Clinical Imaging 56 (2019) 58–62

Contents lists available at ScienceDirect

Clinical Imaging

journal homepage: www.elsevier.com/locate/clinimag

Musculoskeletal and Emergency Imaging

MR imaging of pubic symphysis after uncomplicated vaginal delivery and planned caesarean delivery in the first postpartum week

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ARTICLE INFO

Keywords:
Pubic symphysis
Postpartum period
Magnetic resonance imaging

ABSTRACT

Purpose: To compare changes in the pubic symphysis between women with vaginal delivery and women with caesarean sections within the first postpartum week.

Materials and methods: After institutional review board approval 30 healthy women were prospectively examined with MRI (transverse STIR-sequence) three days after delivery. 17 women with vaginal delivery (mean age 33.2 ± 4 years) and 13 with caesarean delivery (35.2 ± 5.6 years) were compared by two musculoskeletal radiologists. Bone marrow edema (location and extent), fluid in the joint gap, joint space width and stress fractures were assessed.

Results: Prevalence of bone marrow edema was high and not different between groups (13/17 (76.5%) vaginal deliveries) and 10/13 (76.9% caesarean deliveries) for reader 1 ($p = 0.992$) and 14/17 (82.4%) and 10/13 (76.9%) for reader 2 ($p = 0.762$). Size of bone marrow edema was not statistically significantly different for both readers (results reader 1: right side 2.5 ± 3.3 mm vs. 6.3 ± 7.3 mm, $p = 0.300$; left side 3.4 ± 4.1 mm vs. 4.1 ± 4.6 mm, $p = 0.837$). Fluid in the joint was seen in 4/17 (23.5%) vs. 2/13 (15.4%) ($p = 0.580$) for reader 1 (similar for reader 2). Joint space width did not differ between groups (2.6 ± 0.7 mm vs. 3.1 ± 1.2 mm, $p = 0.198$). Pubic symphysis diastasis (joint space width > 10 mm) was not observed. Interreader agreement for these parameters was substantial to almost perfect (0.671–0.984, kappa values/intraclass correlation). Reader 1 found no stress fractures, while reader 2 suspected 1 stress fracture on a right pubic bone in a woman after caesarean delivery.

Conclusions: Pubic bone marrow edema is present in 3 of 4 women in the first postpartum week unrelated to the delivery mode.

1. Introduction

Musculoskeletal injuries of pubic bones and pelvic floor muscles can occur during vaginal delivery. Disruption of the pubic joint and fractures of the pubic bones may result from strong forces in the pelvis during childbirth. The prevalence of pubic symphysis injuries varies between studies and ranges from 1 in 36 to 1 in 30,000 women [1,2]. Bone marrow edema in the pubic bones after childbirth reflects mechanical stress injury, e.g. bone bruising or fracture. Differential diagnoses are septic arthritis and pre-existing inflammatory disease or osteitis pubis [3,4]. Studies have reported a high prevalence of bone marrow edema after vaginal deliveries in high-risk and low-risk groups for pelvic floor injuries [5,6]. Risk factors for pubic injuries are age (over 35 years), fetal macrosomia (> 4000 g), instrumentally-assisted vaginal delivery such as forceps or vacuum delivery, prolonged second stage of labor or short second stage of labor (< 30 min) [7].

However, in most of these studies magnetic resonance imaging (MRI) was performed several weeks after delivery to resolve birth-related soft tissue hematoma in the pelvic floor so that any remaining soft tissue abnormality likely reflects significant injury. Literature with assessment of the pubic joint with MRI very early after childbirth is scarce and limited to very small sample sizes [6]. In addition, less is known

Abbreviations: BME, bone marrow edema; ICC, intraclass correlation coefficient; MRI, magnetic resonance imaging; STIR, short-tau inversion recovery

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https://doi.org/10.1016/j.clinimag.2019.03.009
Received 21 November 2018; Received in revised form 6 March 2019; Accepted 18 March 2019

about changes in the pubic joint after caesarean delivery. As we have shown in a recent study in postpartum women, substantial bone marrow edema in the sacroiliac joints can be seen even after planned caesarean deliveries (reference blinded for review). This indicates that the increased mechanical stress during pregnancy causes this bone stress reaction rather than delivery mode. Correspondingly, we wanted to assess the pubic symphysis within the first few days after uncomplicated childbirth to see the effects of pregnancy and delivery. We hypothesized that substantial bone marrow edema in the pubic bones can be detected in patients after planned caesarean delivery, again as a direct result of pregnancy and not as a consequence of delivery mode

Therefore, the purpose of our study was to compare changes in the pubic symphysis between women with vaginal delivery and women with caesarean sections within the first postpartum week.

2. Materials and methods

2.1. Study design

This is a sub-group analysis of a prospective multicenter cohort study, which primarily investigated the sacroiliac joints postpartum (reference blinded for review). MR images of the pubic joints within one week after uncomplicated childbirth were compared between women after vaginal delivery and women after caesarean delivery. MR images for the purposes of this study were acquired in two different hospitals with around 1100 births per year (study site A, private hospital) and 1650 births per year (study site B, teaching hospital), respectively.

2.2. Study subjects

Women were recruited on the postnatal ward after childbirth, either uncomplicated vaginal delivery (no forceps- or vacuum assistance, no prolonged second stage of labor, no higher degree of perineal tears (grad III or IV), baby weight $<$ 4000 g) or planned caesarean delivery. Inclusion criteria were childbirth after 36 weeks' gestation and written informed consent. Non-inclusion criteria were contraindications for MRI, claustrophobia, suspected or known inflammatory disease (rheumatoid arthritis, spondyloarthritis), or metal implants in the pelvis. Recruitment started in June 2014 and ended January 2016.

2.3. MR imaging

Each woman underwent MR imaging during the stay in the hospital, ensuring imaging within the first postpartum week. The following scanners were used: Study site A: Siemens Avanto and Siemens Symphony (both 1.5-T), Siemens Skyra and Philips Ingenia (both 3.0-T); study site B: Philips Achieva and Philips Ingenia (both 1.5-T) and Philips Achieva (3.0-T). The imaging protocol comprised an axial short-tau inversion recovery (STIR) sequence of the pelvis with a slice-thickness of 5 mm (parameters depending on scanner model). The MR images covered the pelvis from the upper border of the sacroiliac joints to the ischial tuberosity, fully covering the pubic symphysis.

2.4. Image analysis

All MR images were de-identified and analyzed in a randomized order (random number generator, Microsoft Excel 2010, Microsoft Corp.). Two radiologists (a fellowship-trained musculoskeletal radiologist with 4 years post-fellowship experience and a musculoskeletal fellow) analyzed all images. The readers were blinded to clinical information. However, based on pelvic floor edema or visible caesarean section wounds, they were not necessarily blinded to delivery mode.

The following parameters were assessed:

- Presence of bone marrow edema in pubic bones (no edema, right side only, left side only, bilateral edema).
- Lateral extent of bone marrow edema in the pubic bones, defined as the distance (in mm) of bone marrow edema from the medial joint cortex to the maximum lateral extension.
- Presence of fracture lines in the pubic bones, defined as hypointense linear signal within a bone marrow edema zone (no fracture, right side, left side, bilateral fracture).
- Pubic joint distension (distance (in mm) between cortical bones).
- Fluid in the pubic symphysis joint (yes/no).

2.5. Statistics

REDcap (Research Electornic Data Capture) was used to manage all study data [8]. Patient demographics were compared between both groups (vaginal delivery vs. caesarean delivery), either using *t*-test (if normally distributed based on Shapiro-Wilk test for normality) or Mann-Whitney *U* test. Bone marrow edema location (chi-squre test), size (Mann-Whitney *U* test), fractures (Fisher's exact test), joint distension (Mann-Whithney *U* test) and joint fluid (Chi-square test) were compared between groups. A joint distension over 10 mm was considered abnormal, as suggested by Lindesy et al. [9,10]. Interreader agreement was calculated using Kappa statistics or intraclass correlation coefficients (ICC) where appropriate. Interreader agreement was rated as fair (0.21–0.40), moderate (0.41–0.60), substantial (0.61–0.80), and almost perfect (0.81–1.00). IBM SPSS Statistics version 24 (IBM Corp.) was used for the analyses.

3. Results

3.1. Demographics

In total, 30 women were included in the study (15 per study site), 17 after uncomplicated vaginal delivery, and 13 after planned caesarean delivery. Mean age between groups (vaginal vs. caesarean delivery) was not different (33.2 ± 4.0 years vs. 35.2 ± 5.6 years respectively, $p = 0.265$). Baby weight between groups was not different (3365 ± 343 g vs. 3164 ± 610 g respectively, $p = 0.563$). Delivered babies were on average one week older in the vaginal delivery group, compared to the planned caesarean delivery group (39 ± 1 vs. 38 ± 1 weeks' gestation, $p = 0.012$). MRI in all subjects was acquired around 3 days after childbirth (mean 3.1 ± 1.3 days, median 3 days, range 1–6).

3.2. Bone marrow edema and fractures

Pubic bone marrow edema at any location was a common finding and present in 13/17 (76.5%) of vaginal deliveries, Fig. 1 and 10/13 (76.9%) of caesarean deliveries, Fig. 2 (reader 1) and 14/17 (82.4%) and 10/13 (76.9%) (reader 2). Distribution of bone marrow edema is shown in Table 1. The extension of bone marrow edema on each side was not different between vaginal deliveries and caesarean deliveries (Table 2). No fractures were found by reader 1, while reader 2 rated one right sided pubic bone fracture in one woman after caesarean delivery ($p = 0.433$).

3.3. Joint distension and fluid

No pubic diastasis (joint distension $>$ 10 mm) was detected. Fluid in the pubic symphysis joint was present in one out of four women. Details on pubic joint distension and pubic joint fluid are presented in Table 3.

3.4. Interreader agreement

Interreader agreement for the presence and location of bone marrow edema was substantial (kappa = 0.717, $p < 0.001$). Interreader

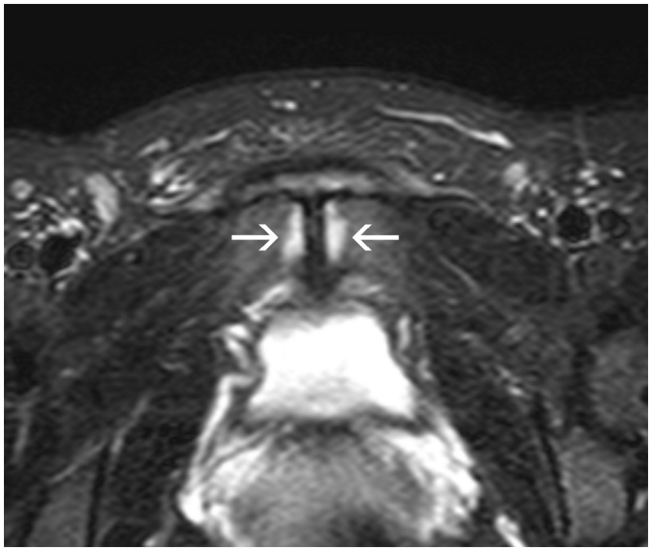

Fig. 1. 30-year-old women two days after vaginal delivery (41 weeks' gestation). Transverse STIR image shows bilateral subchondral bone marrow edema at the pubic symphysis (arrows).

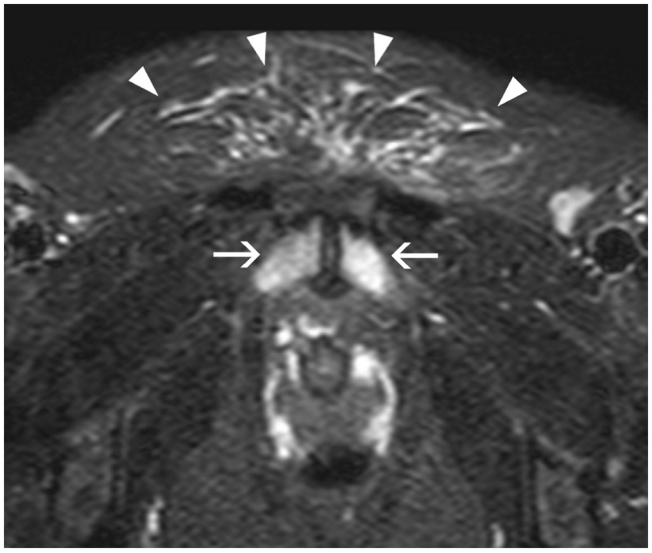

Fig. 2. 38-year-old woman three days after caesarean delivery (39 weeks' gestation). Transverse STIR image shows marked bilateral pubic bone marrow edema (arrows). Diffuse subcutaneous soft tissue edema (arrowhead) in the mons pubis below to the caesarean scar (not visible).

agreement for bone marrow edema size was almost perfect (right side: ICC = 0.859 (95%CI 0.704–0.933), $p < 0.001$, left side: ICC = 0.984 (95%CI 0.967–0.993), $p < 0.001$). Interreader agreement for joint distension was substantial (ICC = 0.671 (95%CI 0.324–0.842), $p = 0.001$). Interreader agreement for fluid in the pubic symphysis joint was almost perfect (kappa = 0.815, $p < 0.001$).

4. Discussion

In this study, we found an equally high prevalence of bone marrow edema in pubic bones after uncomplicated childbirth, independent of delivery mode. Correspondingly, pubic joint distension and pubic joint fluid were similar between women after uncomplicated vaginal deliveries and planned caesarean deliveries. Therefore, we attribute these findings to chronic increased mechanical stress to the pelvic ring during pregnancy, at least to a substantial degree. This confirms our initial hypothesis that women after planned caesarean delivery can demonstrate significant stress changes to the pubic joint as a result of their pregnancy. Hence, pubic bone marrow edema some weeks after caesarean sections may still be a result of that chronic stress to the pubic joint during pregnancy and not necessarily reflect joint infection or inflammation.

A strength of our study was the prospective study design with two participating hospitals, which increases external validity of our results. In vaginal deliveries, there is some degree of variation in healthcare assistance, which might be different among centers, while there is less variation in planned caesarean sections. All our study subjects volunteered, meaning none of them showed alarming symptoms of pelvic ring injuries that would have warranted further investigation, let alone MR imaging. Hence, findings in our study population approximate physiologic and expected changes from pregnancy and childbirth. Compared to other studies in the literature that assessed the pubic joint with MRI postpartum, our sample comprises a higher sample of caesarean deliveries.

Wurdinger et al. compared 19 postpartum women with 11 non-pregnant nulliparous women [10]. In their sample 13 women had uncomplicated vaginal deliveries and 8 of them (62%) showed bone marrow edema in pubic bones. This is a little less than in our study. However, their MRI protocol consisted of T1 and T2 weighted sequences without a STIR sequence. Our and their conclusion match — small bone marrow edema zones after vaginal delivery should be considered a normal finding [10]. Miller et al. focused on levator ani injuries and assessed women after childbirth with increased risk for pelvic floor injuries [11]. While they showed a similar high prevalence of bone marrow edema in the pubic bones (66%) in their high risk sample, the number of fractures was substantially higher (29%) compared to the uncomplicated deliveries in our study. Of note, in that reported study, the MRI was acquired around 7 weeks after childbirth and they did not include women after planned caesarean deliveries [11]. Brandon et al. compared pubic bone injuries between high-risk (n = 45) and low-risk women (n = 32) for pelvic injuries [5]. In their sample only 13% in the low risk group showed pubic bone fractures, compared to 38% in the high-risk group. Bone marrow edema in pubic bones over all study subjects was reported as 61% [5]. In that study, women were scanned around 6 weeks postpartum and their low-risk sample comprised 6

Table 1
Presence and location of bone marrow edema

BME	Reader 1				Reader 2			
	Vaginal delivery n = 17		Caesarean delivery n = 13		Vaginal delivery n = 17		Caesarean delivery n = 13	
None	4	23.5%	3	23.1%	3	17.6%	3	23.1%
Right side	3	17.6%	2	15.4%	4	23.5%	3	23.1%
Left side	2	11.8%	2	15.4%	2	11.8%	3	23.1%
Bilateral	8	47.1%	6	46.2%	8	47.1%	4	30.8%
			$p = 0.992$				$p = 0.762$	

Note — p-value for comparison between vaginal and caesarean delivery for each reader separately. BME = bone marrow edema.

Table 2
Bone marrow edema size.

	Reader 1			Reader 2		
	Vaginal delivery n = 17	Caesarean delivery n = 13	*p* value	Vaginal delivery n = 17	Caesarean delivery n = 13	*p* value
BME size right side (mm)	2.5 ± 3.3	6.3 ± 7.3	0.300	3.1 ± 2.6	4.5 ± 5.3	0.805
BME size left side (mm)	3.4 ± 4.1	4.1 ± 4.6	0.837	3.4 ± 3.9	4.2 ± 4.9	0.837

Note — *p*-value for comparison between vaginal and caesarean delivery for each reader and side separately. BME = bone marrow edema.

Table 3
Joint distension and joint fluid

	Reader 1			Reader 2		
	Vaginal delivery n = 17	Caesarean delivery n = 13	*p* value	Vaginal delivery n = 17	Caesarean delivery n = 13	*p* value
Fluid in pubic symphysis joint	4/17 (23.5%)	2/13 (15.4%)	0.580	5/17 (29.4%)	3/13 (23.1%)	1.0
Joint space width (mm)	2.6 ± 0.7 (1.9–5)	3.1 ± 1.2 (1.3–5.9)	0.198	2.6 ± 1.0 (0.6–4.4)	2.5 ± 1.1 (0.5–4.2)	0.837

Note — *p*-value for comparison between vaginal and caesarean delivery for each reader and side separately.

women with caesarean section without labor. In contrast to our study, they included women with caesarean deliveries after prolonged second stage of labor in the low risk group [5]. In another study by Miller et al., they scanned women with high-risk for pelvic injury after 1 month and 7 months [6]. In that small sample, 6/11 (55%) showed bone marrow edema in the pubic bones after 1 month and in all except one woman, the bone marrow edema resolved after 7 months [6]. Hermann et al. used MRI to demonstrate pelvic ring changes in different groups, among others, 21 asymptomatic postpartum women (only two of them after caesarean delivery). In that sample, 76% of women showed bone marrow edema in the pubic bones after delivery. As in our study, fractures in the pubic bones after uncomplicated vaginal delivery were rare in another study [12]. In summary, our results are consistent with the literature. The slightly higher prevalence of bone marrow edema in our study was most likely related to MR imaging on average 3 days after childbirth compared to later scanning in some of the reported studies. Of note, concomitant sports-related injuries to the pubic symphysis may co-exist [13].

The pubic symphysis is a non-synovial joint. The medial contour of the pubic bones is covered with hyaline cartilage [14]. There is a fibrocartilaginous disc between the two bones. The pubic joint capsule is reinforced by the superior, anterior, inferior and posterior pubic ligament. A strong aponeurosis connects the enhanced joint capsule with the rectus abdominis tendons and adductor longus tendons, functioning as an anchor in torso movements. The disc and anterior pubic ligament are the most important structures for pubic joint stability [14]. During pregnancy, the hormone relaxin increases laxity of musculoskeletal structures, preparing the female pelvis for childbirth [14]. Childbirth requires substantial movement of the pelvic ring to facilitate vaginal delivery, as assessed by computed tomography within one day after vaginal delivery [15]. As a complication, pubic diastasis (> 10 mm pubic bone width) or pubic rupture (> 25 mm) can occur [16].

Our study had a few limitations. The sample size was relatively small. However, compared to the reported high prevalence of postpartum pubic bone marrow edema in other studies and especially based on the high frequency of findings in our caesarean delivery group, our conclusion is still valid. The variety of MR scanners was a direct result of the multicenter study setup. By using a STIR sequence, we tried to get a homogenous set of images. Next, we examined the pubic joint only in axial orientation with relatively thick sections (5 mm). Hence, interpretation of other soft-tissue structures around the pubic symphysis, such as pubic ligaments or levator ani muscle was omitted. This would have been further complicated by diffuse soft tissue edema/hematoma in the perineum (only in vaginal delivery group). Another limitation is the lack of a T1 weighted sequence, which would have helped in assessing subtle fracture lines and erosions. The reason for this is that we tried to keep scan time as short as possible for our volunteering new mothers.

More research is needed to focus on the differences in women before pregnancy and after pregnancy, as well as follow up and assessment of temporal changes of these bone stress reactions. This is true for the pubic symphysis and the sacroiliac joints.

5. Conclusions

In conclusion, pubic bone marrow edema is present in 3 of 4 women in the first postpartum week, unrelated to delivery mode and is most likely related to chronic mechanical stress during pregnancy.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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