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Original Article

Vacuum phenomenon in multiple joints; prevalence and association with age and gender

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ABSTRACT

Introduction: Our purpose was to determine the prevalance ratio of vacuum phenomenon (PRVP) in the sacroiliac (SIJ), sternoclavicular (SCJ), shoulder (ShJ) and symphysis pubis (SP) joints of adult population and to assess the relationship between the presence of the vacuum phenomenon (VP) and demographic factors.

Methods: The presence of gas density within joints was recorded as positive finding on images of thorax and abdominopelvic CT scans of 161 patients.

Results: The overall PRVP for each joint were as follows: 16.7% for ShJ, 32.3% for SCJ, 71.4% for SIJ, 7.5% for SP. The mean ages of the patients who had VP were significantly lower than the patients who did not have VP in ShJ and SCJ, but mean ages of patients who had VP in SP were significantly higher than the patients who did not have VP. There was a significant positive correlation between ShJ and SCJ and negative correlation between SCJ and SIJ.

Discussion: VP may be detected as an incidental finding in various joints at the same time. Therefore, its presence may not have any clinical relevance. Examination technique, joint position and patient population may affect the PRVP in the joints. Knowledge of this anatomical phenomenon may prevent faulty diagnosis of joint pathology and prevent suboptimal treatment of patients.

1. Introduction

The vacuum phenomenon (VP) which is the presence of gas in the joint space, is an anatomical entity. It has been described in multiple joint areas such as the temporomandibular, sternoclavicular (SCJ), shoulder (ShJ), wrist, metacarpophalangeal, sacroiliac (SIJ), hip (HJ), knee and subtalar joints. VP is generally associated with degenerated joint disease, but it is also associated with bone fracture, metastasis, abscess, trauma, septic arthritis, multiple myeloma. The VP can be detected on direct radiography, computed tomography (CT), magnetic resonance imaging (MRI) and ultrasonography.[1–5]

There were several articles reporting the prevalence of the VP (PRVP) in SIJ but limited number of articles reported the PRVP in ShJ, SCJ and symphysis pubis (SP) and most of these studies were published a long time ago (Table 1).[6–14] We couldn't find a study that compared PRVP in different joints of same patient population.

Our aim was to investigate the PRVP in the SIJ, SCJ, ShJ and SP in adult population; to assess the relationship between the presence of the VP and demographical factors such as age and sex in this retrospective study. Also, we aimed to investigate the reliability of the detection by assessing inter-observer correlations.

2. Material and methods

The study was approved by the local ethics committee. The requirement to obtain informed consent was waived. Consecutive thorax and abdominopelvic (TAP) CT scans of 226 patients that included shoulder and the hip joints between the dates of 1st June of 2016 and 30th November of 2016, were retrospectively reviewed. Patients with open wounded major traumas extending to the SIJ, SCJ, ShJ and were excluded. 177 patients (ninety-two males, sixty-nine female) who underwent both thorax and abdominopelvic CT scans for various indications (e.g. 98 patients for malignity follow up, 34 patients for suspected malignity, 29 patients for evaluation of thorax and abdominal trauma, 16 patients for evaluation of

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Table 1
shows the published articles that reported the prevalence of vacuum phenomena in Sacroiliac (SIJ), Symphysis Pubis (SP), Sternoclavicular (SCJ) and Shoulder (ShJ). Ref; Reference number.

Joint	First Author, Year[Ref]	Mean age	Patient number	Prevalence (%)	Prevalence in females (%)	Prevalence in males (%)
SIJ	Peh, 1997[6]	69.2	60	68.5	Not reported	Not reported
	Loo, 2011[7]	50.6	652	34	41	27
	Faflia, 1998[8]	51.5	288	61.1	62.7	58.8
	You, 2016[10]	9.9	60	31.9	30	33.3
	Sze, 2002[9]	39.2	104	12	Not reported	Not reported
	Takata, 2016[11]	63.5	100	39	91.2	8.5
SP	Williams,1955[21]	Not reported	232	41.5	41.5	Not reported
	Camiel, 1956[20]	Not reported	100	30	30	Not reported
SCJ	Goodman, 1983[24]	Not reported	25	4	Not reported	Not reported
	Patten, 1999[12]	>50	234	21	Not reported	Not reported
ShJ	Patten, 1994[13]	32	44	20	Not reported	Not reported

aortic pathology) were selected for the study. Images of sixteen patients (5 patients with pelvic fixation due to fracture, 1 patient with shoulder prosthesis, 5 patients with median sternotomy surgery and 5 patients with chronic sacroiliitis) were also excluded during image evaluation. A total of 161 including 92 males and 69 females were included in the study.

Patients underwent scanning by using a 64 -detector (Toshiba Aquilion, Toshiba Medical Systems Corporation, Tochigi, Japan) TAP CT protocol in which both arms were raised above the shoulder region. Thorax and Abdominopelvic CT images were obtained in 1-mm-thick axial slices. All images were reviewed at bone window using local PACS system (Probel PACS Systems, Izmir, Turkey). The presence of gas density within each SP, SIJ, SCJ, ShJ was recorded as a positive finding (Figs. 1–3). Data concerning gender and age were also recorded for each patient. These scans were evaluated in two settings by a musculoskeletal radiologist [(O.T) experienced with musculoskeletal radiology for 12 years] to assess the presence of gas in each joint and to assess the intra-observer reliability. Additionally, a radiology resident [(A.C) experienced with computed tomography for 20 months (3 months in abdominal radiology, 3 months in thorax radiology, 14 months in emergency radiology] evaluated all CT scans to establish inter-observer reliability between radiology resident and musculoskeletal radiologist.

2.1. Statistical analysis

Descriptive statistics for each study variables were calculated and provided throughout the article. Frequency and percentage for qualitative variables were calculated while mean, standard deviation, median, minimum and maximum were calculated for quantitative variables. Since the data did not satisfy the parametric assumptions, non-parametric tests were used for the analysis. For two independent group comparisons of quantitative variables, Mann Whitney U test was applied. Pearson chi square test or Fisher's Exact test were performed for the analysis of qualitative variables, were appropriate. Possible associations between ordinal variables were analyzed using Spearman Correlation test. To understand the inter and intra-observer reliabilities, Cohen's Kappa coefficient were calculated. All statistical analyses were carried out with SPSS (Version 18.0) statistical package. Level of significance was accepted to be 0.05 for the whole study.

3. Results

A total of 161 patients (mean ages 60.09 ± 14.68 years; 95% CI: [57.8–62.4]), including 92 males and 69 females were included in the study. The age and the gender distributions of the patients who did and those who did not have VP for each joint are provided in Tables 2 and 3. The overall PRVP for each joint were as follows: 16.7% for ShJ (12.0% in males vs 23.2% in females, $p = 0.06$), 32.3% for SCJ (34.8% in males vs 29.0% in females, $p = 0.44$), 71.4% for SIJ (55.4% in males vs 92.8% in females, $p < 0.01$), 7.5% for SP (5,4% in males vs 10.1% in females, $p = 0.26$) (Table 2).

VP was seen bilaterally in 81% of SIJ, (93/115 patients; 87% of female patients, 56/64 female patients; 72% of male patients, 37/51 male patients), 36.5% of SCJ (19/52 patients; 40% in 8/20 female patients; 34% in 11/32 male patients) and 22% of ShJ (6/27 patients; 25% in 4/16 female patients; 18% in 2/11 male patients).

The effect of age on joints was also evaluated. The mean ages of patients who had VP were significantly lower than the patients who did not have VP in ShJ (54.48 ± 13.18 and 61.22 ± 14.75, respectively; $p = 0.018$), as well as SCJ (56.23 ± 12.83 and 61.93 ± 15.19, respectively; $p = 0.010$). The mean ages of patients who had VP in SP were significantly higher than the patients who did not have VP (69.50 ± 17.66 and 59.33 ± 14.21, respectively; $p = 0.019$). The mean ages of patients who had VP on SIJ were higher than those who did not have VP but the difference was insignificant (60.18 ± 14.76 and 59.85 ± 14.63, respectively; $p = 0.019$) (Table 3).

We evaluated the correlation between joints who had VP. We found a significantly positive correlation between SJ and SCJ ($r = 0.282$; $p < 0.001$) and a significant negative correlation between SCJ and SIJ ($r = -0.164$; $p = 0.037$).

We also evaluated the intra and inter-observer reliability in detecting VP. Inter-observer reliability was graded with kappa values as followed; 0.642 for SIJ, 0.719 for ShJ, 0.725 for SCJ, 0.902 for SP. Inter-observer kappa values indicated the substantial agreement for SIJ, SCJ and ShJ; and also, perfect agreement for SP. Intra-observer reliability was graded with kappa values as followed; 1.000 for ShJ and SP, and also 0.975 for SCJ, 0.966 for SIJ.

4. Discussion

In this study, we investigated the PRVP in the SIJ, SCJ, ShJ and SP. We found that VP was present at SIJ of most female patients (90%). VP was detected in ShJ and SCJ at relatively younger ages and in SP at older ages. There was a significant positive correlation between ShJ and SCJ; and also, a significant negative correlation between SCJ and SIJ. Inter-observer reliability which was graded with kappa values ranging from 0.642 to 0.902 (lowest for SIJ, highest for SP) indicated a substantial to perfect agreement.

Degenerative changes, traumatic impact, gas producing micro-organisms, joint traction and motion were reported to cause VP. Knutson et al reported a correlation between VP and degenerated intervertebral disc disease.[15] The major component of the intra articular gas is a mixture of oxygen, carbon dioxide and nitrogen, which has a similar constituent ratio as the ratio of the gas components

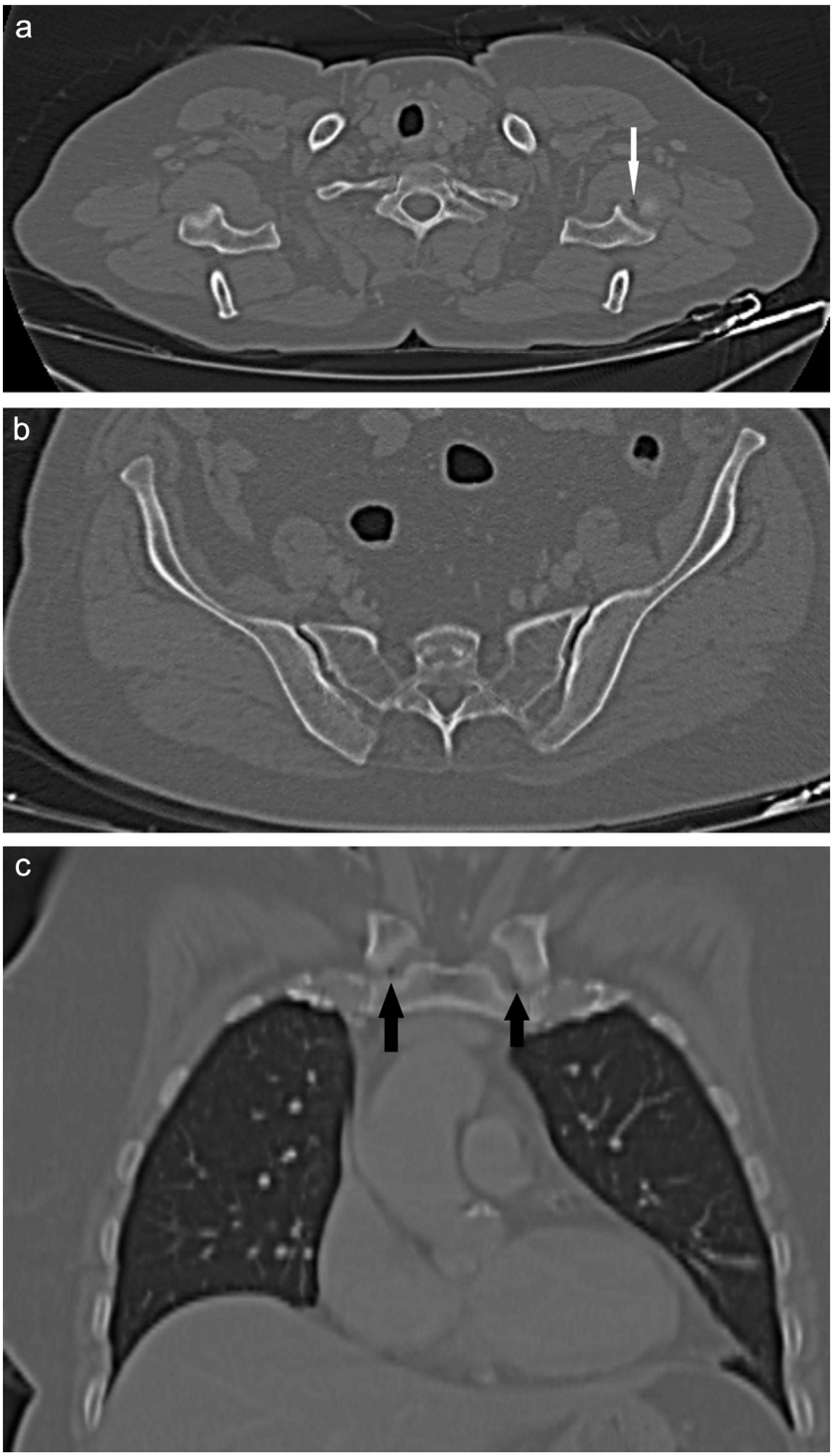

Fig. 1. Axial CT image with bone window shows the gaseous density dark line in left shoulder joint (arrow) (a) and both sacroiliac joint (b) of 68-year-old woman. Coronal reformatted CT image with bone window (c) shows the air in both sternoclavicular joints.

in the circulating blood. This phenomenon is well noticed in synovial joints like SIJ and ShJ; in which stress and motion distracts the opposing articular surfaces, which creates a negative pressure and a potential space allowing blood gases to collect within that spaces.[3,16,17]

The VP has been described in several pathological and nonpathological situations in SIJ, SCJ, ShJ.

The SIJ is special type of synovial joint which permits little movement and is classified as amphiarthrodial.[18] We have found a significantly higher PRVP in SIJ of females (92.8% in female's vs 55.4% in male's, $p = 0.00$) as reported in previous studies. These studies suggested that the higher PRVP in females can be explained by increased levels of estrogen.[7,8] Several authors also reported PRVP with a wide range between 12 and 68.5% (Table 1).[6–11] We found slightly higher ratio (71.4%) than previously reported. Population characteristic, image resolution and quality may explain the difference between mean ages of our and previous studies.

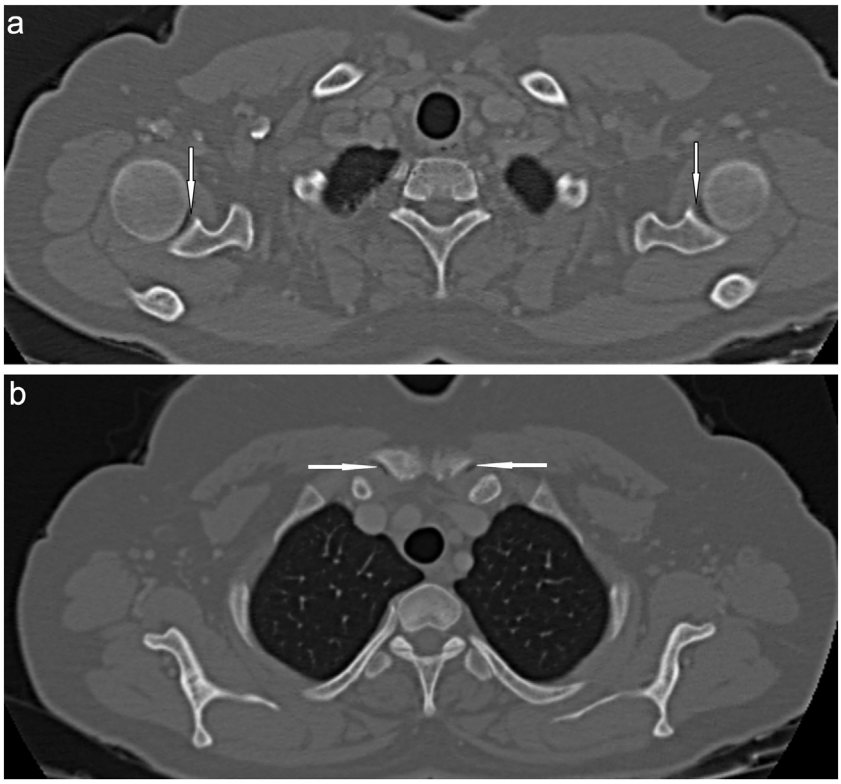

Fig. 2. Axial CT image with bone window shows the gaseous density dark line (white arrows) in both shoulder (a) and sternoclavicular joints (b) of 43-year-old man.

VP in SP was reported in ancient articles. The SP is a secondary cartilaginous joint which permits little movement and is classified as amphiarthrodial like SIJ.[19] Camiel et al and Williams et al investigated the PRVP in pregnant patients on pelvimetry and reported higher PRVP when compared with our study (Table 1).[20,21] We found the PRVP in SP as 7.5% (5,4% in males' vs 10.1% in females, $p = 0.26$). The mean ages of patients who had VP on SP (69.5 ± 5.09, min 32 max 90) were significantly higher than the patients who didn't have VP. We didn't find any article reporting the PRVP in male and in adult female non-pregnant patients. Women have a greater thickness of the fibrocartilaginous disc which allows more mobility of the pelvic bones. During pregnancy, circulating hormones such as relaxin which induce resorption of the symphyseal margins and structural changes in the fibrocartilaginous disc increase symphyseal width and mobility.[19] Higher PRVP in SP of females can be explained by increased mobility of joint.

The SCJ is a diarthrodial saddle type synovial joint which is inherently unstable.[22] Goodman et al reported 4% of PRVP in SCJ on chest CT scans of healthy subjects (age, >50 years).[23] Patten et al reported PRVP in SCJ as 38% in trauma patients (Table 1).[12] They suggested that the VP in the sternoclavicular joints of trauma patients may be associated with distraction-type force or injury. We found the PRVP in SCJ as 32.3% in non-trauma patients. Ligamentous and capsular laxity changes with age, exposing both joints to greater strain, which may explain the higher PRVP in SCJ.

The ShJ, which is known as the glenohumeral joint, is a ball and socket type synovial joint. Patten et al reported PRVP in shoulder joints as 20% (9/44 patients) which was slightly higher than our results (16.8%).[12] Shoulder position (degree of shoulder abduction during examination) and examination technique (MRI vs CT) may explain the difference between PRVP.

We evaluated the effect of age on joints. The mean ages of patients who had VP on ShJ (54.48 ± 2.53, min 30 max 83 years) and SCJ (56.23 ± 1.77, min 30 max 90) in our study were significantly lower than those who didn't have VP. We didn't find any article reporting the effect of age on the PRVP in ShJ and SCJ. We don't know why VP were seen mostly in younger ages at ShJ and SCJ, but decreased mobility of joints in older patients may explain why PRVP in these joints were lower in younger ages.

We also found a positive significant correlation between ShJ and SCJ ($r = 0.282$; $p < 0.001$), and a negative significant correlation between SCJ and SIJ ($r = -0.164$; $p = 0.037$). It means that, it is more likely to detect VP in both ShJ and SCJ of the same patient at the same time due to the positive correlation between them. It is less likely to detect VP in both SIJ and SCJ of the same patient at the same time due to the negative correlation in-between. We didn't find any other correlation between other joints.

We found that the inter-observer reliability graded with kappa values was ranging from 0.640 to 0.902 (lowest for SIJ, highest for SP). In the literature, the kappa statistics was interpreted as follows: <0.00, poor agreement; 0.00–0.20, slight agreement; 0.21–0.40, fair agreement; 0.41–0.60, moderate agreement; 0.61–0.80, substantial agreement; and 0.81–1.00, almost perfect agreement.[24] As a result, there was good to excellent intra- and interobserver reliability in assessment of VP in joints. Our results also show that VP can be detected in SP with perfect and in SIJ, ShJ and SCJ with substantial agreement by the different radiologists with different radiological experiences. These results are similar to the results of Lo's study that reported the interobserver reliability in detecting the VP within SIJ.[7]

Our study has some limitations. Firstly, we didn't correlate our findings with clinical findings or symptoms. Such correlations may have been of interest, but was not the primary emphasis of our study. Secondly our sample size was small. Further studies in larger populations are required to assess the PRVP in joints. Another limitation is that we did not measure the Hounsfield units of intra-articular gas, as we were unable to set cut-off values for intra-

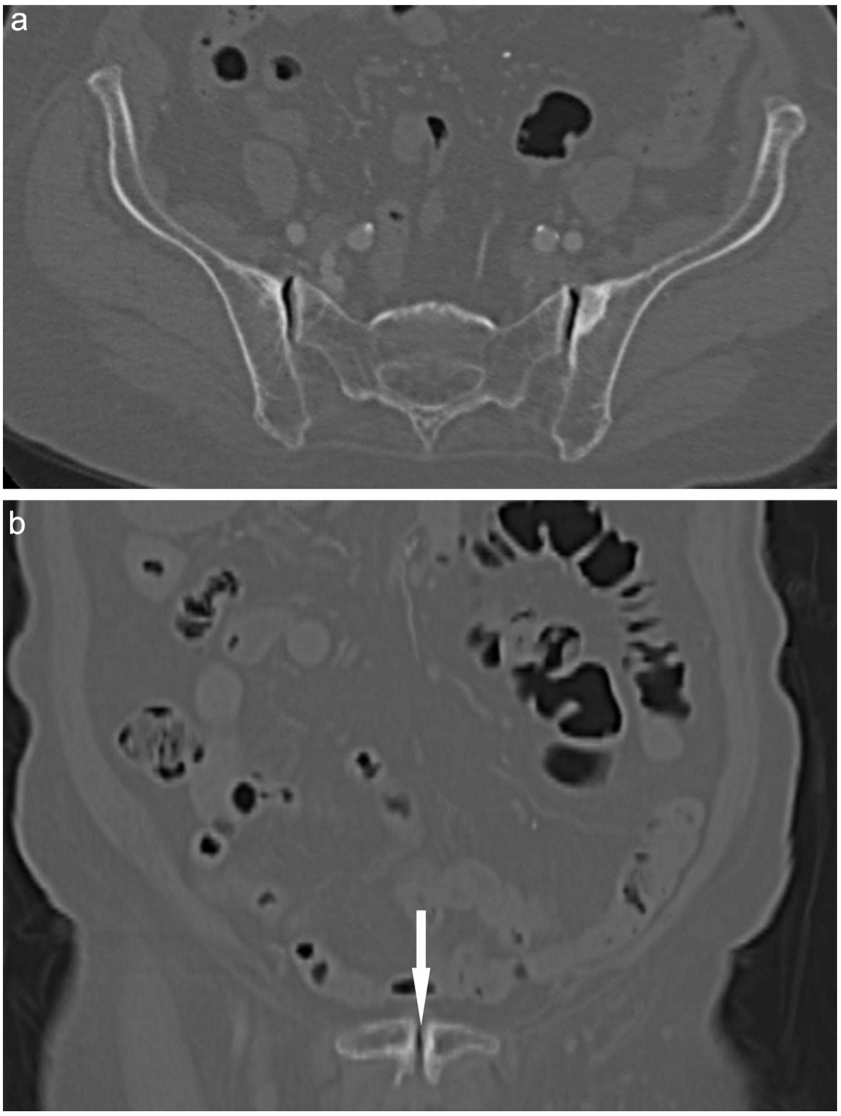

Fig. 3. Axial CT image with bone window shows the gaseous density dark line in both sacroiliac joint (a) of 80-year-old woman. Coronal reformatted CT image with bone window (b) shows the gaseous density in symphysis pubis (arrow).

Table 2
shows the gender distributions of patients who had vacuum phenomenon for each joint. (N = number of patients, % percentage value).

	Shoulder Joint N/%	Sternoclavicular Joint N/%	Sacroiliac Joint N/%	Symphysis Pubis N/%
Female	16/23.2%	20/29%	64/92.8%	7/10.1%
Male	11/12%	32/34.8%	51/55.4%	5/5.4%
Total	27/ 16.7 %	52/ 32.3%	115/ 71.4%	12/ 7.5%
p value	0.059	0.436	0.000	0.260

articular gas. Thus, we employed strict visual evaluation using either bone window settings for the assessment of VP. Another minor limitation is that positioning of joint during examination may have an effect on the PRVP. Unlike a disease entity, observing vacuum in patients will likely depend on positioning of the ShJ which was taken with abduction. The effect of positioning on SCJ, SIJ and SP may be negligible due to limited motion of these joints. Further studies that evaluate the effect of positioning on PRVP of ShJ are required.

5. Conclusion

In conclusion, VP was found in multiple joints of same patients; detected mostly in SIJ; being mostly bilateral in SIJ, and unilateral in SCJ and ShJ. VP may be detected as an incidental finding in various joints at the same time. Therefore, its presence may not have any clinical relevance. Examination technique, joint position and patient population may affect the PRVP in the joints. Different radiologists with

Table 3
shows the age distributions of patients who did and those who did not have vacuum phenomenon (VP) for each joint.

Joint		Age (Mean ± Std. Dev. (95%CI))	p value
Shoulder Joint	With VP	54.48 ± 13.13 (49.27–59.7)	0.018
	Without VP	61.216 ± 14.75 (58.7–63.74)	
Sternoclavicular Joint	With VP	56.23 ± 12.83 (52.66–59.8)	0.010
	Without VP	61.93 ± 15.19 (59.04–64.8)	
Sacroiliac Joint	With VP	60.18 ± 14.76 (57.46–62.91)	0.978
	Without VP	59.85 ± 14.63 (55.5-64.19)	
Symphysis Pubis	With VP	69.5 ± 17.66 (58.28–80.72)	0.019
	Without VP	59.32 ± 14.21 (57.03–61.63)	
	Without VP	60.09 ± 14.68 (57.8–62.4)	

different radiological experiences (radiology residents and specialists) may detect VP within joints. Knowledge of this anatomical phenomenon may prevent faulty diagnosis of joint pathology and prevent suboptimal treatment of patients.

Conflicts of interest

All authors declare that they have no conflict of interest.

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