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Heterotopic Ossifications after Fractures of the Anterior Pelvic Segment: Overview of Morphology and Clinical Correlations

Heterotopické osifikace po zlomeninách předního segmentu pánve: přehled morfologie a klinický význam

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ABSTRACT

PURPOSE OF THE STUDY

In certain patients after treated pelvic fractures, heterotopic ossifications can be observed in the area of the pubic bone, which protrude ventrally, and often also laterally and distally into surrounding soft tissues of the groin or even medially into the proximal thigh. These ossifications are shaped like sharp spikes of various lengths, which is why the authors refer to them as “spicules”. In some patients, these ossifications are also associated with pain. The aim of this study was to provide an overview of the morphology of heterotopic ossifications of the anterior segment of the pelvis and to discuss the etiology of their origin, and further to determine the incidence, risk factors and clinical significance of these “spike-like” ossifications.

MATERIAL AND METHODS

X-ray images of patients treated for pelvic injuries between 2009 and 2018, in whom radiological documentation was available at least 12 months after the injury or surgery were evaluated. Patients with acetabular fractures or combined pelvic and acetabular injuries were not included in the study. Possible risk factors studied included gender, severity of injury, type of fracture according to the AO / ASIF classification, concomitant bladder injury, method of treatment and type of osteosynthesis of the anterior segment of the pelvis. The categorial data concerning risk factors for the observed “spicule” type ossifications was statistically evaluated using the chi-square test at the 5% level of significance.

RESULTS

The studied group consisted of 218 patients (121 women, 97 men) aged 13 to 92 years of age (mean age was 54 years, median age was 55 years). Heterotopic "spicule" type ossifications occurred in 21 patients (4 females, 17 males) aged 18 to 76 years (mean 39 years, median 41 years). Significant risk factors in the observed ossification group included male sex ($p = 0.0004$), severity of trauma (predominance of “spicules” was seen in multiple trauma patients, ($p = 0.0024$), unstable pelvic injury according to AO / ASIF classification (predominance of “spicules” in type B and C fractures over type A fractures, ($p = 0.0013$), concomitant bladder injury ($p = 0.0009$) and in patients undergoing surgical treatment of the fracture ($p < 0.0001$), where all the observed spicules were seen in patients undergoing anterior pelvic segment osteosynthesis. A statistically significant difference was also evident when comparing the osteosynthetic material used in the anterior segment (a increased incidence of ossifications was seen in patients undergoing plate fixation compared to patients in whom pubic screws were used, $p = 0.0050$).

DISCUSSION

Heterotopic ossifications are described as relatively common consequences of pelvic fractures, but are not considered a major problem because they usually do not produce any clinical correlations. The causes of post-traumatic and post-operative ossifications in the pelvic area include the effects of high energy traumas, extensive surgical procedures, prolonged artificial lung ventilation, and post-infectious states after complications of surgical treatment.

CONCLUSIONS

The study identified risk factors for heterotopic “spicule” type ossifications. The identified risk factors include male sex, severity of injury, unstable type of fracture, concomitant bladder injury, surgical treatment, and the use of massive implants. Only the effect of bladder injuries can be partially influenced by performing less invasive surgical techniques during combined pelvic and bladder injuries.

Key words: pelvic fracture, pelvic injury, complications, heterotopic ossifications, multiple trauma, unstable pelvic trauma, urinary bladder injury.

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INTRODUCTION

According to various authors, post-traumatic heterotopic ossifications (HO) occur after pelvic and acetabular injuries in 1% to 50% of cases, mainly in patients after surgical treatment (3, 15, 19, 20). The ossifications are usually clinically silent and are usually detected incidentally during follow-up X-ray examinations. In our cohort of patients, we noted that some HO occurring on the pubic bone, more often parasymphyseal, are symptomatic and cause pain. These ossifications protrude ventrally, often even laterally and distally into soft tissues or medially into the adjacent thigh or rarely into the area of the perineum. They have the shape of a sharp spike, varying in length (2 to 8 cm), which is why we have professionally named them "spicules" (Fig. 1). The aim of this study was to determine the incidence of the spicular type of HO and to identify risk factors for their development based on morphological descriptions of post-traumatic and postoperative HO located in the anterior segment of the pelvis. We were also interested in the amount of patients under surveillance for the spicular type of HO that had symptomatic pain and how many of them required subsequent surgical treatment.

MATERIAL AND METHODS

Patient selection

In a retrospective analysis, we evaluated data from a database of patients treated for pelvic injuries and acetabular fractures in our trauma center level 1. In the evaluated period of ten years (2009 to 2018), 861 patients (508 female, 363 male) with pelvic injuries were treated in our center. Patients with acetabular fractures or combined pelvic and acetabular injuries were excluded from the study. Inclusion criteria included the availability of complete X-ray documentation from the course of treatment, with follow-up images at least 12 months after the injury or surgery.

Methods

We examined the incidence and development of HO located in the anterior segment of the pelvis on X-ray images taken during the fracture healing process and on post-treatment control images. We analyzed data about gender, severity of injury (mono-trauma, multiple trauma with ISS < 16, polytrauma with ISS ≥ 16) (5), type of fracture according to the AO / ASIF classification (12), concomitant bladder injury, method of treatment and the type of pelvic anterior segment osteosynthesis used. We also analyzed data about accompanying head injuries, but in the end excluded this parameter from the final evaluation of data. We also focused on determining clinical symptomatology of the observed "spicules" and the need for their subsequent surgical treatment.

Statistical analysis

For the statistical analysis of categorical data used in determining the risk factors for HO development, we used a chi-square test at the 5% level of significance.

RESULTS

The analyzed group consisted of 218 patients (121 female, 97 male) aged 13 to 92 years (mean age – 54 years, median age – 55 years). More in depth information in terms of analyzed risk factors about the group is given in Table 1.

Spicule-type HOs occurred in 21 patients (9.6%; 4 female, 17 male) aged 18 to 76 years (mean 39 years, median 41 years). Tables 2 and 3 evaluate the analyzed risk factors and their influence on the development of "spicules". We identified male sex as the first significant risk factor ($p = 0.0004$).

The second most significant factor was the severity of accompanying trauma, with the predominance of "spicules" occurring in multiple traumas (both groups, ISS <16 and ISS ≥ 16) when compared to monotraumas ($p = 0.0024$). The difference between monotrauma and multiple traumas (ISS ≥ 16) patients was statistically

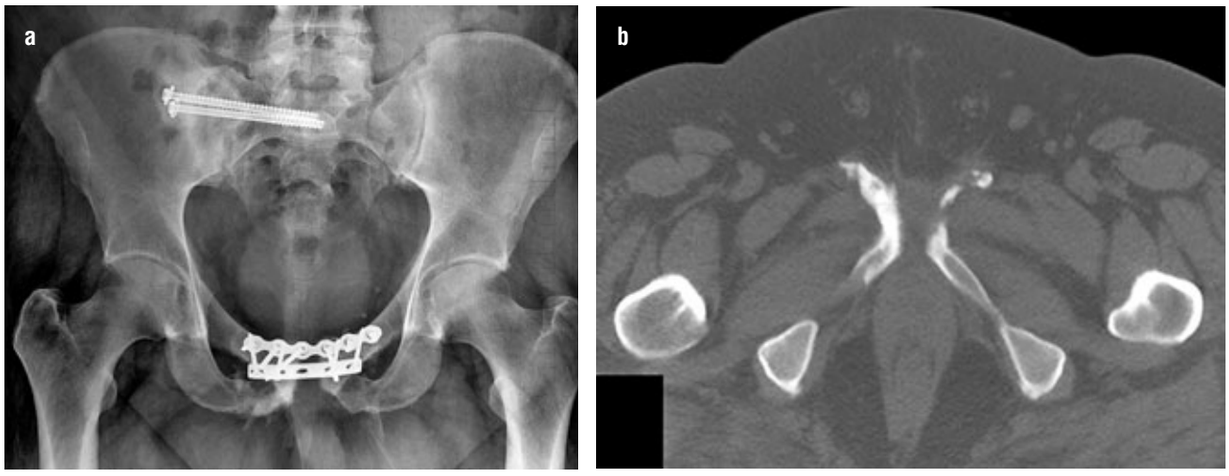

Fig. 1. Imaging documentation of a 45-year-old patient 12 months after a type B2.3 pelvic injury treated with two plates in the area of the anterior segment and two iliosacral screws on the right:
a – X-ray of the pelvis with noticeable "spicule" HOs bilaterally,
b – follow-up CT scan showing "spicule" positioning.

Table 1. Basic parameters observed in the studied group of patients

	Total	Female	Male
Number	218 (100%)	121 (55%)	97 (45%)
Age (years)			
- range	13-92	18-92	13-87
- mean	54	61	46
- median	55	65	44
Severity of injury			
- monotrauma	99 (45%)	63	36
- multiple trauma (ISS < 16)	52 (24%)	27	25
- multiple trauma (ISS ≥ 16)	67 (31%)	31	36
Type of fracture (AO/ASIF)			
- A	59 (27%)	40	19
- B	120 (55%)	67	53
- C	39 (18%)	14	25
Urinary bladder injury	10 (5%)	4	6
Treatment			
- conservative	105 (48%)	74	31
- surgical	113 (52%)	47	66
"Spicule" type of ossification	21 (10%)	4	17

Table 3. Statistical significance of observed risk factors in comparison to the development of spicular type heterotopic ossifications

	p
Gender	
- female (4) vs. male (17)	**0.0004**
Severity of injury	
- monotrauma (3) vs. multiple trauma (ISS < 16) (15)	**< 0.0001**
- monotrauma (3) vs. multiple trauma (ISS ≥ 16) (3)	0.6862
- monotrauma (3) vs. multiple trauma (both groups) (18)	**0.0024**
- multiple trauma (ISS < 16) (15) vs. multiple trauma (ISS ≥ 16) (3)	**0.0005**
Type of fracture (AO/ASIF)	
- A (0) vs. B (11)	**0.0170**
- A (0) vs. C (10)	**< 0.0001**
- A (0) vs. B a C (21)	**0.0013**
- B (11) vs. C (10)	**0.0135**
Urinary bladder injury	
- without ossification (5) vs. with ossification (5)	**0.0009**
Method of treatment	
- conservative (0) vs. surgical (21)	**< 0.0001**
Definitive fixation of the anterior pelvic segment	
- pubic screws (1) vs. one plate (7)	**0.0448**
- pubic screws (1) vs. two plates (13)	0.0512
- pubic screws (1) vs. one or two plates (20)	**0.0050**
- one plate (7) vs. two plates (13)	0.5710

Table 2. Observed risk factors in relation to the development of spicular type heterotopic ossifications

	Total	Without "spicule" type of HO	With "spicule" type of HO
Total	218	197	21 (100%)
- female	121	117	4 (19%)
- male	97	80	17 (81%)
Severity of injury			
- monotrauma	99	96	3 (14%)
- multiple trauma (ISS < 16)	52	37	15 (72%)
- multiple trauma (ISS ≥ 16)	67	64	3 (14%)
Type of fracture (AO/ASIF)			
- A	59	59	0
- B	120	109	11 (52%)
- C	39	29	10 (48%)
Injury to urinary bladder	10	5	5 (24%)
Treatment			
- conservative	105	105	0
- surgical	113	92	21 (100%)
Length of operation (minutes)			
- range	20-230	20-230	80-200
- mean	97	92	147
- median	90	90	120
Definitive fixation of anterior segment			
- external fixation	5	5	0
- one or two pubic screws	21	20	1 (5%)
- one plate	21	14	7 (33 %)
- two plates	50	37	13 (62 %)

insignificant (p = 0.6862). We consider an interesting finding to be that there is a statistically significant predominance of "spicules" that develop after "simple" multiple traumas (ISS < 16) when compared to "severe" multiple traumas (ISS ≥ 16) (p = 0.0005).

We expected to see a statistically significant increase in "spicules" according to the type of pelvic injury according to the AO / ASIF classification. We found HO only in unstable pelvic injuries, with the statistical significance given in more detail in Table 3. In addition, it is clear from Table 2 that surgical treatment of patients in whom "spicules" arose after surgery required lengthier surgical procedure time – which further confirms the thought that "spicules" develop in more severely injured pelvises.

Furthermore, it is evident from Table 3 that a statistically significant factor in the development of "spicules" was accompanying bladder injury (p = 0.0009) and surgical treatment of the fracture (p < 0.0001). Additional data regarding surgical treatment can be found in Table 2, from which it is clear that the observed ossifi-

cations always occurred in patients undergoing open surgical procedures of the anterior segment.

In 21 patients with "spicule" type HO, the anterior segment was treated with pubic screws in one case, with one plate in seven cases and with two plates in 13 cases. As can inferred from Table 3, the difference when comparing the use of pubic screws and one or two plates was marginally significant ($p = 0.0448$, $p = 0.0512$), but was clearly significant when comparing the use of pubic screws and plate fixation in general ($p = 0.0050$). When comparing fixation performed by one or two plates, we did not find any significant difference in the occurrence of "spicules" ($p = 0.5710$).

Three patients who underwent plate fixation required re-operations during the postoperative period (one for haematoma, two for infectious complications, with one patient undergoing removal of both plates and subsequent treatment of the pelvic injury using external fixation).

Another analyzed factor was the presence of any accompanying skull or intracranial injury. This occurred in seven patients (concussion of the brain occurred in five cases, with facial fractures occurring in two cases).

During the observed period (1 to 10 years after the injury or surgery), we performed surgical removal of "spicules" in two of our patients (10% of all patients with "spicules"). In both cases, these patients presented after type C pelvic injuries, in whom there was an associated bladder injury (rupture of the urinary bladder). The stabbing pain reported by the patients was permanent and worsened with prolonged sitting. Surgical removal of the ossification led to a significant reduction in pain. Another 9 patients with spicules (43%) had pain upon palpation, but this was not severe enough for patients to request or consent to surgical excision. Ten patients with "spicules" (48%) had no specific pain or had other pelvic, hip, or lower leg problems which obscured any specific problems.

DISCUSSION

The wide range of HO incidence after pelvic fractures (1% to 50%) described by the cited authors is thought to be due to not only the specificity of phenomenon, but also the attention paid by the authors to the issue of HO incidence (3, 15, 19, 20). We did not find any study specifically focused on morphological description or evaluation of the clinical significance of HO as a consequence of pelvic injuries. In our view, this is because the problems associated with HO in the anterior segment of the pelvis are usually minor or marginal compared to other chronic difficulties seen in patients after severe pelvic trauma, which are often associated with other injuries, most commonly lower extremity injuries (20). This is also confirmed by our cohort of patients, where during the 11-year follow-up it was only necessary to treat the pain in only two patients surgically.

A somewhat different issue is the presence of para-articular ossifications around the hip joint after acetabular fractures, especially those in those treated surgically. In these patients, HO may have a negative effect on the functional result of treatment. The problem is similar to para-articular ossifications seen in patients after hip replacements. The localization of these ossifications is different from the ossifications of the anterior segment of the pelvis that we monitored (6–8, 10, 13). We deliberately did not include patients after acetabular fractures or after combined pelvic and acetabular injuries in our study, as we consider HO in the hip area to be a different issue from a clinical point of view.

The causes of post-traumatic and postoperative pelvic complications are as follows: 1. high energy trauma, which usually results in comminutive fractures with significant dislocation of fragments, severe soft tissue injury and / or the formation of large haematomas (9, 15, 23); 2. extensile approaches which, like high energy trauma, can lead to significant soft tissue damage and the development of large haematomas (23); 3. severe brain injury and / or prolonged artificial lung ventilation (Fig. 2a) in these cases the cause of HO formation is unclear (1, 11); 4. severe spinal cord injury with also an unclear cause of HO formation, but which are only rarely localized in the area of the anterior segment of the pelvis (4, 16); 5. conditions after infectious complications of surgical treatment (Fig. 2f), where the formation of HO probably involves extensive formation of granulation and subsequently fibrous tissue predisposing to the formation of calcifications and ossifications (4, 23).

From a morphological point of view, the HOs of the anterior segment are very diverse. The results of our observations during the evaluation of our cohort are shown in Table 4 and Figure 2. In our study, we studied in detail the third type of HO that we named "spicules". This type of HO has not yet been described about in literature, however we have found publications in which "spicules" were evident in picture form (14, 20). We also found other types of HO described in this work in the picture form in publications by other authors (3, 4, 18, 20, 21, 23).

Risk factors for the development of the observed "spicule" type of HO, which we identified in our study (male gender, severity of injury, unstable fracture type, bladder injury, surgical treatment, massive implants), are generally associated with a higher incidence of complications and permanent disabilities in patients after pelvic injuries (7, 15). These risk factors are usually the result of a serious mechanism of injury, which cannot be influenced during treatment. There are two risk factors that we can partially influence. First, it is imperative to pay special attention to patients with urinary bladder rupture, who are naturally at risk of higher morbidity and mortality during pelvic injuries (2, 17, 24). Open reduction of the anterior segment should be particularly conservative in these patients, tissues that may have come into contact with urine should be thoroughly washed out repeatedly peri-operatively, and the wound should be closed without any soft tissue tension. These recommendations generally valid for any open reduction and internal fixation of the anterior segment of the pelvis. The question still remains whether or not it is appropriate to

Fig. 2. Types of post-traumatic HO in the ventral segment of the pelvis:
a – ossification of connective tissue structures of the symphysis (X-ray of a 73-year-old patient 3 months after type B2.3 injury; the patient was conservatively treated during 4 weeks of artificial lung ventilation);
b – flat ossifications bridging osteosynthetic material (X-ray of a 40-year-old patient 12 month after type B3.3 injury treated with an insufficiently stable osteosynthesis of the anterior pelvic segment – combination of a double cerclage and plates);
c – hypertrophic callus (X-ray of a 86-year-old patient 9 months after B2.1 injury treated conservatively with a finding of a prominent ossification around the inferior pubic rami bilaterally; the examination took place due to a fresh trochanteric femur fracture on the left);
d – beak shaped ossification after avulsion in adolescent age (X-ray of a 19-year-old patient, 5 years after type A1.2 injury – after avulsion of the left anterior inferior iliac spine);
e – cylindrical ossification after external screw fixation (X-ray of a 20-year-old patient 4 months after type B2.1 injury treated by external fixation and two iliosacral screws on the right; the screws of the external fixation were implanted supracetabularly);
f – extensive flat ossification after infectious complications (X-ray of a 77-year-old patient, 15 months after type C2.3 injury treated primarily will plate fixation of the anterior pelvic segment and two iliosacral screws on the right, with subsequent conversion to external fixation for infectious complications.

Table 4. Overview of HO types occurring in the anterior pelvic segment (described according to positioning from the midline laterally)

Type of HO	Description
1. Ossification of connective tissue structures of the symphysis (Fig. 2a)	this type of ossification was found in a patient dependent on artificial lung ventilation for 4 weeks
2. Ossifications bridging osteosynthetic material (Fig. 2b)	are often found in patients with unstable osteosynthesis
3. "Spicule" type of ossification (Fig. 1)	they have a spike-like shape, begin on the pubic bone and often point ventrally, laterally and distally into soft tissues of the groin or proximal thigh
4. Hypertrophic callus (Fig. 2c)	are often found around the inferior pubic rams during dislocations larger than the bone width or during ventrally dislocated fragments
5. Ossifications after avulsions in adolescent age (Fig. 2d)	localized to the area around the anterior superior and inferior iliac spine
6. Ossifications after screws of external fixation (Fig. 2e)	supra-acetabular HO of cylindrical shape
7. Ossifications after infectious complications (Fig. 2f)	extensive HO of soft tissues, often take up occupy an extensive area around the anterior pelvic segment

administer indomethacin or perform postoperative irradiation in these patients, when the view of this issue varies from clear recommendations (22, 23) to dismissal (7). Based on the results of our study, we believe that none of these preventive measures need to be included in the treatment guidelines due to the low incidence of specific clinical difficulties in patients with HO in the anterior segment of the pelvis.

The second partially influenceable factor is the choice of surgical implant. The advantage of a less invasive approach during fixation with pubic screws compared to plate fixation is obvious, with this fact being confirmed in our study However, in accordance with the literature and our experience, we must perform sufficient stabilization of the fracture during the osteosynthesis rather than perform minimally invasive fixations (9, 15). Therefore, fixation of the anterior segment utilizing pubic screws is not the most common way of treatment of unstable pelvic fractures in our study.

Fig. 3. X-ray of a 37-year-old patient, 6 years after type B2.3 injury in conjunction with a urinary bladder injury, with extensive "spicule" formation – the patient had minimal clinical manifestation at the time of the follow-up.

We cannot satisfactorily explain the statistically significant predominance of the studied "spicule" type HOs in patients with multiple traumas (ISS < 16) in comparison to those with multiple traumas (ISS ≥ 16) in our group. Nor can we describe why "spicules" did not occur in fractures of the anterior segment of the pelvis treated by definitive external fixation, although similar findings were described other authors (3). In our study, this notion could however be influenced by low numbers of external fixations as definitive treatment, although a purely speculative explanation could also be that the development of HO in the anterior segment of the pelvis is more likely to occur in patients undergoing open fixation rather than the extent/severity of primary soft tissue injury caused by trauma itself.

The question of statistically significantly higher incidences of "spicule" type HOs in patients undergoing plate fixation compared to those pubic screw is, in our opinion, explained by the greater extensiveness during the surgical approach, which has also been described authors who noted increased complications associated with extensive surgical procedures (15, 23).

In our follow-up, we are also unable to describe whether clinical difficulties are affected by the size or orientation of the "spicules". We recorded relatively large "spicules" that had minimal clinical correlations (Fig. 3).

In accordance with the literature, we did not evaluate the suspected risk factors of skull fractures and intracranial injuries (1, 11). The finding of brain concussions (five patients) and facial fractures (two patients) did not correspond to our original idea that a serious intracranial injury that could produce prolonged unconsciousness or the need for prolonged artificial lung ventilation.

The weakness of our study was its retrospective nature, which always limits the volume of patient data collected compared to prospective studies. The second problem was the evaluation of only 218 patients out of 861 treated during the study period. Nevertheless, we consider the inclusion criteria regarding the availability of X-ray documentation one year after the accident or operation to be correct. HOs in the area of the anterior

segment of the pelvis were evident on follow-up images, usually three months after the injury or surgery, and during the further course of monitoring they "matured". However, it was not until 12 months later post injury that patients with clinical difficulties became more aware of the local pain that may have been associated with maturation of the HO. The condition of a twelve-month follow-up also excluded a number of our patients from the study – the patients excluded included those treated for a shorter period of time, as well as those treated at other centers, which took over patient care after primary treatment in our trauma center.

CONCLUSIONS

The study focused on the development of "spicule" type HO located in the anterior segment after pelvic fractures and identified risk factors such as male gender, severity of injury, unstable fracture type, bladder injury, surgical treatment, and the use of larger implants. These factors are generally associated with a higher incidence of all complications and permanent disability after the treatment of pelvic fractures. From the mentioned risk factors, we consider urinary bladder injury to be a modifiable risk factor, by focusing on less invasive surgical techniques and repeated tissue wash-out during surgical treatment. However, the requirement of less invasive surgical techniques during the treatment of anterior segment injuries applies to the surgical treatment of pelvic fractures in general. The question of HO prevention by preferring pubic screws over plate fixation is debatable due to the need to always perform a sufficiently stable osteosynthesis.

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