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Original article

Usefulness of 3D computed tomography in surgical planning of pelvic fractures

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ABSTRACT. ***Background:*** **To determine the utility of 3D computed tomography for the preoperative planning of pelvic rim fractures assessing possible changes in fracture classification as well as in the surgical indication itself.** ***Methods:*** **We retrospectively reviewed patients who had undergone surgery for complex pelvic fractures during a 15-month period. The mechanism of injury was recorded and the availability of a multi-slice spiral volumetric CT scan was requested as a preoperative study.** ***Results:*** **Ten cases (58%) were pelvic rim fractures and 7 were acetabular fractures. The mean ISS was 23.82 (9-50), and 82.3% of cases were severe traumas (ISS >16). After the CT scan was obtained, the initial classification of the fracture was changed in four cases (23.5%), without any changes in the surgical indication. An artifact was detected in the volumetric reconstruction but it did not limit the surgeon's interpretation.** ***Conclusion:*** **Tridimensional CT-based modeling is very helpful in the surgical planning of pelvic fractures and is a complement of the plain X-rays.**

Key words: fracture, hip, pelvis, preoperative care, tomography, classification, evaluation, surgery.

RESUMEN. ***Antecedentes:*** **Estudiar la utilidad de la tomografía computarizada tridimensional en la planificación preoperatoria de las fracturas del anillo pélvico, valorando posibles cambios en la clasificación de la fractura así como en la propia indicación quirúrgica.** ***Métodos:*** **Revisamos retrospectivamente a pacientes intervenidos de fractura compleja de pelvis en un espacio de tiempo de 15 meses. El mecanismo de lesión y que se haya hecho tomografía computarizada (TC) volumétrico helicoidal multicorte como estudio preoperatorio.** ***Resultados:*** **En 10 casos (58%) se trató de fracturas del anillo pélvico y en 7 casos de fracturas acetabulares. El ISS medio fue de 23.82 (9-50), siendo traumatismos graves el 82.3% de los casos (ISS > 16). Tras el estudio por tomografía se cambió la clasificación inicial de la fractura en cuatro casos (23.5%) sin registrarse cambios en la indicación quirúrgica. Tuvimos un artefacto en la reconstrucción volumétrica que no limitó la interpretación por parte del cirujano.** ***Conclusión:*** **El modelado tridimensional a partir de TC sirve de gran ayuda en la planificación quirúrgica de la pelvis fracturada resultando ser complementario a la radiografía simple.**

Palabras clave: fractura, cadera, pelvis, cuidados preoperatorios, tomografía, clasificación, evaluación, cirugía.

Level of evidence: IV (Act Ortop Mex, 2010)

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Introduction

Historically, fractures of the pelvic rim have posed problems to the surgeon in terms of diagnosis, treatment, evolution and prognosis. The physician faces a fracture that not only endangers the functionality but the patient's life as well.[1,2] On the one hand, we have the vital prognosis of the multi trauma patient we see in our setting, according to recently published series a 15% incidence of pelvic rim fractures. With the need for urgent intervention in case of hemodynamic instability and the damage control criteria, the physician's medical and surgical ability must be clear, quick and following a protocol.[2,3] Likewise, and in a second look procedure, we find the need to restitute the pelvic rim complex in an anatomical manner in order to satisfy biomechanical solicitations and avoid an eventual functional limitation or the clinical presence of pain.[4,5]

For all of this, emphasis should be made on an accurate diagnosis of the pelvic injury, therefore, it is essential to have the support of good X-ray images and profound knowledge of anatomical relationships, as well as a good preoperative planning.[6,7]

With the new technological advances, both in helical Computed Tomography and 3D multi-slice devices like volumetric processing software for images, we are able to guarantee better evaluation of injuries. Thus, with the possibility of having an accurate 3D model of the pelvis we will study, we get rid of the uncertainty we could have had before the surgery and we are also limiting the need to improvise intra-operatively.[8,9] Computer assisted orthopedic surgery (CAOS) has been designed as a technology application based on computers to assist the surgeon in increasing the precision of his surgical performance. Visualization of 3D models allows for a global view of the entire pelvic rim, as well as a detailed view of each element damaged.[10] From the field of virtual surgery, it is possible to plan the intervention steps one by one on a model that is identical to the patient's osteo-articular structure.

The display possibilities that most work stations have now, have allowed us to obtain spectacular results by dominating three dimensional (3D) representations. When it comes to the three dimensional reconstruction of the osteomuscular system, the pelvis turns out to be one of the most complex modeling elements *(Figure 1)*. The volumetric representation of the pelvic cavity, as well as the individualized subtraction of elements, allows for a thorough study of injuries in this region.[11]

Material and methods

We collected retrospective information between October 2006 and December 2007 in the Trauma and Orthopedics Surgery Service of the *Hospital General Universitario Gregorio Marañón* in Madrid, of patients with pelvic injuries considering the following variables: demographic data, type of accident, care in the Resuscitation Unit, radiological examination performed and moment when it was performed, time to CAT scan and three dimensional reconstruction, ISS, fracture classification, time to surgical intervention, type of intervention (reduction and percutaneous fixation, Matta® pelvic fixation system, Phannen® system, AO system, I-S screws) and duration of the procedure.

We used the Injury Severity Score (ISS) as the trauma prognosis index. An ISS 16 is considered severe trauma that predicts a mortality of at least 10%. In terms of the radiological examination, the following were the possible variables collected: simple X-ray taken in the ER, X-ray in three views, inlet and outlet X rays and CAT scan in the ER.

Before each surgery, all patients underwent a full radiological examination that included, a 3D reconstruction performed with a 3D (helical volumetric) 16 channel multislice CAT scanner (Philips Brilliance CT®).

The classification of the fracture was performed first after the simple X-ray, being reviewed on two occasions: once the CAT scan was performed it was then done with 3D reconstruction *(Figure 2)*. In order to classify the fractures that could affect the pelvic rim, we used the Tile classification (based on concepts of stability, anatomopathology and direction of forces applied), while if the fracture was a socket fracture, the AO classification was used. Once the fracture pattern was defined and was classified appropriately, the therapeutic technique was decided. For the surgical planning we considered the approach and the fixation to be performed. After the three dimensional reconstruction, any changes made to the preoperative plan was recorded.

The statistical analysis used was descriptive, using the SPSS® v.16 software tool.

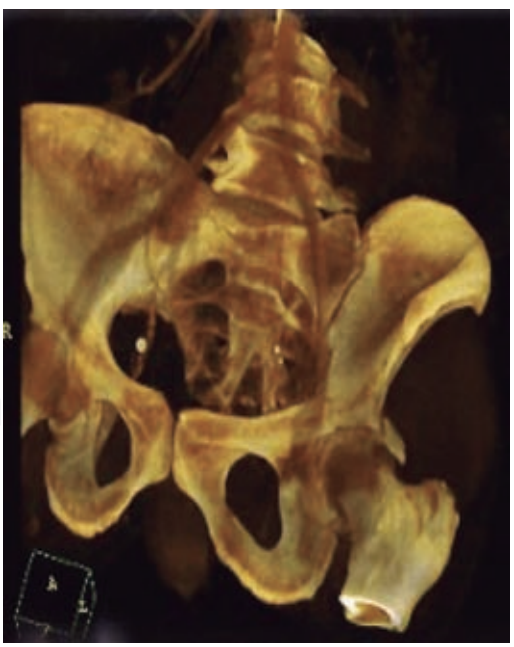

Figure 1. Volumetric reconstruction that allows for virtual navigation through bone and vascular structures of the pelvis.

Results

17 patients underwent surgery for pelvic fractures without any significant medical-surgical background. The sample was made up of 11 men and 6 women with an average age of 44.7 years (20-73).

In 12 cases, high energy trauma corresponded to automobile accidents. Three to occupational accidents (two cases were falls from a height of over five meters and one case was crushing caused by a collapse). In one patient the source of the fracture was a casual low energy accident (this was a 73 year old male who suffered a fracture in a pathological site with osteoporosis). And one case was a suicide attempt, a fall from a third floor. 47.1% of patients were transferred from another hospital once the clinical stability was assessed (hemodynamic and neurological).

When patients were seen in the ER a CAT scan examination was performed in 58% of them. Those who did not undergo an emergency radiological examination (basically because the patient's clinical condition was unstable), the mean time until the examination was done was 3,56 days. All patients had an emergency simple AP X-ray of the pelvis; 17% had 3 view X-rays and no inlet or outlet tests were performed *(Table 1)*.

The calculated ISS produced a mean value of 23.82 (9-50). According to this scale we can determine that there was severe trauma in 82.3% of cases, since 14 patients had an ISS greater than 16, considered after the trauma is established as severe (with a mortality rate greater than 10%).

In five cases (29.4%) emergency external fixation was placed due to the patient's hemodynamic instability. Four cases were type B2 fractures from Tile and one B3 type. The fixation method chosen was two supra-acetabular screws implanted percutaneously (entry through the antero-inferior iliac spine towards the sacroiliac joint, with 20° of caudal inclination and 20° of lateral inclination) under radiological control and general anesthesia, fixed to a carbon bar to complete the mounting *(Figure 3)*. The mean time of the surgical procedure was 20 minutes.

Regarding the classification of pelvic rim fractures, once we defined them in the three types and corresponding subtypes of Tile through a simple AP X-ray, we again reviewed the imaging pattern through the CAT scans and lastly, through the 3D reconstruction. For that, the pelvic rim was divided into posterior and anterior arch taking the acetabular area as a reference.

In 10 cases (58%) there were pelvic rim fractures and 7 cases of acetabular fractures *(Table 2)*. In the cases of type A3 pelvic fractures (sacro-coccyx without affecting the pelvic rim) and B1 the classification did not change when performing the tomography or the 3D reconstruction. As was expected, the greatest difficulty emerged when evaluating posterior elements and when differentiating types B and C. The CAT scan was essential for that since it allowed for

Table 1. Radiological examinations performed.

Radiological examination	
AP X-ray	100%
X-ray in three views (AP, alar and obturator)	17%
in-out X-ray	0%
Emergency CAT scan	58%
3D reconstruction	100%

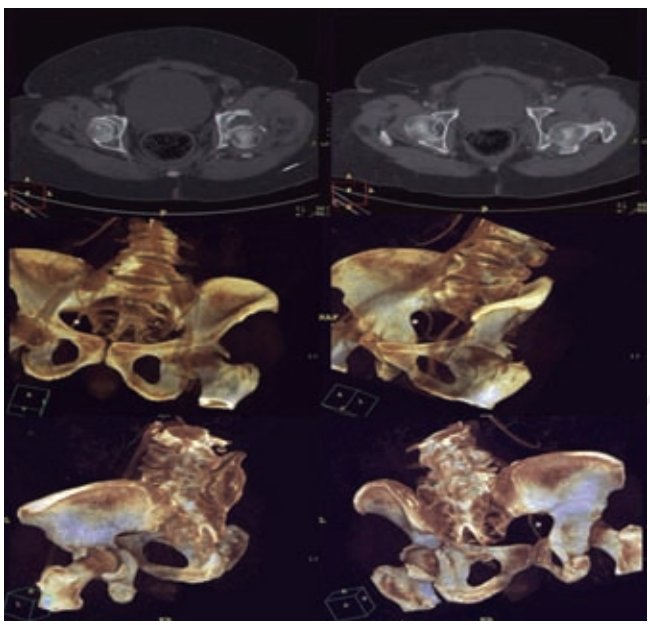

Figure 2. 3D reconstruction sequence of a type B1 acetabular fracture (cross sectional + posterior wall) in a 35 year old woman. 3D model used for surgical planning.

Figure 3. A preliminary reconstruction can be obtained instantly giving us information of the regional vascular bundle. Very useful for placement of external supra-acetabular nails (arrows) safely.

the diagnosis of a single case of a B3 fracture of the series (evaluating the severity of sacroiliac involvement) and the four cases of type C fractures (where rotational and vertical instability was evident in the physical examination and the axial views allowed for a direct classification).

Specifically, there were two cases where the initial classification after the simple X-ray changed when assessing the CAT scan: one case of a fracture classified as A2 with fracture of the left iliopubic and ischiopubic rami, was finally defined as B2.1 when observing an ipsilateral sacrum compression fracture in the axial slices of the CAT scan; in the other case, the bilateral fracture «open book» (B3) initially diagnosed in the AP pelvic X-ray was defined as C3 due to the complete disruption of the posterior arch found in the CAT scan *(Table 3)*.

With regards to acetabular fractures, in one case there was a cross sectional fracture trace that was not observed in the simple X-ray, which allowed to change the classification from A1 (posterior wall) to B1 (Cross + posterior wall). In another patient, an A2 type fracture of the socket (posterior spine affected in X rays) was classified as an A2 pelvic fracture of Tile since there was no evidence of acetabular involvement in the CAT scan, showing only fracture of the rami *(Figure 4)*.

The surgical technique chosen was planned in all patients using the three dimensional model obtained with the reconstruction of CAT scan images, whether obtained upon admission into the ER or specifically when the 3D reconstruction was performed.

The posterior route was used in vertically unstable fractures (1 C1, 2 C2, 1 C3), in order to place I-S screws (17.6%). The ilioinguinal route was used to place pelvic plates (Matta® pelvic system, Stryker, in 58.8% of patients) mainly in cases of «open book» fractures (B3). Likewise, AO synthesis was used in 35.3%. Surgery was percutaneous in 11.7% of cases.

The mean duration of the surgical intervention was 210 minutes.

Eight patients were admitted directly into the intensive care unit where they were clinically stabilized, with a mean stay of 3,29 days. Half of them underwent surgery upon admission to said unit. The mean time until surgical intervention was 8,82 days. The mean stay in the Trauma department was 25 days, and the mean hospital stay was 28,3 days.

We did not perform emergency fixations with open reduction in any patients.

Discussion

The introduction of new surgical planning concepts entails the exploration of new techniques, leaving behind traditional methods.[12,13] Making surgery virtual in its planning becomes difficult to accept. Nevertheless, virtual models allow for surgical development before the intervention which can avoid improvisation, at the same time it allows for its continuous use in the surgical procedure itself applying operative location and navigation technology (calculation of entry routes, trajectories and implant lengths in the surgical intervention itself, etc.). Observing all fragments of the fracture from different views may help when it comes to choosing the surgical approach (anterior, posterior, percutaneous), for example in the surgical approach of type «T» cross sectional fractures of the acetabulum[14,15] *(Figure 5)*.

Currently there are commercial software packages for any work station that perform display functions of 3D struc-

Table 2. Series of pelvic and acetabular fractures intervened.

Types of pelvic fractures intervened	
Pelvic Rim. *Tile*	Acetabulum. *AO*
1 A3	2 Posterior wall (A1)
2 B1	2 Anterior spine (A3)
2 B2	2 Cross sectional + post. wall (B1)
1 B3	1 «T» Fracture (B2)
1 C1	
2 C2	
1 C3	
N = 10	N = 7

Table 3. Change in the initial classification after CAT scan.

Change in the classification.	
Simple X-r	CAT
Pelvic rim: A2	Pelvic rim : B2.1
Pelvic rim : B3	Pelvic rim : C3
Acetabulum: A2	Pelvic rim : A2

Figure 4. Diagnosis of a posterior spine fracture in a simple X-ray. In the CAT scan and the 3D reconstruction we can not see acetabular involvement. It is classified as an A2 pelvic fracture.

tures automatically, mainly for synthetic image applications.[16] In our center we have used multi-slice volumetric reconstruction through axial tomography images since it is a quick and versatile system.

Apart from not changing the fracture classification in this work by the 3D reconstruction, the studies performed up to date with virtual models taken from CT images have proven clear advantages in understanding fractures from a mechanical and anatomical perspective.[17] Under the same token, Seal García B, et al. have studied the structural behavior of different bone elements through finite models, among which is the pelvis. This author specifically has studied the behavior of the pelvic rim, the acetabulum and different internal and external fixation systems in models that simulate rotationally and/or vertically unstable fractures («open book»).[18]

Letournel said that «an acetabular fracture should only be treated once its full compression is reached», and it could be thanks to the three dimensional perspective of the reconstructions that said premise is will be overcome.

In our series, the mean time to surgical intervention was 8,82 days. In this sense, the time sequence described by Guerardo E, et al. is fulfilled, in it he defines that the best window period to perform final programmed surgery is between days 5 and 10 after trauma; while on day 1 the objective is to «save the life», recommending what these authors call «a second look» on day 2 after the trauma has occurred.[19] Since there is no control group, we cannot say that the mean duration of the surgical intervention (210 minutes) is decreased thanks to the complete surgical planning.

No patient underwent an emergency open reduction fixation surgery to control hemodynamic instability. Renaldo N, et al. describe the impossibility to control retroperitoneal bleeding when said space is open, a more appropriate attitude of *early total care* and go on to defend damage control management.[20]

With regards to the radiological examination, none of the views allow for full evaluation of the pelvic rim; nevertheless, assessment of a trauma patient should start, as happened in our series, always with the AP view. This is useful in identifying most of the pelvic injuries and in the asymmetry of the pelvic limbs length, but in these it is difficult to evaluate the degree of displacement.[8,14]

Conventional axial tomography is a very useful additional test in the evaluation of posterior elements, mainly the sacroiliac joint. In fact, axial views are still the ones that define sacral fractures better, as has happened in some cases picked up in this work.[21] 3D reconstruction provides useful data for better understanding of injuries and for three dimensional collection of information together with the three views.

As to the assessment of trauma severity, and in terms of morbidity and mortality, the use of the ISS is evident as a predictor of prognosis. In this study the value of said index did not coincide with the final surgical decision, although it was useful to decide a damage control surgery in the first place. Many studies have confirmed the usefulness both of the AIS as well as of the ISS in the description of injury severity, in the prediction of mortality, duration of the hospital stay, inability produced, functional recovery and long term psychological repercussions in patients who have suffered automobile accidents.[22]

Generally, the 3D model reproduces the findings that the surgeon will find intra-operatively. However, the images obtained through three dimensional reconstructions may present changes if the technique is not the right one, even hiding injuries that would be identified in conventional axial tomography. A known problem is the error made by the software when interpreting attenuation coefficients of the image. In our study we had an example of that *(Figure 6)*.

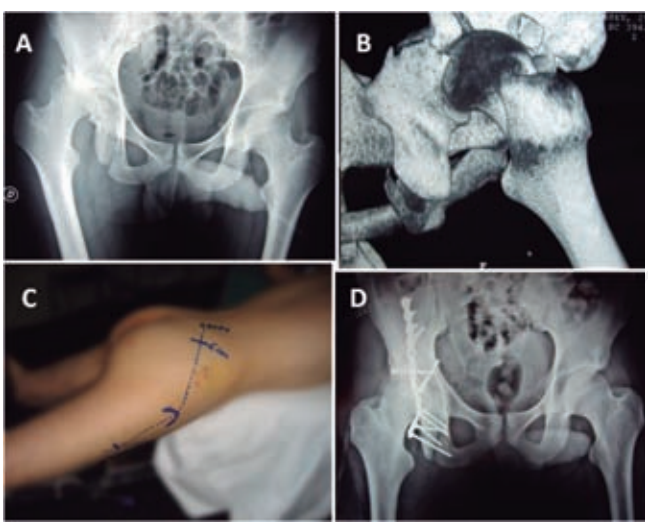

Figura 5. A: AP X-ray of a "T" B2 type AO right socket fracture. **B:** 3D Reconstruction. **C:** Posterolateral approach route. **D:** Postsurgical control.

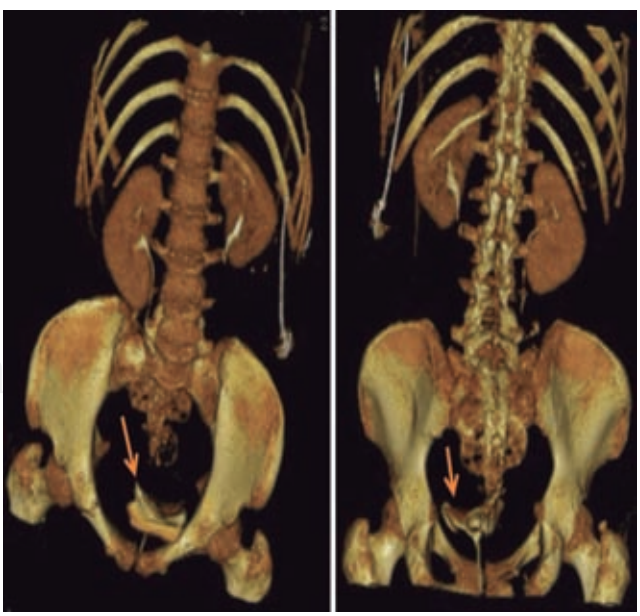

Figure 6. Radiological artifact (arrows): the bladder contrast is recognized when volume subtraction is performed as bone structure.

In spite of the theoretical advantages of computed tomography, which can make of surgery an easy and precise procedure, it is necessary to justify the significant investment and implementation costs of the IT equipment, and on the other hand, surgeons have to become familiar with their use. We should consider the 3D computed tomography as a complement to the simple X-ray in the surgical planning of a fractured pelvis. We believe it is an advanced medical tool in the technological framework but it still hasn't reached good practical development.

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