CLINICAL ARTICLE

The Temporal Impact of Prosthesis Implantation and Semi-Quantitative Criteria on the Diagnostic Efficacy of Triple-Phase Bone Scanning for Periprosthetic Joint Infection

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Objective: To evaluate the diagnostic efficacy of triple-phase bone scanning and the temporal impact of prosthesis implantation on the diagnostic efficacy of triple-phase bone scanning for periprosthetic joint infection (PJI).

Methods: Patients who were admitted to our hospital for joint pain and dysfunction after total joint arthroplasty between 2014 and 2020 were retrospectively included. Triple-phase bone scanning was performed, and the blood pool images were evaluated to obtain the semi-quantitative criteria. The patients were then grouped into six groups according to the time interval from index primary arthroplasty to triple-phase bone scanning. We examined whether there were significant differences in sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy between the groups.

Results: Overall, 66 patients who underwent total hip arthroplasty (THA) and 74 patients who underwent total knee arthroplasty (TKA) were analyzed. No significant differences were observed between visual analysis and semi-quantitative measurement in terms of sensitivity, specificity, PPV, NPV, and accuracy. For patients with a time interval from prosthesis implantation to bone scanning of >1 year, visual analysis had a higher PPV (100%) in patients who underwent THA and the use of semi-quantitative criteria had a higher NPV (85.7%) in patients who underwent TKA.

Conclusion: The semi-quantitative criteria showed no advantages in the diagnosis of PJI. In addition, triple-phase bone scanning demonstrated good clinical diagnostic efficacy when the time interval from prosthesis implantation to bone scanning was >1 year.

Key words: Arthroplasty; Prosthesis-related infections; Nuclear medicine; Radionuclide Imaging; Diagnostic Imaging

Introduction

Periprosthetic joint infection (PJI) or aseptic failure (AF) is the cause of arthroplasty failure.[1,2] PJI is a devastating complication that may be experienced after arthroplasty, with a reported incidence of 2% to 2.4% after primary total joint arthroplasty (TJA).[3] Although PJI occurs is uncommon, its frequency has increased due to the rise in the number of arthroplasties performed each year, with nearly 11,000 patients affected by PJI yearly in the United States alone.[4] As PJI results in a decline in functional outcomes and high financial costs,[5] the combined annual hospital costs related to PJI in the United States is estimated to be $1.85 billion by 2030.[6]

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Early differentiation of PJI from AF is crucial for the successful treatment of arthroplasty failure. Severe infections caused by highly virulent bacteria presenting with swelling, erythema, fever, or a draining sinus are easy to identify. However, the diagnosis of low-grade infection caused by low-virulence bacteria can be extremely difficult when clinical and biological signs are subtle or absent. The use of laboratory tests in cases of low-grade infection lacks specificity and sensitivity, and joint aspiration data are unreliable when dry tap occurs.

The International Consensus recommends against infiltration of saline or other fluids into a "dry" joint. When saline lavage is used, the WBC count has been found to decrease significantly. As the positive rate of lavage fluid culture decreased, the culture could potentially mix with external pathogenic bacteria.[7] Additional imaging modalities may improve diagnostic accuracy; however, artifacts frequently limit the utility of computed tomography (CT) and magnetic resonance imaging.[8] Nuclear medicine procedures, which are not affected by metallic hardware, can potentially provide more specific physiological information about joint infections.[9] It includes triple-phase bone scanning, gallium scanning, white blood cell imaging, and single-photon emission/CT (SPECT/CT).[10–12] Among these, triple-phase bone scanning is a low-cost, high-sensitivity examination that can fully unlock the metabolic and morphological information for the diagnosis of patients suspected of having infections.[13]

Presently, triple-phase bone scanning images are analyzed by nuclear medicine physicians to determine the presence of infection by visual observation of increased radioisotope uptake on the images.[14] When the radioisotope uptake of the blood pool phase is increased, the blood flow during dynamic and blood pool imaging is increased, and the uptake on delayed imaging is increased, the patient is diagnosed with infection. This method of evaluation is called visual analysis. Contrastingly, semi-quantitative criteria are used to measure the grayscale of the high-uptake area and the control area in the image, and the ratio of the two grayscales is compared with the semi-quantitative criteria to determine whether infection is detected. While quantitative measurement of positron emission tomography-CT is possible, there are no numerical criteria for the interpretation of triple-phase bone scanning images.[15] The diagnostic result depends on visual evaluation by nuclear medicine physicians; hence, subjective factors have an impact on diagnosis.[8,16] Semi-quantitative criteria that are theoretically effective for diagnosis have not yet been determined. Pelosi *et al.* were the first to study semi-quantitative analysis in the interpretation of WBC scintigraphy and found that the addition of semi-quantitative evaluation led to a significant improvement in both sensitivity and specificity.[17] Similarly, a semi-quantitative measurement could be used for triple-phase bone scanning. Nevertheless, there is still debate as to whether the use of semi-quantitative criteria leads to improved diagnostic accuracy in patients after TJA.

At present, multiple diagnostic criteria have been proposed for the diagnosis of PJI, but none of them incorporate nuclear medicine tests into the diagnostic criteria.[18–21] Blood tests for the traditional inflammatory markers, C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR) may be used to detect the presence of systemic inflammation,[22] while imaging examination by triple-phase bone scanning may be used to localize the site of inflammation. These two methods provide different types of clinical information that can be used for the diagnosis of PJI. As systemic indicators, ESR and CRP levels are influenced by inflammatory arthritis. These indicators may be at normal levels in of low-grade infection, but differences can be noted in local blood flow using triple-phase bone scanning. It has been proposed in the literature that bone scan imaging may show positive results for 2 years after hip prosthesis placement and 5 years after knee prosthesis placement.[23,24] However, clinical evidence of the impact of the duration from primary implantation to scanning on the diagnostic efficacy is lacking, and semi-quantitative criteria of triple-phase bone scanning need to be determined. Therefore, the purposes behind conducting this retrospective study were: (i) comparing visual analysis and the semi-quantitative criteria of triple-phase bone scanning for the diagnosis of PJI; and (2) determining whether the diagnostic performance of triple-phase bone scanning is influenced by the time interval from primary implantation to bone scanning.

Patients and Methods

General Information

The collection of patient information during hospitalization was approved by the Institutional Review Board of our hospital (approval no. 2017–104). The patient medical records contain all the diagnosis and treatment information and examination reports of patients during their hospitalization. Through this system, the medical history of all patients meeting the inclusion criteria between 2014 and 2020 was retrospectively determined.

Inclusion and Exclusion Criteria

The inclusion criteria were as follows: (i) the patient had undergone total joint arthroplasty or revision arthroplasty; (ii) pain and dysfunction of the replacement joint after TJA; and (iii) the patient had undergone triple-phase bone scanning in the nuclear medicine department of our hospital. The exclusion criteria were as follows: (i) the patients that were lost to follow-up; and (ii) patients whose medical chart lacked complete PJI diagnostic information.

We collected a total of 831 cases; 240 cases were selected according to the inclusion criteria, 93 cases were excluded according to the exclusion criteria, and finally 147 cases were included in the study.

Diagnosis of PJI

The definite diagnosis of PJI was based on the 2013 Musculoskeletal Infection Society (MSIS) criteria,[19] which takes the patient's detailed history and clinical symptoms, laboratory examination results, culture results, and findings of the pathological examination of intraoperative samples into consideration. The results of triple-phase bone scanning were analyzed by nuclear medicine physicians.

Definition of Periprosthetic Joint Infection

PJI is present when either one of the major criteria is present or three of the minor criteria are present.

Major criteria:

1. Two positive periprosthetic cultures grew phenotypically identical organisms.
2. A sinus tract communicating with the joint.

Minor criteria:

1. Elevated serum erythrocyte sedimentation rate (> 30 mm/h) and C-reactive protein level (> 10 mg/L).
2. Elevated synovial fluid white blood cell count (> 3000 cells/μL) or 2+ change on the leukocyte esterase test strip.
3. Elevated synovial fluid polymorphonuclear neutrophil percentage (> 80%).
4. Positive result on the histologic analysis of periprosthetic tissue (>5 neutrophils per high power field in 5 high power fields (× 400)).
5. A single positive culture result.

Imaging Protocol and Analysis

Technetium 99m-methyl diphosphonate (Tc-99m-MDP) bone scintigraphy was performed using a hybrid system, which was equipped with a pair of low-energy, high-resolution collimators, and a dual-head gamma camera with an integrated 16-slice CT scanner (Discovery NM670, GE Healthcare, Chicago, Il, USA). All patients received a commercial injection of 740 MBq of 99mTc-MDP. Dynamic flow images were obtained in the perfusion phase (immediately after injection; one frame every 2s for a total of 20 frames), blood pool images were obtained in the soft-tissue phase (2–5 min after injection; one frame per minute, four frames in total), and delayed images were obtained in the delayed metabolic phase (4 h after injection).

The images were assessed by nuclear medicine physicians and analyzed according to the second image of the blood pool phase (3 min after injection). Considering the high sensitivity of the blood pool and the soft tissues involved in infection, the blood pool image was chosen for semi-quantitative analysis. The site with the highest concentration of radioactive uptake in the joint replacement area was selected as the region of interest 1 (ROI-1), and the same position in the contralateral limb was selected as the control area (ROI-2; Fig. 1). If the patient underwent bilateral TJA, the ROI-1 and ROI-2 values were measured in the adjacent muscle on the same side as the control area, and the ratio of ROI-1 and ROI-2 was calculated.

Determining the Semi-Quantitative Criteria

After obtaining the ROI ratio of the images and the clinical diagnosis results of all the patients, the receiver operating characteristic (ROC) curve was obtained, and the Youden index was calculated. The point with the largest area under the curve, that is, the ROI ratio corresponding to the maximum Youden index, was identified. Taking this ratio as the threshold value of the semi-quantitative criteria for diagnosing PJI, a case was diagnosed as infection when the ROI ratio of the image was higher than the threshold value of the semi-quantitative criteria, and a case was diagnosed as non-infection if the ratio was less than the threshold value of the semi-quantitative criteria.

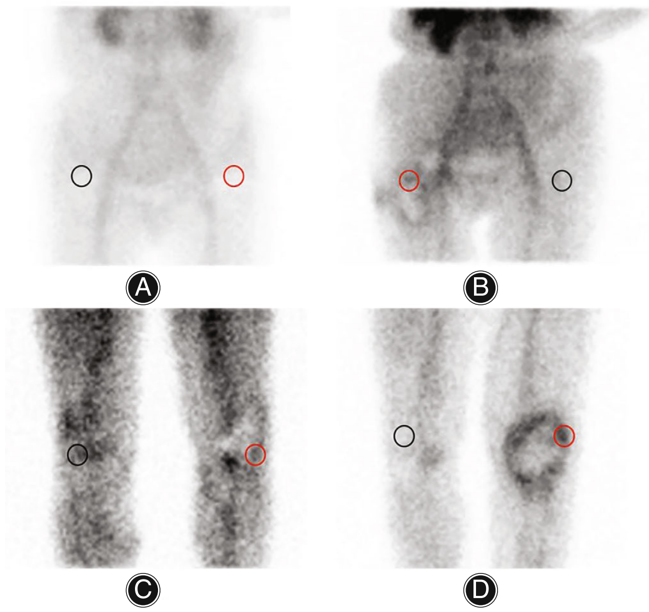

Fig. 1 (A), (B): Blood pool image of patients with THA. (C), (D): Blood pool image of patients who underwent TKA. The area of the red circle is the area with a high uptake (ROI-1); the area of the black circle is the control area (ROI-2). THA, total hip arthroplasty; TKA, total knee arthroplasty. ROI, region of interest.

The Temporal Impact of Prosthesis Implantation

The THA patients and TKA patients were divided into the following six groups according to the time interval from prosthesis implantation to triple-phase bone scanning: patients with a time interval of 1 year or less (THA control group and TKA control group), 1–10 years (THA 1-year group and TKA 1-year group), 2–10 years (THA 2-years group and TKA 2-years group), 3–10 years (THA 3-years group and TKA 3-years group), 5–10 years (THA 5-years group and TKA 5-years group), and 7 to 10 years (THA 7-years group and TKA 7-years group) (Table 1). As the number of patients with a time interval of >10 years from prosthesis implantation to triple-phase bone scanning was too small to perform grouped analysis, we excluded them from this part of the analysis. The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy of triple-phase bone scanning using both visual analysis and the use of semi-quantitative

TABLE 1 Characteristics of the patients included in this study

Characteristics	THA	TKA
Number of patients	66	74
Age, years (mean [range])	61.9 (24–89)	64.7 (23–82)
Sex, number (%)		
Female	34 (51.5%)	49 (66.2%)
Male	32 (48.5%)	25 (33.8%)
Time interval (from implantation to bone scanning) (mean [range])	4.4 (0.08–10.0)	3.3 (0.08–10.0)
Laterality, number (%)		
Left	28 (42.4%)	35 (47.3%)
Right	38 (57.6%)	39 (52.7%)
Diagnosis, number (%)		
Infection	32 (48.5%)	50 (67.6%)
Non-infection	34 (51.5%)	24 (32.4%)

Abbreviations: THA, total hip arthroplasty; TKA, total knee arthroplasty

criteria were calculated for each group. Considering that physiological bone remodeling after TJA will generally last for at least 1–2 years, data from patients with a time interval of 1 year or less (THA control group and TKA control group) were used as the baseline and were compared with those of the other groups to evaluate the temporal impact of prosthesis implantation on the diagnostic efficacy of triple-phase bone scanning for PJI.

Statistical Analysis

Statistical analyses were performed using SPSS version 22.0 (IBM Corp., Armonk, NY, USA). After obtaining the clinical diagnosis and diagnosis results according to the nuclear medicine physicians, the semi-quantitative criteria were obtained through the ROC curve, and the difference in results between the semi-quantitative criteria and visual analysis was compared using the chi-square test. The chi-square test and Fisher's exact test were used for univariate analysis to assess the temporal impact on the sensitivity, specificity, and accuracy of triple-phase bone scanning. For all analyses, statistical significance was set at $P < 0.05$.

Results

A total of 147 cases from January 2014 to December 2020, including 69 cases of total hip arthroplasty (THA) and 78 cases of total knee arthroplasty (TKA), were finally analyzed (Fig. 2). Because of the small number of patients with a time interval of >10 years, seven patients were not included, and the characteristics of these patients are shown in Table 1.

Semi-Quantitative Diagnostic Criteria of Triple-Phase Bone Scanning

By analyzing data from 66 THA cases and 74 TKA cases, the ratio of the ROI at the maximum Youden index for hip PJI was determined to be 1.1747 (Fig. 3A). When this ratio was selected as the diagnostic threshold for hip PJI, the sensitivity of triple-phase bone scanning was 81.4%, the specificity was 85.7%, and the accuracy was 83.7%. The diagnostic threshold of the blood pool image for knee PJI was 1.7713 (Fig. 3B); the sensitivity was 94.3%, the specificity was 56.0%, and the accuracy was 82.1%.

Diagnostic Efficacy of the Semi-Quantitative Criteria and Visual Analysis

The sensitivity, specificity, PPV, NPV, and accuracy of visual analysis and semi-quantitative measurement were not significantly different. Semi-quantitative measurement and visual analysis showed similar performance in the diagnosis of PJI (Table 2).

Temporal Impact of Prosthesis Implantation on the Diagnostic Efficacy of Triple-Phase Bone Scanning for Hip PJI

Sixty-six patients who underwent THA were included in the final analysis, and both visual analysis and semi-quantitative criteria were used for evaluation.

According to the visual analysis criteria, 23 patients were determined to be true positive, 33 true negative, one false positive, and nine false negative. We then calculated the sensitivity, specificity, PPV, NPV, and accuracy for each group (Table 3, Panel A), and data for all the other groups were compared with those of THA control group (patients with a time interval of 1 year or less) (Table 3, Panel B). There were no significant differences in sensitivity, specificity, PPV, NPV, and accuracy for any comparison. According to the semi-quantitative criteria, 29 patients were determined to be true positive, 30 true negative, four false positive, and three false negative. The sensitivity, specificity, PPV, NPV, and accuracy for each group are shown in Table 3, Panel C. Similarly, no significant differences were found in the sensitivity, specificity, and accuracy for any comparison (Table 3, Panel D).

Temporal Impact of Prosthesis Implantation on the Diagnostic Efficacy of Triple-Phase Bone Scanning for Knee PJI

Seventy-four patients who underwent TKA were included in the final analysis. According to the visual analysis criteria, 49 patients were determined to be true positive, 11 true negative, 13 false positive, and one false negative. According to the semi-quantitative criteria, 47 patients were determined to be true positive, 13 true negative, 11 false positive, and three false negative. Table TABLE 4 shows the diagnostic efficacy of triple-phase bone scanning using both criteria for each group, as well as the results of comparisons between the groups. Regardless of the criteria used, the sensitivity of triple-phase bone scanning for knee infection was always high, while the specificity was lower. When visual analysis was used, the specificity for TKA control group was extremely low (20%), and there were statistically significant differences in specificity between TKA control group and TKA 1 year group ($p = 0.047$), as well as between TKA control group and TKA 2 years group ($P = 0.043$).

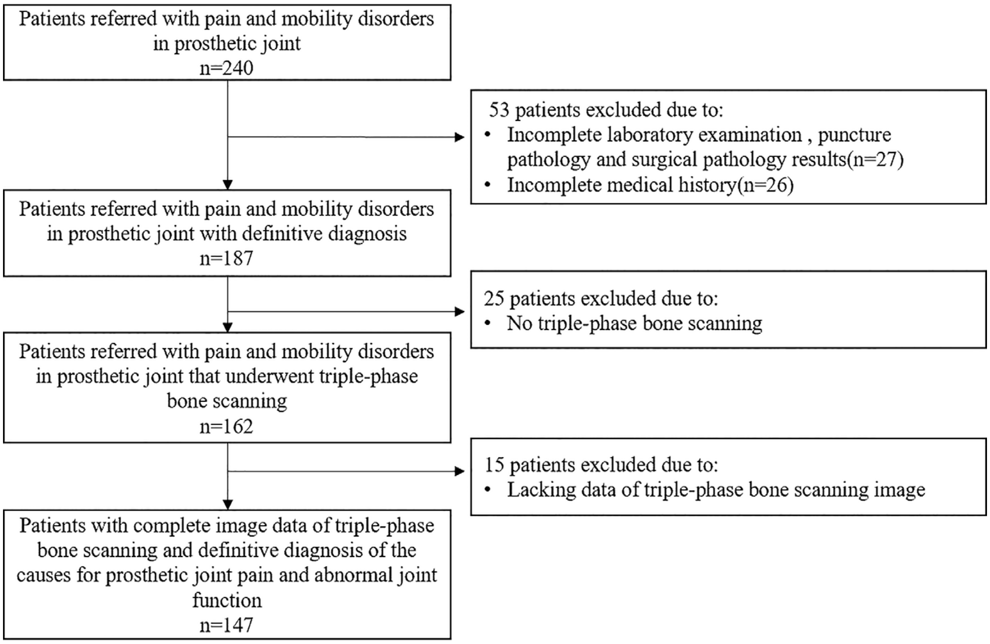

Fig. 2 Flowchart of patient inclusion.

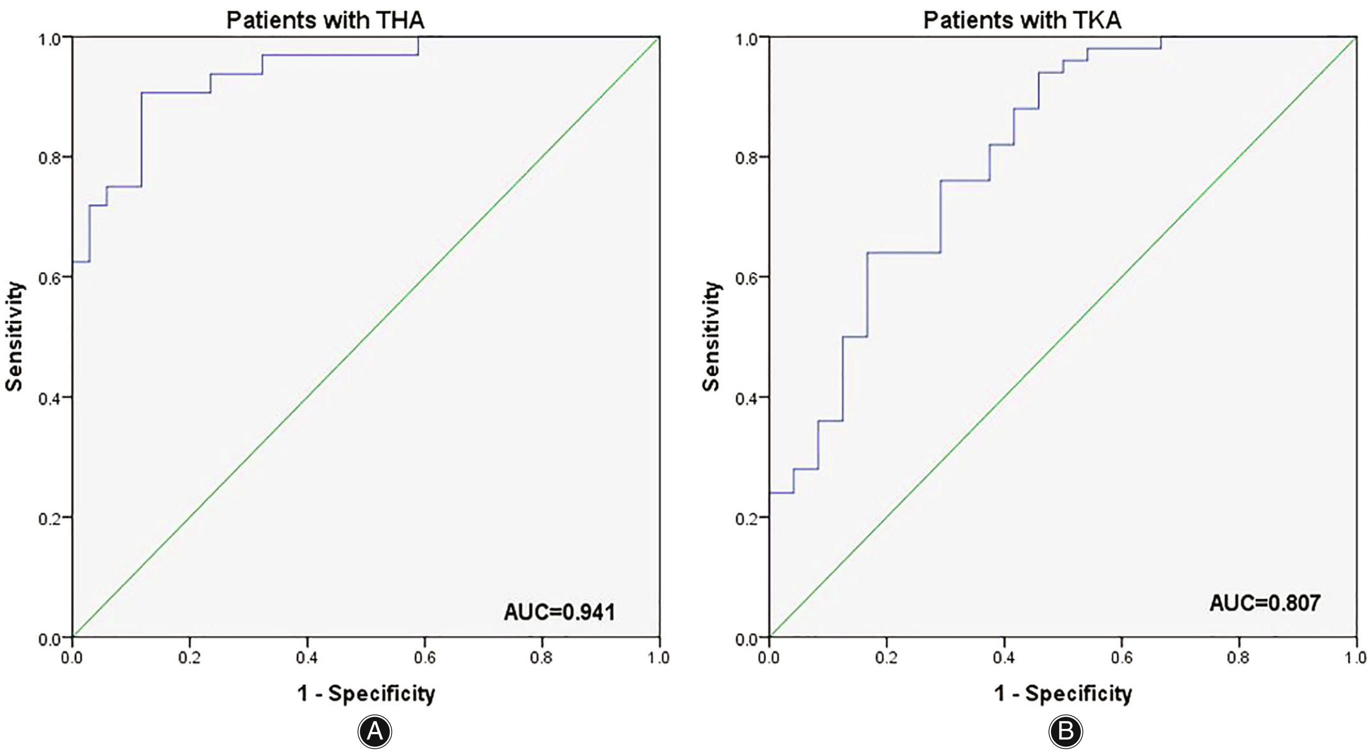

Fig. 3 ROC curve of the ratio of ROI in the blood pool image of patients who underwent THA (A) and TKA (B). ROC, receiver operating characteristic; ROI, region of interest; THA, total hip arthroplasty; TKA, total knee arthroplasty.

TABLE 2 Comparison of the diagnostic efficacy of visual analysis and semi-quantitative measurement for PJI diagnosis

		Sensitivity	Specificity	PPV	NPV	Accuracy
THA	Visual analysis	71.8%	97.1%	95.8%	78.6%	84.8%
	Semi-quantitative measurement	90.6%	88.2%	87.9%	90.9%	89.4%
	p	0.107	0.356	0.385	0.209	0.436
	χ	3.692	1.943	1.099	2.093	0.608
TKA	Visual analysis	98.0%	45.8%	79.0%	91.7%	81.1%
	Semi-quantitative measurement	94.0%	54.2%	81.0%	81.3%	81.1%
	P	0.617	0.773	0.823	0.613	1.000
	χ	1.042	0.333	0.075	0.608	0.000

Abbreviations: NPV, negative predictive value; PPV, positive predictive value; χ, χ^2 value.

TABLE 3 Diagnostic efficacy of triple-phase bone scanning at different time points after THA using visual analysis (A) and semi-quantitative criteria (B); comparison of sensitivity, specificity, and accuracy between the groups for visual analysis (C) and semi-quantitative criteria (D)

(A)

Group	Sensitivity	Specificity	PPV	NPV	Accuracy
THA control group	88.9%	87.5%	88.9%	87.5%	88.2%
THA 1 year group	65.2%	100%	100%	76.5%	83.6%
THA 2 years group	63.2%	100%	100%	75.9%	82.9%
THA 3 years group	56.3%	100%	100%	72.0%	79.4%
THA 5 years group	62.5%	100%	100%	81.3%	85.7%
THA 7 years group	60.0%	100%	100%	84.6%	87.5%

(B)

Group	Sensitivity	Specificity	PPV	NPV	Accuracy
THA control group	100%	75.0%	81.8%	100%	88.2%
THA 1 year group	87.0%	92.3%	90.9%	88.9%	89.8%
THA 2 years group	84.2%	90.9%	88.9%	87.0%	87.8%
THA 3 years group	81.3%	94.4%	92.9%	85.0%	88.2%
THA 5 years group	100%	92.3%	88.9%	100%	95.2%
THA 7 years group	100%	90.9%	83.3%	100%	93.7%

(C)

A versus B	P(Sen)	χ	P(Spe)	χ	P(PPV)	χ	P(NPV)	χ	P(Acc)	χ
THA control group versus THA 1 year group	0.383	1.793	0.235	3.348	0.375	1.739	0.662	0.468	1.000	0.204
THA control group versus THA 2 years group	0.214	1.981	0.267	2.845	0.429	1.400	0.655	0.501	1.000	0.258
THA control group versus THA 3 years group	0.182	2.820	0.308	2.340	1.000	1.059	0.643	0.793	0.699	0.607
THA control group versus THA 5 years group	0.294	1.639	0.381	1.706	1.000	0.598	1.000	0.150	1.000	0.052
THA control group versus THA 7 years group	0.505	1.593	0.421	1.451	1.000	0.364	1.000	0.034	1.000	0.004

(D)

A versus B	P(Sen)	χ	P(Spe)	χ	P(PPV)	χ	P(NPV)	χ	P(Acc)	χ
THA control group versus THA 1 year group	0.541	1.295	0.229	1.765	0.586	0.569	1.000	0.733	1.000	0.032
THA control group versus THA 2 years group	0.530	1.592	0.284	1.285	0.622	0.287	1.000	0.873	1.000	0.002
THA control group versus THA 3 years group	0.280	1.918	0.215	2.052	0.565	0.711	1.000	1.017	1.000	0.000
THA control group versus THA 5 years group	1.000	0.000	0.531	1.212	1.000	0.194	1.000	0.000	0.577	0.634
THA control group versus THA 7 years group	1.000	0.000	0.546	0.882	1.000	0.006	1.000	0.000	1.000	0.303

Abbreviations: NPV, negative predictive value; PPV, positive predictive value; THA, total hip arthroplasty; χ, χ^2 value.

TABLE 4 Diagnostic efficacy of triple-phase bone scanning at different time points after TKA using visual analysis (A) and semi-quantitative criteria (B); comparison of sensitivity, specificity, and accuracy between the groups for visual analysis (C) and semi-quantitative criteria (D)

(A)

Group	Sensitivity	Specificity	PPV	NPV	Accuracy
TKA control group	100%	20.0%	70.4%	100%	72.4%
TKA 1 year group	96.7%	64.3%	85.7%	90.0%	86.7%
TKA 2 years group	95.5%	66.7%	84.0%	88.9%	85.3%
TKA 3 years group	93.3%	66.7%	82.4%	85.7%	83.3%
TKA 5 years group	90.0%	57.1%	75.0%	80.0%	76.5%
TKA 7 years group	100%	57.1%	62.5%	100%	75.0%

(B)

Group	Sensitivity	Specificity	PPV	NPV	Accuracy
TKA control group	89.5%	40.0%	73.9%	66.7%	72.4%
TKA 1 year group	96.8%	64.3%	85.7%	90.0%	86.7%
TKA 2 years group	95.5%	58.3%	80.8%	87.5%	82.4%
TKA 3 years group	100%	55.6%	78.9%	100%	83.3%
TKA 5 years group	100%	42.9%	71.4%	100%	76.5%
TKA 7 years group	100%	42.9%	55.6%	100%	88.2%

(C)

A versus B	P(Sen)	χ	P(Spe)	χ	P(PPV)	χ	P(NPV)	χ	P(Acc)	χ
TKA control group versus TKA 1 year group	1.000	0.625	0.047	4.608	0.209	2.165	1.000	0.218	0.126	2.335
TKA control group versus TKA 2 years group	1.000	0.885	0.043	4.791	0.329	1.358	1.000	0.244	0.230	1.585
TKA control group versus TKA 3 years group	0.441	1.305	0.070	4.232	0.486	0.799	1.000	0.321	0.512	0.894
TKA control group versus TKA 5 years group	0.345	1.968	0.162	2.487	1.000	0.088	1.000	0.467	1.000	0.091
TKA control group versus TKA 7 years group	1.000	0.000	0.162	2.487	0.685	0.177	1.000	0.000	1.000	0.029

(D)

A versus B	P(Sen)	χ	P(Spe)	χ	P(PPV)	χ	P(NPV)	χ	P(Acc)	χ
TKA control group versus TKA 1 year group	0.549	1.113	0.408	1.386	0.316	1.258	0.518	1.340	0.126	2.335
TKA control group versus TKA 2 years group	0.588	0.538	0.670	0.733	0.734	0.330	0.538	0.884	0.344	0.895
TKA control group versus TKA 3 years group	0.492	1.678	0.656	0.460	1.000	0.145	0.455	2.037	0.512	0.894
TKA control group versus TKA 5 years group	0.532	1.131	1.000	0.014	1.000	0.027	0.500	1.286	1.000	0.091
TKA control group versus TKA 7 years group	1.000	0.574	1.000	0.014	0.407	1.015	0.500	1.286	0.721	0.135

Abbreviations: NPV, negative predictive value; PPV, positive predictive value; TKA, total knee arthroplasty; χ, χ^2 value.

Discussion

Visual Analysis and Semi-Quantitative Criteria

From the results of our statistical analysis, the use of semi-quantitative criteria did not show any superiority over the visual analysis in this study. Moreover, in some cases, diagnosis using semi-quantitative criteria was less effective than that using visual assessment. An effective diagnostic criterion can improve the performance of a test as a simple and efficient non-invasive examination; thus, it is still necessary to further clarify the objective criteria of triple-phase bone scanning images for PJI. In the optimal analysis protocol proposed by Glaudemans *et al*., images are first evaluated visually, and if the results are unclear, semi-quantitative analysis is performed.[14]

Temporal Impact of Prosthesis Implantation on the Diagnostic Efficacy of PJI

Triple-phase bone scanning has been widely used in orthopedics. Some studies have demonstrated the importance of metabolic and morphological information in the diagnosis of PJI.[1,25] Although metabolic and morphological information has been extensively studied in the diagnosis of PJI, there are still many confounding factors to be identified. Existing studies in the field of nuclear medicine regarding PJI have suffered from some serious shortfalls. Glaudemans *et al.* suggested that bone scans may be positive for at least 2 years after THA and 5 years after TKA due to physiological bone re-modeling after implantation.[24] In the present study, we found that the false-positive rate of triple-phase bone scanning was significantly reduced if the scan was taken >1 year after THA. When visual analysis was used under these circumstances, the specificity was close to 100%. Alternatively, THA-related infection can be effectively diagnosed with a positive result. In patients who underwent THA, the sensitivity of triple-phase bone scanning decreased with an increased time interval, which may lead to a missed diagnosis of PJI. In patients who underwent TKA, although the specificity of the test was significantly increased >1 year after implantation, it is still not adequate to be used as a confirmative diagnostic test. Meanwhile, when the semi-quantitative criteria were used in patients with a time interval of >1 year after prosthesis implantation for knee PJI, the sensitivity of the test was above 95%; thus, a negative result could be used to exclude a TKA-related infection with great certainty if other laboratory tests were also considered.

We did not distinguish between bacterial and fungal infections in our study, as it is currently impossible to distinguish fungal PJI from bacterial PJI on triple-phase bone scanning. In infected patients, triple-phase bone scanning can determine the degree and site of infection, but the area of radioactive uptake depends on the degree of infection and is not related to the type of pathogen. There are currently few studies on distinguishing different bacterial and fungal infections; this will be a meaningful research direction.

Limitation

Being retrospective in design, the current study has some limitations. Owing to the limited financial capacity of patients and the unstandardized process of diagnosis and treatment in the past, the number of cases that could be included was small, which might be the major cause of not being able to show statistically significant differences. Further prospective multicenter studies with a larger number of cases are warranted.

Conclusion

Compared with visual analysis, the semi-quantitative criteria of triple-phase bone scanning showed no advantages in the diagnosis of PJI. An infected THA can be effectively diagnosed with a positive result using visual analysis >1 year after prosthesis implantation. An infected TKA can be excluded with a negative result using semi-quantitative criteria >1 year after prosthesis implantation. However, the results of triple-phase bone scanning within 1 year after TJA should be interpreted with caution and must be considered in conjunction with other test results.

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Data Availability Statement

The data used to support the findings of this study are available from the corresponding author upon request.

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