Severe pelvic injury: Which type of vascular lesions is detected on ante- and post-mortem CT? Does their bleeding reflect a certain fracture constellation?

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Aims and objectives

Pelvic fractures occur in 4%-9.3% of patients with blunt trauma and the prevalence of associated organ injuries ranges from 11% to 20.3 %. [1]. Pelvic haemorrhage is the most serious complication associated with pelvic fractures, and active haemorrhage remains the leading cause of death in polytrauma patients [2]. Life-threatening pelvic haemorrhage may originate from the small vessels running within the fractured bone, the pelvic venous plexus, major pelvic veins and/or iliac arterial branches [1].

In most emergency departments, polytrauma patients are initially evaluated by intravenously (IV) iodinated contrast material-enhanced multidetector computed tomography (MDCT) in order to detect active haemorrhage allowing for immediate patient's management and straightforward therapeutic decisions. The detection of contrast media extravasation on MDCT well corresponds to the site of bleeding seen at following conventional angiography [1]. Furthermore, the early and accurate detection of active bleeding by MDCT may lead to prompt angiographic embolization, which can be lifesaving. Thus, immediate angiography and subsequent trans-catheter embolization are currently accepted as the most effective methods for controlling arterial bleeding resulting from pelvic fractures [1]. In contrast, venous haemorrhage associated with a fracture can only be treated with external fixation in order to restrict space occupying haemorrhage and stabilize the fracture. [3].

The recent development of multi-phase Post-Mortem CT Angiography (MPMCTA) has enabled the detection of vascular lesions in cadavers, in particular present after severe trauma [4]. At present, MPMCTA is mainly performed for legal issues [4].

The intravascular injection of a specific oily contrast media allows for several distinct acquisition phases, including complete vascular filling and vessel perfusion [5]. Thus, MPMCTA seems to provide a more detailed diagnosis than classical autopsy by displaying these structures that are not readily apparent on the latter: First, small vessel injuries may not be evident on a purely morphological examination, and second, certain regions, like the pelvis, are not reviewable in classic autopsies without causing major damage of the corpse. [4]

We were wondering which type of vascular pelvic lesion was predominantly responsible for the active bleeding that was detected by MDCT in these blunt pelvic trauma victims. By including not only polytrauma patients, but also cadavers undergoing MPMCTA, we thought to get the most accurate diagnostic and morphological information. Furthermore, we wanted to know if the anatomical site of the vascular lesions corresponded to a certain, well-defined pattern of pelvic fracture, since both are related to the same kinetics of the underlying trauma.
To the best of our knowledge, our scientific approach with cadavers and acute pelvic trauma patients has not yet been described in the literature.
Methods and materials

Our institutional review board and the local ethical committee had approved our study protocol. We retrospectively included two different cohorts of severe blunt trauma victims referred to our hospital because of acute traffic accident, crush or fall. They all had undergone contrast-medium enhanced MDCT.

Polytrauma patients

After entering the keywords "polytraumatism", "pelvic fracture", "active bleeding" and "acute haemorrhage" in our comprehensive database of examinations reports we retrieved 142 polytrauma patients that had been admitted to our emergency department since 2002. These patients were immediately investigated with intravenously contrast enhanced pelvic CT. We only included patients in whom active contrast medium extravasation of the pelvic vessels was described on examinations reports and that had been treated by angiographic embolization immediately after MDCT. We excluded all patients who did not demonstrate active bleeding, children under 16 years, all the CT performed after surgery or angiographic embolization of pelvic haemorrhage and finally patients with extra-pelvic haemorrhage.

Among 142 patients, we only included these patients who had undergone conventional angiography after CT in order to confirm the vascular lesions detected on CT by angiography. Among these 65 patients we excluded the following 16 patients: Ten patients did not show active haemorrhage on CT at admission, 3 patients had undergone CT at a different hospital without transmission of their images, 2 patients performed CT after treatment (surgical and embolization of pelvic haemorrhage) and finally we excluded one patient with haemorrhage due to anticoagulant therapy without history of pelvic traumatism. In our final cohort, we included 49 patients (15 women, mean age 51.9 years, age range 16-93 years) (Fig. 1).

MDCT data acquisition

Our polytraumatism protocol was performed on a 64-detector row CT machine (Light Speed VCT 64 Pro; GE Healthcare, Milwaukee, Wisconsin, USA). We acquired 1.25/1 mm reconstructed axial slices during arterial phase (25s) centred on the thorax and 2.5/2mm reconstructed axial slices during venous phase (80s) centred on the abdomen and pelvis, after intravenous (IV) injection of the iodinated contrast medium Accupaque®, (Iohexol, 300 mgI/ml; GE Healthcare, volume in milliliters = body weight + 30ml) at a flow rate of 4ml/s (120kV, 300mA, table speed 55m per rotation (0.8s), pitch 1.375). We
used automatic tube current modulation in all 3 axes (SmartmA) as well as the iterative reconstruction algorithm ASIR (40%).

**Cadavers**

Since January 2009, our institute of legal medicine has been performing MPMCTA on cadavers, referred for medicolegal reasons. Based on the institutional written report system we selected all these cadavers admitted after severe blunt trauma (from traffic accident, crush or fall) between January 2009 and February 2014, in whom active pelvic bleeding had been shown by MPMCTA.

We excluded children under 16 years, all PMCTA realized after surgical or radiological treatment of arterial bleeding, and finally all extra-pelvic bleeding.

Among 52 cadavers who demonstrated pelvic haemorrhage, we excluded 7 cases for the following reasons: In 6 of them pelvic haemorrhage were described on radiological report, but not confirmed during our review on workstation and one case was excluded because of an absent arterial phase due to a problem in femoral arterial cannulation. Finally, we included 45 cadavers (15 women, 30 men, mean age 53.1 years, age range 22-87 years). The delay between death and MPMCTA varied from 24 to 72 hours.

**MPMCTA acquisition**

Our cadavers were examined on a 8-detector row CT machine (GE Lightspeed, GE Healthcare, Milwaukee, WI, USA), using a field of view 50 cm, a slice thickness of 1.2mm/0.6mm for the arterial phase, 1.25/1mm for the venous phase, and 2.5mm/2mm for the circulating phase (120kV, 300mA, noise index 15, pitch 1.35mm, rotation time 0.8sec).

For contrast media injection, arterial and venous femoral cannulas were connected to an extracorporeal pomp. Contrast media was composed of paraffin oil (Paraffinum perliquidum) and iodized linseed oil Angiofil® (Fumedica AG, Muri, Switzerland), diluted at 6% (3.5L oil paraffin with 210 ml of Angiofil) [4,6]. The oily paraffin component was necessary to keep the contrast media in the vascular compartment of the corpse and to avoid extravasation into the surrounding interstitial tissue. [4,6]. Four different acquisitions were performed: a native, arterial and venous phase followed by a circulating phase. We started the arterial acquisition at 1min30sec after injecting 1,200 ml of contrast-agent mixture at a flow rate of 800 ml/min and the venous acquisition at 2min15sec after injecting 1,800 ml of contrast-agent mixture at a flow rate of 800ml/min. The circulating phase was acquired at 70-80 sec after reinjecting 500 ml of contrast media at a flow rate of 200 ml/min.
Image analysis

In consensus, the two principal investigators (M.H, S.S) reviewed all the MDCT-images of the polytrauma patients and the MPMCTA-images of the cadavers on the electronical workstation (Carestream Solution). They exactly described the type of contrast media extravasation (arterial versus venous) and the precise site of the vascular lesion. The pattern and type of pelvic fracture, if any, according to the TILE classification were recorded. According to the Tile classification, category A corresponds to a stable pelvic ring fracture (anterior or posterior ring fracture without articular disjunction), category B to a partial unstable ring fracture (symphysis or sacroiliac disjunction) and category C to an unstable pelvic fracture (symphysis and sacroiliac disjunction or open-book fracture) (Table 1).

Table 1 shows the arteries and veins we included in our image analysis. We analysed the right and left vascular pelvic bleedings separately, as well as the right and left pelvic fractures.

Statistical analysis

The presence or absence of vascular lesions or pelvic fractures was measured as categorical numbers and percentages.

In order to determine the relation between the site of any vascular lesion and the type of fracture we used the Fisher test. The Chi-square test was used to evaluate the relation between any vascular lesion and the severity of pelvic ring fracture (Tile classification). Statistical analyses were performed by using JMP 10 statistical package (SAS Institute, Inc, Cary, NC) and all differences were considered significant for a p value of < 0.05.
Fig. 1: Organigram of patients’ inclusion process

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Table 1 Analysis of the different pelvic vessels and pelvic bones

| Pelvic vessels<sup>a</sup> | common iliac; external iliac; internal iliac  
| Posterior branches: iliolumbar; lateral sacral; superior gluteal  
| Anterior branches: obturator; inferior gluteal; internal pudendal [1] |
| Pelvic bones | iliac wing; iliopubic branch; ischiopubic branch; acetabulum; sacral wing |
| Articulations | sacroiliac joints; symphysis |
| Tile Classification | stable pelvic ring fracture (Tile A); partial unstable pelvic ring fracture (Tile B); unstable pelvic ring fracture (Tile C) |

<sup>a</sup> arteries and veins

Table 1

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Results

Patients’ findings

According to our inclusion criteria, all 49 patients demonstrated at least one hemorrhage on MDCT. Our image analysis only revealed arterial lesions without any venous lesion.

Forty-two of the 49 patients had pelvic fractures (85%). Twenty-four (49%) patients had a stable pelvic ring fracture corresponding to type Tile A, 8 patients (16%) presented a partial unstable pelvic fractures according to Tile B, and 10 patients (20%) an unstable pelvic fracture Tile C.

Five arterial bleeding sites significantly correlated with a pelvic fracture site. (Table 2, Fig. 2, Fig. 3).

Among all the 49 patients, the three most often injured arteries were 22 superior gluteal artery bleeding sites, 21 bleedings from the sacral lateral artery and 20 from the obturator artery. In decreasing order of frequency, we detected 43 sacral wing fractures, 38 ischiopubic fractures, 34 iliopubic, 15 acetabulum and 14 iliac wing fractures. We found 15 symphysis disjunctions and 14 sacroiliac disjunctions.

We did not found a significant correlation between the number of arterial bleeding sites and the severity of pelvic ring fracture (Tile classification) (p >0.05).

Cadavers’ findings

According to the inclusion criteria all our 45 cadavers presented at least one pelvic bleeding site. 35 (78%) cadavers presented at least one arterial pelvic bleeding site without venous bleeding. Unlike our patients group, 13 (29%) cadavers presented at least one venous pelvic bleeding site without arterial bleeding, and 25 (56%) cadavers showed at least one arterial and one venous pelvic bleeding. Forty-one cadavers had pelvic fractures (91%).

Among all 49 cadavers, the three most often injured arteries were the obturator (n=26), iliolombar (n=22) and lateral sacral (n=15) artery. The most often injured venous lesions were the obturator vein (n=13), lateral sacral (n=12) and external iliac veins (n=11).
In decreasing order of frequency, we found 38 sacral wing fractures, 38 ischiopubic fractures, 35 iliopubic, 31 acetabulum and 21 iliac wing fractures, as well as 18 sacroiliac disjunctions and 14 symphysis disjunctions.

The severity of pelvic ring fractures was distributed as follows: In 21 (47%) cadavers we found stable pelvic ring fractures corresponding to type Tile A, six out of them (13%) presented partial unstable pelvic fractures Tile B, and 14 (31%) unstable pelvic fractures, Tile C.

Seven arterial bleeding sites significantly correlated with 7 sites of pelvic fractures, and 4 venous bleeding sites significantly correlated with 4 pelvic fracture sites. (Table 3, Fig. 4, Fig. 5, Fig. 6, Fig. 7, Fig. 8, Fig. 9). The numbers of arterial lesions were significantly associated with the severity of pelvic ring fracture according to TILE classifications (p=0.012), unlike the number of venous bleeding sites (p=0.34)
Table 2: Polytrauma patients – Correlation between arterial bleeding site and pelvic fracture

<table>
<thead>
<tr>
<th>pelvic vessels</th>
<th>bone/articulation</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>left lateral sacral artery</td>
<td>left iliac wing</td>
<td>0.0002</td>
</tr>
<tr>
<td>left gluteal superior artery</td>
<td>left sacral wing</td>
<td>0.0099</td>
</tr>
<tr>
<td>left gluteal superior artery</td>
<td>left sacroiliac disjonction</td>
<td>0.0151</td>
</tr>
<tr>
<td>left pudendal artery</td>
<td>left ischiopubic branch</td>
<td>0.0081</td>
</tr>
<tr>
<td>right obturator artery</td>
<td>symphysis disjonction</td>
<td>0.0067</td>
</tr>
</tbody>
</table>

Fig. 2: Axial contrast-enhanced MDCT-image shows a right pudendal artery bleeding associated with an ischiopubic branch fracture in a 52 year-old man occurring after a motor vehicle accident

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Fig. 3: Same patient as in Fig. 2. The immediately performed arterial angiography confirms the active bleeding from the right pudendal artery followed by an embolization procedure.

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Table 3

Table 3 Cadavers – Correlation between bleeding site and pelvic fracture

<table>
<thead>
<tr>
<th>pelvic vessels</th>
<th>bone/articulation</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right inferior gluteal artery</td>
<td>Right iliac wing</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Left iliolumbar vein</td>
<td>Left sacroiliac disjonction</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Right iliolumbar artery</td>
<td>Right iliac wing</td>
<td>0.02</td>
</tr>
<tr>
<td>Bilateral lateral sacral artery</td>
<td>sacral wing</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Right lateral sacral vein</td>
<td>Right sacral wing</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Right superior gluteal artery</td>
<td>Right iliac wing</td>
<td>0.006</td>
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<tr>
<td>Right superior gluteal artery</td>
<td>Right sacral wing</td>
<td>0.03</td>
</tr>
<tr>
<td>Bilateral obturator artery</td>
<td>iliopubic branch</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Bilateral obturator artery</td>
<td>acetabulum</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Bilateral obturator vein</td>
<td>iliopubic branch</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Bilateral obturator vein</td>
<td>acetabulum</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>arterial lesions (n)</td>
<td>severity of fractures (Tile A,B,C)</td>
<td>0.012</td>
</tr>
<tr>
<td>veinous lesions (n)</td>
<td>severity of fractures (Tile A,B,C)</td>
<td>0.34*</td>
</tr>
</tbody>
</table>

Fig. 4: A 67-year-old male cadaver after fatal fall injury. The axial MPMCTA-image (arterial phase) shows right pudendal artery bleeding (arrow) associated with bilateral ischiopubic rami fractures.

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Fig. 5: Same cadaver as in Fig. 4. The axial MPMCTA-image (circulating phase) demonstrates bleeding of the iliac branches of the right iliolumbar artery (arrow) and left superior gluteal artery (arrowhead) associated with bilateral iliac wing fractures (not shown).

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Fig. 6: 30-year-old male cadaver after fatal motor vehicle accident. Axial MPMCTA image during arterial phase shows left lateral sacral artery bleeding (short arrow), left iliac wing (long arrow) and left sacral wing fractures (not shown). Note the cannula in the right external iliac vein (arrowhead).

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Fig. 7: Same cadaver as in Fig.6, the axial image during venous phase demonstrates an important extravasation of contrast-agent mixture from the superior gluteal vein (long arrow) and from its superficial branch (short arrow). Note the contrast media filling of the right external iliac vein (arrowhead).

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**Fig. 8:** 52-year-old man cadaver after fatal motor vehicle accident. The axial MPMCTA image during venous phase shows severe blunt pelvic trauma with multiple arterial and venous bleeding associated with bilateral iliac wing fractures and bilateral sacroiliac disjunctions. Note right superior gluteal vein bleeding (long arrow) and bilateral lateral sacral arterial (short arrow) and venous (arrowhead) bleeding.

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Fig. 9: Coronal reformatted MPMCTA-image during circulating phase in the same patient as in Fig. 8, shows right superior gluteal vein bleeding (long arrow) and left iliolumbar vein bleeding (short arrow) associated with left sacroiliac disjunction and left iliac wing fracture.
Conclusion

Pelvic fractures are more often associated with nearby bleeding from arteries than veins, thus reflecting the severity of injury.

In our study, venous bleeding was only visible on MPMCTA performed in cadavers, unlike on MDCT performed in polytrauma patients.

This difference could be related to the different intravenous injection conditions and acquisition parameters.
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