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Estimation of sacroiliac joint index in normal subjects of various age groups: comparative evaluation of four different methods of quantification in skeletal scintigraphy

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Abstract

BACKGROUND: To estimate and compare the sacroiliac joint (SIJ) index in skeletal scintigraphy by four different methods of quantification employed in normal subjects of different age groups.

MATERIAL AND METHODS: The whole-body skeletal survey of 100 subjects, who underwent skeletal scintigraphy three hours after injection of ^{99m}Tc-Methylene Diphosphonate (MDP), were selected for this analysis. The patients having previous history of low back pain, joint pain or any benign bone joint disorders (e.g. ankylosing spondylitis, metabolic bone disease, and osteoarthritis), documented bone lesions or tumors within the pelvis region were excluded from the study. All subjects had normal posterior pelvis view on visual assessment in the respective study. Sacroiliac joint index was calculated by quantitative sacroiliac scintigraphy. In each subject, four different methods of quantification were carried out: 1. irregular region of interest (ROI) method, 2. rectangular ROI method, 3. profile peak counts (PPC) method and 4. profile integrated counts (PIC) method and applied to calculate SIJ index. SIJ indices for left and right sacroiliac joints were calculated by dividing the count for each joint by the count for the sacrum. Results obtained by the four methods were compared statistically.

RESULTS: The overall SIJ index was found to range from 1.06 to 1.36 in the study population of 100 subjects encompassing all age groups. There was no significant difference in the estimated SIJ index within each age group obtained by the four different methods employed in this study. The values of SIJ index were as follows: in patients aged 2–20 years — they ranged from 1.22 to 1.36; in patients aged 21–40 years — from 1.07 to 1.19; for patients aged 41–60 years — from 1.08 to 1.19 and in patients aged 61 years and older, SIJ values were slightly lower than in other groups and ranged from 1.06 to 1.13.

CONCLUSION: Methods of selecting a region of interest have no significant effect on the calculation of SIJ index and in healthy subjects its values range between 1.06 and 1.36, depending on the age of the subject. The maximum value was observed in patients aged 2–20 years and minimum values were noted in patients aged 61 and older.

KEY words: sacroiliac joint index, bone scan, ^{99m}Tc-Methylene Diphosphonate (MDP)

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Background

In spite of controversial results, quantitative sacroiliac scintigraphy has been utilized as a diagnostic procedure to detect early sacroiliitis in patients having low back pain [1–5]. Various methods of quantification have been described in literature [1, 2, 6–8]. It has been reported that the technique is of limited value for the diagnosis of sacroiliitis [6]. Age and gender have been reported to be a prime factor affecting the SIJ index [8]. Most of the authors have applied a single method to calculate the sacroiliac joints-to-sacrum count ratio and the number of control subjects studied has been relatively small. In the present study, we compared the results obtained by four different methods of ROI (region of interest) selection to calculate the sacroiliac joint index in 100 normal patients. The aim of the study was to evaluate whether there exists any discrepancy in the results obtained by these methods and whether a particular method could be applied with minimum variation.

Materials and methods

Over a period of one year, subjects were selected from the patients referred to our Institute for whole body bone study to exclude metastases. Whole body bone scan (spot views) were obtained 3 hours after intravenous injection of 740 MBq 99m-Tc-methylene diphosphonate (99mTc-MDP). Total 300K-500K counts were collected for each view. An additional view of posterior pelvis was acquired with 500k counts. We used a large field of view Gamma Camera (Elscint Apex 400, Elscint Ltd. Haifa Israel) for our study. Low energy medium resolution collimator was used to acquire the images. The data were recorded in a 256 × 256 byte matrix for computer analysis. The patients having history of low back pain, joint pain or any benign bone joint disorders (e.g. ankylosing spondylitis, metabolic bone disease, osteoarthritis), documented bone lesions or tumors within the pelvis region were excluded from the study.

^{99m}Tc-pertechnetate was obtained from the solvent extraction generator system available at Radiation Medicine Centre and methylene diphosphonate (MDP) was obtained in freeze-dried form from Board of Radioisotope Technology (BRIT), Mumbai. 99mTc-MDP was prepared by adding required quantity of Na^{99m}TcO4 to the MDP kit. The dose was adjusted for body weight while injecting in children.

Sacroiliac joint to sacrum ratio was calculated by four different methods. Separate posterior view of pelvis was selected for this purpose. The methods are given below.

Irregular ROI method (Figure 1)

An irregular region of interest (ROI) was drawn over the left SIJ covering the iliac bone. Another mirror ROI was copied and placed over right sacroiliac joint covering the right iliac bone. A third ROI was drawn over sacrum region between the two ROIs. Total counts in each region were determined and counts per pixel were calculated for each region.

Rectangular ROI method (Figure 2)

This method was similar to the earlier method except that the ROIs drawn were rectangular in shape. Size of the ROIs was adjusted as required to cover left and right sacroiliac joints and sacrum regions as well. Counts per pixel were calculated for the three regions.

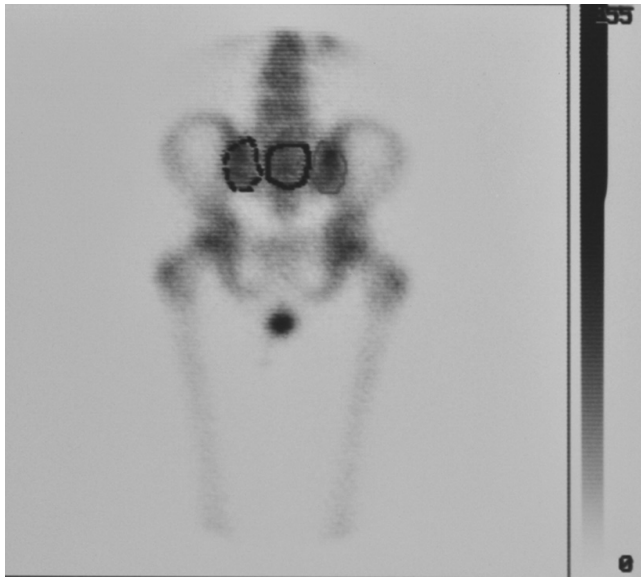

Figure 1. Method-1 for selecting region of interest (ROI). Technetium-99m-MDP bone scintigraphic image of posterior pelvis view. Three irregular ROIs are seen placed over both sacroiliac joints and sacrum region

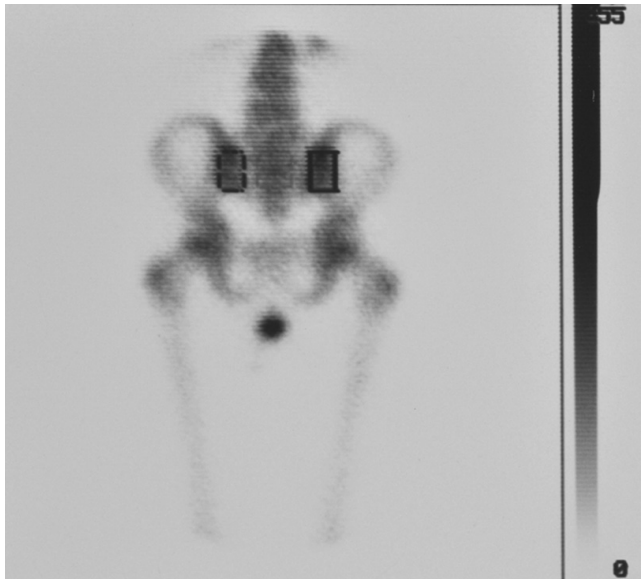

Figure 2. Method-2 for selecting region of interest (ROI). Technetium-99m-MDP bone image of posterior pelvis view. Three rectangular ROIs are seen placed over both sacroiliac joints and sacrum region

Profile peak counts (Figure 3)

A long rectangular region was drawn horizontally covering both the sacroiliac joints and sacrum. Width of this ROI was kept 5–15 pixels depending on the size of pelvis. A profile of the counts present in the ROI was generated. Peak counts over both sacroiliac joints and sacrum were noted.

Integrated profile peak counts method (Figure 4)

Two vertical electronic cursors were placed, covering 10–20 pixels profile peak symmetrically on both sides. Integrated counts between the two cursors were determined separately for both the SI

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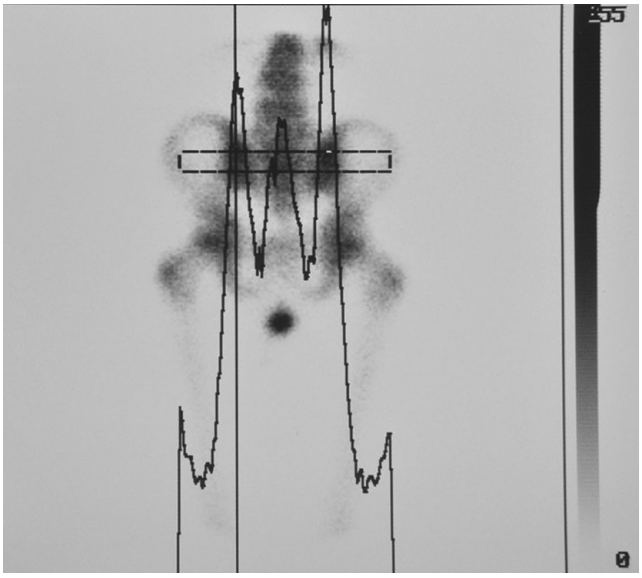

Figure 3. Method-3 for calculating SIJ index (Profile peak counts method to determine sacroiliac joint index). Posterior pelvis view bone scan with Tc-99m-MDP. Three distinct peaks on the profile. Maximum counts at the peak are computed by moving an electronic cursor on the profile for the three regions. Single cursor is seen at the peak position of left sacroiliac joint profile

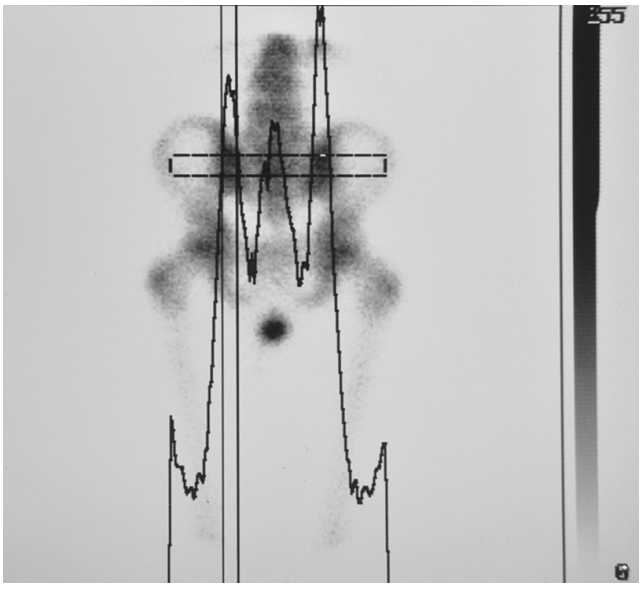

Figure 4. Method-4 for calculating SIJ index. Two cursors are placed symmetrically both sides of each profile peak and integrated counts between the two cursors are computed. In the figure, the two cursors are placed over the profile peak of left sacroiliac joint

joints and sacrum. Care was taken to keep the width between the two cursors equal for all the three regions.

Left and right sacroiliac joint indices were calculated by taking the ratio of counts obtained over the both joints to the counts obtained over sacrum region as determined by the four methods separately.

The patient population included 100 patients. Age varied between 2–72 years. There were 54 females and 46 males. All

Table 1. The comparative data of sacroiliac joint/sacrum ratio as calculated by the four methods in mixed population of different age groups

Age groups (years) (Nos.)	METHOD NO.	Sacroiliac joint index (mean of left and right SIJ Indices)		
		MEAN	SD	SE
2–20 (23)	1	1.215	0.16557	0.03452
	2	1.28852	0.18515	0.03861
	3	1.35826	0.24109	0.05027
	4	1.29339	0.2573	0.05635
21–40 (27)	1	1.0741	0.13728	0.02642
	2	1.14759	0.15693	0.0302
	3	1.20204	0.19224	0.037
	4	1.19463	0.17969	0.03458
41–60 (36)	1	1.08736	0.12572	0.02095
	2	1.16486	0.19375	0.03229
	3	1.15903	0.17916	0.02986
	4	1.19236	0.19158	0.03193
> 61 (14)	1	1.06786	0.12405	0.03315
	2	1.11179	0.16642	0.04448
	3	1.13464	0.20242	0.0541
	4	1.13214	0.18885	0.05047

the patients were divided into four age groups: 2–20 yrs, 21–40 yrs, 41–60 yrs and 61 years or more. Mean value of left and right sacroiliac joint index (SIJ index) was calculated for each patient. The mean SIJ index was calculated for each group of patients separately. Standard deviation, standard error and variance among all four methods were also calculated for each age group. Unifactorial ANOVA was employed to calculate the p value to compare the variation between the 4 methods in each age group.

Results

Mean SIJ index for each group of subjects, as obtained by the four methods, is demonstrated in Table 1. The mean SIJ index value ranges were as follows: from 1.22 to 1.36 in the age group of 2–20 years; from 1.07 to 1.19 in the age group of 21–40 years; from 1.08 to 1.19 in the age group of 41–60 years, and from 1.13 to 1.06 in the age group 61 years or older of subjects. In patients aged 61 years or more the value was slightly lower than in other groups. Overall, the variation in standard deviation was found to range from 0.12 to 0.26 among the four groups. Variance among the four methods was found to be 0.06, 0.03, 0.03 and 0.05, respectively. The p-values indicated that there was no significant difference in the SIJ indices calculated by the four methods in each age group (Table 2).

Discussion

SIJ index has been used as an important parameter to evaluate patients of low back pain and for detection of sacroiliitis in a number of clinical settings [1, 9–13, 15–17]. Zafeirakis et al. [15] examined the utility of SIJ index in the setting of chronic low back pain. They found that the numerical index lambda (calculated by the equation lambda=total counts/total pixels of the "hottest" of the two

Table 2. The p values when the four methods were compared in different age groups

Age group (years) (Nos.)	METHOD NO.	SACROILIAC JOINT INDEX (mean of left and right SIJ Indices)		
		Mean	Variance	p value by ANOVA
2–20 (23)	1	1.215	0.02741	0.17353
	2	1.28852	0.03428	
	3	1.35826	0.05812	
	4	1.29339	0.0662	
21–40 (27)	1	1.10741	0.01885	0.13942
	2	1.14759	0.02463	
	3	1.20204	0.03696	
	4	1.19463	0.03229	
41–60 (36)	1	1.08726	0.01581	0.07369
	2	1.16486	0.03754	
	3	1.15903	0.0321	
	4	1.19236	0.0376	
> 61 (14)	1	1.06786	0.01539	0.72751
	2	1.11179	0.02769	
	3	1.13464	0.04097	
	4	1.13214	0.03566	

sacroiliac joints area divided by the counts/pixels corresponding to the L4 values) demonstrated a decreasing trend with ageing in patients aged from 18 to 36 years, regardless of the presence of LBP. The authors concluded that the clinical utility of this parameter was confined to distinguishing patients with inflammatory LBP from healthy subjects ($P < 0.0005$) and that the method cannot distinguish patients with LBP of the mechanical type.

To evaluate the usefulness of bone scintigraphy in the detection of the articular involvement of Behçet's disease, Sahin et al. [16] studied 32 patients with a diagnosis of this disease. Using the diagnostic criterion for sacroiliitis of SIJ index higher than 1.34, the authors observed that among patients who were clinically asymptomatic and had normal pelvis radiography, sacroiliitis was found in 8 patients (25%). They concluded that skeletal scintigraphy is sensitive for earlier diagnosis of articular involvement, especially in SI joints.

In a recently published report [17], Strobel et al. studied the performance of (18)F-fluoride-PET/CT (PET/CT) for the diagnosis of sacroiliac joint (SIJ) arthritis in patients with active ankylosing spondylitis (AS). With plain radiography as the gold standard and SIJ/S uptake ratio of > 1.3 as the threshold value, the sensitivity, specificity and accuracy on a per patient basis were 80%, 77% and 79%, respectively. The authors concluded that the diagnosis of sacroiliitis in active AS using quantitative (18)F-fluoride PET/CT is feasible and can be considered as an alternative to conventional bone scintigraphy.

Influence of age and gender on SIJ index has also been described [8, 14, 18] which makes this a variable parameter and hence accurate estimation in each age group and method remains crucial for using this index in routine clinical scenario [3]. In a study published in 2009, Bajner [17] reported SI indices in 740 non-arthritic control subjects that were calculated by standard method. The ranges of normal SI indices were different for males and females and for different age groups. The upper limit of 99% confidence interval was considered as optimal cut-off value for diagnosing bilateral sacroiliitis, whereas the data between upper limits of 95% and 99% confidence intervals was interpreted as uncertain.

The use of different methods to determine SIJ index by various group of authors has been contemplated by some authorities as one of the reasons of discordance. Thus, in the present study, we compared the findings of four methods applied to calculate SIJ index in normal subjects. There has been limited data on this specific topic. Davis et al., compared various methods to calculate SIJ index in normal subjects [6], though the number of subjects studied was very small. We included 100 patients having normal posterior pelvis view on bone scan in our study. Four methods were applied to calculate SIJ index (Figures 1–4). We tried to establish normal variation in SIJ index due to different methods of ROI selection. This, we believed, would be useful to further optimize this approach for routine use in various joint diseases. One of the shortcomings of the study is the youngest age group (2–20 y) where the population ranges from children to young adults and hence some variability of SIJ index could be expected due to physiological changes. However, split into smaller age subcategories was not done, as not enough reliable data from each subcategory could be obtained.

The study by Davis et al. included 23 controls and 27 patients. Age of the normal subjects varied from 17–59 years and mean SIJ index was 1.40–1.63 in this mixed population [6]. In our study we considered mean of left and right SIJ index for each subject because we wanted to evaluate the variations caused only by selection of methods. Age of the patients (man and women) ranged from 2–72 years. We divided the patients into four age groups, as described above, to create the normal values database for the SIJ index. The values of mean SIJ index as calculated by the four methods were 1.2–1.36, 1.07–1.20, 1.08–1.19 and 1.06–1.13 for the four age groups, respectively (Table 1). Dodig et al. had reported SIJ index values of 1.02–1.35 that were determined with rectangular ROI method [14], as described in method No. 3 (Figure 3) in our study. Wan Yu et al. applied profile peak counts by generating three profiles [8]. They reported SIJ index values of 1.16–1.63. The mean SIJ indices were found slightly lower than the values reported by other authors. This validates the values greater than 1.3 as diagnosis criterion of sacroiliitis in ongoing clinical studies Strobel et al. The variations in the values obtained by the four methods were not statistically significant.

We found the p values to be 0.17, 0.14, 0.07 and 0.17 when the four methods were compared for each group of patients respectively (Table 2). Size of the ROIs varied in all the subjects depending on the size of patients. To further analyze the variation due to age and gender data from large number of patients are needed, nonetheless, this data obtained from 100 patients in the present study will be a useful resource for such future endeavor.

Conclusion

We conclude that SIJ indices do not vary significantly depending on the methods of region of interest selection. Any method can be applied depending on the suitability of the Gamma Camera and the person carrying out the study. In a normal subject, the value may vary from 1.06 to 1.36 depending on age. The maximum value

was observed in the age group of 2–20 years and minimal value in the group of patients aged 61 years or more. Studies on a large number of normal subjects are required to further determine the influence of age and gender separately on the SIJ index.

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