

R E V I E W

Apophyseal avulsion fractures of the pelvis. A review

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Summary. *Background and aim of the work:* Fractures of the pelvis classically occur in adolescent during sports activities with forceful and repetitive contractions or passive lengthening acting on not yet ossified growth plates. Their misdiagnosis lead to disability, chronic pain and decrease of performances. Evidence based treatment guidelines do not exist; aim of this paper is to point out clinical outcomes, return to sport rates and complications of surgical and conservative approach. *Methods:* A systematic search based on MEDLINE database was performed in August 2017 to identify all published articles from 2010 to 2017 reporting outcomes, return to sport and complications rates after surgical and non-operative treatment of avulsion fractures of the pelvis. *Results:* Mean age was 14,5 years with anterior inferior iliac spine avulsion representing the most common injury (46%), followed by anterior superior iliac spine avulsion (32%), ischial tuberosity avulsion (12%) and iliac crest avulsion (11%). Rates of excellent outcome and return to sports at pre-injury levels were higher after surgical treatment; surgery has a higher risk of heterotopic ossification (9%) compared to conservative treatment (1,8%), whereas the risk of non-unions is lower (0% versus 2,5%). *Conclusions:* Surgery is preferred for major dislocations and fragment sizes, providing a faster return to pre-injury level of activity, decreasing the risk of pseudoarthrosis. Conservative treatment is advisable for minimally displaced fractures when a rapid recovery is not required; patient and his family should be informed on the risk of non-unions and the eventuality of a delayed surgical approach. (www.actabiomedica.it)

Key words: avulsion fractures of the pelvis, treatment, return to sport

Introduction

Apophyseal avulsion fractures of the pelvis are rare injuries typically affecting young athletes with not yet ossified cartilaginous growth plates (1-4).

Structurally the anterior and posterior margins of the pelvis have a lesser trabecular density as shown by Cunningham and Black (5, 6) and growth plates are more prone to trauma compared to the musculotendinous units having a hormonally induced increase in strength (7).

Avulsion fractures involve the main bundle of the rectus femoris insertion at the anterior inferior iliac

spine (AIIS), the sartorius insertion at anterior superior iliac spine (ASIS), the hamstring insertion at the ischial tuberosity (IT), the tensor fasciae latae on the iliac crest (IC) and the rectus abdomens insertion on the superior corner of the pubic symphysis (SCPS).

In most cases (8-10) these fractures are consequent to a sudden and forceful contraction or passive lengthening of the muscles that take their origins on the aforementioned structures during an acceleration, a jump or a kick; less frequently they follow a direct trauma or an overuse situation with the onset of a stress fracture following a prolonged apophysitis of the pelvis.

Though an accurate anamnesis, a simple clinical assessment and a standard AP radiograph are enough to make a diagnosis, these injuries are often misdiagnosed as simple muscle strains leading to ineffective treatments and a delayed return to sport (8, 11).

Even if the diagnosis is confirmed, there are still controversies whether a conservative or a surgical approach should be used, over the treatment modalities and over which patient and fracture pattern could benefit from the surgery.

In the current literature the long-term outcome of these fractures has not been well studied; the available articles on this topic are small case series with no specific guidelines of daily clinical practice.

The aim of this review was to analyze the most recent published articles, since 2010, summarizing patient demographics, mechanism of injury, criteria leading to operative and conservative treatment, clinical outcomes and complications and return to sports rates of these two different treatments.

Epidemiology and mechanism of injury

Avulsion fractures of the anterior superior iliac spine (ASIS) and the anterior inferior iliac spine (AIIS) with indirect mechanism are the consequence of a forceful contraction of the sartorius and the rectus femoris, respectively, with the hip extended and the knee flexed (8, 12).

AIIS avulsions can occur with a concentric or eccentric contraction of the rectus femoris; the most common injury mechanism is concentric contraction during the acceleration phase of sprinting, a jump or a kick with sudden-onset groin pain; less commonly is an uncontrolled passive elongation of the musculotendinous unit during gymnastic movements (13).

Indirect avulsion fractures of the ischial tuberosity are the result of a vigorous flexion of the hip joint with an extended knee and a concomitant activation of hamstring muscles; patient's perception of a "crack" during the violent contraction is followed by a simultaneous pain of the proximal and dorsal thigh.

Fractures involving the IC apophysis are caused by a massive contraction or repetitive actions of the tensor fasciae latae with a sharp pain localized on the

antero-lateral side of the pelvis (14); the injured area is swollen and tender to palpation and despite the patient is able to walk, the extension of the hip, against resistance mainly, causes an acute pain.

The trend to study different subtypes of pelvic avulsion separately and the little data on their incidence make difficult to assess the patient demographics accurately.

In a retrospective review of 228 cases Schuett (15) analyzes the overall epidemiology and the distribution of fracture types related to age, sex and skeletal maturity.

In an age range from 10,7 to 18,2 years, males comprise the most of fractures (76%), due to the greater muscle masses, with a prevalence of AIIS (49%) and ASIS (30%) avulsion fractures compared to ischial tuberosity (11%) and iliac crest (10%) fractures; the most common cause of AIIS avulsion was kicking whereas running and sprinting were responsible of the majority of ASIS, ischial tuberosity and iliac crest fractures.

Using the Risser classification to grade skeletal maturity (16), older patients are more prone to suffer injuries to the iliac apophysis (ASIS and iliac crest), while younger are more likely to sustain a fracture of AIIS or ischial tuberosity; the timing of complete ossification of the apophysis of the pelvis is probably accountable for these differences, with the AIIS secondary ossification center closing first and the iliac apophyses closing last (1).

Methods

A systematic review of the MEDLINE database was performed in August 2017 to identify studies reporting clinical outcomes and return to sport rates after avulsion fractures of the pelvis.

The research comprised the Boolean operators (AND; OR) that included the following terms in the title and abstract fields: apophyseal, apophysis, fracture, injury, avulsion, pelvic and pelvis.

Inclusion criteria:

- date of publication from 2010 to August 2017
- english language
- published online
- clinical studies of all kind and all levels of evidence reporting clinical outcomes after opera-

tive and conservative treatment of avulsion fractures of the pelvis.

Exclusion criteria:

- none english language
- in vitro or animals study
- radiologic and diagnostic studies
- narrative reviews
- single case report.

Two reviewers (AN, FC) separately screened all articles for relevance by title and abstract according to defined inclusion and exclusion criteria.

The full text of articles that met the inclusion criteria was obtained and reviewed by two reviewers (AN, FC).

Data from included articles (mean age, gender, mean follow-up, clinical outcome, complication rate and proportion of patients returning to sport) were extracted by two reviewers and checked by a third reviewer (CG). Any disagreement was resolved through discussion.

Excellent outcome was specified as a reported outcome and absence of complications at the follow-up.

Return to sport was defined as the rate of patients returning at pre injury levels.

Results

Out of 348 articles identified through the initial search only 8 studies met the inclusion criteria (8, 13-15, 17-20).

In total 314 patients were enrolled in these studies; there were 242 males representing 77% of the total study population.

The mean age ranged from 13,6 to 16,5 years, with a mean age across all studies of 14,5.

The most common site of injury was the anterior inferior iliac spine in 46%, anterior superior iliac spine in 31%, ischial tuberosity in 12% and iliac crest in 11%.

Conservative treatment was performed in 270 patients and surgical treatment in 44 injuries.

The rate of excellent outcome was higher in patients receiving surgery with 97% compared to the rate of patients receiving non-operative treatment with 81%.

The return to sport rate was evaluated on a population of 86 patients; 90% of the conservative group and 95% of the surgical patients returned to sports at follow-up.

Complications were assessed in 6 studies and 59 patients (non-unions, functional restriction, persistent hip pain, heterotypic ossifications and meralgia paraesthetica); the complication rate in the conservative group was 18% compared to surgical group 22%.

The rate of non-unions was lower in the surgical group (0%) than in the conservative group (2,5%), whereas there were more heterotypic ossifications in patients treated surgically (9% versus 1,8 %).

Serbest (13) analyzed a series of 5 cases on AIIS avulsion fractures all treated conservatively with bed rest with the affected hip flexed at 90 degrees for the first 2 weeks, a total weight bearing after 6 weeks and complete return to sportive activities allowed at 10 weeks; he reported a total recovery of the range of motion and a full return to pre-injury sports activity levels with excellent outcomes and absence of complications.

Similar outcomes were shown by Uzun et al. (18) in 9 males patients treated non surgically for AIIS avulsion; no limitation of motion, restriction of sports activities or complications were mentioned.

Pogliacomini (8) reported a cohort of 24 adolescent athletes affected by anterior iliac spines avulsion (19 AIIS and 5 AIIS avulsion) and treated surgically patients with fragment size and displacement >2 cm at the computed tomography (CT) scan. The surgery performed with screws was followed by a period of 30 days of immobilization with a progressive return to sports allowed at 2 months; the conservative group was treated with bed rest in cast immobilization for 1 month. Despite the clinical outcomes were not significantly different between the surgical and conservative group, a faster return to sport (78 versus 91 days) was noticed in patients treated surgically; whilst a transient meralgia paraesthetica was reported as the main complication of the surgical treatment, almost half of patients treated conservatively developed an excessive bone formation during healing with a case of visible and painful impingement of the hip joint.

Same inclusion criteria, based on greater fragment dislocation, were used by Kautzner et al. (18) for the surgical treatment of ASIS avulsions; they also

Table 1. Study characteristics. Clinical outcome, return to sport and complications rates

	Year	Patients	Sex	Mean age	Injury site	Mean follow-up, months	Treatment	Return to sport at preinjury level	Clinical Outcome	Surgical complications	Conservative complications
Schuett	2015	228	173 M 55 F	14,4	ASIS 68 AIIS 112 IC 23 IT 25	10	2 Surgery 226 Conservative	Not available	Surgery: 2/2 Excellent Conservative: 189/226 Excellent		5 non-unions 32 persistent pain
Serbest	2015	5	3M 2 F	13,6	AIIS 5	2,5	5 Conservative	5/5	5/5 Excellent		
Uzun	2014	9	9 M	14	AIIS 9	26	9 Conservative	9/9	9/9 Excellent		
Kautzner	2014	23	19 M 4 F	15,1	ASIS 23	12	13 Surgery 10 Conservative	12/13 Surgical 8/10 Conservative	Surgery: 13/13 Excellent Conservative: 10/10 Excellent	2 heterotopic ossifications. 1 persistent pain and functional restriction	2 functional restriction 3 meralgia paraesthetica
Li	2014	10	Not available	14,6	IC 10	11,2	10 Surgery	10/10	10/10 Excellent	0	
Pogliacomì	2013	24	24 M	15	ASIS 5 AIIS 19	48	12 Surgery 12 Conservative	11/12 Surgical 12/12 Conservative	Surgery: 12/12 Excellent Conservative: 12/12 Excellent	1 heterotopic ossification 1 meralgia paraesthetica 3 impingement with soft tissues (screw removal necessary)	5 heterotopic ossifications
Ferlic	2013	13	12 M 1 F	14,7	IT 13	>24	5 Surgery 8 Conservative	4/5 Surgical 6/8 Conservative	Surgery: 4/5 Excellent Conservative: 4/8 Excellent		2 non-unions
Willinger	2017	2	2 M	16,5	ASIS 2	18	2 Surgery	2/2	2/2 Excellent	1 transient meralgia paraesthetica 1 heterotopic ossification	

showed a faster return to full activity (16 weeks) in the surgically treated group than the conservative group (17 weeks), choosing the operative treatment in competitive athletes and non-operative for the majority of noncompetitive sporting adolescents. Nevertheless, long term results were comparable between two methods with same rate of complication (minor heterotopic ossification) founding no evidence of superiority of a treatment over the other.

Willinger (19), in a case report of 2 athletes treated surgically for ASIS avulsion, found a complete return to sports in 10 weeks with a regained pain-free range of motion, confirming the surgical indication on the extent of the loose fragment and the dislocation assessed with CT scan.

Ferlic (20) reported a retrospective series of 13 patients with the ischial tuberosity; the decision for surgery was based on the radiological findings and the level of activity of the patient and was performed in all patients with a displacement >1,5 cm. All athletes treated operatively in acute had an excellent outcome and full return to athletic activities at 6 months. One patient was treated surgically after an initial conservative treatment as consequence of persisting pain and

development of a pseudoarthrosis; he had a good outcome with residual occasional pain and abandonment of the previous sport activity. In the group of patients treated conservatively, the author founded excellent outcomes with a dislocation less than 15 mm; conversely he reported the development of pseudoarthrosis in half of patients with a fragment displacement >1,5 cm and a significantly decreased ability to perform sports at the pre-injury level.

Li (14) presented a series of 10 patients surgically treated for avulsion fractures of the iliac crest apophysis; the fracture fixation using cannulated screws enabled immediate and active rehabilitation 2 days after surgery with the recovery of full athletic activities 4 weeks after the injury and no complications mentioned.

A larger retrospective case series of pelvic avulsion fractures including 228 cases was provided by Schuett (15); nearly all injuries were managed conservatively with only 2 athletes treated operatively with a displacement >2 cm. Author reported excellent outcomes with the non-operative approach in almost all patients; nevertheless 14% of patients had recurrent or continued pain >3 months especially in AIIS fractures. A

high rate of nonunions (16%) was observed in ischial tuberosity avulsions with a displacement >2 cm; since most nonunions in the series were asymptomatic, the author considered that the fracture displacement alone should not necessarily be an indication for surgery.

Discussion

Apophyseal fractures in adolescent are considered a particular challenge for orthopedic surgeon due to their low frequency, representing the 4% of all pelvic fractures (21) and just 1,4% of all fractures in young athletes; evidence based guidelines for the ideal treatment method are lacking.

Moreover the lack of awareness of this kind of injury and the aspecificity of reported symptoms (22-24) result in a high risk of misdiagnosis as muscular or tendinous tears or tendinitis; in the report of Serbest (13) all 5 patients were admitted to the emergency department and misdiagnosed for muscle strains.

Dealing with high demanding patients, sometimes professional athletes with expectations of a quick recovery, a wrong diagnosis leads to an inappropriate and premature return to practice with persistent hip pain, decrease in performances and higher risk of complications such as pseudoarthrosis.

Nearly all the apophyseal avulsion can be identified with standard antero-posterior and lateral X-rays of the hip (15, 21); plain radiographs are adequate to make a precise diagnosis and to determinate the fragment size and the displacement. Advanced imaging techniques, as CT scan and magnetic resonance imaging (MRI) should be used when the diagnosis is in doubt, to have a more accurate view of the fracture pattern and to differentiate AIIS fractures from the avulsions of the upper rim of the acetabulum; these injuries are caused by a pull of the reflected head of the rectus femurs arising from the superior acetabular ridge and the posterolateral hip joint capsule. Sometimes apophyseal fragments could be radiographically undersized if the apophyses are only partially ossified (25); in this situation a MRI is advised in the diagnosis in order to better evaluate the cartilaginous element of the fragment.

Furthermore the MRI is effective in assessment of musculotendinous tears that might be associated with

a bone avulsion (26).

In the literature the overwhelming part of the apophyseal avulsion is treated conservatively with many non-operative protocols consisting of a period of rest at bed followed by protected weight bearing and progressive return to sport generally allowed at 6 weeks after surgery (13, 15, 18, 20).

All the authors previously mentioned report excellent clinical outcomes with the conservative treatment with scores not significantly different from the surgical option; nonetheless, in the most of cases the indication to conservative treatment was provided for smaller displacement and fragment size, thus making impossible a real comparison of two methods as in a prospective randomized controlled trial. Furthermore, the scores commonly used in the evaluation of the hip, with very good or excellent results, have a ceiling effect providing a further limitation in the analysis of outcomes.

Frequent complications of this kind of treatment include heterotopic ossifications (8, 18) and pseudoarthrosis (15, 20); the risk of non-unions is significantly increased for ischial tuberosity avulsions with a displacement more than 1,5 cm. Potential development of a "hamstring syndrome", in which shortening and fibrosis at the origin of the hamstrings entrap the sciatic nerve, can be associated with chronic pain, inability to sit for a longer period of time and decreased ability to perform sports. A persistent pain after AIIS avulsion, as shown in Schuett case series (15), could be caused by a concomitant antero-superior tear of the acetabular labrum (27) at the insertion of the indirect head of the rectus femoris or by subspinal hip impingement with progression into femoro-acetabular impingement (28, 29).

Operative treatment has been recommended for greater fragments and displacements (14, 18, 19); Pogliacomì (8) uses as a cut-off a dislocation and a size >2 cm whereas Ferlic (20) is more restrictive with a 1,5 cm cut-off.

All the authors agree on the fact that (3, 5, 9-11) physical demand of the athlete who requires a rapid rehabilitation is another significant factor in the decision for or against surgery; they report all excellent outcomes.

In a recent systematical review with meta-analysis (30) comparing avulsion fractures with a displacement

of more than 1,5 cm, it was founded a significant difference with better outcomes of the operatively treated group over the conservatively treated; delay of return to sport was also founded to be shorter after the surgery, 12,6 weeks versus 17 weeks in the conservative therapy.

The earlier return to active exercises, due to a stable fixation and decreased level of pain, allows athletes to preserve the thigh muscle strength and the cardiorespiratory endurance shortening the achievement of pre-injury performances.

Complications of the surgery are represented by heterotopic ossifications that can be removed during screw extraction if symptomatic (18, 19) and transient meralgia paraesthetica for ASIS and AIIS avulsions (31). The use of a surgical anterior approach increases the risk of damage at the lateral femoral cutaneous nerve; the nerve has to be carefully localized and protected during the whole procedure (32).

The possibility of impingement between fixation devices and surrounding soft tissues also needs to be considered (8); in order to avoid this eventuality it's advised to embed and cover the screw during the placement or the use of absorbable screws (33).

Conclusion

Awareness of apophyseal avulsion fractures of the pelvis due to better imaging techniques has increased.

High levels of sport performances required in young patients can be compromised if a sudden diagnosis is not followed by a proper treatment.

Despite conservative and operative methods provide excellent outcomes in most cases, the surgical option ensures a shorter recovery time and is preferable in athletes with greater displacements.

However prospective randomized controlled trials are necessary in order to provide evidence-based guidelines.

Author contribution

Filippo Calderazzi: study design, data collection, writing.
Alessandro Nosenzo: data collection, writing.
Cristina Galavotti: data collection.
Margherita Menozzi: data collection.

Francesco Pogliacomì: study design.

Francesco Ceccarelli: study design, supervision.

All authors contributed to and approved the final version of manuscript.

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