presence of fluid in case of hypotension.
- Early, non-invasive and repeatable diagnosis; 86-97% reliability.
- Takes approximately 5 minutes; doesn't require any preparation.
- US is operator-dependent. In addition, US is distorted by intestinal gas, obesity, subcutaneous emphysema and might not detect diaphragm and bowel lesions and some pancreatic injuries.
- Learning the procedure requires from 2 to 8 hours' training for the emergency doctor to be able to perform it.
- With the following technical considerations: Being able to detect 250 ml or less of intra-abdominal free fluid with anatomical markers identification: anterior, middle and posterior axillary lines.
  - To identify intra-abdominal anechoic collection; presence of intra-thoracic anechoic collection.
  - Free, anechoic intra-peritoneal images: non-coagulated blood.
  - Scan in the 4 standard views: The 4 "p's": Perihepatic, perisplenic, pelvic and pericardial. Why these views?: Morison space (hepatorenal space) is one of the most posterior abdominal compartments of the abdomen and blood tends to accumulate there; pelvic cavity, abdomen's most tilted space; retrovesical and Douglas pouch bottom (posterior pouch bottom) spaces.
  - Injury to solid viscera: anecho- and/or hyperechogenicity focal areas.
- Study that is repeated, at second intention (at 30 min to 6 h, according to patient status).
- A second scan should be always performed, approximately 30 min after the first one.
- Doesn't matter which intra-abdominal organ is injured, Morison fossa –hepatorenal area– scanning is commonly positive.
- All signs should be evaluated in the context of the clinical picture and periodic observation of the patient.
- Contact of the transducer with the patient's skin should be facilitated by using conducting gel, preferably at body temperature.
- Detection of injury to solid viscera:
  - If feasible, ask the patient to indicate the site of pain.
  - Remember starting the exploration at a point opposite to the site of pain.
- It is indispensable for the doctor to notice the subject´s expression while performing any abdominal exploration in search of diagnostic signs.
- Sectional imaging methods such as US and CT enable the study of the thoraco-abdominopelvic contents as a whole, thereby enabling to demonstrate anomalies that maybe clinically are not suspected. The Rapid Ultrasound in Shock (RUSH) method[11,12], with exploration on parasternal foci, subxiphoid view and apical view and with an emphasis on localization of:
  - inferior vena cava indentation
  - right hypochondrium and pulmonary base FAST
  - left hypochondrium and pulmonary base FAST, with the purpose to identify pneumothorax and/or pulmonary acute edema (PAE).
  - pelvis and vascular structures suprasternal aorta (Ao), parasternal Ao, epigastric Ao, supraumbilical Ao, femoral vein FAST in order to define the presence of deep venous thrombosis (DVT) and popliteal vein (PV)[11,12].

Improvement in radiology and imaging techniques in the last 30 years has deeply modified the management and direction of trauma patients. Prior to the advent of CT and US, surgery was used both diagnostically and therapeutically, with the disadvantage of non-therapeutic surgical procedures, with a significant morbidity increase (20% of negative exploratory laparotomies).

The increasing use of CT has enabled better patient selection for surgery and reduction in the number of life-threatening serious injuries that might be overlooked on initial assessment and as an improvement in the decision and supervision of patients that have not undergone surgery.

Current management of the trauma patient involves the integration of teams that include multidisciplinary medical personnel with the inclusion of the physician radiologist for supervision and evaluation of patients with blunt thoraco-abdominopelvic trauma. Sometimes, even the responsibility for the patient and his/her diagnosis show a counterbalance shift: the diagnosis that can be attained with radiology and imaging comes to outperform clinical suspicion (most times wrongly integrated), either by some incidental findings or, most of the times, by the physician radiologist clinical skills.

Figure 1. A: *Motor vehicle-runover polytrauma patient who underwent thoracoabdominal multiphasic computed tomography scan with intravenous contrast. Right kidney is demonstrated with morphology loss from the cortex to its lower pole, with a perirenal hematoma;* **B:** *Motor vehicle-runover polytrauma patient with right renal surgical bed image, where tearing is appreciated at the interpolar junction level, with upper pole preserving its usual coloration.*

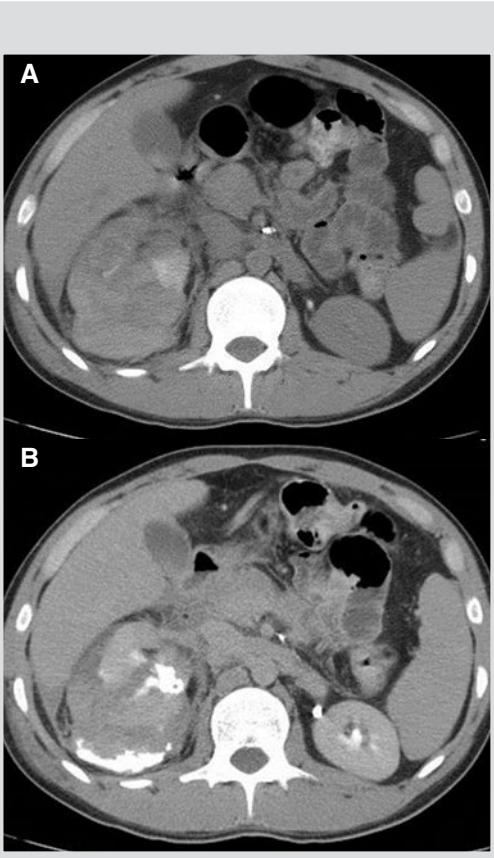

Figure 2. A: *Motor vehicle-runover polytrauma patient with blunt thoraco-abdominopelvic trauma who underwent computed tomography scan with intravenous contrast medium. In the selection of simple phase images, grade IV renal trauma was identified, with perirenal hematoma with parenchymal laceration extending up to the medulla, cortex and renal collecting system;* **B:** *Motor vehicle-runover polytrauma patient with blunt thoraco-abdominopelvic trauma who underwent computed tomography scan with intravenous contrast medium. In the selection of excreting phase images, grade IV renal trauma is identified, with perirenal hematoma with parenchymal laceration extending up to the medulla, cortex and renal collecting system and contrast medium extravasation of the right pyelocaliceal system.*

CT is, since many years ago, the gold standard for the diagnosis of thoraco-abdominopelvic injuries. Originally, given the characteristics of equipments, CT was reserved only for those patients with hemodynamic stability. CT has allowed for organ-specific injuries to be assessed and categorized and for selective treatments to be carried out, and enables assessing both the peritoneal cavity and the retroperitoneum. It has a sensitivity to detect intraperitoneal bleeding higher than 90%%. In addition, it enables assessing renal function and contrast leaks and considering the need for minimally invasive procedures in selected cases of injury to pancreatic, renal, hepatic[13] or splenic[14] viscera (Figs. 1 A and B, 2 A and B, and 3 A and B).

In selected cases, in patients not presenting with hemodynamic anomalies, it is possible to proceed with preoperative evaluation to propose therapeutic alternatives. In splenic injuries, CT allows for the degree of injury to be established[15]. Contrast-enhanced CT evaluates vascular leaks or quantifies the presence of hematomas. In a compensated patient without any other associated injury, without splenic hilar vascularization involvement, non-operative treatment (NOT) is possible with selective embolization if required. Additionally, in the management protocol for hemodynamically unstable blunt thoraco-abdominopelvic trauma, MDCT allows for extreme rapidness to be achieved in the diagnosis of vascular injuries, both their source and extension, by means of the computed angiotomography technique[16] (Figs. 4 A and B). Unstable patients could not be brought to the CT suite, since transportation could be deleterious because these equipments were found at the radiology departments, away from

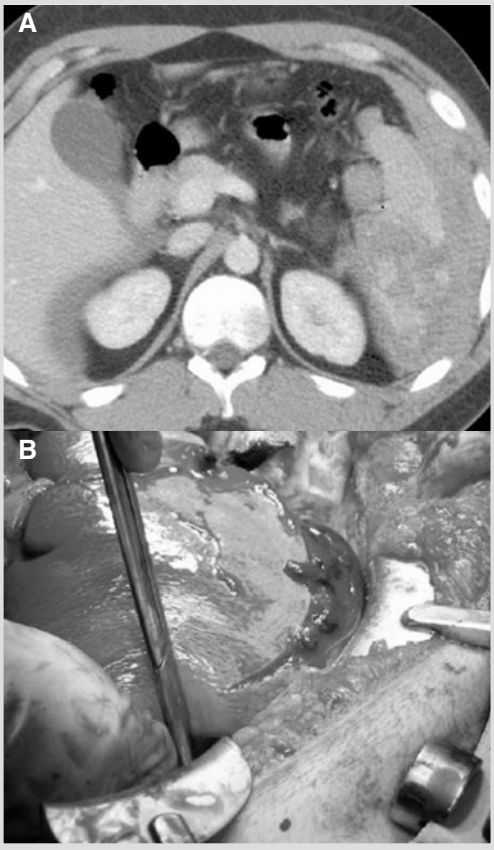

Figure 3. A: *Polytrauma patient with blunt thoraco-abdominopelvic trauma who underwent computed tomography scan with intravenous contrast medium, which demonstrates perisplenic hematoma, capsular disruption and splenic parenchymal laceration;* **B:** *Polytrauma patient with blunt thoraco-abdominopelvic trauma who demonstrates computed tomography with intravenous contrast medium correlation with surgical findings of perisplenic hematoma, capsular disruption and parenchymal laceration affecting the hilum, grade IVa.*

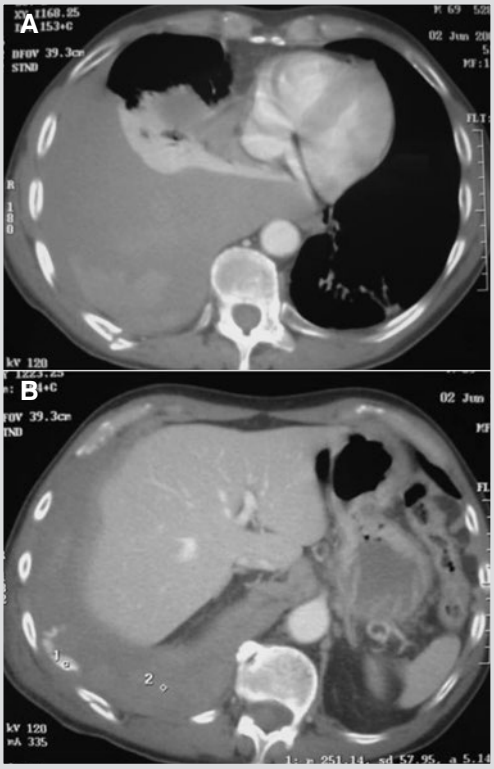

Figure 4. A: *5-meter-fall polytrauma patient who underwent computed tomography scan with intravenous contrast medium, where right costal fractures and post-traumatic hemothorax are demonstrated.* **B:** *5-meter-fall polytrauma patient who underwent computed tomography scan with intravenous contrast medium, where right costal fractures, post-traumatic hemothorax are demonstrated, with identification of the blood extravasation site, characterized by evident hyperdense images on the right pulmonary base.*

the emergency zone, and the personnel in charge of operating the apparatus was not always available when it was required, although this situation, by the way, has already been analyzed, demonstrating that CT cost-effectiveness is not influenced by its location and doesn't impact on bedridden days[17]. Even the philosophy of ATLS suggested this at its beginnings. The advent of faster, multi-slice, multi-detector new CT equipments went on making the technique increasingly accessible, in addition that the quality of images went on becoming increasingly better. The possibility to reconstruct obtained images even in three dimensions has made it an indispensable tool in all trauma wards. The beginning of the 21st century marked the advent of those technologies based on faster equipments, better image quality and incorporation of that technology to emergency rooms. Nowadays, CT is even being used as an essential part of primary evaluation, especially in European centers[18].

Although German works[18] pointed towards a different model of care for the patient with blunt thoraco-abdominopelvic trauma with early CT use, it is by the middle of current decade when the whole-body MDCT protocol concept started spreading in English-written literature, which proposes the use of this technique as primary assessment method of all, even unstable, polytrauma patients[18].

– Does the use of oral contrast improve CT diagnostic capability in abdomen closed trauma? The use of oral contrast is not necessary for abdomen closed trauma assessment[5]. MDGT without oral contrast medium has been shown to be useful to

Table 1. ATLS primary assessment components

	Primary assessment	
	ATLS	**Radiology and Imaging**
A	Airway and cervical spine stabilization	NO
B	Breathing	Yes, chest X-ray
C	Circulation	Yes, FAST/ATUS and pelvic AP X-ray
D	Neurological deficit	
E	Exposure	
AP and lateral cervical spine radiologic projections can be requested.		

Adapted from Allen et al.[20]

demonstrate intestinal and mesenteric injuries requiring surgical intervention. The results are comparable with previous series carried out with helical CT and MDCT of 4, of 8, of 26, 32 and 64 where oral contrast was used[19,20].

Initial CT scan at the arterial phase early stage for the detection of hemorrhage in trauma patients is useful to assess for lesions caused by trauma[16] and the need for angiographic interventions. CT with triphasic intravenous contrast has revolutionized the diagnosis and treatment of patients with hepatic and splenic trauma. "Once intravenous contrast is started, there is no more time to lose". The obtained information enables damage extension determination, as well as identification of other non-visceral abdominal injuries. The coupling of this information with clinical and interventional radiology findings enables optimizing the management of all grades of visceral injuries, specifically of the kidney, the liver[13] and the spleen[14] (Figs. 1 A and B, 2 A and B and 3 A and B).

– What is CT diagnostic capacity to demonstrate significant thoraco-abdominopelvic injuries in those patients requiring surgery in blunt trauma? When renal, hepatic and /or splenic injury is suspected, CT can reasonably exclude injuries that would require immediate and urgent intervention. CT cannot exclude by itself intestinal, diaphragmatic or pancreatic lesions and enables accurate identification of hemoperitoneum in patients with blunt thoraco-abdominopelvic trauma[5].

MDCT enables accurate identification of hemoperitoneum in patients with blunt abdomen thoraco-abdominopelvic trauma. MDCT with triphasic intravenous contrast has revolutionized the diagnosis and treatment of patients with hepatic and splenic trauma (Figs 3 A and B).

The obtained information enables damage extension determination, as well as identification of other non-visceral abdominal injuries. The coupling of this information with clinical and interventional radiology findings enables optimizing the management of all grades of visceral injuries, specifically of the liver[13] and the spleen[14] (Figs. 3 A and B).

In ATLS[6], it is in the primary assessment where life-threatening injuries are detected, including major thoracic injuries affecting breathing and that must be identified and treated: Tension pneumothorax, open pneumothorax, unstable pneumothorax and massive pneumothorax[21]. ATLS does not appropriately address imaging requirements a patient with blunt thoraco-abdominopelvic trauma might need. ATLS proposes a systematic, quick and effective trauma approach and management based on clinical skills. In ATLS, only 50 minutes are used for the teaching of chest and cervical spine radiology studies performed at the emergency department in critical patients[21-23] (Tables 1 and 2).

In ATLS training[6], if the director of the course decides not to teach the peritoneal lavage technique, then the new station of skills about FAST would be imparted, and the reason is because in this course, as an indispensable requirement, one of the ways to identify potential sources of blood loss has to be taught. This new station of skills about FAST uses the same scenarios than that of peritoneal lavage and shows positive and negative cases. If teaching this new station is not possible in the ATLS course, then the participants are only explained the concept of FAST use to assess structures demonstrated in images that they will have to learn and recognize.

Table 2. ATLS secondary assessment components

	Secondary assessment
ATLS	IMAGING. This is where performing appropriate radiologic projections and radiology and imaging studies is possible, including:
1. Thoraco-lumbar spine and limbs radiologic projections.	
2. Cranium, thorax, abdomen and pelvis (whole-body) simple-phase CT, with oral and intravenous phases, or else only multiphasic intravenous phase, with multiplanar reconstruction, maximal intensity and volumetric projection in 3D with pulmonary, bone and soft tissue windows.	

Adapted from Allen et al.[20].

Many times, radiology studies performed at the emergency department lack diagnostic quality and this is a non-contemplated factor that may induce medical error in the management of trauma patients by making inadequate decisions. From our perspective, the inclusion of an image specialist, the physician radiologist is essential to allow, even with those deficient cases, for quality care above recognized standards to be achieved. In ATLS there is no skills station that enables establishing minimum parameters of knowledge on CT[6,23,24].

This way, in less than 20 years, simple radiology almost exclusive use has shifted to MDCT direct application in primary assessment[23]. Thoraco-abdominopelvic CT indications in hemodynamically stable patients, based on the information provided by clinical-radiologic-US assessment are[23,24]:

- Positive FAST/ATUS, to identify the bleeding organ.
- Negative FAST/ATUS and abdominal injury suspicion.
- Positive/negative FAST/ATUS with other injuries implying high-energy trauma (pelvic/femur fracture) owing to occult injury elevated prevalence.
- Suspicion/evidence of cervical injury or cervical spine incomplete visualization on lateral X-ray.
- Evaluation of mediastinal thickening on chest AP radiography to investigate possible hemorrhage and its origin (venous, arterial, aortic)[21].

The polytrauma patient is usually approached by radiology and imaging with a series of portable studies consisting in spine lateral projection, portable chest projection and pelvic X-ray. Pelvic fractures account for 5% of all admissions to trauma centers, with an associated morbidity of 5-15%. MDCT is the most accurate diagnostic means to define pelvic anatomy and to detect its fractures, as well as to diagnose associated lesions. Free fluid identification by means of FAST/ATUS is useful, since 20% of pelvic lesions have vascular[25], genitourinary tract or gastrointestinal-associated injuries. Intra-abdominal free fluid identification in patients with pelvic fractures is generally an indicator for the need of surgery.

In addition, pelvic radiograph is not necessary for the diagnosis of pelvic fracture in stable patients who can undergo thoraco-abdominopelvic CT; eliminating it would reduce exposure to radiation, would make care more expedite and would avoid unnecessary expenses[26].

Pelvic X-ray is less sensitive than CT to detect pelvic fractures, and in the beginning of current decade, eliminating it in stable patients, in whom a CT-scan is practiced on initial assessment, has already been proposed. Recent studies confirm that CT allows for up to 33% of pelvic fractures not detected by pelvic X-ray to be identified, and, therefore, its exclusion from the ATLS protocol is proposed in cases where CT is feasible[25,26].

Pelvic fractures account for 5% of all admissions to trauma centers, with an associated morbidity of 5-15%. CT enables the division of the pelvic cavity in 6 extraperitoneal areas:

- Abdominal rectum region
- Right gluteus region
- Left gluteus region
- Right lateral pelvic wall
- Left lateral pelvic wall
- Presacral region[25,26]

CT has modified the approach in patients with cervical trauma by detecting those with unstable spine without alertness state alteration, in whom CT or magnetic resonance imaging (MRI) are recommended. The recognition of clinical rules to avoid unnecessary radiological studies such as the Rules of Canada for cervical spine[22], or the Ottawa rules for ankle bone lesions has tried to control such disproportionate and indiscriminate use of resources, which are already limited in our institutions.

Unfortunately, in many situations, clinical examination in patients with blunt thoraco-abdominopelvic trauma, which includes dorso-lumbar spine assessment[27] or pelvic fracture clinical identification, is inadequate. CT has enabled identifying the totality of dorso-lumbar spine[27] or pelvic[25,26] fracture lesions. A combination of physical examination and CT is recommendable, both based on a judgment that includes the lesion mechanism and that enables ensuring adequate sensitivity with acceptable specificity in the diagnosis of dorso-lumbar spine and pelvic significant post-traumatic injuries. Further investigation is still needed to enable identifying those high-risk patients with a negative clinical examination in which, owing to the mechanism of their injury, performing a focused CT-scan is indispensable[27].

Vascular structures with a fixed point in their trajectories are the most susceptible to harm in blunt trauma; the most important examples are the pulmonary veins, the cava veins and the descending Ao at the level of the arterial ligament and the diaphragm (Figs. 4 A and B).

Some vessels such as the innominate artery and the aortic arch can get injured by compressive mechanisms between the sternum and the vertebral column. Although sudden deceleration was thought to be the trauma mechanism most frequently associated with Ao blunt injuries in motor vehicle frontal crash, the study by Williams et al.[28] found that in up to 50% of cases these injuries can be observed in accidents with lateral impacts. The most frequently injured site in all studies is the aortic isthmus, which is compromised in up to 85% of patients.

Thus, pelvic X-ray is acknowledged as not being necessary in polytrauma patients. MDCT was more sensitive and specific to demonstrate pelvic fractures and soft tissue injuries that failed to be visualized in the pelvic X-ray. When hepatic and/or splenic injury is suspected, MDCT can reasonably exclude lesions that would require immediate and urgent intervention, and enables accurate identification of hemoperitoneum in patients with blunt abdomen trauma, but cannot exclude by itself intestinal, diaphragmatic or pancreatic injuries.

The whole-body MDCT protocol needs some requirements such as a multidisciplinary medical team, guarantee of care continuity in the out- and inpatient settings, and accessibility to the CT ward, including architectural proximity, adequate equipment for reanimation maneuvers and 24-hour CT availability.

Early incorporation of MDCT to the management of trauma, known as Focused Assessment with Computed Tomography in Trauma (FACTT)[29], has an impact on polytrauma patients survival, with formation of a well-organized multidisciplinary team being necessary for its application, as well as an adapted flow to the environment where it is to be applied[30], allowing for rapid responses to immediately life-threatening problems to be established, as well as for follow-up of each relevant injury in the polytrauma patient. For the management of the polytrauma patient, the required time for the CT scan performance includes the transfer of the patient to the equipment, which takes approximately 20 minutes. This is why in some hospital centers, a MDCT equipment with a sliding table that enables not only scanning the patient on the CT equipment, but also assessing the patient on that same table with a C-arch for invasive radiology procedures such as, for example, arterial embolization, or for salvage procedures that can be performed at the same place without mobilizing the patient[30,31], has been placed in the emergency departments.

Whole-body MDCT protocol application as first diagnostic tool in polytrauma patients reduces, but does not eliminate, the risk of unnoticed injuries and, therefore, does not replace trauma patients close and tight monitoring or clinical follow-up[32-34].

Modern MDCT equipments are the best diagnostic tool in serious polytrauma patient initial management, owing to its rapidness, wide coverage, high sensitivity and accuracy in the detection and characterization of injuries, since they provide comprehensive information on the head, neck, thorax, abdomen, vertebral column and limbs, with the three-dimensional image definition that is characteristic of isotropic voxel routine use, which offers real multiplanar images as quickly as FAST/ATUS. Its sensitivity in the detection of active arterial hemorrhage is similar to that of digital angiography, and predicts the need for urgent treatment with a sensitivity higher than 95%, which enables getting ahead of hemodynamic instability, which is crucial if we consider that the probability of death increases by one point for every 3 minutes intervention is delayed. This way, the concept that hemodynamic instability should not be a contraindication for MDCT performance prevails, when barriers have been eliminated and exploration can be carried out immediately, with a well-designed protocol and a well-prepared patient. Exploration can be completed in less than 15 minutes, with acquisition times lower than 15 seconds and information on serious injuries immediately available. The usual exploration protocol starts with a sequential cranial baseline exploration, followed by a second phase

from the odontoid apophysis to the lesser trochanter in portal phase (70 s after injection initiation, at 30 cc/s, total dose adjusted by weight). At the suspicion of vascular injury, a regional arterial phase can be added, previous to the portal phase and using the same contrast injection. Contrast extravasation or hematuria identification or suspicion of excretory system injury, mandate the performance of a late phase (5 min), usually with low-dose technique[31-34] (Figs. 2 A and B).

When the whole-body MDCT protocol results are compared with those of conventional approach, quality indicators yield positive results favoring the former: shorter exploration times (12 vs. 30 min), larger number of early-identified injuries (490%), lower percentage of errors and reduction of emergency department length of stay, door-operating room and door-intensive care unit times. In addition, the number of days with respirator and intensive care unit and hospital length of stay are reduced, as well as the percentage of multiorgan failure. A recent multicenter review found an improvement in polytrauma patients' survival that were early studied with the MDCT protocol and recommends its use in the primary assessment[18].

Trauma patient exploration with MDCT has a minimum additional cost and adds significant changes to the management. We consider that it is beneficial to routinely practice whole-body examinations when CT scan is performed in closed head injury. MDCT with rectal, oral and intravenous contrast medium (triple-contrast) has been used to assess hemodynamically stable patients with flanks and back penetrating trauma. In patients with peritoneal injury, MBCT has demonstrated accuracy to predict the necessity of exploratory laparotomy, as well as to confirm visceral lesions and therefore to allow for treatment/NOT to be established.

MDCT enables determining solid organ injuries justifying intracavitary fluid and this way considerable operative treatment. Identification of a perisplenic hematoma of considerable size is a clear indicator for angiography[35] (Figs. 3 A and B).

The whole-body MDCT protocol as first diagnostic tool in polytrauma patients with multiple injuries[18,32], during primary examination, in an initial, early and immediate manner[36,37] enables the shortening of the time interval for decision-making at emergency department, thus allowing for a management plan to be established in these patients with multiple injuries and this way contributing to an improvement in their medical-surgical management[18,32,38,39], with treatment modifications from 2 to 27%[40,41], without evidence of injuries on physical exploration[42] in hemodynamically stable patients[43], including patients with altered state of consciousness, with a Glasgow score of 3-12 and in whom cranial tomography was also necessary[44].

In the past few years, the possibility of abdominal trauma management with NOT has been considered. In general, it is applicable to those patients with blunt trauma although in selected cases; in centers with experience and wide diagnostic-therapeutic 24 h-available resources it has been able to be established in certain cases of penetrating thoraco-abdominopelvic trauma. NOT has the purpose to selectively manage patients with abdominal closed trauma who meet strict conditions. It is a dynamic treatment option, since the patient's status might vary or the protocol might not obtain the expected results and, hence, proceed with surgical intervention.

Conditions to apply NOT:

- Patient with hemodynamic stability and normality
- Stable systolic pressure higher than 90 mmHg
- Heart rate lower than 100 beats/min
- Dieresis higher than 50 ml/h
- No inotropic requirements to maintain hemodynamic normality
- No hollow viscus or diaphragm injury
- No abdominal-associated injury with formal surgical indication
- With specific solid organ injury diagnosis and categorization
- CT, operating room and experienced surgeons 24-h availability

Conclusions

The practice of medicine in the 21st century demands a multidisciplinary approach. The physician radiologist should participate in the decision making process for those trauma patients who undergo any type of imaging modality, in order to favor the establishment of correct indications and adequate approaches. The physician radiologist plays a crucial role in the multidisciplinary management of the polytrauma patient, which in the past few decades has suffered an evolutionary change from plain X-ray to whole body MDCT, fostered by technological advances and healthcare cultural changes. The physician radiologist, integrated to a multidisciplinary team, must decide the ideal imaging technique and protocol for each situation, adapting him/herself to the available technological resources.

Blunt thoraco-abdominopelvic trauma is a pathology of multidisciplinary nature and elevated morbidity and mortality, which are avoidable with adequate coordination in

Table 3. Management of the patient with thoraco-abdominopelvic trauma with initial use of whole-body MDCT

Hemodynamically stable	FAST/ATUS + Monophasic computed tomography
Stable patient with suspected hemorrhage, with high-energy trauma, positive fast/atus, with pelvic fracture:	Multiphasic computed tomography
Hemodynamically unstable, normal physical examination	Multiphasic computed tomography
Exsanguinating unstable patient:	Damage-control surgery + Multiphasic computed tomography

Adapted from Poletti et al.[15], Inaba K et al.[27], Williams JS et al.[28], Kanz KG et al.[29], Wada D et al.[30], Kon-Jin PHPF et al.[31], Rieger M et al.[32], Yeguiayan JM et al.[33], Salim A et al.[34], García-Núñez et al.[35], Sierink JC et al.[36], Tillou A et al.[37], Huber-Wagner S et al.[38], Hutter M et al.[39], Sierink JC et al.[40], Van Vugt R et al.[41], Stengel D et al.[42], Saltzherr TP et al.[43].

resuscitation, extreme diagnostic quickness when using MDCT, in addition to interventional radiology support for damage control.

In view of all this, with liberal use, based on a policy of clinical guidelines and flow charts that allow for whole-body MDCT initial, early use, which would reduce blunt thoraco-abdominopelvic trauma-associated mortality, we conclude with the management of the patient with thoraco-abdominopelvic trauma (Table 3).

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Conflict of interests

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