Computed tomography in trauma patients

Why Trauma CT
CT techniques
Research in trauma radiology

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Why CT in trauma patients?

• Trauma is leading cause of death for men and women < age of 45.
• Substantial economic impact on health care systems
  – Over one-third of all ED visits
• MDCT attributes to prompt and accurate diagnosis and treatment
  – Increasing non-operative management
• CT is superior to clinical evaluation and diagnostic peritoneal lavage for diagnosing important abdominal injuries
Advantages og MDCT in trauma

– Fast
  • Patient transport
  • Image acquisition
  • Image reconstruction
  • Image reading

– Evaluation of all body tissues and all body regions
– Highly specific and accurate (npp ~ 97%)
Down-sides

- Sensitivity 80-90%
- Ionizing radiation
- Use of nephrotoxic contrast
- May delay immediate treatment
CT techniques

• Robust, general protocol for majority of trauma patients!
  – IV contrast mandatory (100-170 mL, total of 35-60 g iodine
  – Dual syringe power injector for 30-70 ml saline chasing bolus
  – Delay of 15 sec for arterial imaging and 70-95 sec for solid organ imaging
  – Single or spit bolus
  – Arterial phase, solid organ phase, renal collecting phase
  – No oral contrast as default
Group 1

• Majority of patients with low or intermediate risk of injuries to several organ systems

• Protocol 1 (segmental scanning)
  – Non-contrast head and cervical spine
  – (Chest CT with arterial phase scanning)
  – Abdomino-pelvic CT in portal venous phase
  – In case of injuries to the kidneys or collecting system: late scan
Protocol 1

• Advantages
  – Less radiation for abdominal organs
  – Optimal depiction of larger vessel in chest

• Disadvantages
  – Still double radiation in the diaphragmatic region
  – Motion artifacts when arterial and portal venous phase are fused on reformats
Examples
Serious injuries expected

• Indicators:
  – Fall from large height
  – Hemodynamically abnormal
  – Crush injuries to the chest or pelvis
  – Free fluid on FAST
  – Pericardial fluid on FAST
  – Pelvic fracture with dislocation > 1 cm posterior
  – Large hematoma on Chest x-ray

→ Higher probability of injury to large vessels and of ongoing bleeding
→ Tailored protocol for vessel injury mandatory
Protocol 2 segmental scan

1. Non-enhanced CT of head and cervical spine

2. Arms up: Arterial scan from Circulus Willisi to upper thigh

3. Portovenous scan from above the diaphragm to symphysis

4. In case of injuries to the kidneys or collecting system: Late scan
Protocol 2 Serious injured patient

• Advantages
  – Excellent depiction of aortic injuries and other larger vessel injuries
  – Excellent depiction of parenchymal injuries to the abdomen and pelvis
  – Possibility to differ between arterial injuries and non-arterial injuries in the pelvis
    • Different treatment approaches

• Disadvantages
  – Higher radiation dose for sensitive organs
  – More noise at neck vessels
  – More series – time consuming
Research in trauma radiology

- Many challenges
  - Patient agreement usually not possible prior to examination and not always afterwards
  - Retrospective studies easier to perform
  - Quality assurance studies
  - Trauma registry OUS – application
  - Ethical committee – application
  - Purely methodological studies with unidentified patient material
  - PACS – how to store de-identified images
Examples of recent studies on CT protocols

• 2009 Geneve, Switzerland and Baltimore, Maryland, USA: Single Pass Continuous Whole-Body 16-MDCT protocol

• 2008 Berne, Switzerland:

• Whole-body computed tomography for multiple traumas using a triphasic injection protocol

• 2012 Tel Aviv, Israel:
Revised protocol for whole-body CT for multi-trauma patients applying triphasic injection followed by a single-pass scan on a 64-MDCT
Evaluation of a Single-Pass Continuous Whole-Body 16-MDCT Protocol for Patients with Polytrauma

OBJECTIVE. The purpose of this study was to compare a conventional multiregional MDCT protocol with two continuous single-pass whole-body MDCT protocols in imaging of patients with polytrauma.

SUBJECTS AND METHODS. Ninety patients with polytrauma underwent whole-body 16-MDCT with a conventional \( n = 30 \) or one of two single-pass \( n = 60 \) protocols. The conventional protocol included unenhanced scans of the head and cervical spine and contrast-enhanced helical scans (140 mL, 4 mL/s, 300 mg I/mL) of the thorax and abdomen. The single-pass protocols consisted of unenhanced scans of the head followed by one-sweep acquisition from the circle of Willis through the pubic symphysis with a biphasic (150 mL, 6 and 4 mL/s, 300 mg I/mL) or monophasic (110 mL, 4 mL/s, 400 mg I/mL) injection. Acquisition times and interval delays between head, chest, and abdominal scans were recorded. Contrast enhancement was measured in the aortic arch, liver, spleen, and kidney. Diagnostic image quality in the same areas was assessed on a 4-point scale.
Whole body protocols:

Conventional protocol

- Head, spine (Face)
- 140 ml, 4ml/s
- Automatic triggering at aortic arch
- **Delay** between chest and abdomen

Single pass

- Head
- Automatic triggering
- Subgroup 1
  - Biphasic injection
    - 90 ml, 6ml/s, immediately followed by 60 ml, 4ml/s
- Subgroup 2
  - Monophasic injection
    - 110 ml, 4ml/s
- One single pass from vertex to pelvis
Main results

• Single pass continuous whole-body scanning leads to
  – Reduced acquisition time by 42%
  – Higher interscan delay in group A due to higher reconstruction time and scan programming
  – No difference in image quality
    • Especially important for cervical spine with arms up vs. arms down

• Drawbacks:
  – Time spent in CT room not measured
  – No information on radiation
Whole-body computed tomography for multiple traumas using a triphasic injection protocol

- 50 patients
  - 25 arms up, 25 arms down
- 16 slice MDCT, Care dose for optimizing mAS
- 70 ml, 3 ml/s, followed by low-flow-rate 0.1 ml/s, followed by 75ml, 4ml/s
- Compared to similar non-trauma patient cohorts that were sampled from the same CT system with 4 standard protocols
  - For pulmonary embolism (CTA pulmonary mains tem)
  - standard late-arterial-phase chest protocol (CT chest)
  - Abdominal exams in the portovenous phase (mainly tumor staging and exclusion of abscess) and
  - whole-body computed angiography(CTA) (mainly for aneurysms, bleeding and planning of interventions).
- Visual assessments scale (1-5)
Whole-body computed tomography for multiple traumas using a triphasic injection protocol

Scanning protocol:

- Scanning starts after 50 s.
- Chest run aprox. 15 sec.
- Abdominal pelvic aprox. 20 sec.

23.3 sec  
70ml, 3ml/s

8sec  
1ml, 0.1ml/s

23.3 sec  
70ml, 3ml/s
Main results:

– Better visualization of arterial vessels than in the other standard protocols except for CTA

– Better visualization of parenchymal organs compared to standard abdominal CT (probably due to more contrast volume in trauma protocols)

– Arms down cause significant reduced image quality of portal vein and IVC
Example, laceration in spleen
Revised protocol for whole-body CT for multi-trauma patients applying triphasic injection followed by a single-pass scan on a 64-MDCT

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b Trauma Unit, Sheba Medical Center, Tel Hashomer, Israel
c Sackler Faculty of Medicine, Tel Aviv University, Tel Aviv, Israel
Conventional protocol diagram

- 90 ml contrast (4 ml/s) + 30 ml Saline
- Hands Elevation

(a)

Revised protocol diagram

- 80 ml contrast (3 ml/s)
- Hands Elevation
- 50 ml contrast (4 ml/s) + 30 ml Saline

(b)
<table>
<thead>
<tr>
<th>SITE</th>
<th>Conventional protocol (HU)</th>
<th>Revised protocol (HU)</th>
<th>Abdominal CTA (HU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ascending aorta</td>
<td>285 ± 10.5</td>
<td>217 ± 15.84</td>
<td>-</td>
</tr>
<tr>
<td>Descending aorta</td>
<td>278.3 ± 9.6</td>
<td>213.7 ± 16.6</td>
<td>-</td>
</tr>
<tr>
<td>Aorta above kidneys</td>
<td>125.6 ± 3.15</td>
<td>208.8 ± 15</td>
<td>322.5 ± 7.4</td>
</tr>
<tr>
<td>Aorta below kidneys</td>
<td>132.4 ± 3.3</td>
<td>207.4 ± 15</td>
<td>334.7 ± 9.7</td>
</tr>
<tr>
<td>Common Iliac arteries</td>
<td>127.2 ± 3.5</td>
<td>209.2 ± 15.3</td>
<td>328.8 ± 12.8</td>
</tr>
<tr>
<td>IVC</td>
<td>111.5 ± 2.7</td>
<td>147.6 ± 6</td>
<td>62.6 ± 4.1</td>
</tr>
<tr>
<td>Liver</td>
<td>96.2 ± 2.2</td>
<td>109.9 ± 5.6</td>
<td>56.6 ± 1.8</td>
</tr>
<tr>
<td>Spleen</td>
<td>94.9 ± 1.7</td>
<td>131.2 ± 6.1</td>
<td>88.9 ± 2.8</td>
</tr>
<tr>
<td>Right kidney</td>
<td>151 ± 5</td>
<td>205 ± 9.6</td>
<td>116.2 ± 5.3</td>
</tr>
<tr>
<td>Left kidney</td>
<td>154.1 ± 4.8</td>
<td>204.1 ± 9.4</td>
<td>116.2 ± 9.3</td>
</tr>
</tbody>
</table>

(a) | (b)
Radiation issues

Table 4
Mean effective radiation dose in selected series.

<table>
<thead>
<tr>
<th>Series in scan</th>
<th>Conventional protocol (mSv)</th>
<th>Revised protocol (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest angiography</td>
<td>7.3 ± 2.3</td>
<td></td>
</tr>
<tr>
<td>Porto-venous abdomen and pelvis</td>
<td>10.9 ± 6.1</td>
<td></td>
</tr>
<tr>
<td>Chest abdomen and pelvis</td>
<td>12.4 ± 4.4</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>18.2 ± 8.2</td>
<td>12.4 ± 4.4*</td>
</tr>
</tbody>
</table>

* $p = 0.0054$. 
**Triple Injection Protocol, Ullevål**

<table>
<thead>
<tr>
<th>Step</th>
<th>Time</th>
<th>Volume</th>
<th>Flow Rate</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <strong>Bolus after head scan</strong></td>
<td>20s</td>
<td>20 ml contrast + 50 ml saline</td>
<td>5 ml/s</td>
<td>20 ml contrast + 50 ml saline</td>
</tr>
<tr>
<td>2. <strong>20s, 9s, 32s</strong></td>
<td>100 ml contrast 5 ml/s</td>
<td>100 ml saline 5 ml/s</td>
<td>Pause</td>
<td>100 ml contrast 5 ml/s</td>
</tr>
<tr>
<td>3. <strong>11s, 11s</strong></td>
<td>55 ml contrast 5 ml/s</td>
<td>55 ml saline 6 ml/sek</td>
<td>Start scanning</td>
<td>55 ml contrast 5 ml/s</td>
</tr>
</tbody>
</table>

**One shot imaging**

1. **collecting system phase**
2. **Parenchymal phase**
3. **Arterial phase**

- 5-15 min delay
- 80-85 s delay
- 15-20 s delay
- Manual start with ROI in aorta
Triple injection protocol

• 46 y/o man, bicycle accident
• GCS 5 Serious head injury with EDH and SDH, contusions
• Orthopedic injuries
• Negativ FAST
• Hemodynamically stable
• 25 y/o man. Fall from snowboard 4m.
• Abdominal pain right upper quadrant
Advantages

• Multiple injection protocols reduce cumulative radiation dosage in polytrauma patients, who are often young
• Less time is needed for additional acquisitions
• Less time for the reporting of these additional images and for communication of potential new diagnoses from late-phase CT studies to the referring physician.
• This saves important time in the first and “golden” hour of patient management
Emergency Room Management of Patients With Blunt Major Trauma: Evaluation of the Multislice Computed Tomography Protocol Exemplified by an Urban Trauma Center

Patrick Weninger, MD, Walter Mauritz, MD, PhD, Peter Fridrich, MD, Ralf Spitaler, MD, Markus Figl, MD, Bernhardt Kern, BME, and Harald Hertz, MD, PhD

- 185 pat. with "pre-MSCT" vs. 185 pat. with MSCT
- No demographic differences

Under the new management algorithm, the patients were transported directly to the MSCT located in the center of the ER. During transport from the helicopter or ambulance to the MSCT the attending anesthesiologist checked oxygen saturation ($\text{Sao}_2$), electrocardiogram (ECG), heart rate (HR), and blood pressure (BP) using a small portable monitor, and oxygen administration or ventilation were continued. All patients were placed on the CT table in supine position with the arms alongside the body. The MSCT was started immediately for patients whose vital signs were within an acceptable range ($\text{Sao}_2 > 90\%$, HR $< 130$ b/min, systolic BP $> 70$ mm Hg). In required fluid therapy before MSCT. Efficacy and sensitivity of diagnostic procedures were significantly higher in “MSCT protocol” patients (Table 4). The full extent of injuries was definitively diagnosed after $12 \pm 9$ minutes in 92.4% of the “MSCT protocol” cohort. In only 76.2% of the “Pre-MSCT protocol” cohort, a definitive diagnosis was possible after $41 \pm 27$ minutes; in 23.8%, the full extent of injuries was not

Weninger 2007, J Trauma
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pre-MSCT Protocol (mean ± SD)</th>
<th>MSCT Protocol (mean ± SD)</th>
<th>(p) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients</td>
<td>185</td>
<td>185</td>
<td></td>
</tr>
<tr>
<td>ER time (min)</td>
<td><strong>104 ± 21</strong></td>
<td><strong>70 ± 17</strong></td>
<td>0.025</td>
</tr>
<tr>
<td>ER-OR (min)</td>
<td><strong>132 ± 93</strong></td>
<td><strong>103 ± 61</strong></td>
<td>0.009</td>
</tr>
<tr>
<td>ER-ICU (min)</td>
<td>202 ± 90</td>
<td>192 ± 100</td>
<td>0.045</td>
</tr>
<tr>
<td>OR-ICU (min)</td>
<td>186 ± 147</td>
<td>159 ± 114</td>
<td>0.038</td>
</tr>
<tr>
<td>Fluid load first 24 h (mL)</td>
<td>4761 ± 2698</td>
<td>5251 ± 3588</td>
<td>n.s.</td>
</tr>
<tr>
<td>Packed red cells (mL)</td>
<td>426 ± 136</td>
<td>453 ± 142</td>
<td>n.s.</td>
</tr>
<tr>
<td>Fluid balance first 24 h (mL)</td>
<td>1766 ± 1954</td>
<td>1791 ± 2165</td>
<td>n.s.</td>
</tr>
<tr>
<td>ICU stay (days)</td>
<td>16.8 ± 18.7</td>
<td>13.6 ± 14.3</td>
<td>0.042</td>
</tr>
<tr>
<td>Ventilation (days)</td>
<td>14.3 ± 15.9</td>
<td>10.9 ± 15.3</td>
<td>0.042</td>
</tr>
<tr>
<td>Total inhospital stay (days)</td>
<td>32.5 ± 33.3</td>
<td>29.0 ± 29.4</td>
<td>0.046</td>
</tr>
<tr>
<td>Hospital mortality rate</td>
<td>0.16</td>
<td>0.17</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

ER, emergency room; OR, operating room; ICU, Intensive Care Unit; SD, standard deviation; n.s., not significant.
Weninger 2007 cont.

• Main results:

   a significant reduction in in-hospital stay in ICU stay and in ventilation days for trauma patients initially scanned with whole-body MSCT

   Significantly lower rate of organ failure
• Four studies, 5470 pat., all non-randomized
• Non difference in overall mortality
• Admission-to-operation time significantly shorter in seriously injured patients (ISS >25), but not in less seriously injured patients
Conventional diagnostic work-out

Advantages:
- Less radiation doses
- Tailored diagnostic flow for each patient
- No violation from the traditional ATLS philosophy

Draw-backs:
- Limited sensitivity
- Redundancy of exam.
- More time consuming
- Negative impact on time to early surgery, hospital stay, ICU stay and organ failure

Whole-body CT in/nearby the ER

Advantages:
- Reduction in hospital stay
- Reduction in IUC stay and ventilation days
- Lower rate of organ failure
- Trend towards earlier neurosurgical intervention
- Reduced time to early surgery
- Increased probability to survival

Draw-backs:
- Impact on mortality unclear
- Higher radiation dose
- Risk of indiscriminate use of WBCT in minor trauma
Summary

Retrospective studies
Collaborate with trauma registry
Compare groups
Design new protocols
Define important and useful parameters
  Time in ..., time to final diagnosis
  Radiation reduction ... visualisation...
What is your gold standard
Good luck!