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SCIENTIFIC ARTICLE

Femoral head subchondral impaction on CT: what does it mean in patients with acetabular fracture?

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Abstract

Objective To evaluate the prevalence of isolated femoral head impactions associated with acetabular fractures and to assess whether impactions may be predictive of the development of delayed major complications requiring total hip arthroplasty.

Materials and methods A total of 128 consecutive adult patients with acetabular fracture and no femoral head fracture were included. Admission CTs were re-interpreted for the presence of hip dislocation and femoral head impactions. Radiological and clinical reports were reviewed in patients in whom conservative management of the femoral head was attempted, to determine if total hip arthroplasty was eventually required over a 48-month follow-up period. Univariate and multivariate analyses were performed to assess whether impaction is an independent predictor of failure of conservative management.

Results Impaction was found in 40% of all patients (51 out of 128), in 58% of those with dislocation (19 out of 33), and in 34% of those without dislocation (32 out of 95; $p < 0.05$). One hundred and five patients underwent conservative management of the femoral head; 12.5% of them (13 out of 105) eventually required total hip arthroplasty. An impaction was present in 77% of the latter (10 out of 13) and in 33% of patients with successful conservative management (30 out of 92; $p = 0.0042$). At multivariate analysis, impaction and dislocation were significantly and independently associated with a higher risk for delayed total hip arthroplasty (odds ratio of 4.8 and 4.0 respectively).

Conclusion Femoral head impactions are frequently seen on CT of patients with acetabular fractures; they are independent predictive factors for the need for delayed total hip arthroplasty. They should be systematically mentioned in the CT report.

Keywords Acetabular fracture · CT · Impaction · Femoral head

Introduction

Acetabular fractures represent 3% of fractures in traumatology with an incidence of about 3 out of 100,000 inhabitants per year [1]. They result from high-energy trauma, mainly road accidents and high falls [2], but also from lower energy trauma in elderly people in whom the incidence increases [3]. The Letournel and Judet classification (Fig. 1) [4] defines acetabular fractures types [5] and guides treatment, which remains challenging and requires individualized management by experienced teams [6].

Femoral head fractures are frequently found in association with hip dislocations and are the consequence of impaction against the edges of the acetabulum; they have been reported in 6–15% of hip dislocations [7].

Less frequently, femoral head fractures occur without dislocation, by colliding with the acetabulum cavity; they have been reported as a factor of poor prognosis with a subsequent need for total hip arthroplasty (THA) [8].

Femoral cortical or osteochondral impactions are articular cartilage and subchondral bone notches that have been reported in association with hip dislocation and considered as the equivalent to the Hill–Sachs lesion of the humeral head [9]. These

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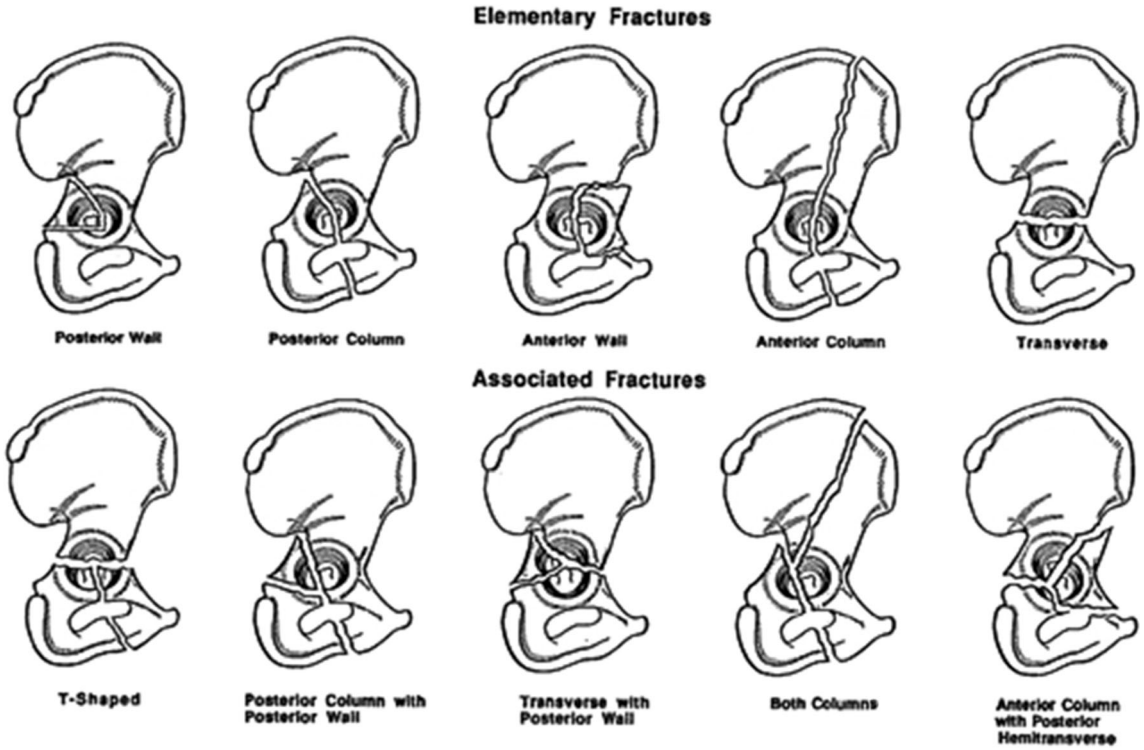

Fig. 1 Acetabular fracture classification by Letournel and Judet. Reprinted with permission [4]

notches are often not recognizable on plain radiographs and may be subtle on CT [9]. The location of the femoral head impaction has been shown to be related to the type of hip dislocation (anterior or posterior) and may be the sole indicator of dislocation in the case of instantaneous relocation of the hip [10].

However, no femoral head fracture classification has ever taken into consideration the presence of focal cortical impactions (subchondral notches) [6, 8–11]. Furthermore, no series has specifically focused on the potential interest of depicting femoral head impactions, when isolated (without other femoral head injury), in patients with acetabular fracture, with regard to the development of delayed femoral head-related complications after initial treatment.

This study is aimed at evaluating the prevalence of isolated femoral head impactions associated with acetabular fractures and at assessing whether impactions may be predictive of the development of delayed major complications requiring THA, such as osteonecrosis, severe osteoarthritis, heterotopic ossifications, and pseudarthrosis.

Materials and methods

Patients' population

A retrospective study was conducted on patients admitted with acetabular fracture to our level I trauma center over a 14-year period (1 January 2000 to 28 February 2014). A computer search was performed on the radiological report database using the keywords "acetabular fracture," and 138 patients were identified.

Inclusion criteria consisted in patients with acetabular fracture who underwent a CT at admission and in whom no concomitant fracture of the femoral head or neck, based on Pipkin classification [11], was reported. Thus, 10 of the 138 patients who had a Pipkin IV type fracture (7.3%) were excluded from further analysis.

Overall, 128 patients formed our study population.

This retrospective study was approved by our local ethics committee (CER 05-239); informed consent was waived.

Radiological and medical reports review

The following parameters were recorded from the radiological reports and the patients' clinical file:

1. Age, gender, cause of trauma, reported as road accident, fall, and others.
2. Presence of a femoral head impaction mentioned by the radiologist on the admission CT report and/or by the orthopedist during acetabular surgery.
3. Type of initial acetabular treatment (open surgery, external fixation, conservative management). For surgical treatment, an acetabular reduction was considered satisfactory when a residual displacement was less than 2 mm, and unsatisfactory when it was more than 2 mm, according to Matta [8].

4. THA immediately placed at admission. An immediate THA was defined as a THA that was placed within 1 month after trauma (no attempt of conservative management of the femoral head).
5. Development of delayed complications in a 1- to 48-month delay after admission, in the group of patients who underwent a conservative management at the femoral head (in whom a decision on THA placement was not taken within the first month after admission) and whether a THA was eventually required.

For point 5, the following detailed information were drawn from the post-therapeutic functional evolution, which was assessed by regular surgical consultations and radiographs of the operated hip and was systematically reported in the medical file:

- Osteonecrosis of the femoral head
- Severe osteoarthritis, defined as grade 3 on the Tönnis classification [12]
- Heterotopic ossification (class 1 to 4 according to the Brooker classification) [13]
- Pseudarthrosis (non-union of the acetabular bone fragments)

A failure of conservative management of the femoral head was defined as a THA that was placed later than 1 month after trauma.

The need, or not, for a THA within a period of 48 months after admission was considered the reference standard for failure or success of the conservative management of the femoral head respectively.

Exclusion criteria

Patients in whom a 48-month follow-up could not be obtained, because they died or left the city, and who did not undergo THA during the available observational period, were excluded from the study group.

CT reinterpretation

Admission CTs were re-interpreted by two board-certified radiologists with at least 10 years' experience in reading emergency trauma CTs.

The radiologists reviewed the images together, by consensus, not independently. This decision was based on a preliminary analysis by consensus of a limited amount of cases (n = 30), which revealed that the identification and the location of the impactions on the smooth femoral head was an easy task that was not subject to divergent opinion between readers.

Both radiologists were blinded to the patients' demographics and follow-up medical and radiological information.

The following CT features were reported:

- Acetabular fracture type, sorted as wall, transverse, and column fracture according to the Letournel and Judet classification [5].
- Severity of the acetabular fracture, defined as low, when the displacement of the bone fragments was less than 3 mm, moderate when the displacement was ≥3 mm and severe when it was comminuted.
- Presence of a dislocation, defined as a displacement of the femoral head that required a manual or a surgical reduction.
- Isolated femoral head impaction defined as localized subchondral bone notches without associated femoral head or neck fracture. The length of the impaction was measured in the maximal dimension (millimeters). An impaction was considered small if it was less than 10 mm and large if it was 10 mm or more. The location of the impaction was reported, with regard to the fovea, on a coronal plane (superior, inferior or at the fovea) and on an axial plane (anterior, posterior, lateral or medial).

Statistical analysis

The data were recorded and analyzed using a dedicated statistical software pack (IBM®SPSS® Statistics 22, IBM Corporation, USA). Univariate analyses were performed on all patients who met our inclusion criteria at admission, to seek associations between impactions and hip dislocations and between impactions and the type of acetabular fracture. Univariate analyses were performed on the group of patients who underwent a conservative management of the femoral head, and in whom a 48-month period follow-up was available, to seek imaging parameters that might be associated with delayed complications. A multivariate analysis was performed on the parameters that were significant at univariate analysis. A p value <0.05 was considered statistically significant.

Technical parameters

Most pelvic CTs were performed within the framework of a standard total body i.v. enhanced CT polytrauma protocol, using two different scanners:

1. From 2000 to 2010, a 16-row Philips MX 8000 scanner (Philips Medical Systems, Best, The Netherlands), tube potential 120 kV, automated tube current modulation, pitch 1.35, 16 × 1.5 mm collimation, acquisition, and reconstruction thickness 3-3 mm
2. Since 2010, a 64-row GE 750 HD CT (General Electric Company, Milwaukee, WI, USA), tube potential 120 kV, automated tube current modulation, pitch 0.9, 64 × 1.25 mm collimation, acquisition thickness 2-1 mm,

reconstruction slice thickness 2-1 mm, using 40% adaptive statistical iterative reconstruction.

Results

Radiological and medical report review

Patient population

The 128 patients who formed our study population included 96 men (75%) and 32 women (25%), with a mean age of 47 years (range 16–87 years). Seventy (55%) were admitted after a motor vehicle accident, 50 (39%) after a fall, 8 (6%) had another mechanism (associated with professional accidents).

A surgical open osteosynthesis of the acetabulum was performed in 121 of these patients (95%), a minimally invasive approach (external fixation) was performed in 3 (2%), and non-operative management was obtained in 4 (3%). The mean time from admission to acetabular surgery was 7.7 days (median 6 days). The quality of the acetabular reduction was considered satisfactory in 125 patients (98%) and unsatisfactory in 3 (2%).

Immediate THA

In 11 of the 128 patients who had severe preexisting hip osteoarthritis or developed protrusive periarticular ossification soon after admission (9%), the orthopedic surgeon decided to immediately perform a THA in addition to the acetabulum osteosynthesis, during the initial surgery ($n = 5$) or in a delayed fashion ($n = 6$), but still within 1 month after admission. Seven (64%) of them had a transverse fracture of the acetabulum, 2 (18%) a column fracture, and 2 (18%) a wall fracture. The mean age of these 11 patients was 62 years (median 62); 10 (91%) of them were older than 50. At imaging, 8 (73%) of them had a femoral head impaction, 4 (36%) a dislocation, and 8 (73%) had either an impaction or a dislocation.

Femoral head impactions

An impaction on the femoral head was mentioned in the admission CT report in 5 of the 128 patients and in the surgical report of 4 patients; one of them was mentioned in both reports.

Conservative management of the femoral head and 48-month follow-up

In 117 (91%) patients the orthopedist did not intend to place a THA after acetabular treatment and thus attempted a conservative management of the femoral head.

Of these 117 patients, 12 were definitively lost to follow-up (transfer to another country or death due to severe injuries during hospitalization).

A 48-month follow-up was obtained in the 105 remaining patients.

During the follow-up period, 3 (3%) of the 105 patients developed an osteonecrosis of the femoral head, 7 (7%) a severe osteoarthritis, 9 (9%) heterotopic ossification of class 1 to 4, and 4 (4%) a pseudarthrosis.

Total hip arthroplasty was eventually required in 13 (13%) of the 105 patients in whom a clinical follow-up was available, within a 48-month delay after trauma (range 2–40 months, mean = 13, median = 9). Nine (69%) of the 13 patients who underwent a THA were over 50 years old, compared with 40 (43%) of the 92 patients who did not ($p = 0.1$).

The reasons for THA placement in these patients were: development of severe osteoarthritis ($n = 7$), osteonecrosis of the femoral head ($n = 3$), pseudarthrosis ($n = 2$), and severe heterotopic ossification ($n = 1$). Therefore, THA was justified in 11 (85%) of these 13 patients by a direct pathological femoral head condition and by an acetabulum-related condition in 2 (15%).

Of the 3 patients in whom the acetabular fracture reduction was considered unsatisfactory, 1 was lost to follow-up, the other 2 (aged 20 and 24 years) had no complications and therefore no THA.

Admission CT reinterpretation

Type of acetabular fracture

Fifty-three (42%) of the 128 patients had a column fracture of the acetabulum, 49 (38%) a transverse fracture, and 26 (21%) a wall fracture. Acetabular fracture was comminuted in 116 patients (91%), linear with a >3-mm displacement of the fragments in 8 (6%) and linear with a ≤ 3-mm displacement in 4 (3%).

Femoral head dislocation

A dislocation was found at admission CT in 33 (26%) of the 128 patients. It was posteriorly located in 32 (97%) patients, and anteriorly in 1 (3%).

Femoral head impaction

At review of the CT images, a femoral impaction was found at admission CT in 51 (40%) of the 128 patients. Nineteen (37%) of these 51 patients also had a femoral head dislocation, 32 (63%) were isolated. An impaction was present in 19 (58%) of the 33 patients with hip dislocation.

Twenty-three (45%) of the 51 impactions were large, and 28 (55%) were small.

The presence of an impaction was significantly associated with a dislocation (Fig. 2), with a transverse fracture, whereas an impaction was statistically less frequently encountered in patients with a column fracture (Table 1).

The exact location of the impaction, with regard to the level of the fovea on the coronal and axial planes, and their association with the presence or absence of dislocation, is reported in Table 2. Superiorly located impactions (Fig. 3) were significantly more frequently encountered in the absence of dislocation, whereas inferiorly located impactions (Fig. 4) were significantly more frequently associated with hip dislocation. No other relation between the location of the impaction and the presence or not, of a dislocation, was significant.

Table 1 Femoral head impaction at admission CT of 128 patients with acetabular fracture with regard to the presence of a dislocation and the type of fracture according to the Letournel and Judet classification

	Impaction $n = 51$	No impaction $n = 77$	p value	N
Dislocation	19	14	0.022	128
No dislocation	32	63		
Column fracture	9	44	0.0001	128
Transverse or wall fracture	42	33		
Wall fracture	13	13	0.26	128
Column or transverse fracture	38	64		
Transverse	29	20	0.0007	128
Wall or column fracture	22	57		

Statistical analysis

Figure 5 summarizes the outcome of 128 patients with an acetabular fracture with regard to the need for a THA, and the outcome of the 105 patients who underwent conservative management of the femoral head, with regard to the presence of an impaction and to the need for a delayed THA.

Table 3 shows the relationship between femoral head impaction at admission CT of 105 patients and the onset of complications, 48 months after admission.

All cases femoral head necrosis ($n = 3$) were associated with an impaction. When the size of the impaction was large ($\geq$1 cm) the relationship was highly significant.

An impaction was found in 9 (82%) of the 11 patients who developed a femoral head-related pathological condition. The two remaining patients with a pathological condition of the femoral head and no impaction were two men (54 and 56 years old respectively) who underwent a THA 12 and 31 months after trauma for severe, invalidating hip osteoarthritis.

Table 4 shows the relationship between admission CT findings and the need for THA within 48 months in the 105 patients in whom a conservative hip treatment was attempted. The presence of an impaction was significantly associated with the need for THA, in addition to the presence of a dislocation and a transverse fracture of the acetabulum. The two other types of fractures (wall and

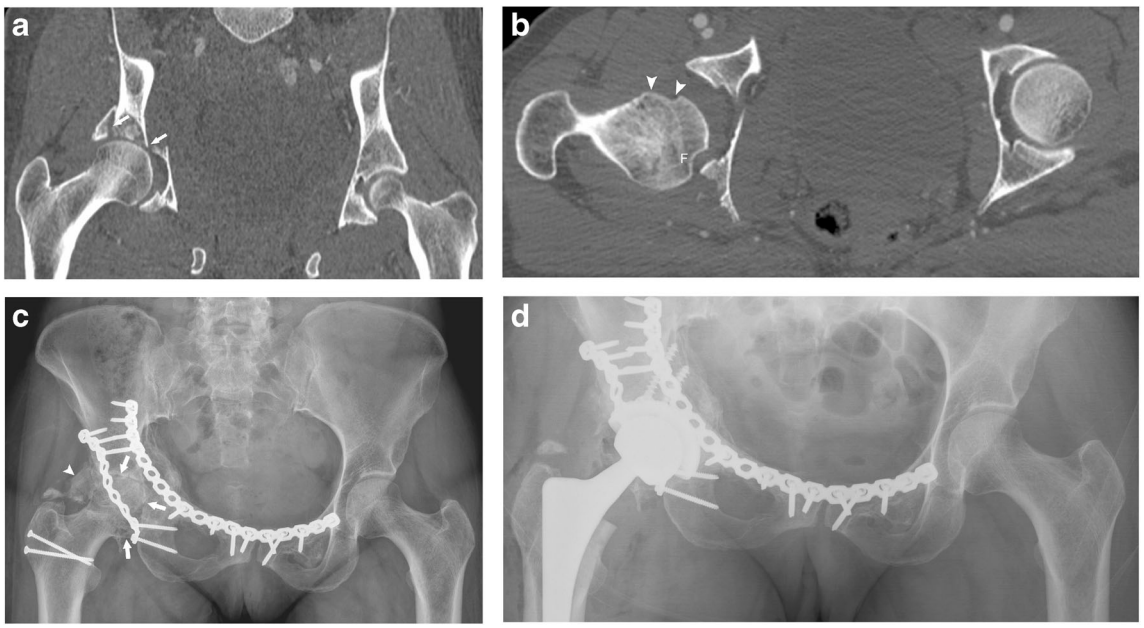

Fig. 2 A 35-year-old woman, admitted after a motor vehicle accident. **a** Admission CT (coronal reformation) shows a transverse fracture of the right acetabulum (*arrows*). **b** Admission CT (axial plane) shows a posterior dislocation of the femoral head. A large cortical impaction is located on the anterior aspect of the femoral head (*arrowheads*), at the same level as the fovea (*F*). **c** An antero-posterior radiograph of the pelvis was performed 6 months after trauma for intense right hip pain. The image shows severe osteoarthritis of the right hip, with loss of the joint space, sclerosis, and deformity of the femoral head (*arrows*); peri-articular ossification is also present (*arrowhead*). **d** Patient underwent a total hip arthroplasty

Table 2 Location of femoral head impactions ($N = 51$) on admission CT of 128 patients, with regard to the presence of hip dislocation

Location of femoral head impaction		Hip dislocation $n = 19$	No hip dislocation $n = 32$	p value
Superior				0.0027
	Anterior	1	10	
	Posterior		6	
	Lateral	1		
	Medial		1	
Inferior				0.0008
	Anterior	8	2	
	Posterior	3	3	
	Lateral			
	Medial	1		
Fovea[a]				0.76
	Anterior	5	5	
	Posterior		4	
	Lateral		1	
	Medial		0	
Anterior[b]		14	17	0.11
Posterior		3	13	

Locations of femoral head impactions are reported with regard to the fovea

[a] Level of the fovea on the coronal plane

[b] Two medial and two lateral impactions (level of the fovea on the axial plan) have been removed from the 51 impactions. One of them is the only patient of the series with anterior dislocation. Therefore, displayed data correspond to patients with posterior dislocation

column) were not significantly associated with a higher risk for delayed THA.

At multivariate analysis, only impactions and dislocations remained significantly associated with delayed THA (Table 5).

Discussion

In the current series, isolated femoral head impactions were frequently associated with acetabular fractures with a prevalence of 39% (51 out of 128). Borg and Hailer reported a 11% (11 out of 101) prevalence of femoral head impaction [14], Mears et al. [15] 9% (38 out of 411), which is lower than what has been found in our study. This can be explained by the difference in the methodology between series. To our knowledge, no prior survey specifically evaluated the prevalence of isolated femoral head impaction associated with acetabular fracture irrespective of the presence of a hip dislocation, by systematically re-analyzing admission CTs; they mainly relied on the CT and/or surgical reports, which are probably insufficient, because impactions are under-reported on both CT and surgical reports. Indeed, if the current series had relied on radiological and/or surgical files only, instead of on a re-analysis of CT images, only 8 (16%) of the 51 patients with femoral head impaction would have been detected, which corresponds to a prevalence of 6.2% (8 out of 128), close to that reported in the aforementioned previous series.

Some earlier surveys on post-traumatic lesions of the femoral head focused on fractures secondary to femoral head dislocation [6, 8–11]. In our study, femoral head dislocations occurred in 26% (33 out of 128) of cases, which is within the range of 12 to 41% reported in the literature [5, 13, 14]. In this specific group of patients, with hip dislocation, impactions of the femoral head were previously reported with a prevalence of 63%, in a series with a systematic review of CT images [10]. In the current study, we observed a similar association (57%, 19 out of 33) between impaction and dislocation, which was significantly higher than the rate of impaction in the group without dislocation (34%, 32 out of 95). Impactions in posterior hip dislocations were located anteriorly in 82% (14 out of 17), which is comparable to the 85% (17 out of 20) reported in the series by Tehranzadeh et al. [10]. In the latter survey, the authors speculated that impactions that occur without imaging-proven dislocation could correspond to dislocation with instantaneous relocation before imaging was performed [10]. Our analysis of the group of patients without dislocation does not completely bolster this stand. Indeed, our data show that impactions in the group without dislocation were less frequently located anteriorly 57% (17 out of 30) and significantly more frequently superiorly compared with the group with dislocation. These findings suggest

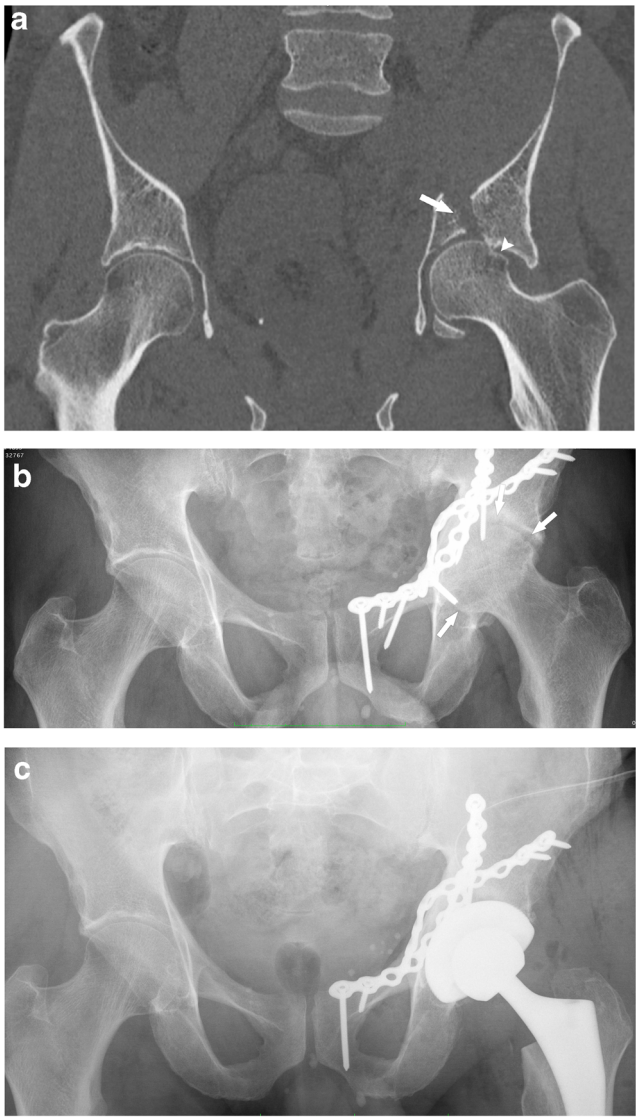

Fig. 3 A 58-year-old patient, admitted after a motor vehicle accident. **a** Admission CT (coronal reconstruction) shows a transverse acetabular fracture (*arrow*). A cortical impaction (*arrowhead*) is located superolaterally on the femoral head. **b** An antero-posterior radiograph of the pelvis was performed 40 months after trauma for intense left hip pain. The image shows severe osteoarthritis of the left hip (*arrows*), with loss of the joint space, sclerosis of the acetabular rim, and subchondral cysts of the femoral head. **c** Patient underwent a total hip arthroplasty: control radiograph after surgery

that impactions might not only be associated with dislocations, but could also be produced by other force mechanisms, without dislocation. If so, impactions would not always be the equivalent of Hill–Sachs lesions for the humeral head, as suggested by Richardson [9].

Our results show that an impaction is significantly associated with a 25% (10 out of 40) risk of failure of conservative management of the femoral head, with delayed THA, compared with a 5% (3 out of 65) risk in the absence of impaction. A series by Borg and Hailer already reported a relationship between impaction and the need for THA [14]. However, the percentages of impaction associated with failure (77%, 10 out of 13) and with successful conservative treatment (33%, 30 out of 92), were higher in our series than in the latter one, which reported a 35 and 4% impaction rate respectively [14]. As CTs were apparently not systematically reviewed in the series by Borg and Hailer [14], the difference between our results and theirs can be explained by the under-reporting of impaction on radiological and surgical reports in the latter series, as mentioned above.

Many factors have been reported in the literature as being predictive of the need for delayed THA, such as age >50 [14, 16], dislocations [17], and transverse acetabular fracture [1, 2]. In the current series, in spite of the fact that patients over 50 were more prone to failure of non-operative management, in addition to those with transverse acetabular fracture, the trend was not significant. Only impactions and dislocations were significantly and independently associated with failure of conservative management of the femoral head. A femoral head impaction is probably the hallmark of severe force mechanisms that predispose to complications and to the need for delayed THA, whereas its absence suggests that the femoral head might have been exposed to lower traumatic strain, and might predict a better potential outcome.

None of the currently used classification for acetabulum [5] and femoral head fracture [11, 18] consider femoral head impaction. Based on our study result, we estimate that the clinical relevance of this CT sign justifies considering it in further revisions of the classification systems for acetabulum and hip fractures.

In our study, large impactions were more frequently (39%, 7 out of 18) associated with the failure of conservative management compared with smaller impactions (14%, 3 out of 22). However, the difference was not significant, which is probably due to the small number of cases, constituting a limitation of the study. The fact that large impactions were significantly more frequently associated with delayed osteonecrosis of the femoral head support the idea of a correlation between the size of the impaction and the outcome of conservative management, as already suggested in earlier surgical series [15]. Further series are recommended to precisely answer this question.

Our results showed the significant relationship between impactions and severely delayed hip complications, all types included. However, owing to the various types of complications, with a small number of cases in each subgroup, the exact association between impactions and each type of complication could not be assessed, except for osteonecrosis in patients with large impactions.

Furthermore, our methodology did not allow us to determine whether impactions might be associated with the development of a milder form of osteoarthritis that will eventually justify the placement of a THA in a longer delay than our follow-up study period.

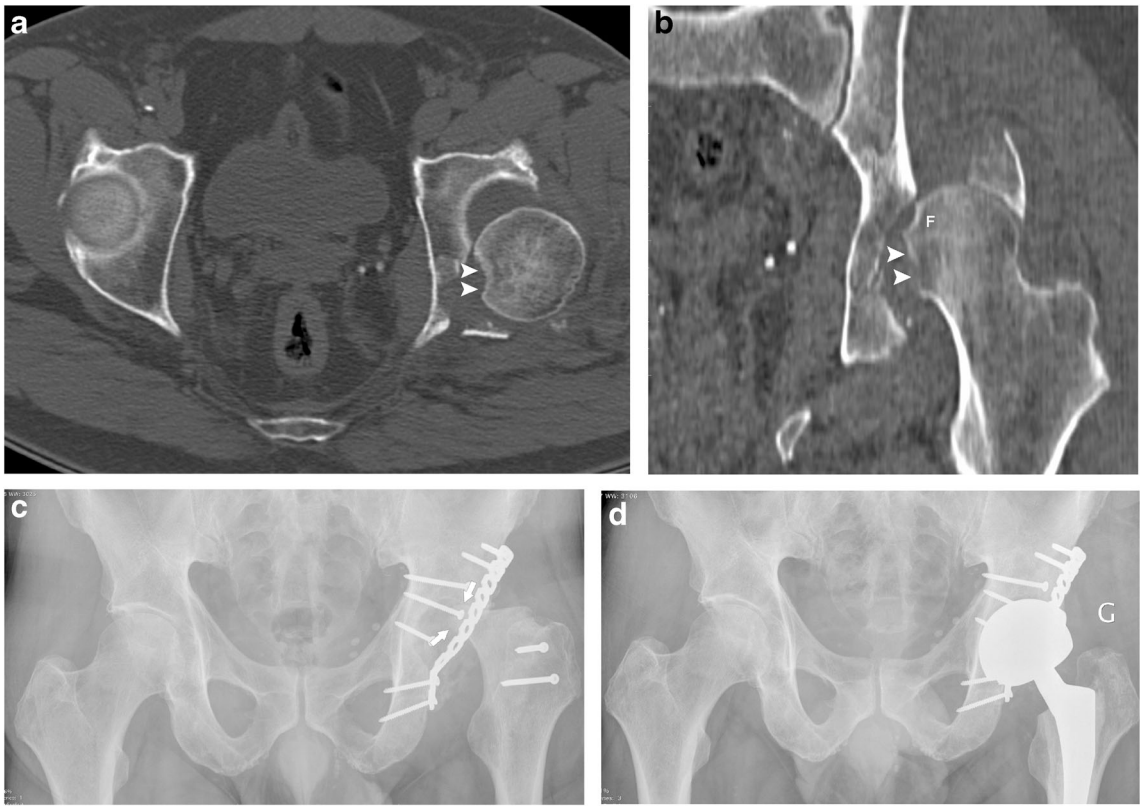

Fig. 4 A 64-year-old man, admitted after a motor vehicle accident. **a** Admission CT (axial plane) shows a posterior dislocation of the femoral head. A large cortical impaction is located on the medial aspect of the femoral head (*arrowheads*). **b** CT coronal reformation of the left hip shows the femoral head impaction (*arrowheads*), located medially and inferior to the fovea (*F*). **c** An antero-posterior radiograph of the pelvis was performed 4 months after trauma for invalidating pain. The image shows the extreme destruction of the femoral head (*arrows*), due to osteonecrosis. **d** Patient underwent a total hip arthroplasty

Besides, owing to its retrospective nature, our analysis was only focused on impaction of the subchondral bone, detected by CT, and did not consider chondral lesions and their potential impact on failure of conservative management of the

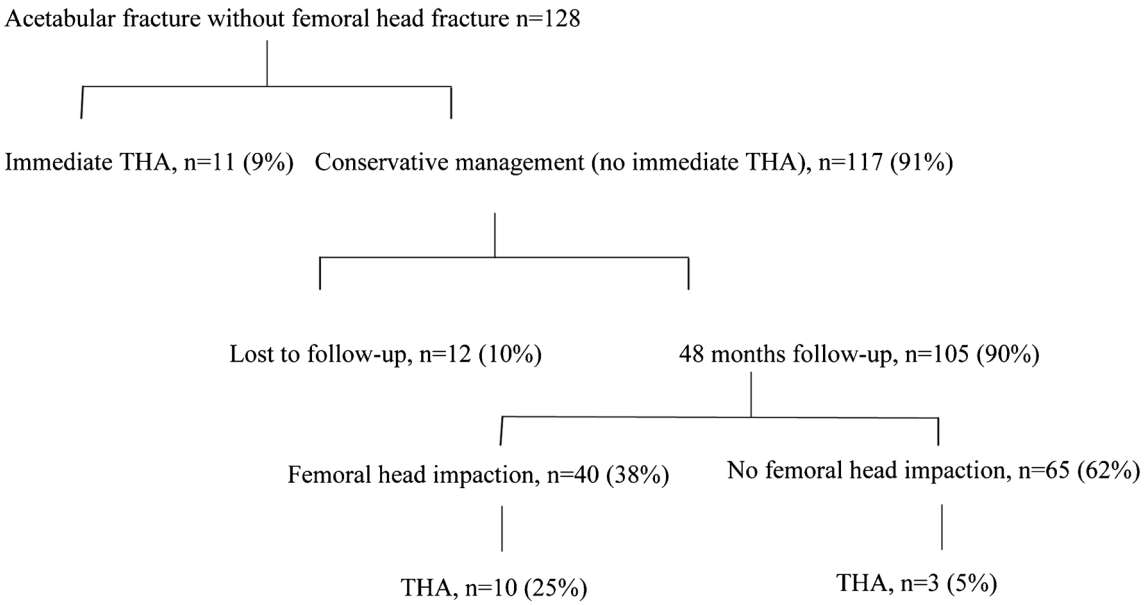

Fig. 5 Descriptive flow-chart of the study population with regard to the need for immediate or delayed total hip arthroplasty and the presence of femoral head impaction

Table 3 Femoral head impaction on admission CT of 105 patients with acetabular fracture with regard to the onset of complications, 48 months after trauma

	Impaction	No impaction	*p* value
Osteonecrosis	3	0	0.0052
No osteonecrosis	37	65	
Size of impaction ≥ 10 mm[a]			
Osteonecrosis	3	0	0.0044
No osteonecrosis	15	87	
Severe osteoarthritis	5	2	0.10
No severe osteoarthritis	35	63	
Heterotopic ossification	5	4	0.29
No heterotopic ossification	35	61	
Pseudarthrosis	3	1	0.15
No pseudarthrosis	37	64	
Severe osteoarthritis, osteonecrosis, heterotopic ossification or pseudarthrosis[b]	11	2	0.0004
No severe osteoarthritis, osteonecrosis, heterotopic ossification or pseudarthrosis	29	63	

[a] Only impactions ≥10 mm were considered; smaller impactions were considered as no impaction

[b] Multiple complications are considered as a single event

femoral head. Doing so would have required a straightforward prospective report of peroperative findings.

Moreover, because only admission CTs were analyzed, it was not possible to assess whether some impactions could also occur after the initial trauma, as peroperative iatrogenic lesions, or while awaiting acetabular surgery, by direct contact between the femoral head and the jagged acetabular fracture fragments. The answer to this question, and the clinical relevance of such impactions, could also be the topic of further research projects.

In conclusion, our study shows that the prevalence of isolated femoral head impactions in association with acetabular fracture is more frequent than previously reported. The locations of impactions suggest that they might be caused by various mechanisms, and not only by dislocations. In patients with conservative management of the femoral head, impaction at initial CT is associated with a higher risk for complications with the need for THA over a 48-month follow-up. Our data show that only a minority of impactions are mentioned on admission CT reports and/or surgical records, in spite of their clinical relevance. Based on our findings, we strongly recommend performing further prospective analyses to refine the role of the size and location of impactions on the patients' outcome, mainly with regard to the development of osteoarthritis and osteonecrosis. Besides, owing to their clinical implications, we believe that impactions should be

Table 4 Need for delayed total hip arthroplasty (THA) in 105 patients with acetabular fracture who did not undergo initial femoral head replacement, with regard to the presence of impaction and/or dislocation of the femoral head and to the type of acetabular fracture

	THA (2–48 months) *N* = 13	No THA *N* = 92	*p* value	Total number
Impaction	10	30	0.0042	105
No impaction	3	62		
Impaction ≥10 mm	7	11	0.14	40
Impaction <10 mm	3	19		
Superior impaction	4	13	1	29[a]
Inferior impaction	3	9		
Anterior impaction	4	21	0.096	36[b]
Posterior impaction	5	6		
Dislocation	7	21	0.038	105
No dislocation	6	71		
Transverse fracture	9	29	0.012	105
Wall or column fracture	4	63		

[a] Eleven out of 40 impactions, located at the level of the fovea, have been excluded

[b] Two medial and two lateral impactions, out of 40 impactions, have been excluded

Table 5 Logistic regression modeling of CT parameters significantly associated with delayed total hip arthroplasty (THA), 48-month follow-up, in 105 patients with initially conservative management of the femoral head

	Odds ratio (95% confidence interval)	*p* value
Femoral head impaction	4.8 (1.2–20)	0.031
Femoral head dislocation	4 (1.1–15)	0.033
Transverse fracture of the acetabulum	3.9 (0.99–15.3)	0.052

systematically mentioned on CT reports and that they should also be considered in further overhauls of acetabular and hip fracture classifications.

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Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflicts of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Informed consent The requirement for informed consent was waived by our Institutional Review Board.

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