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ORIGINAL PAPER/PŮVODNÍ PRÁCE

Pelvic Avulsion Fractures in Children: a Retrospective Study from Four Trauma Centers

Avulzní zlomeniny pánve u dětí: retrospektivní studie ze čtyř traumacenter

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ABSTRACT

Purpose of the study
Pelvic avulsion fractures in children are rare and usually associated with sports. The study aimed to evaluate the epidemiology, complications, and displacement cutoff value for surgical treatment.

Material and methods
In a retrospective study (2007–2022), we used a group of 201 boys and 20 girls ($p < 0.0001$). The mean age of boys was 14.9 ± 1.7, and 14.0 ± 1.9 years for girls ($p = 0.0129$). Injuries included 86 anterior superior iliac spine (ASIS), 83 anterior inferior iliac spine (AIIS), 28 ischial tuberosity (ITU), 13 iliac crest, nine reflected head of the rectus femoris avulsions, and two ipsilateral ASIS + AIIS avulsions. The displacement cutoff value was determined using logistic regression. Complications were assessed using Cox regression and Kaplan-Meier plots.

Results
The mean incidence of avulsions was 21 per 1,000,000 children per year. The highest prevalence of osteosynthesis was in ITU (10 out of 28, 35.71%); iliac crest and reflexed head avulsions were treated conservatively. Running was related to the highest risk of ASIS, football for AIIS, and gymnastics for ITU. Most avulsions occurred in September, the fewest in July.

Displacement cutoff values were calculated as 10.5 mm for ASIS, 9.5 mm for AIIS, and 14.5 mm for ITU. The most common healing complication was distraction 31 (14.0%), refracture in 2 ITU and non-union in 1 ITU; ITU complications were treated with osteosynthesis. According to the Cox regression, the following items significantly affected outcomes: fracture type ($p < 0.0001$), early verticalization ($p = 0.0062$), and initial displacement ($p < 0.0001$).

Discussion
Our study had several limitations, such as it was retrospective, there was a loss of patients from follow-up, and a lack of functional evaluations, for example, using Majeed's score modified for pediatric patients. The positives of the study included a relatively large group of patients from multiple hospitals, the use of logistic regression to determine displacement values to help differentiate between OS and conservative treatment, the inclusion of fracture incidence data, and the inclusion of patients with both surgical and conservative treatment.

Conclusions
In the case of ASIS and AIIS avulsions, osteosynthesis can be considered for displacements ≥ 1 cm and ≥ 1.5 cm for ITU avulsions. Early verticalization was associated with a lower risk of healing complications in distraction injuries.

Key words: avulsion injury, pediatric pelvic fracture, multicentric study, epidemiology, complication.

INTRODUCTION

Avulsion fractures associated with the pelvis in children are rare injuries, with an overall incidence estimated at 10 per 1,100,000 children per year (7). Avulsion fractures (type A) are mostly caused by low-energy injuries, especially during sports activities (1–10). In the treatment pelvic avulsion fractures in children, both conservative and surgical treatments have a place (11–20, 22, 24–30). So far, there are no general recommendations regarding the degree of displacement, age, the degree of soft tissue injuries that would unambiguously identify patients best suited for surgical treatment to achieve better functional and radiological outcomes. Our study had three basic objectives: (1) to evaluate the overall incidence of childhood pelvic avulsion fractures needing conservative or surgical treatment, (2) to determine displacement cutoff values, using clinical and radiological data, that would indicate the need for surgical treatment of the three most frequently occurring avulsion fractures, and (3) to evaluate complications with regard to the type of fracture and type of therapy.

MATERIAL AND METHODS

Ours was a retrospective study using data from four pediatric trauma centers. Patients were followed for at least 0,5 year or until fractures had healed. The group consisted of 201 boys and 20 girls (**$p < 0.0001$**). On average, boys were older (14.9 ± 1.7) than girls (14.0 ± 1.9 years; $p =$ **0.0129)**. The following avulsion fractures were documented: 86 anterior superior iliac spine (ASIS), 83 anterior inferior iliac spine (AIIS), 28 ischial tuberosity (ITU), 13 iliac crest (ICR), 9 reflected head of the rectus femoris muscle (RH) and two ASIS and AIIS. Both surgical and conservative treatments were used to treat ASIS, AIIS, ITU, and combination ASIS and AIIS avulsions, while all ICR and RH avulsion fractures were treated conservatively. The initial displacement and the remaining displacement after healing (displacement 2) were evaluated using anteroposterior (AP) images only – in the case of a rotation fragment displacement or image rotation, measurements were always performed at both peripheral edges of the fragments and at the central part of the fragment, the three values were used to determine the mean. During hospitalization, basic epidemiological data (age, gender, type of fracture, cause of fracture), time to verticalization, time to complete healing, occurrence of prolonged healing, non-union, the incidence of thromboembolic and infectious complications were monitored. We arbitrarily chose a displacement value ≥ 10 mm on AP images to define post-healing distraction. When fracture displacements were in the range of 1 to 20 mm, surgeons were given a choice between surgical and conservative therapy, while fractures with displacements > 20 mm were primarily indicated for surgical treatment regardless of type (5, 7, 11, 24). In surgical treatments, most patients underwent primary surgical stabilization. Secondary stabilization was needed in three cases where refracture occurred during conservative therapy; all three were avulsion fractures of the ischial tuberosity.

Table 1. **Type of implants according to the fracture type**

IMPLANTS	ASIS	AIIS	ASIS + AIIS	ITU
Screws	5	10	0	9
Screws + K-wires	6	5	0	0
K wires	1	0	0	0
Suture	0	2	0	0
Anchors	0	0	0	1
Anchors and K-wires	0	0	1	0
ASIS vs. ITU	**$p = 0.0106$**			

Operative approaches by types of avulsion fractures

For ASIS avulsions, the iliac window of the ilioinguinal approach was used to a limited extent in the ASIS region; AIIS avulsion fractures were treated from the anterior approach (Smith-Peterson). The lateral femoral cutaneous nerve (LFCN) must be located and protected. If an ultrasonographic examination is available in the operating room, displaying the course of the LFCN before the skin incision, especially in the ASIS area, is desirable since there is variability in its course (18).

In the case of ITU avulsions, a dorsal approach was used, which begins in the area of the gluteofemoral groove and continues longitudinally distal in the range of 10 cm (a less preferable alternative is an incision in the gluteofemoral groove). After superficial preparation of the subcutaneous tissue, an incision in the gluteal fascia is made, and the hematoma is evacuated. Subsequently, the sciatic nerve is located and protected.

The implants used for fixation are shown in Table 1; the table also shows that regardless of the type of fracture, screws were the most frequent choice.

Conservative therapy in ASIS, AIIS, and RH included resting until the acute pain subsided and positioning the injured lower limb in mild semi-flexion of the knee and hip. For ICR avulsions, positioning to the injured limb was further restricted. For ITU avulsions, sitting was restricted for at least one week. The exact time until the first verticalization was left to the discretion of individual workplaces; it was not strictly prescribed. Walking on crutches to reduce stress on the injured limb was prescribed for at least one month after the injury or until the fracture had healed.

Statistical methods

Simple exponential smoothing was used to evaluate the overall incidence. Categorical epidemiological data were

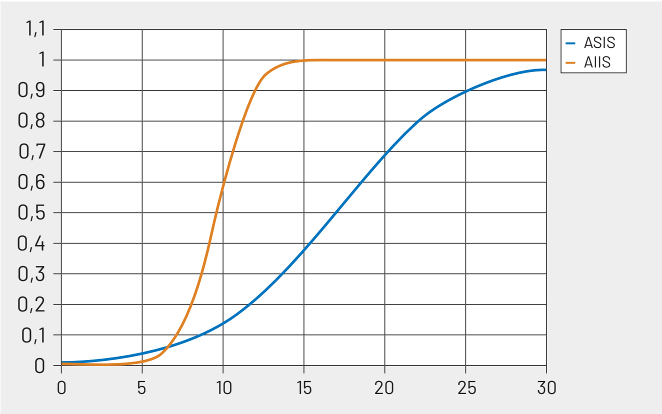

Fig. 1. **Probability of surgical treatment (OS) in ASIS and AIIS avulsions.**

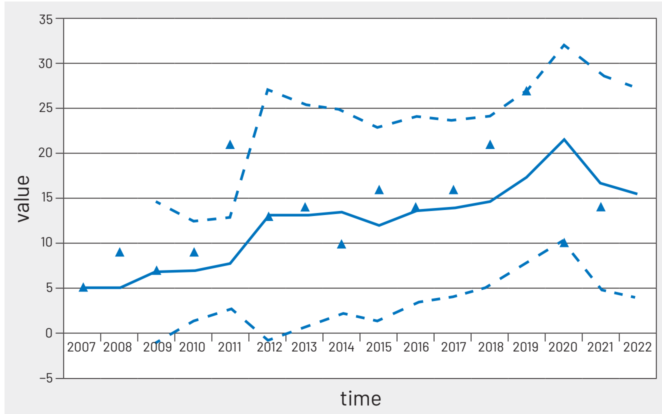

Fig. 2. **Total incidence of pelvic avulsion fractures per year.**

evaluated using Fisher's exact test, the Chi-squared (χ^2) test with Yates correction. Examining whether the relative distribution of surgical treatment significantly varied by fracture type, a Chi-squared test with Yates correction was utilized. Post hoc comparisons were employed to investigate differences in the frequency of surgical treatment among different fracture types. Quantitative epidemiological data were evaluated using the Mann-Whitney-Wilcoxon test. With more than two data groups, data were evaluated using the Kruskal-Wallis test with post hoc comparison and the paired MWW exact tests. Linear regression analysis was used to determine the effect of therapy on the final displacements in relation to the initial displacements and type of fracture. Logistic regression curves and accuracy analyses were utilized to determine cutoff values for initial displacement, serving as indicators for surgical treatment. For the probability of surgical treatment,

$$p \text{ was } p = (1 + e^{-kl-q})^{-1}$$

where *k* is the slope of logistic regression and *q* is the intercept of logistic regression and *l* the initial displacement. For the ASIS + AIIS combined injury, we used an estimate using the probability equality of ASIS and AIIS surgical treatment *p (SIAS) = p (SIAI)* from where we are a solution of linear equations from both exponents received an estimated displacement, 95% of CI was determined again by Wilson. We also verified the obtained estimate graphically by combining the ASIS and AIIS regression curves into one graph (Fig. 1).

Multivariate analysis evaluated the risk of complications dependent on time, utilizing Cox regression to analyze how multiple factors influence complication risks. Kaplan-Meier curves were used to visually depict the incidence rates of complications over time for different fracture types, facilitating comparative analysis of relative risks.

Statistical analysis was performed in MS Excel 2019 with the realstat add in, version from the end of 2022 (https://real-statistics.com/). Significance was set at $p < 0.05$.

RESULTS

During the study period (2007–2022), the average incidence of avulsion fractures was 21.1 ± 8.7 (16.8–25.4) per 1 million children per year (± SD, 95% CI). The incidence of surgical treatment was 3.8 ± 2.8 (2.4–5.2), and the incidence of conservative treatment was 17.3 ± 7.1 (13.8–20.8). When comparing the actual incidence from the four trauma centers by individual years, an upward trend was observed for all incidences: for the overall incidence, the upward slope was 0.896 (95% CI 0.597–1.086), **$p < 0.0001$** (Fig. 2), for surgical treatment, the upward slope was 0.329 (95% CI 0.219–0.371), **$p = 0.0002$,** and for the incidence of conservative treatment, the upward slope was 0.607 (95% CI 0.521–0.698), **$p < 0.0001$**. The most common fractures in boys were AIIS fractures (81 fractures, 40.3%). The most common fractures in girls were ASIS (7 fractures, 35.0%) A comparison of fracture types by sex is shown in Fig. 3. When compared in the 6x2 table, there were significant differences in fracture types between boys and girls – χ^2 with Yates correction **$p = 0.0015$**. Pairwise post hoc comparisons showed differences in AIIS fractures, which were highly significantly more common in boys ($p = 0.0071$), while in girls, ITU avulsions were significantly more common (**$p = 0.0146$**) (Table 2). The mean age of patients varied not only by gender

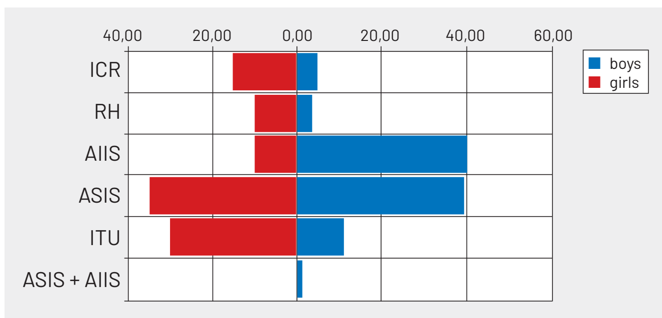

Fig. 3. **Relative numbers of fractures according to fracture type and sex.**

Table 2. **Numbers and mean age according to fracture type and sex**

	ICR	RH	AIIS	ASIS	ITU	ASIS+AIIS	TOTAL
Girls							
count	3	2	2	7	6	0	20
rate %	15.0	10.0	10.0	35.0	30.0	0	100.0
mean age	15.0	12.5	11.5	15.6	13.1		14.0
Boys							
count	10	7	81	79	22	2	198
rate %	5.0	3.5	40.3	39.3	11.0	1.0	100.0
mean age	14.3	14.1	14.4	15.6	14.8		14.9

Table 3. **Etiology and fracture type**

	ASIS	AIIS	ITU	ICR	RH	ASIS+AIIS
Soccer	35 (31.8%)	54 (**49.1%**)	13 (11.8%)	4 (3.6%)	4 (3.6%)	0
Running	22 (**48.9%**)	15 (33.3%)	3 (6.7%)	1 (2.2%)	3 (6.7%)	1 (2.2%)
Gymnastics	3 (37.5%)	1 (12.5%)	4 (**50.0%**)	0	0	0
Jumping	5 (**41.7%**)	2 (16.7%)	1 (8.3%)	3 (25.0%)	0	1 (8.3%)
Others	21 (**45.7%**)	11 (23.9%)	7 (15.2 %)	5 (10.9%)	2 (4.3%)	0

Table 4. **Rates of internal fixation according to fracture type**

	SURGICALY	CONSERVATIVELY	% OS	95% CI	
ASIS	12	74	14.0	7.42	23.11
AIIS	17	66	20.5	12.41	30.76
ITU	10	18	35.7	18.64	55.93
ICR	0	13	0	0.00	24.71
RH	0	9	0	0.00	33.63
ASIS + AIIS	1	1	50.0	1.26	98.74

but also by type of fracture; the lowest mean age was found in girls with AIIS fractures (11.5 ± 0.7 years; 95% CI 10.5–12.5), while the highest mean age was recorded in boys with ASIS fractures (15.6 ± 1.1 yrs.; 95% CI 15.4–15.9). The relationship between fracture types and age in boys was $p < 0.0001$; for girls, the relationship between fracture types and age was **p = 0.0134,** detailed comparisons for these relationships are shown in Table 2. The differences in the mean ages between boys and girls are due to the difference in the appearance and maturation of secondary ossification centers.

The mechanism of avulsion fractures varied according to the type of fractures. When comparing the relative risk of fracture occurrence by mechanism, the following was noted: for ASIS fractures, running had the greatest risk (48.89%); for ASIS, it was European football (soccer) (49.09%), for ITU the greatest risk involved gymnastics (50.00%), for ICR it was jumping (25.00%), for RH it was running (6.67%) and for ASIS and AIIS combinations it was jumping (8.33%). Pairwise comparisons of sport vs. fracture types are shown in Tables 3.

In total, 40 patients (18.10%) underwent surgical treatment (OS). OS representation varied by fracture type – it did not occur in ICR and RH avulsions. OS was most common in the ITU fractures (10 out of 28) Table 4. Surgical treatment of an ASIS and AIIS combination could not be statistically evaluated (one patient was treated surgically and one conservatively). The relative distribution of surgical treatment varied significantly (Yates **p = 0.0097**). There were significantly more OS in ITU vs. ASIS (**p = 0.0244**) and ITU vs. ICR (**p = 0.0172**).

The surgical treatment was associated with a significantly smaller displacement after healing (ASIS **p = 0.0016**, AIIS **p = 0.0006**, and ITU **p = 0.0255)**; details are shown in Fig. 4a, 4b, 4c.

The cutoff values for the initial displacement that served as an indication of surgical treatment were determined using a logistic regression curve (dependence of probability of OS on initial displacement) and accuracy analysis. For ASIS avulsion fractures, a displacement of **10.5 mm** (8.4–12.7), accuracy of 84.71% (75.27–91.60). In AIIS fractures, the cutoff

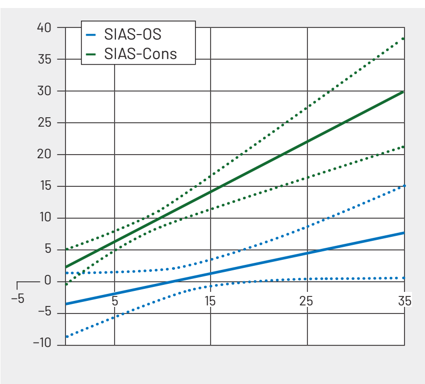

Fig. 4a. **Dependence of the final displacement on the initial displacement in ASIS.**

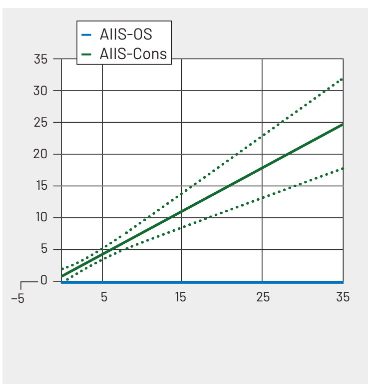

Fig. 4b. **Dependence of the final displacement on the initial displacement in AIIS.**

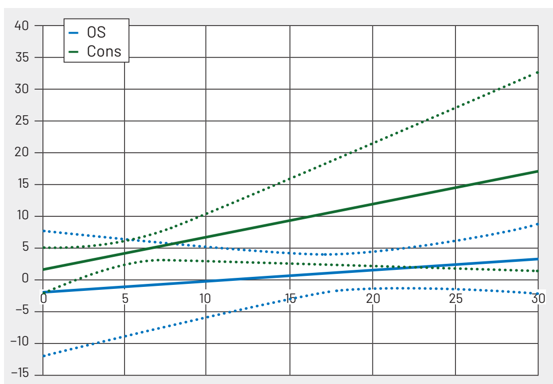

Fig. 4c. **Dependence of the final displacement on the initial displacement in ITU.**

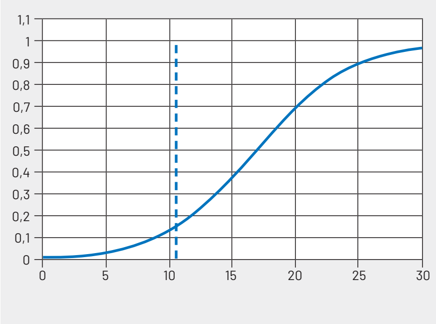

Fig. 5a. **Logistic regression in ASIS fractures (probability of surgical treatmant based initial displacement), cut off 10.5 mm.**

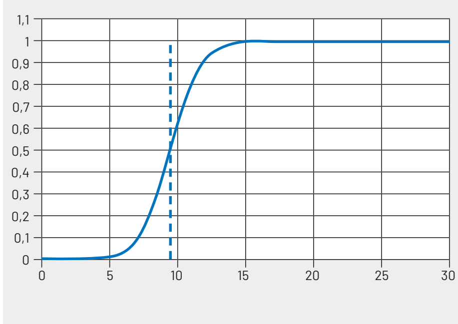

Fig. 5b. **Logistic regression in AIIS fractures (probability of surgical treatmant based initial displacement), cut off 9.5 mm.**

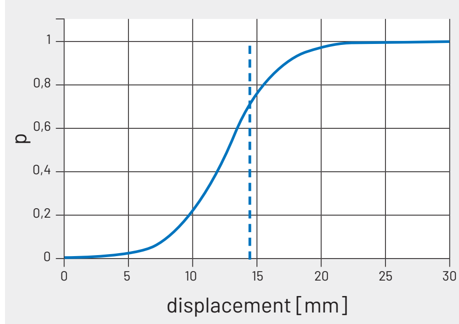

Fig. 5c. **Logistic regression in ITU fractures (probability of surgical treatmant based initial displacement), cut off 14.5 mm.**

was slightly lower at **9.5 mm** (9.0–9.9); accuracy of 92.77% (84.93–97.30). In ITU avulsion fractures, the cutoff displacement was the largest at **14.5 mm** (12.9–16.2), accuracy 96.43% (81.65–99.91). Individual logistic regression curves, together with the cutoff, are shown in Fig. 5a, 5b, and 5c.

For the ASIS and AIIS combination, a cutoff displacement was estimated based on a comparison of the probability of surgical treatment from the ASIS and AIIS regression curves; this estimate yielded a displacement of 6.6 mm (95% CI 5.7–7.5) (Fig. 1); due to the lack of data for these combined injuries, it was not possible to perform analysis of accuracy from ROC curve.

Analysis of the overall complication incidence using Cox regression showed three important factors in the multivariate analysis: fracture type (**$p < 0.0001$**), initial displacement (**$p < 0.0001$**), and time to verticalization (**$p = 0.0062$**). The highest relative proportion of complications was in ASIS fractures (31.40%), while no complications were found in ICR, RH, and ASIS + AIIS fractures. For the entire group of patients (regardless of fracture type), the relative incidence of complications was 15.84%. The mutual comparison of fracture types and incidence of complications is shown using Kaplan-Meier curves (Fig. 5) and detailed in Table 5.

The initial displacement was a presumed risk factor since the most common complication was healing in distraction.

Table 5. **Relative risk of complications according to fracture type**

	COMPLICATIONS	WITHOUT	% RISK	95% CI (PERC.)	
ASIS	**27**	**59**	**31.40**	**21.81**	**42.30**
AIIS	3	80	3.61	0.75	10.20
ITU	5	23	17.86	6.06	36.89
ICR	0	13	0.00	0.00	24.71
RH	0	9	0.00	0.00	33.63
ASIS + AIIS	0	2	0.00	0.00	84.19
Total	**35**	**186**	**15.84**	**11.29**	**21.33**

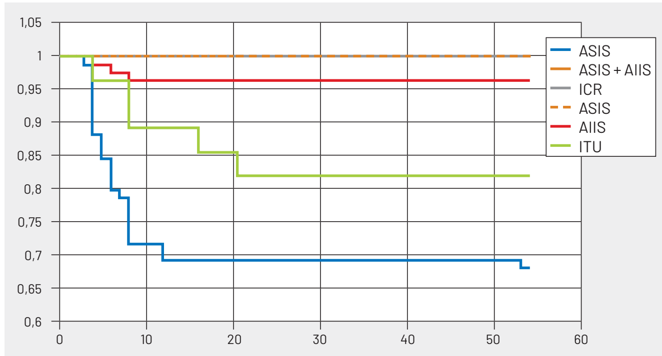

Fig. 6. **Complications according to fracture type, multiple log-rank test $p < 0.0001$.**

An increase in the initial displacement of 1 mm corresponded to a Cox regression risk ratio of 1.1514 (95% CI 1.0983–1.2070), **$p < 0.0001$**.

Early verticalization was associated with a significantly lower risk of complications; for every seven days of earlier verticalization, the Cox regression risk ratio improved by 0.5281 (95% CI 0.3343–0.8344), **$p = 0.0062$**.

In the evaluation of individual complications, fracture line distraction was the most common (31 patients; 14.30%; 95% CI 9.73–19.32). Other complications were noted in four patients: LFCN dysaesthesia and ITU non-union occurred once each (0.45%; 95% CI 0.01–2.50), and ITU refracture occurred in two cases (0.90%; 95% CI 0.11–3.23). ITU refracture, which occurred, in both cases, during conservative treatment, was stabilized using cannulated screws. There were no infectious complications or thromboembolic problems associated with the avulsion fractures in our study group (95% CI 0.00–1.66).

DISCUSSION

Pelvic avulsion fractures are rare in children, they represent the vast majority of type A pelvic injuries. In our earlier study, avulsion fractures of the pelvis were found in 187 of 281 patients type A – 66.55%; in an updated group of 358 patients, this corresponded to 52.23%; the data show that avulsion fractures are the most common pelvic injury in children (22). Our overall incidence of avulsion fractures was 21.1 ± 8.7 (16.8–25.4) per 1 million children per year was higher than the value reported in the literature, i.e., 10 per 1 million per year (7) but quite comparable to our previous study (21.9 per 1 million per year) (22). Fig 2a and 2c showed a slight decrease in the incidence of these fractures during the COVID-19 pandemic, but this did not significantly affect the increase in pelvic avulsion fractures in children over the 16-year period studied.

The etiology of childhood avulsion fractures involves excessive muscle contraction, which indirectly leads to the loosening of apophyseal growth cartilage (8–10,12). Only rarely is there a direct fracture mechanism, which is more frequent before the appearance of secondary ossification centers and can lead to chondral and osteochondral fractures (7-11). Therefore, the incidence of pelvic avulsion fractures correlates with the age of appearance of secondary ossification centers. Recently, the time course of secondary ossification centers was studied by DeFrancesco et al. 2017 (7). The apophysis of the iliac crest appears between 13 and 15 years of age and disappears between 15 and 17 years of age; the apophysis of the ischial tuberosity is noticeable between 15 and 17 years and fuses around 19 years of age. The apophyseal centers of the superior anterior iliac spine and anterior inferior iliac spine form around 14 years of age and disappear around 16 years of age.

ASIS avulsions are most often caused by contraction of m. sartorius, rarely, it may involve contraction of the tensor fasciae latae muscle (30), the most common mechanism is rapid flexion of the hip and knee when starting a run or tripping over an obstacle, which is consistent with running being the riskiest mechanism (1, 4, 15). AIIS avulsions are associated with abnormal contraction of the rectus femoris m. during hip flexion, or associated with hip flexion and knee extension, e.g., when kicking a ball (4, 12, 20, 27, 29). In our study, football was the riskiest activity associated with AIIS avulsions. Avulsion of anterior inferior iliac spine, where the rectus femoris originates near the supraacetabular sulcus, is associated with forced hip flexion greater than 90°, and is associated with hurdles and sprinting (27). Combined ASIS and AIIS avulsions are most often caused by the joint contraction associated with the sartorius m. and the rectus femoris m. (21); in our group, this injury only occurred in two patients; the avulsion is linked to jumping injuries.

The iliac crest is the insertion of the abdominal external oblique muscle and the origin of the internal obliques m. and insertion of the transverse abdominal muscle, so a sharp contraction of the muscles of the abdominal wall can lead to an avulsion, which occurs, e.g., during various jumps and landings (16). The ischial tuberosity is the origin of several muscle groups: the hamstrings, the gemellus inferior muscle, the superficial transverse perineal muscle, the quadratus femoris muscle, and the superior parts of the adductor magnus muscle, but from the biomechanical point of view, only the hamstrings and the superior part of the adductor magnus have a major influence – the long head of the biceps femoris muscle (located most dorsally and caudally), the semimembranosus muscle (originates on the outer and upper surfaces) and the semitendinosus muscle (originates on the lower and inner parts of the ischial tuberosity). The most common mechanism is violent "side splits or front splits," or a violent, sudden extension of a flexed knee. The injury is caused by slipping in soccer, which is more common in boys, and gymnastics, which is significantly more common in girls (2, 3).

In the diagnosis of avulsion fractures, in addition to a clinical examination, a simple X-ray image in AP projection is needed, but it is recommended only after the appearance of secondary apophyseal ossification centers; in younger patients, a musculoskeletal ultrasound examination (USG) is preferable since it can also help visualize chondral and osteochondral fractures (7, 19). In cases with a negative USG and X-ray but an ongoing clinical suspicion, an MRI of the pelvis is advisable. An MRI is also advantageous when assessing the development of the pelvis or the "freshness" of a refracture. An MRI should always be preferred to a CT scan in patients under 15 years of age, not only because of the radiation load but because of the greater specificity of MRIs (14, 17).

As far as we know, our study was the first to analyze the criteria for OS using logistic regression curves (occurrence of OS based on the degree of displacement) and, at the same time, ROC curve analyses to find the cutoff displacement value for the best outcomes. For ASIS, AIIS, and ITU, we found values of 10.5 mm, 9.5 mm, and 14.5 mm, respectively, were in good agreement with the reported indications in the literature (5, 6, 11, 18, 24, 27). However, the initial displacement should not be the only indication for OS; it is necessary to evaluate associated injuries, local soft tissue findings, and the presence of neurological lesions. For ASIS and AIIS fractures, injury to the lateral femoral cutaneous nerve (LFCN), and ITU fractures, a possible lesion of n. sciatic (13) need to be considered.

In ITU fractures, the extent of the avulsion needs to be assessed. Two basic types of injury are newly distinguished, (1) partial avulsion of the lateral part of the tubercle (usually involving only m. semimembranosus), (2) complete avulsion fracture of the ischial tuberosity (additionally involving the origin of the m. adductor magnus) (14).

According to our study, complete ITU avulsion fractures (type 2) have a significantly greater risk of non-healing. The two types of ITU fractures are distinguishable using an MRI examination (14).

The analysis of ROC curves showed the best outcomes for ITU avulsions, where there was 100% specificity; the OS cutoff displacement value for ITU avulsions was 14.5 mm. In contrast, for ASIS avulsions, sensitivity and AUC below the ROC curve were lower, which is due to a relatively lower proportion of surgical treatment and lack of patient randomization. With the combination of ASIS and AIIS avulsions, ROC curve analysis was not possible, and therefore further studies are needed on these rare injuries. However, due to the greater extent of injury compared to isolated ASIS and AIIS avulsions, these combined fractures are more actively considered for surgical treatment.

Complications depend primarily on the size of the displacement after healing; the most common healing complication in our study was distraction. In our study, we chose 10 mm as the limit value for a good post-healing position. Fortunately, healing in distraction was not associated with an unfavorable functional outcome in either patient, but we are aware of the possible functional limitation in flexion after AIIS avulsions that healed in distraction and the possible development of femoroacetabular impingement (FAI), especially in active athletes (2, 11, 13, 24, 25, 26). Relatively recently, we operated on a patient with AIIS healed in distraction (he did not fit into our group), he had limited flexion by about 10 degrees, it did not matter, but he was not an athlete. We think that healing in distraction, especially in AIIS, is a complication precisely because of extraarticular impingement. In accordance with other studies, we recorded an increased incidence of refractures and non-union in ITU avulsions only (2, 11, 13, 24, 25). Prevention of thromboembolic complications was carried out according to the protocols recommended in the individual trauma centers. Low-molecular-weight heparin (LMWH) was used in all high-risk patients (obesity, smoking, hormonal contraception, positive personal or family history) aged ≥ 13 years for 7 to 10 days after injury, always on the recommendation of a pediatric hematologist (23).

Our study had several limitations, such as it was retrospective, there was a loss of patients from follow-up, and a lack of functional evaluations, for example, using Majeed's score modified for pediatric patients. The positives of the study included a relatively large group of patients from multiple hospitals, the use of logistic regression to determine displacement values to help differentiate between OS and conservative treatment, the inclusion of fracture incidence data, and the inclusion of patients with both surgical and conservative treatment.

CONCLUSIONS

The incidence of avulsion fractures in our study was about twice as high as reported in the literature. For ASIS and AIIS avulsion fractures, surgical treatment should be considered for displacements greater than 1 cm, and for ITU avulsions, displacements greater than 1.5 cm. Early verticalisation of patients was associated with a lower risk of healing in distraction. Further prospective multicenter studies would be appropriate to specify OS and conservative indications as well as optimal time-to-verticalization using randomization and paired matching of patient groups according to initial displacement. ■

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