UNIVERSITY OF MEDICINE AND PHARMACY CRAIOVA

DOCTORAL THESIS

ABSTRACT

IMAGING EVALUATION OF THORACIC INJURIES IN POLYTRAUMA PATIENTS

SCIENTIFIC COORDINATOR:
PROF. DR. ANDREI BONDARI

GRADUAND:
DANIELA STAN

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INTRODUCTION

Trauma is a major concern for health systems all over the world and probably one of the most severe problems developed states must confront, as trauma is one of the main death causes in individuals over 40 years old, which reaches every year a number over 800,000 deaths in Europe and in the U.S.A. 39 deaths / 100,000 inhabitants.

Following the experience of several countries (the U.S., Canada, France, the Great Britanie, Norway, the Netherlands, Japan etc.) and due to the critical situation of the ambulance traditional system in Romania, in 1990 in Târgu-Mureș was established the first SMURD service (Serviciul Mobil de Urgență, Reanimare și Descarcerare – Emergency Mobile Service for Resuscitation and Extrication). At present this service has been extended to important centers all over the country, while in Bucharest, Târgu-Mureș and Iași it works together with the Aviation Special Unit of MIRA (Ministry of Interior and Administration).

Over the past years, due to the greater accessibility of the multi-slice CT units has ensured more accurate and detailed patient data by means of a fast, whole body scan, followed by the image postprocessing with extended possibilities of MPR, MIP, VR, 3D reconstruction. This new technology has reestablished a new role and place of radiography and sonography in major traumas evaluation.

CHAPTER I

1. CHEST TRAUMA

Thoracic trauma is associated with a high morbidity and mortality, after the head and spinal injuries. Vehicle accidents are the main cause of these injuries, with a 60-80% percent, followed by accidental falls with a 10-17% percent, violence and explosions. About 33% of all thoracic traumas need hospitalization. Global mortality in trauma is estimated at about 10%, out of which thoracic traumas count for 25% of the deaths directly and for other 25% indirectly.

The mechanisms of injury of the blunt thoracic trauma:
- rapid acceleration/deceleration
- important chest compression
- force action of a sudden and significant impact.

2. STAGES OF THE THORACIC TRAUMA EVALUATION

Primary survey must be performed using the „Advanced trauma and life support (ATLS)” protocol, in order to identify life threatening injuries:
1. Airway obstruction and traumatic asphyxia
2. Tension Pneumothorax
3. Massive hemothorax
4. Open Pneumothorax
5. Flail Chest
6. Cardiac tamponade
Secondary survey is multidisciplinary evaluation to identify potential life threatening injuries:

1. Pulmonary contusion
2. Myocardial contusion
3. Traumatic aortic rupture
4. Diaphragmatic rupture
5. Esophageal rupture
6. Superior vena cava and other thoracic veins lesions
7. Spinal injuries

CHAPTER II – THORAX ANATOMY

The Thorax consists of:

a) chest wall
b) chest cavity, with its internal organs.

a) The chest wall’s components are:

- bones
- muscles
- soft tissues and mammary gland.

The bones are: rib cage, sternum and thoracic spine.

Thoracic muscles include intercostal muscles and a series of muscles which support the thoracic wall.

The diaphragm is a musculofibrous, arch-shaped structure, which separates the thoracic and abdominal cavities.

b) The chest cavity is divided into two pleural cavities with the lungs and the mediastinum and its organs.

The internal organs of the thorax are: heart, lungs and pleura, thymus, aorta and its branches, pulmonary arteries, pulmonary veins, superior vena cava, inferior vena cava, trachea and main bronchi, nerves, azygos and hemiazygos venous systems, lymphatic structures.

CHAPTER III – IMAGING EVALUATION METHODS IN THORACIC TRAUMA INJURIES

The imaging methods used after clinical evaluation are:

1. Radiography
2. Ultrasonography
3. Computed Tomography (CT)
4. Angiography
5. Magnetic Resonance (MRI)
CHAPTER IV – THORACIC TRAUMA IN CHILDREN

Thoracic trauma is the second cause of traumatic mortality in children over 1 year old, after the head injuries. Most of them are blunt thoracic injuries (80-90%), especially after car accidents; penetrant injuries after gunshot and body wound are increasing in teenagers.

Thoracic trauma contributes significantly in infant mortality, especially when is associated to multisystemic lesions. Clinical and imagistic evaluation must be focused on diagnosis of the life threatening and potential life threatening injuries, with important impact in morbidity and mortality.

SPECIAL PART

CHAPTER V – THESIS OBJECTIVE AND WORKING CONDITIONS

This work presents a prospective imaging study of the traumatic thoracic lesions, from September 2008 until December 2010 in the Clinical Emergency Hospital Bucharest (SCUB), performed on a group of 1824 polytrauma patients. The study has several objectives:

1. Presenting the algorithm of imagistic investigations used in SCUB in polytrauma patients.
2. Presenting imagistic the protocols (radiographic, ultrasonographic, CT and MRI examinations) in polytrauma patients.
3. Evaluation of the chest trauma incidence in polytrauma patients and their association to extrathoracic lesions.
4. Incidence of different thoracic injuries.
5. Presenting several imagistic aspects of the traumatic thoracic lesions.
6. Imaging methods accuracy according to the of the hospital’s equipments.
7. Presenting several difficulties occurred during the imaging evaluation activity and suggestions for improvements.

CHAPTER VI – MATERIALS AND METHODS

The study group was consist of all the polytrauma patients presented in the Emergency Department (UPU) of the SCUB during September 2008 - December 2010. The group counted 1824 patients, divided into two categories:

I. polytrauma patients presenting extrathoracic injuries only;
II. polytrauma patients presenting both thoracic and extrathoracic injuries;

Patients with suspected thoracic injuries, after the initial clinical evaluation and imaging examination consisted of chest X-ray and FAST protocol ultrasonography, were additionally CT and MRI-evaluated. Patients with extrathoracic lesions underwent standard chest X-ray and abdominal ultrasonography only, for a general screening.

All imaging examinations have been performed with the existing equipments in the SCUB.
CHAPTER VII – STUDY RESULTS

1. Presentation of imaging algorithm in polytrauma patients used in SCUB

The polytrauma patient imaging evaluation is performed in several steps, strictly related to the clinical evaluation and the hemodynamic stability. Any change in vital parameters during the evaluation may lead either to changes in the imaging protocol, or to a re-evaluation of the lesions.

I – Hemodynamically unstable patients, after undergoing a fast clinical evaluation, must undergo an imaging screening - ultrasonographic and chest X-ray, of the life threatening lesions. Ultrasound examination is performed using FAST protocol, in the UPU department for all patients.

II - Hemodynamically stable patients: after a multidisciplinary clinical evaluation, all the patients had abdominal ultrasound to identify hemothorax, hemoperitoneum and hemopericardium (as of recently, pneumothorax as well), followed by a radiographic examination which consists of standard radiographs. A complete imaging evaluation is necessary, using additional methods-CT, MRI, angiography, if there is ultrasound or radiographic suspicion of traumatic injuries.

2. Presentation of the imaging protocols, radiographic, ultrasound, CT and MRI in trauma patients

I. Radiographic protocol
   - radiographs are performed using the fix units in the special areas of the UPU department or using a mobile unit
   - patients are usually examined in supine position, avoiding their mobilization until excluding the possibility of spine injuries
   - cables, electrodes and other monitoring devices must be removed from the X-ray field, if it is possible, as well as clothes which may artifact the images
   - in case the patient is not lying directly on the X-ray table, it is advisable to be lying on a plastic or metal-free transport board
   - in order to perform radiographic evaluation, the following examinations must be performed:
     - frontal chest X-ray
     - lateral X-ray (in sternal fracture suspicion, in hemodynamically stable patients)
     - thoracic spine radiographs (frontal and lateral).

II. Ultrasound protocol
   - must be performed for all the polytrauma patients, hemodynamically stable or unstable
   - the FAST (Focused Assessment with Sonography for Trauma) protocol must be used.

III. CT examination protocol:
   Thorax CT examination is a part of the thoraco-abdominal or thoraco-abdomino-pelvic evaluation. Must be performed with iv contrast, only, using a debit injection- 2 ml/sec, with a 40-50 seconds delay acquisition, 5 mm collimation, 1.5 pitch and 3 mm reconstructions; the
scan is performed starting from the superior thoracic aperture down to sacroiliac junction or, in case of pelvic injuries, down to the ischiadic tuberosities.

If there are radiographic or CT findings for spine fracture, and the patient is hemodynamically unstable, a targeted CT scan of the affected vertebral bodies is recommended, also including adjacent unaffected vertebral bodies. Scan must be performed in supine-head first position, starting with a lateral survey, followed by a 1 mm – 1.25 mm section width acquisition (in case there are many affected vertebral bodies, a 1.5 mm to 2.5 mm collimation can be used), with 1-1.5 mm reconstruction in bone (kernel sharp 60-spine) and soft tissue (kernel 20-spine) window. Post processing data provides MPR and 3D reformations.

**IV. MRI examination protocol for spinal injuries:**

Examination must be performed without contrast administration, in supine head-first position and permanently cardio respiratory monitored, after the removal of all metallic or MRI-incompatible devices.

The following acquisitions may be obtained: sag T1SE, sag T2SE, sag T2FFE, sag STIR, axial T2, sag FLAIR. If the injury is localized above the T7 level, the examination must be performed as to include the cervical spine; if the injury is below this level the examination must include the lumbosacral segment.

3. Evaluation of the chest trauma incidence in polytrauma patients and their association to extrathoracic lesions

   **I. Sex distribution** of the 1824 patients was: 502 women (27.52%) and 1322 men (72.48%), aged between 4 - 94 years old, with a median age of 40.82 years old.

   **II. Age distribution of all polytrauma patients**
   - 1-20 years: 255 patients (13.90%)
   - 21-30 years: 385 patients (21.10%)
   - 31-40 years: 330 patients (18.09%)
   - 41-50 years: 295 patients (16.17%)
   - over 50 years: 560 patients (30.74%)

   **III. Injury regional distribution**
   The 1824 patients have counted 2905 lesion locations, divided as it follows:
   - 1106 (38.08%) head injuries
   - 582 (20.04%) chest injuries (including patients with thoracic spine and thoracolumbar junction fracture)
   - 295 (10.15%) abdominal lesions
   - 167 (5.74%) pelvic injuries
   - 648 (22.30%) extremities injuries
   - 107 (3.68%) spine fractures, with different localization than thoracic spine and thoracic-lumbar junction.

   **IV. Distribution by number location**
   - 368 (20.18%) patients with two lesion locations
   - 705 (38.65%) patients with three lesion locations
   - 618 (33.88%) patients with four lesion locations
   - 133 (7.29%) patients with more than four lesion locations.
V. Age distribution of the thoracic trauma patients

- 1-20 years: 49 patients (8.2%)
- 21-30 years: 116 patients (19.93%)
- 31-40 years: 149 patients (25.60%)
- 41-50 years: 127 patients (21.82%)
- over 50 years: 141 patients (24.23%)

4. Incidence of different thoracic injuries

582 polytrauma patients had one or more thoracic injuries, counting 1575 lesions, divided as it follows:

<table>
<thead>
<tr>
<th>Division by thoracic lesion type</th>
<th>No. of lesions</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rib fractures</td>
<td>409</td>
<td>25.96%</td>
</tr>
<tr>
<td>Sternal fracture</td>
<td>17</td>
<td>1.08%</td>
</tr>
<tr>
<td>Lung contusions</td>
<td>276</td>
<td>17.52%</td>
</tr>
<tr>
<td>Pulmonary dilacerations, hematoma</td>
<td>104</td>
<td>6.60%</td>
</tr>
<tr>
<td>Cardiac contusion</td>
<td>28</td>
<td>1.77%</td>
</tr>
<tr>
<td>Hemopericardium</td>
<td>23</td>
<td>1.46%</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>317</td>
<td>20.13%</td>
</tr>
<tr>
<td>Hemothorax</td>
<td>342</td>
<td>21.71%</td>
</tr>
<tr>
<td>Diaphragm rupture</td>
<td>4</td>
<td>0.89%</td>
</tr>
<tr>
<td>Tracheal/bronchial rupture</td>
<td>3</td>
<td>0.19%</td>
</tr>
<tr>
<td>Esophagus rupture</td>
<td>3</td>
<td>0.19%</td>
</tr>
<tr>
<td>Traumatic aortic rupture</td>
<td>8</td>
<td>0.51%</td>
</tr>
<tr>
<td>Vertebro-medullary trauma</td>
<td>31</td>
<td>1.97%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1575</strong></td>
<td><strong>100.00</strong></td>
</tr>
</tbody>
</table>

31.90% of the polytrauma patients had one or more chest injuries. They had also many intra- and extrathoracic lesions associations which usually needed an radiographic, ultrasound or CT examination, and, in the case of vertebro-medullary lesions, a MRI examination was also performed.

Out of 582 patients with thoracic lesions, in 135 cases the CT examination included the thoracic base and superior abdomen or the abdomen and pelvis. These patients had minor or no respiratory clinical symptomatology or no significant radiographic and ultrasound findings, like solitary rib fractures or small hemothorax, the main lesions being localized intra-abdominally (or the patients were the FAST ultrasonography positive for hemoperitoneum).

5. Presentation of several imaging aspects of the traumatic thoracic lesions

With respect to the lesion severity there are:

I. **Life threatening lesions** – rule out during the primary survey;

II. **Potential life threatening lesions** – evaluated during the secondary survey.
CHAPTER VIII – CONCLUSIONS

The conclusions of the study are systematised starting from the obtained data and according them with the literature informations:

I. Conclusions regarding the epidemiology of the thoracic trauma
1. Thoracic trauma is an important cause for morbidity and second cause for mortality after cranial lesions.
2. Although only almost 30% of the patients with thoracic injuries need hospitalization and only 4-15% had penetrating injuries, they represent an important death factor for almost 50% of the lethal trauma. More than a quarter of the mortality rate is associated to penetrant injuries.
3. The age of the victims from car accidents is decreasing, representing the second cause for death, after infectious diseases in children over 4 years old.
4. Due to the major improvements in trauma assistance systems, more and more severe cases reach the hospitals and are potentially curable.

II. Conclusions regarding the types of thoracic posttraumatic lesions
1. Less than 10% of the blunt thoracic traumas and between 15-30% of the penetrating lesions need surgery; the majority of the technical procedures used for the treatment are non-surgical.
2. Immediate death is mainly determined by cardiac and main vessel ruptures, while premature death is determined by cardiac tamponade, obstruction of the airways and tracheal/bronchial ruptures.
3. In children, mortality rate is 2% in isolated thoracic traumas, 6% when associated with another lesion, 58% when associated with two extrathoracic lesions and almost 100% in case of three or more injuries.
4. In adult patients, most frequent causes for posttraumatic asphyxia are foreign bodies aspiration and tracheal/bronchial ruptures.
5. Occult pneumothorax, despite of no clinical and radiological expression, must be signaled, especially in patients ventilated with positive pressure, when it may lead to tension pneumothorax.
6. Pulmonary contusion is the most frequent posttraumatic lung parenchyma lesion, both in children and adults.
7. Esophagus rupture is rare among blunt traumas, but frequent among penetrant traumas; when the most affected area is the cervical segment.
8. Diaphragm rupture is 3 times more frequent on the left side in blunt traumas and has a similar left-right incidence in penetrant traumas.

III. Conclusions regarding imaging methods used for the diagnose of the thorax posttraumatic injuries
A. Radiography
1. It is the most frequently used imaging method, both in initial evaluation and in monitoring the evolution of the lesions and treatment or therapeutic methods efficiency.
2. It has a low sensitivity in diagnosis different types of lesions, such as: aortic, tracheal/bronchial, esophagus and diaphragm ruptures; undervalued pulmonary lung
parenchyma lesions, cannot differentiate between their types and some vertebral fractures (especially lesions of the cervical-thoracic junction and of the superior thoracic, above T5-T6 level).

3. Chest X-ray should rather be considered screening examination than a diagnosis, thus, the radiographic findings of some lesions must be confirmed by means of other methods.

**B. Ultrasonography**

1. It is a fast and very accessible method, which may be performed on hemodynamically stable and unstable patients, sometime during the resuscitation maneuvers.
2. It has a high sensitivity in hemothorax (including the radiologically occult), hemopericardium (including cardiac tamponade), hemoperitoneum diagnosis but it is low for retroperitoneal, mesenteric and intraabdominal cavitary organs lesions and undervalued parenchymal organs lacerations.
3. If there is a significant soft tissue emphysema, the examination is useless.
4. Transthoracic echocardiography is fast and useful method for the diagnose of the hemopericardium, valvular lesions and parietal kinetic disorders.
5. Transesophageal echocardiography may be considered an alternative for the CT examination (when impossible to be performed) in diagnosing the aortic rupture.

**C. CT examination**

1. Due to the development of spiral and multislice-CT units, and the increasing accessibility of this new technology, CT examinations are widely used in trauma evaluation.
2. Along with the technical and image resolution improving, examination time has been reduced, the examination areas have been extended (it may include the whole body – „whole-body CT”).
3. This method has high sensitivity in diagnosis and differentiating traumatic aortic lesions, and is useful in patients triage for of their future surgical or non-surgical.
4. CT exam reduced the number of patients who need an angiography
5. CT can differentiate causes for mediastinal enlargement, different types of lung parenchymal lesions and their quantification (possible with modern equipments), the diagnosis of occult pneumothorax, the evaluation of spine injuries.
6. It is useful in follow up the traumatic lesions evolution and their complications.

**D. MRI examination**

1. It has limited indication in acute settings of traumatic injuries.
2. It is accessible only for hemodynamically stable patients, who do not present absolute contraindications for a MRI examination: pacemaker, other electronic devices or implants, orthopaedic devices MRI incompliant, metallic foreign bodies.
3. It can differentiate myocardial contusion from myocardial infarction.
4. It has a major indication in vertebro-medullary injuries evaluation.

**F. Angiography**

1. Due to progress of the CT equipments and the improvement of the examination protocols, the angiography has been partly replaced in the evaluation of the vascular lesions.
2. It is still considered as the „gold-standard” method for vascular injuries evaluation.
3. The angiography must be especially performed in equivocal CT findings or there is a mediastinal hematoma without evidence of aortic parietal injuries, which may highlight fine lesions.

4. Angiography is both a diagnose method, which can establish the presence of a certain lesions, their location, extent, active bleeding and a therapeutic method with the possibility of a rapid and efficient hemostasis using minimum invasive methods (embolisation, using vascular stents or stent-grafts).

IV. Conclusions regarding the study group

1. Most of the patients were 21-50 years old - 392 (67.35%), which represent the active, trauma-prone population, with an important social and economical impact due to the problems raised by this type of morbidity.

2. Hemodynamically unstable patients have been initially evaluated by ultrasonography and chest X-ray followed by emergency surgical or Intensive Care treatment.

3. Traumatic pleural effusions were significantly important; chest X-ray undervalued pneumothorax in 28 cases, with a discrepancy between respiratory failure and the radiographic findings, CT examination presenting large pneumothorax in 17 cases, and in 11 cases tension pneumothorax.

4. Of the 342 cases with hemothorax, ultrasonography was positive in 285 (83.33%); out of the other 57 undiagnosed cases, 29 presented significant soft tissue emphysema with no possibility for evaluation; 17 were overweight patients or with ascended diaphragms with no visualization of the posterior costodiaphragmatic recesses and 13 presented superior limbs fractures in special devices with no accessibility to the base of the thorax.

5. The CT examination has additionally diagnosed, compared to chest X-ray, 39 cases of occult pneumothorax, 44 small hemopneumothorax and 32 cases of hemothorax.

6. Pulmonary contusion was the most frequent parenchymal lesion - 276 cases. Chest X-ray has low sensitivity, of only 20% (55 cases) and undervalued pulmonary lesions in all the cases. In case of patients with high discrepancy between respiratory failure and X-ray aspect, CT examination is recommended, as it may find a significant pneumothorax or extended posttraumatic pulmonary lesions.

7. Most of injuries were parenchymal and pleural with frequent association to extrathoracic lesions and complex lesional combinations (25.18% of the patients (103 of 409) have rib fractures associated to other intraabdominal organs lesions).

8. 19.07% (78 patients of 409) had flail chest.

9. 10 of 17 patients with sternal fractures have associated other severe injuries: cardiac contusion, hemopericardium, aortic rupture, mediastinal hematoma with effraction of internal mammary artery.

10. Regarding the vertebro-medullary injuries, major lesions, with/without neurological symptoms, are often undervalued by the radiographs, requiring a CT and MRI examination.

11. Out of the 8 cases of aortic rupture in the study group, the chest X-ray was positive in one patient for mediastinal hemathoma; MPR, MIP, 3D CT reconstructions were very important for a complete evaluation of the injury and associated lesions.
SELECTIVE BIBLIOGRAPHY


KEY WORDS

Computed tomography, magnetic resonance imaging, radiography, angiography, echography, Focused Assessment with Sonography for Trauma – FAST, chest injuries, blunt thoracic trauma, tracheobronchial injury, pulmonary contusions, lung injuries, vascular lesions, thoracolumbar fractures, skeletal trauma, spinal injuries, traumatic aortic injury, mediastinal hematoma, esophageal trauma, cardiac tamponade, deep sulcus sign, pneumothorax, hemothorax.
CURRICULUM VITAE

Name: Daniela Stan

Studies and specializations:

- Graduate of Military Medical Institute “Carol Davila”, Bucharest, 1993
- Competence in General Echography, Bucharest, 2001
- Competence in Computed Tomography, Craiova, 2006
- Competence in Magnetic Resonance, Craiova, 2007
- Osteoarticular Imaging Course, Craiova, 2002
- RSNA Course, Târgu Mureș, 2004
- Ultrasonography in Emergencies, Euroschool Course, Oradea, 2006
- Emergency Radiology International Symposium, Bucharest, 2006
- Imagerie non-invasive du thorax International Course, Iași, 2006
- Senology Course, Bucharest, 2007

Actually employee:

Emergency Clinical Hospital “Floreasca” Bucharest

Publishing: