Potential MRI findings associated with inguinal hernia and inguinal canal posterior wall weakness in athletes

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Summary

***Introduction*: Inguinal hernia and inguinal canal posterior wall weakness, are a frequent clinical issue in chronic groin pain syndrome. The gold standard imaging is represented by dynamic ultrasound (US), with a high positive predictive value in case of inguinal and sport hernia. However, it is important to consider that groin pain syndrome may be caused by several clinical conditions that often are detectable only with magnetic resonance (MRI) assessment.**
***Methods*: In an observational cross sectional study, 120 patients suffering from groin pain syndrome caused by inguinal hernia and/or inguinal canal posterior wall weakness diagnosed by clinical assessment and US examination, underwent a MRI protocol validated for pelvis and pubic area assessment. The same protocol was performed on a control group of 40 asymptomatic subjects.**
***Results*: Several MRI findings are strongly associated with the presence of inguinal hernia and/or inguinal canal posterior wall weakness.**
***Conclusions*: The presence of some specific MRI findings can make suspect the presence of inguinal hernia or inguinal canal posterior wall weakness.**
Level of evidence: Level IV. Observational cross sectional study.

KEY WORDS: groin pain syndrome, inguinal hernia, inguinal canal posterior wall weakness, MRI, US.

Introduction

Groin pain syndrome (GPS) can be caused by many clinical entities, including inguinal hernia (IH)[1-3] and inguinal canal posterior wall weakness (ICPWW)[3,4]. The inguinal canal posterior wall weakness is the presence of a bulging without signs of a "true" hernia and without the presence of a real hernia sac[3,4]. This condition is described in literature using different terms, like "Gilmore's groin"[5], "incipient hernia"[6], "hockey groin"[7], "groin disruption"[8], "inguinal disruption"[1], "inguinal related groin pain"[2], "sportsman's hernia"[9], "sportsman's groin"[10], "sport hernia"[11]. However, in according with the guidelines of Groin Pain Syndrome Italian Consensus Conference on Terminology, Clinical Evaluation and Imaging Assessment in Groin Pain in Athlete[3], we prefer in this study to define this specific condition using the term of ICPWW. Both IH and ICPWW represent an important disability source and are often an important cause of time loss from sport activities in athletes[12,13]. The gold standard in imaging for IH and ICPWW assessment is currently the dynamic US[14]. Dynamic US shows a positive predictive value (PPV) between 91-100% for

IH and ICPWW[14-17]. However, GPS may be caused by several clinical conditions[2,3,18] often each other associated[3,4,19,20]. Many of these clinical frameworks can be observed by MRI[11,18,21-31]. The aim of this cross sectional study was to verify, with a MRI protocol previously validated for GPS assessment[30], the potential radiological findings associated with IH and ICPWW.

Material and methods

Study design

Observational cross sectional study on 120 patients clinically and radiologically diagnosed of GPS, caused by IH and/or ICPWW (diagnosed by clinical assessment and US examination). All of them underwent to an MRI protocol[30] for the assessment of the pelvis and the pubic area. Ethical approval and written consent by each participant were obtained. The STROBE statement[32] supplemented by TIDieR checklist and guide[33] were followed for the creation of the study design. Furthermore, when designing this study both the Minimal Reporting Standard for Groin Pain in Athlete[34] and Groin Pain Syndrome Italian Consensus Conference on Terminology, Clinical Evaluation and Imaging Assessment in Groin Pain in Athlete[3] were consulted. The Authors declare that this research was conducted ethically according to the principles in line with the Declaration of Helsinki and that this study respects basic principles and recommendations in clinical and field science research required by Muscle, Ligaments and Tendons Journal[35].

Setting

The study included a Study Group (SG) and a Control Group (CG). All patients (172 subjects) registered to our Groin Pain Clinical Centre complaining GPS during the period between December 2015 and May 2016 were included in the SG. All patients were examined by an experienced sports medicine physician, an abdominal surgeon and the images were reviewed by two radiologists in a blinded manner. The clinical assessment was performed according with the guidelines from the Groin Pain Syndrome Italian Consensus Conference on terminology, clinical evaluation and imaging assessment in groin pain in athletes (GPSICC)[3]. There were 40 subjects in the CG.

Eligibility criteria

Inclusion and exclusion criteria were established in accordance with the GPSICC guidelines.

The inclusion criteria for the SG were being a patient with a GPS clinical framework caused by IH or ICPWW and diagnosed by clinical assessment and dynamic US examination. Exclusion criteria were having an acute GPS framework due to indirect muscle injury. Furthermore, all the patients showing a GPS clinical framework due to other causes were also excluded. Inclusion criteria for the CG provided were being a healthy subject practicing sport activities with no experience of GPS during the last year and with demographic data similar to the SG group.

Participants

According to the above mentioned eligibility criteria of the SG, 35 subjects who showed indirect muscle injury at adductors, ileopsoas and rectus abdominis muscles level, 1 subject with pubic symphysis stress fracture, 3 subjects showing apophysitis at anterior inferior iliac spine, 6 subjects with apophysitis at anterior superior iliac spine, 1 subject with apophysitis at ischial tuberosity level, and 6 subjects with gynaecological frameworks were excluded from the study. Following these exclusions criteria, 120 patients were enrolled in the study. Subsequently all the subjects underwent an MRI protocol[30] for the assessment of the pubic area.

Demographic data

The following demographic data, both for SG and CG, were recorded: gender, age, height, body weight. Furthermore, the duration of GPS symptoms in SG subjects was recorded and its average subsequently calculated.

The age, height and body weight of the 116 men and 4 women enrolled in the SG were respectively 29.58 ± 9.85 years, 177.51 ± 5.72 cm and 75.25 ± 9.21 kg.

The age, height and body weight of 10 men and 10 women enrolled in the CG were respectively 29.53 ± 8.73 years, 178.32 ± 4.92 cm and 77.19 ± 8.11 kg.

The average duration of GPS symptoms in the subjects of SG was 13.93 ± 3.6 months.

The type and level of sport activity and the years of practice, both for SG and CG, are shown in Table I and Table II respectively.

US protocol

The US examination was performed by 2 different expert radiologists in a blinded manner using the same equipment (TERASON U SMART 3300 linear probe 15 - 4 MHz). The protocol was in conformity with the GPSICC guidelines[3] and in particular the definition of IH and ICPWW followed met the following criteria:

- IH is classified as a hernia sac, which occupy more or less deeply the inguinal canal, clearly visible through an US image
- ICPWW is classified as a bulging with no the presence of hernia sac, through an US image observation.

The IH were classified according to European Hernia Society classification[36], as direct hernia (M1, M2, M3), indirect hernia (L1, L2, L3) and femoral hernia (F1, F2, F3).

MRI protocol

The MRI protocol was in conformity with the protocol suggested by Branci et al.[30] and provided the use of a 1.5 Tesla MRI (SIEMENS MAGNETOM Espree 1.5 T open bore). During the examination, patients were in supine position and the surface coil was centred at the pubic symphysis covering the total pelvic area.

Table I. Type of sports activity, level and years of practice of the subjects enrolled in the SG.

Sports activity (% of total)	Professionals (% of total athletes practicing the same sport)	Amateurs (% of total athletes practicing the same sport)	Average years of practice ± standard deviation)
Soccer 81 (67.50%)	10 (12.35%)	71 (87.65%)	18.81 ± 3.75
Basketball 3 (2.50%)	---	3 (100%)	10.31 ± 2.11
Volleyball 3 (2.50%)		3 (100%)	11.21 ± 3.83
Ski 1 (0.83%)	1 (100%)		11
Tennis 4 (3.33%)		3 (100%)	8.56 ± 6.41
Other recreational activities 28 (23.33%)	---	28 (100%)	11.81 ± 5.30

Table II. Type of sports activity, the level and years of practice of the subjects enrolled in the CG.

Sports activity	Professionals	Amateurs	Years of practice (average ± standard deviation)
Soccer 26 (65.00%)	---	26 (100%)	17.81 ± 4.73
Basketball 1 (2.50%)	---	1 (100%)	12
Volleyball 1(2.50%)	---	1 (100)	14
Tennis 2 (5%)	---	2 (100%)	8.522 ± 5.39
Other recreational activities 10 (25.00%)	---	10 (100%)	12.31 ± 4.93

The MRI sequence provided the acquisition of images weighed in T1, T2 Fat Sat, STIR and PD Fat Sat into the coronal, axial, sagittal and axial oblique plans. The axial oblique plane was oriented 50° from the horizontal one, and it was placed parallel to the long axis of the superior pubic rami. The total duration of the protocol was about 40'.

The MRI protocol was evaluated by 2 different expert radiologists in blinded manner. In the MRI evaluation protocol the presence of the following findings was verified:

I. bone marrow oedema (BMO)
II. fatty infiltration in bone marrow at symphyseal joint level (FI)
III. symphyseal sclerosis (SS)
IV. parasymphyseal high-intensity line (PHIL)
V. secondary inferior cleft sign (SICS)
VI. secondary superior cleft sign (SSCS)
VII. subchondral cysts / joint surface irregularities (SC-JI)
VIII. central disc protrusion (CDP)
IX. adductor longus tendinopathy (ALT)
X. rectus abdominis tendinopathy (RAT).

The MRI sequences and the details of acquisition are specified in the Table III.

Statistical analysis

The k values for inter-observer reliability for US and MRI findings were calculated.

The data recorded during the MRI protocol in SG and CG were compared with Fisher's exact test to compare the proportion of two groups for each considered value.

A logistic regression was performed on the significant possible value inferred by the Fisher's exact test.

The statistical significance was set to $p<0.05$.

Results

The results of US findings for the SG are showed in Table IV.

The inter-observer reliability values concerning US findings in the SG are showed in Table V.

The findings of MRI studies in the SG are showed in Table VI.

The inter-observer reliability values concerning MRI findings in the SG are showed in Table VII.

The association of US and MRI findings in the SG is showed in Table VIII.

No subject belonging to the CG was positive for inguinal pathology at the US examination. The results of MRI findings in the CG are showed in Table IX.

The inter-observer reliability values concerning MRI findings in the CG are showed in Table X.

The correlation matrix between the MRI findings in SG is showed in Table XI.

The correlation matrix between MRI findings in CG is showed in Table XII.

Table III. The MRI sequences and the details of acquisition concerning the protocol used in the study (from Branci et al.[30]).

MRI finding	MRI sequences	Description
Bone marrow oedema grade 0-3	Coronal STIR and T1. Axial oblique* T2 FS and PD Fat Sat.	The presence of a diffused area of increased intensity in fluid-sensitive sequences and the presence of a decreased signal on T1 sequences, at pubic symphysis level. The BMO staging is performed in accordance with the following parameters: The extension of BMO is measured on the oblique axial sequences PD FS or T2 FS along the long axis of the upper or lower pubic branch. The degree of BMO is based on the area of the signal intensity of the largest extension. A line parallel to the long axis of the upper or lower branch of the middle pubic should be drawn. This line should be median to the anterior and posterior margins of the pubic branch. The extension of BMO is based on the distance existing from the insertion point of this line and the joint surface of the symphysis. The measurement is performed just to the point where, on this line, the increased intensity signal is visible. The degree of BMO is determined according to this distance as follows: grade 0: no BMO, grade 1: BMO ≤1 cm, grade 2: BMO ≥1 cm and ≤2 cm, grade 3: BMO ≥2 cm.
Fatty infiltration in bone marrow at symphyseal joint level	Coronal T1 and STIR. Axial oblique T2 Fat Sat and PD Fat Sat.	Presence of high intensity signal areas at symphysis level in T1 weighed sequences and presence of low-intensity signal areas in Fat Sat sequences.
Symphyseal sclerosis	Coronal T1. Axial oblique T1.	Presence of bone sclerosis along the joint margins of the symphysis.
Parasymphyseal high-intensity line	Axial oblique PD Fat Sat. Coronal STIR.	Presence of a high-intensity signal line in fluid-sensitive sequences dislocated within the pubic bone. The high intensity line is not in communication with the symphysis joint space.
Secondary inferior cleft sign	Coronal STIR. Axial oblique PD Fat Sat. Coronal PD Fat Sat. Sagittal STIR.	Presence of a high-intensity signal line extending laterally and inferiorly to the lower part of the symphysis. This line is in communication with the symphysis joint space.
Secondary superior cleft sign	Coronal STIR. Axial oblique Fat Sat.	Presence of a high-intensity signal line in fluid-sensitive sequences extending parallel to the lower margin of the upper pubic branch. This line, as the secondary inferior cleft sign, is in communication with the symphysis joint space.
Subchondral cyst / joint surface irregularities	Coronal STIR. Axial oblique PD Fat Sat	Presence of subchondral cyst (round hyper-intense element on T2 weights images) and / or irregularities of the joint surface.
Central disc protrusion	Coronal T1. Axial oblique T1.	Protrusion of the central fibrous symphysis disk.
Adductor longus tendinopathy	Axial oblique PD Fat Sat, T2 Fat Sat and T1. Coronal T1.	Increasing of the signal intensity in the fluid-sensitive sequences within the tendon of the adductor longus and / or its enthesis (intra substantia) and / or swelling of the tendon or enthesis morphology.
Rectus abdominis tendinopathy	Sagittal STIR. Axial oblique PD Fat Sat.	Increasing of the signal intensity in the fluid-sensitive sequence at muscle-tendon junction level and /or increasing of the volume of the tendon.

*The oblique axial plane should be oriented approximately 50° with respect to the horizontal plane and parallel to the long axis of the upper pubic branch."
Legend: BMO, bone marrow oedema; PD Fat Sat; proton density fat saturation; STIR, short tau inversion recovery.

Table IV. Results of US findings in the SG. It is important to note that most of the subject (45.8%) presented a bilateral ICPWW.

US findings	Number	Percentage
ICPWW (right)	19	15,8
ICPWW (left)	18	15
ICPWW (bilateral)	55	45,8
M1 (right)	1	0,8
M1 (left)	1	0,8
M1 (bilateral)	6	5
L1 (left)	1	0,8
L1 (bilateral)	1	0,8
F1(right)	1	0,8
ICPWW (right) + M1 (left)	6	5
ICPWW (left) + M1 (right)	7	5,8
ICPWW (right) + L1 (left)	4	3,3
Summary	**120**	**100**

Table V. The inter-observer reliability values concerning US findings in the SG.

US findings	Inter-observer reliability (k value)	Confidence interval (CI) (95%)
F1	1	1
M1	0.76	0.70 - 0.82
M2	0.74	0.66 - 0.82
L1	0.75	0.70 - 0.80
L2	0.76	0.69 - 0.83
ICPWW	0.77	0.72 - 0.81

The results of the Fisher's exact test are showed in Table XIII.
The logistic regression revealed only 3 significant MRI findings correlated with the presence of IH and ICPWW. The results are showed in Table XIV.
The BMO average grade in case of ICPWW was 1.28±0.45.
The BMO average grade in case of IH (F1, M1-M2, L1-L2) was 2.77±0.44.
The difference was statistically significant ($p<0.05$).

Discussion

The main finding of this study is the correlation of some specific MRI findings, derived from a standard MRI protocol, with the presence of inguinal pathologies (i.e. IH and ICPWW). To our knowledge this is the first study present in the literature showing this correlation and these results could be clinically relevant for an accurate GPS diagnosis[3,21].

Table VI. Findings of MRI studies in the SG. The most widespread clinical frameworks are CDP (55.83%), ALT (47.17%) and BMO (28.33%).

MRI findings	Number	Percentage (%)
BMO	34	28.33
BMO grade I	18	52.29 (of the total BMO)
BMO grade II	9	26.47 (of the total BMO)
BMO grade III	7	20.58 (of the total BMO)
FI	6	5
SS	60	50
PHIL	6	5
SSCS	4	3.33
SICS	13	10.83
SC-JI	23	19.17
CDP	67	55.83
ALT	59	47.17
RAT	8	6.67

Table VII. The inter-observer reliability values concerning MRI findings in SG.

MRI findings	Inter-observer reliability (k value)	Confidence interval (CI) (95%)
BMO	0.77	0.70 - 0.84
FI	0.60	0.52 - 0.68
SS	0.74	0.67 - 0.81
PHIL	0.61	0.53 - 0.69
SSCS	0.76	0.69 - 0.83
SICS	0.78	0.71 - 0.85
SC-JI	0.75	0.68 - 0.82
CDP	0.82	0.79 - 0.89
ALT	0.61	0.53 - 0.69
RAT	0.62	0.54 - 0.71

In the present study, some MRI findings (ALT, CDP and BMO) are frequently associated with the presence of IH and ICPWW with an OR value respectively equal to 3.83, 3.77 and 3.68, respectively. They are an indirect evidence of mechanical overload stress both at symphysis (BMO and CDP) and tendon level (ALT and BMO) but also of symphysis intrinsic instability (CDP) [3,4,30,31]. Many studies show that mechanical stress at symphysis level can cause inguinal pathologies[4,37-39], therefore the results of this study suggest that some MRI findings correlated with symphysis mechanical stress

Table VIII. The association of US and MRI findings in the SG.

	BMO	FI	SS	PHIL	SSCS	SICS	SC-JI	CDP	ALT	RAT
ICPWW	25	4	42	4	3	10	16	54	45	7
M1	2	2	5	2	1	2	2	6	5	--
L1	0	--	--	--	--	--	1		1	--
F1	0	--	1						1	
ICPWW (right) + M1 (left)	2	--	2	--	--	1	2	2	--	1
ICPWW (left) + M1 (right)	2	--	5	--	--	--	1	4	3	--

Table IX. Results of MRI findings in the CG.

MRI findings	Number	Percentage (%)
BMO	2	5
BMO grade I	2	100 (of the total BMO)
BMO grade II	—-	—-
BMO grade III	—-	—-
FI	—-	—-
SS	5	12.5
PHIL	—-	—-
SSCS	—-	—-
SICS	—-	—-
SC-JI	4	10
CDP	5	12.5
ALT	5	12.5
RAT	—-	—-

Table X. The inter-observer reliability values concern ing MRI findings in CG.

MRI findings	Inter-observer reliability (k value)	Confidence interval (CI) (95%)
BMO	0.80	0.78 - 0.83
SS	0.74	0.66 - 0.82
SC-JI	0.76	0.70 - 0.81
CDP	0.82	0.78 - 0.90
ALT	0.63	0.54 - 0.70

overload and its intrinsic instability may indicate the presence of an IH and/or ICPWW.

This study shows a high inter-observer reliability for the different US (range 1 - 0.74) and RM (range 0.82 -0.61) findings, these values are in line with the data present in literature[22,23].

MRI findings

ALT (Adductor longus tendinopathy)

ALT finding at the MRI is the most important radiological sign (OR 3.83; 1.27 to 11.54; 95% CI) correlated with IH and ICPWW. Obviously, this does not exclude the possibility of ALT MRI finding without the presence of inguinal pathology.

The ALT (Fig. 1) is radiologically represented by an increasing of the signal intensity at adductor longus (AL) tendon and/or at its enthesis level in the fluid-sensitive sequences. Tendon swelling and/or changes in enthesis morphology is usually also present. On the contrary, in physiological situations, the tendon appears in all the sequences hypo-intense, subtle and well-defined while in axial oblique sequences the tendon appears symmetric, of triangular shape with the base facing the anterior margin of the pubic bone. In the ALT framework, the tendon shows a convex shape and increased signal intensity. In our study, ALT is present in 59% of the SG subjects *versus* 12.5% of the CG subjects. This may be explained by the long duration of GPS symptoms in SG subjects that was 13.93±3.6 months in average. Such long symptoms duration allows us to classify the GPS framework as “long standing GPS“ (LSGPS or chronic GPS) in according with Groin Pain Syndrome Italian Consensus Conference on terminology, clinical evaluation and imaging assessment in groin pain in athlete[3]. In a LSGPS, the clinical framework is frequently based on the association of an inguinal pathology and a pubic osteitis (PO)[3,4,19]. It is important to remember that a PO framework is strongly associated with a chronic ALT[29,40]. Furthermore, a radiological framework of PO includes SS, SC-JI and BMO[29,41]. Indeed, in the subjects of SG suffering of ALT, MRI findings of SS, SC-JI, BMO and CDP are associated respectively in 33.33, 9.17, 13.33 and 35% of the cases, while in the CG subjects this association was respectively equal to 7.5, 7.5, 2.5 and 10.0% of the cases (all $p<0.005$). Unfortunately, no radiological grading scale is currently able to evaluate

Table XI. Correlation matrix between the MRI findings in SG.

	BMO	FI	SS	PHIL	SSCS	SICS	SC-JI	CDP	ALT	RAT
BMO	---	1 (0.83%)	24 (20)	3 (2.5)	2 (1.67)	7 (5.83)	13 (10.83)	28 (23.33)	16 (13.33)	4 (3.33)
FI	1 (0.83)	---	5 (4.17)	1 (0.83)	1 (0.83)	1 (0.83)	3 (2.50)	4 (3.33)	4 (3.33)	2 (1.67)
SS	24 (20)	5 (4.17)	---	2 (1.67)	3 (2.5)	12 (10)	17 (14.17)	46 (38.33)	40 (33.33)	5 (4.17)
PHIL	3 (2.5)	1 (0.83)	2 (1.67)	---	1 (0.83)	2 (1.67)	3 (2.50)	5 (4.17)	4 (3.33)	1 (0.83)
SSCS	2 (1.67)	1 (0.83)	3 (2.5)	1 (0.83)	---	1 (0.83)	1 (0.83)	2 (1.67)	4 (3.33)	1 (0.83)
SICS	7 (5.83)	1 (0.83)	12 (10)	2 (1.67)	1 (0.83)	---	7 (5.83)	13 (10.83)	5 (4.17)	2 (1.67)
SC-JI	13 (10.83)	3 (2.50)	17 (14.17)	3 (2.50)	1 (0.83)	7 (5.83)	---	17 (14.17)	11 (9.17)	4 (3.33)
CDP	28 (23.33)	4 (3.33)	46 (38.33)	5 (4.17)	2 (1.67)	13 (10.83)	17 (14.17)	---	42 (35)	8 (6.67)
ALT	16 (13.33)	4 (3.33)	40 (33.33)	4 (3.33)	4 (3.33)	5 (4.17)	11 (9.17	42 (35)	---	6 (5)
RAT	4 (3.33)	2 (1.67)	5 (4.17)	1 (0.83)	1 (0.83)	2 (1.67)	4 (3.33)	8 (6.67)	6 (5)	---

Table XII. Correlation matrix between MRI findings in CG.

	BMO	FI	SS	PHIL	SSCS	SICS	SC-JI	CDP	ALT	RAT
BMO	---	0	1 (2.5)	0	0	0	1 (2.5)	1 (2.5)	1 (2.5)	0
FI	0	---	0	0	0	0	0	0	0	0
SS	1 (2.5)	0	---	0	0	0	4 (10)	4 (10)	3 (7.5)	0
PHIL	0	0	0	---	0	0	0	0	0	0
SSCS	0	0	0	0	---	0	0	0	0	0
SICS	0	0	0	0	0	---	0	0	0	0
SC-JI	1 (2.5)	0	4 (10)	0	0	0	---	4 (10)	3 (7.5)	0
CDP	1 (2.5)	0	4 (10)	0	0	0	4 (10)	---	4 (10)	0
ALT	1 (2.5)	0	3 (7.5)	0	0	0	3 (7.5)	4 (10)	---	0
RAT	0	0	0	0	0	0	0	0	0	---

the severity of tendinopathy at ALT level[28]. However, it is necessary to note that in some cases ALT, as well as SS, may reflect a functional adaptation against a functional overload due to a hard sport activity[24,30,31,42].

CDP (Central disc protrusion)

In our series, CDP diagnosed at MRI study is present in 67% of the subjects belonging to SG *versus* 12.5% in subjects of CG and represents the second most important radiological sign associated with IH and ICPWW (OR 3.77; 1.19 to11.92; 95% CI).

The CDP (Fig. 2) is observable in coronal and axial oblique T1 weighted images. In the coronal images the central disk cranially protrudes in respect to the symphysis joint edges, while in the axial images it protrudes posteriorly. The symphysis joint shows many anatomic-functional similarities with the inter-

Table XIII. Results of the Fisher's exact test.

MRI findings	P value
BME	<0.001
FI	0,338
SS	<0.001
PHIL	0,338
SICS	0,039
SSCS	0,999
SC-JI	0,573
CDP	<0.001
ALT	<0.001
RAT	0,202

Table XIV. Result of logistic regression. OR: odds ratio.

MRI findings	OR (95% CI)	p value
ALT	3.83 (1.27 to 11.54)	0.017
CDP	3.77 (1.19 to 11.92)	0.024
BMO	3.68 (0.74 to 18.23)	0.111

vertebral joint[30,31,41]. Indeed, both types of joints are amphiarthrosis with a central disk and an adjacent bone marrow containing hematopoietic tissue[41]. Therefore, it is possible to correlate, at least in some aspects, the degenerative changes at the symphysis level observable in a GPS framework to those found in the spinal degeneration, described by Modic et al.[43] as follows:

I. degeneration of the intervertebral disc (Modic type I)
II. fat infiltration (Modic type II)
III. fibrosis and sclerosis (Modic type III and IV).

Therefore the presence of CDP is comparable to a Modic type I and can be considered a typical sign of functional overload at symphysis level[3,30,31]. Furthermore, the CDP is an important indirect sign of symphysis instability caused by functional overload[3]. This instability may cause an important mechanical stress at posterior inguinal wall level leading therefore to the onset of inguinal pathologies[4].

BMO (Bone marrow oedema)

In our study BMO is present in 28.33% of the subjects belonging to SG *versus* 5% of the subject in the CG. In the subjects in SG, BMO is associated with ALT, SS, SC-JI, and CDP respectively for 13.33, 20, 10.83% and 23.3%, while in the CG this association was respectively equal to 2.5% for all considered MRI findings (all p<0.005).

A BMO (Fig. 3) is the presence of an area of increased intensity in fluid-sensitive sequences and, in the same time, the presence of a decreased signal on T1 sequences, at pubic symphysis level. The BMO staging is performed, in accordance with is extension, in grade 0-1[30,31]. BMO is present on average in 90% of the athletes suffering from GPS[21,44,45]. However, it is not yet fully understood whether BMO is only a marker of "bone stress injury" or it represents a primary source of pain in the patient affected by GPS[46].

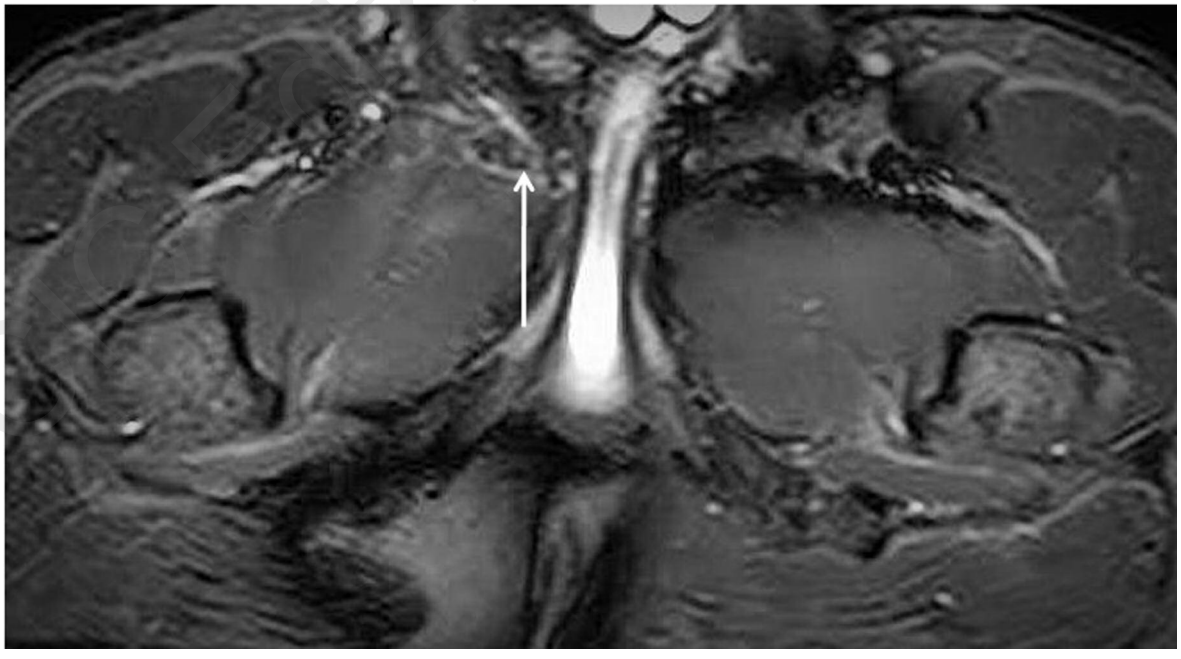

Figure 1. Axial oblique PD Fat Sat showing adductor longus tendinopathy.

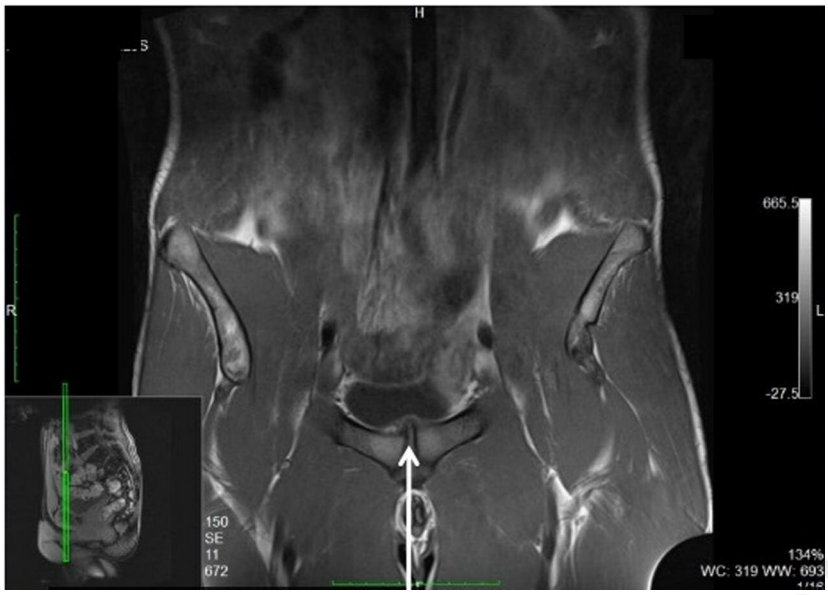

Figure 2. Coronal T1 showing a CDP.

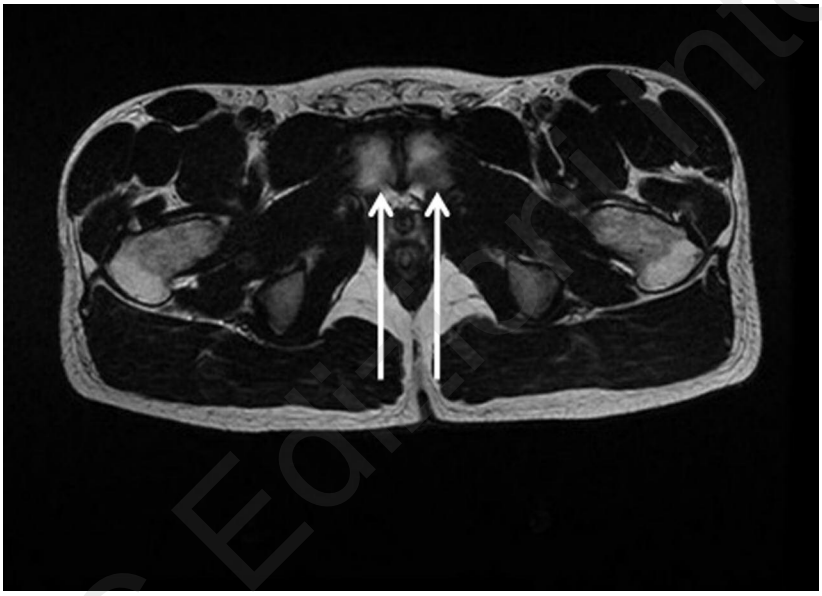

Figure 3. Axial oblique T2 MRI showing a BMO extended across the surface, in the antero-posterior direction. Of both the pubic branches. Depending on its extension, the BMO is classified as grade 3.

Our data confirm the presence of BMO supporting an osteitis framework and hence a situation of mechanical overloading at symphysis level. The presence of BMO is strongly associated (OR 3.68; 0.74 to 18.23; 95% CI) with the presence of IH and ICPWW. Furthermore, it is interesting to note that the BMO average grade in case of ICPWW was 1.28±0.45, while in case of IH (F1, M1-M2, L1-L2) was 2.77±0.44 ($p<0.05$). These data suggest that the BMO severity could be related to the inguinal pathology severity. However, it is important to remember, that the presence of BME may also reflect a simple physiological adaptation to the mechanical stress at symphysis level[26,27].

SS (Symphysis sclerosis)

Our findings showed that 50% of the subjects in SG (*versus* 12.5% in CG) present MRI findings of SS ($p<0.001$). The MRI findings of SS (Fig. 4) is best observed in T1-weighed images. The joint bone portion appears thickened and the sclerotic area appears to be as a bone hypointense formation which extends along the joint margins of the symphysis[3,30,31]. The presence of SS MRI findings in 60% of the subjects in the SG is in line with previous researches showing an important proportion (between 20 and 98%) of SS in athletes suffering from GPS19,[21,24,26,40,46-48]. Moreover, Kunduracioglu et al.[40] showed a relationship between SS severity degree and the chronicity of GPS in football players' population, suggesting that the

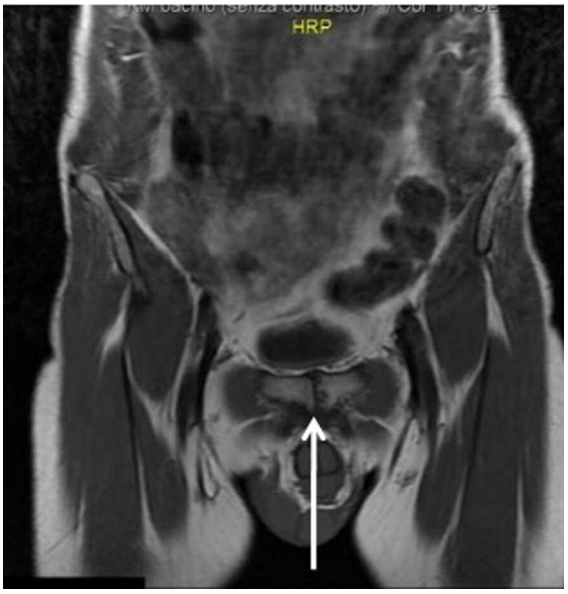

Figure 4. Coronal T1 in which is observable SS.

does not reach a significant statistical level.

SC-JI (Subchondral cyst/joint surface irregularities)

We have found that MRI findings of SC-JI was present in 19.17% of the SG subjects *versus* 10% in CG subjects, but the difference was not statistically significant. The joint surface of pubic symphysis should normally be smooth and regular. SC (Fig. 5) is characterized by the presence of an oval formation at sub-chondral level with hyper-intense signal in T2 weighted images. The JI are joint surface irregularities observable in T1 and PD images. SC-IJ is a typical sign of severe osteitis pubis[49-51]. Indeed, severe grade osteitis pubis includes enlargement of the symphysis, signs of bone reabsorption and sclerosis of pubic branches cystic and/or osteophyte formations, and in some misdiagnosed cases can progress to bone erosion[21]. Our data confirm that CS-JI, as already showed by other Authors[28,31], may be present in asymptomatic athletic subject in a percentage ranging from 27 [24] to 50%[47].

SICS (Secondary inferior cleft sign)

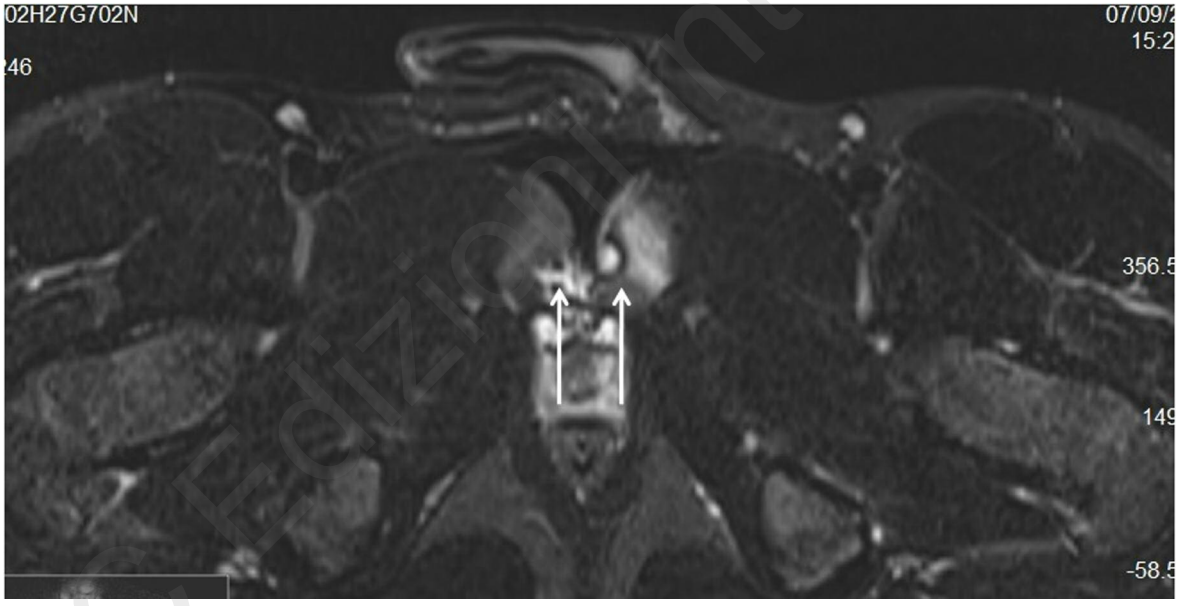

Figure 5. Coronal STIR showing SC-JI.

severity of SS is in correlation to the duration of the GPS symptoms. However, it is important to underline the fact that signs of SS as well as cysts and osteophytes formation at symphysis level may be present also in asymptomatic athletes[31] depending on the sport activity and increasing in athletes practicing sports like football, tennis, hockey implying increase of the shear forces at symphysis level[19,49-51]. For that reason, MRI findings of SS do not necessarily represent a lesion but can be considered more as an indirect sign of overuse at symphysis level. However, the results of this study show that the value of OD between SS and the presence of IH and ICPWW

SSCS was present in 10.83% of SG subjects and was absent in the CG ones, however the difference was not statistically significant. The SICS (Fig. 6) is a hyper-intensity signal line in the fluid-sensitive sequences extending laterally and inferiorly to the lower part of the symphysis. The SICS shows a connection with the symphysis joint space. The SICS must be observable throughout the totality of the joint space and just outside of the symphysis[24,48]. The anatomical dislocation of SICS is inferior to the symphysis, and lower and posterior to the AL insertion[24,48]. SICS is considered a radiological sign of AL, fibrocartilaginous pre-symphysis complex and AL - rectus abdomi-

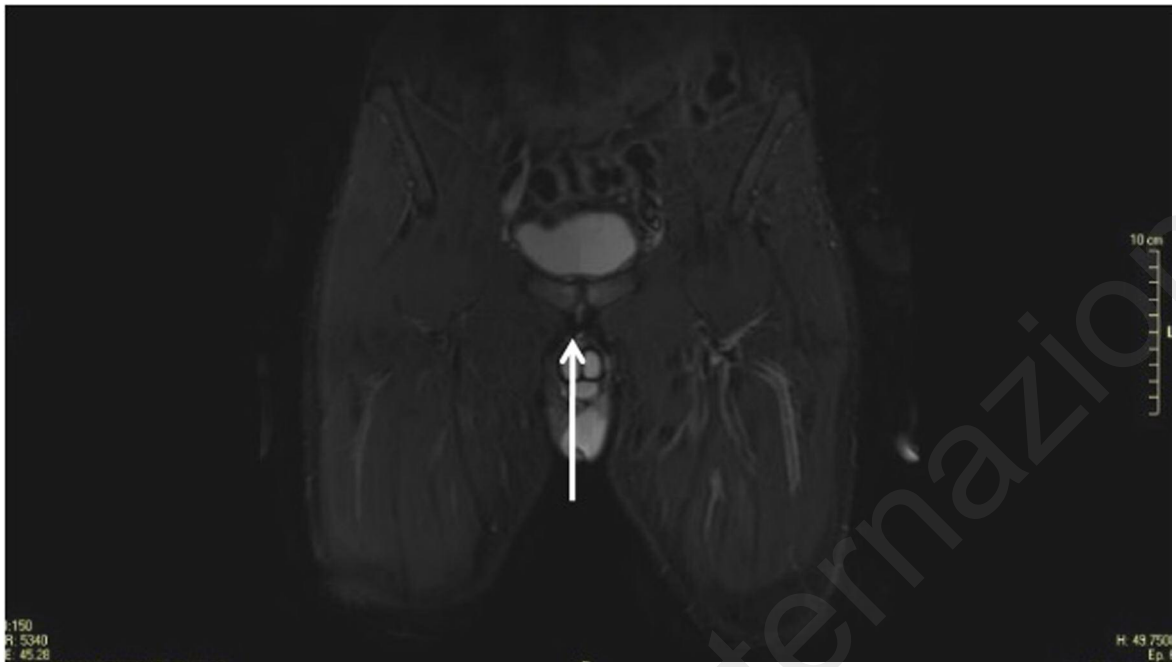

Figure 6. Coronal STIR in which is observable a SICS.

nis common enthesis lesions[24,25,48,52].

FI (Fatty infiltration in bone marrow at symphysis joint level)

In our study FI was present in 5% of the SG subjects and was absent in the CG ones, with no statistical significant difference. FI (Fig. 7) is the presence of some areas at high-signal intensity at symphysis level in T1 weighted images, while the same areas appear as low density signal in the Fat Sat sequences[18,25,30,31]. FI is present only when both signal changes are present in T1 and Fat Sat sequences (if the change of the signal is present only in the Fat Sat sequences it is insufficient to determine the presence of FI). Furthermore, the area/s of altered signal must be very near to the symphysis joint[18,25,30,31]. When the area/s of altered signal observable in T1 weighted sequences are at bone marrow level, but far from the ar-

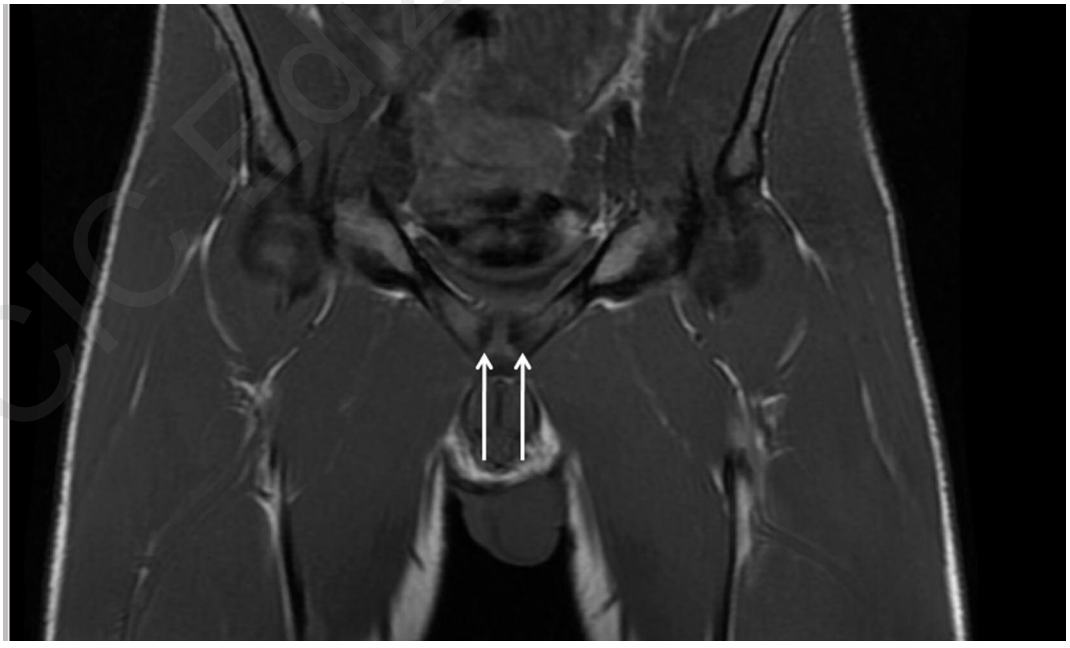

Figure 7. Coronal T1 showing FI.

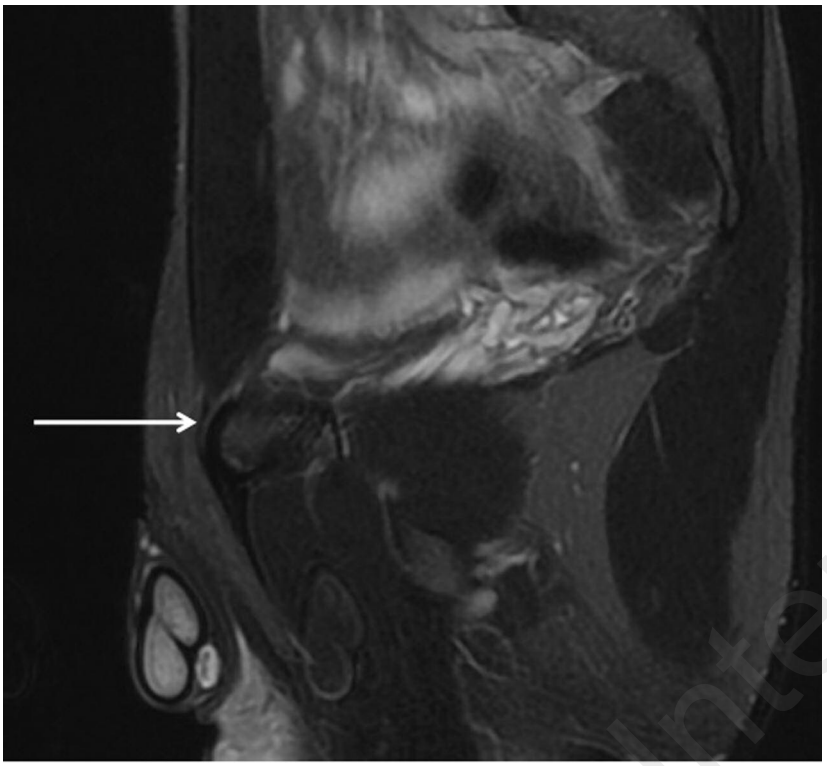

Figure 8. Sagittal STIR showing signs of RAT.

ticular edge of the symphysis, they have to be considered as simple adipose tissue area and not a FI. In other words, FI must directly involve the symphysis[30,31]. The presence of FI is considered by some Authors like a Modic type II, and therefore it is the sign of a high grade degenerative symphysis framework[31].

RAT (Rectus abdominis tendinopathy)

RAT was present in 6% of the SG subjects and was absent in the CG ones with no statistical significant difference. RAT (Fig. 8) is an increased signal intensity in the fluid-sensitive sequence at rectus abdominis muscle-tendon junction level, and/or an increased rectus abdominis tendon volume and is rarely described in literature[53,54]. This may be partially explained by the fact that AL and RA have a common insertion at the pubic symphysis level, and so several RAT could be incorrectly classified as ALT.

SSCS (Secondary superior cleft sign)

In our study SSCS was present in 3.33% of the SG subjects and was absent in the CG ones, with no statistically significant difference. SSCS (Fig. 9) is a hyper-intensity signal line in the fluid-sensitive sequences. SSCS is parallel to the lower edge of the upper pubic branch and, like the SISC, shows a connection with the symphysis joint space. When SSCS is present in the coronal STIR images, it is necessary to verify its presence in the axial oblique Fat Sat images. The SSCS is rarely described in the literature[30,52]. For some Authors SSCS is a sign of damage at the pre-symphysis fibrocartilage complex and/or at the rectus abdominis-adductor longus common enthesis[24,48,52].

PHIL (Parasymphyseal high-intensity line)

PHIL was present in 5% of the SG subjects and was absent in the CG ones with no statistically significant difference. PHIL (Fig. 10) is a hyperintensity signal line in the fluid-sensitive sequences within the pubic bone. PHIL is below and parallel to the contour of the joint surface of the symphysis[30,31]. In a PHIL radiological framework, in contrast to SSCS and SICS, there is no communication between PHIL and the joint space. The clinical significance of PHIL is unclear[30,31].

Limitations

A limitation of this study was that all of the patients belonging by CG were amateur athletes, while the SG subjects consisted in a high percentage of professional athletes. Furthermore, there was heterogeneity of the type of sport activities practiced by the subjects included in the study. For these reasons, an interesting development of this study would be to compare the actual recorded data with those that could be obtained by comparing two groups of professional athletes practicing the same sports activity. Other limitation could be considered the limited size of CG and the different timing of MRI assessment.

Conclusions

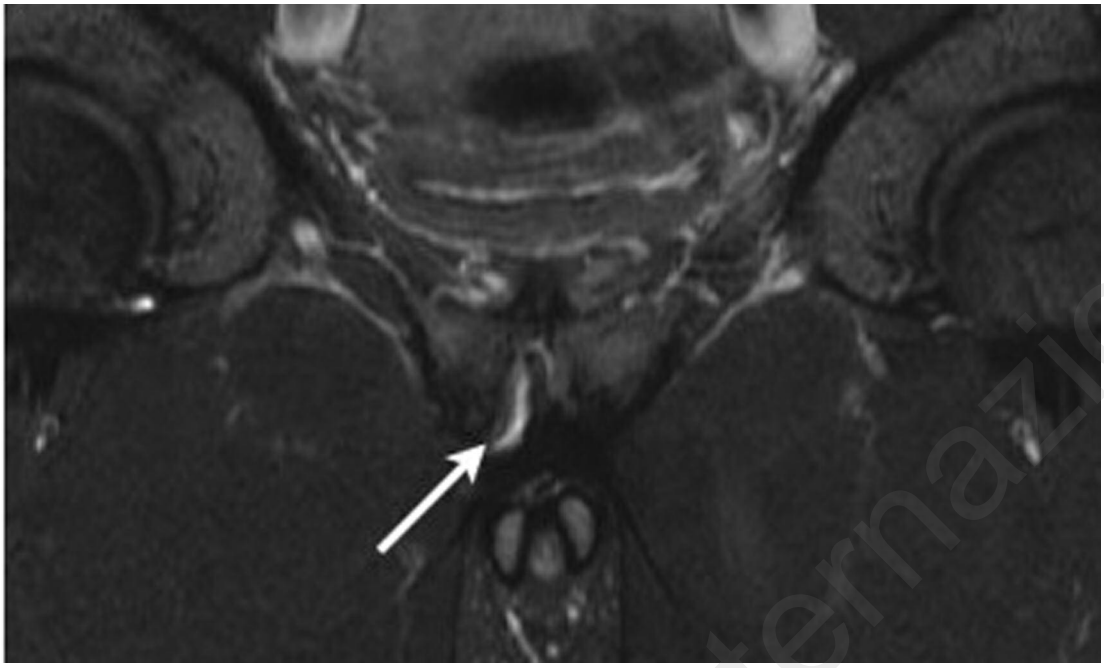

Figure 9. Coronal STIR showing secondary superior cleft sign.

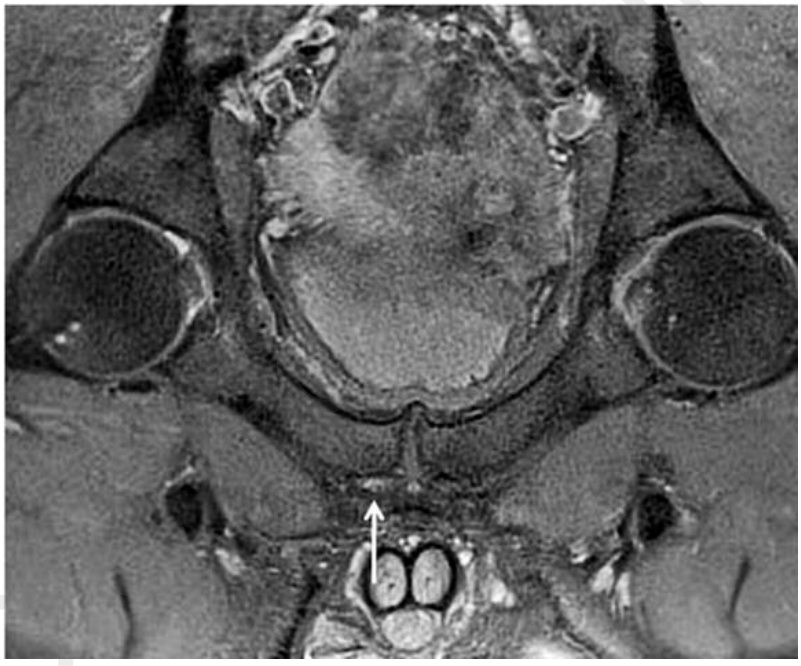

Figure 10. Coronal PD Fat Sat showing parasymphyseal high-intensity line.

IH and ICPWW represent a frequent clinical framework in LSGPS[4,19,20,55]. In case of suspected presence of IH and ICPWW the gold standard imaging is represented by dynamic US[14] which shows a very high PPV[14-17]. This study has confirmed the multifactorial aetiology of GPS, and the overlapping of several clinical frameworks which is a common characteristic of LSGPS[3,4,19]. For this reason a standard MRI protocol can provide some important information concerning potential clinical entities correlated with the presence of IH and ICPWW. Therefore, in the view of these results the presence of ALT, CDP and BMO at MRI assessment can make suspect the presence of IH and ICPWW and obviously vice versa. Furthermore, the results of this study show how in particular

clinical frameworks of GPS (i.e LSGPS) it is necessary both MRI and dynamic US assessment.

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