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Diagnostic Performance of Magnetic Resonance Imaging for the Detection of Bone Metastasis in Prostate Cancer: A Systematic Review and Meta-analysis

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Abstract

Context: Magnetic resonance imaging (MRI) has been tested for detecting bone metastasis and has shown promising results. Yet, consensus has not been reached regarding whether it can replace the role of bone scintigraphy in this clinical setting or not.
Objective: To review the diagnostic performance of contemporary (≥1.5 T) MRI for the detection of bone metastasis in patients with prostate cancer.
Evidence acquisition: MEDLINE and EMBASE were searched up to January 22, 2017. We included studies that used MRI using ≥1.5-T scanners for the detection of bone metastasis in patients with prostate cancer, using histopathology or best value comparator as the reference standard. Two independent reviewers assessed the methodological quality using the Quality Assessment of Diagnostic Accuracy Studies-2 tool. Per-patient sensitivity and specificity of included studies were calculated, and pooled and plotted in a hierarchical summary receiver operating characteristic plot. Meta-regression and sensitivity analyses were performed.
Evidence synthesis: Ten studies (1031 patients) were included. Pooled sensitivity was 0.96 (95% confidence interval [CI] 0.87–0.99) with a specificity of 0.98 (95% CI 0.93–0.99). At meta-regression analysis, only the number of imaging planes (≥2 vs 1) was a significant factor affecting heterogeneity ($p < 0.01$). Sensitivity analyses showed that specificity estimates were comparable and consistently high across all subgroups, but sensitivity estimates demonstrated some differences. Studies using two or more planes ($n = 4$) had the highest sensitivity (0.99 [95% CI 0.98–1.00]).
Conclusions: Contemporary MRI shows excellent sensitivity and specificity for detection of bone metastasis in patients with prostate cancer. Using two or more imaging planes may further improve sensitivity. However, caution is needed in applying our results due to the heterogeneity among the included studies.
Patient summary: We reviewed studies using contemporary magnetic resonance imaging (MRI) for the detection of bone metastasis in prostate cancer patients. MRI shows excellent diagnostic performance in finding patients with bone metastasis.

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1. Introduction

Determining the presence of bone metastasis is important in the management of prostate cancer. It not only represents the most common site of initial metastases, but also is a major cause of morbidity and mortality in patients with prostate cancer. Therefore, it is crucial to accurately detect bone metastasis in order to plan the most optimal management for patients with prostate cancer [1]. Currently, Tc 99m bone scintigraphy (BS) is recommended by guidelines as the initial work-up modality for bone metastasis despite its poor accuracy, because it is widely available compared with more advance modalities [2]. However, magnetic resonance imaging (MRI) has continuously been tested for the purpose of detecting bone metastasis during the past 3 decades and has shown promising results [3]. Recent studies have shown that axial skeleton MRI, whole-body MRI, and even routine prostate MRI are excellent in determining bone metastasis in patients with prostate cancer [4–6]. Yet, consensus has not been reached regarding whether it can replace the role of BS in this clinical setting or not.

Therefore, we performed a systematic review and meta-analysis to evaluate the diagnostic performance of contemporary MRI for the detection of bone metastasis in patients with prostate cancer.

2. Evidence acquisition

The present meta-analysis was written according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. The research question for the purpose of this meta-analysis was formulated based on the following Patient Index test Comparator Outcomes Study design (PICOS) criteria [7]: What is the diagnostic performance of contemporary MRI (magnetic field strength $\geq$1.5 T) for the detection of bone metastasis in patients with prostate cancer, as compared with histopathological results or best value comparator (BVC; a combination of imaging/clinical/biological studies and at least 6 mo of follow-up)?

2.1. Literature search

A computerized search of MEDLINE and EMBASE databases up to January 22, 2017 was performed to identify studies that were relevant to our research question. The search query combined synonyms for prostate cancer, MRI, bone, and diagnostic accuracy as follows: ([“prostat* cancer”] OR [“prostat* carcinoma”] OR [“prostat* neoplasm”] OR [“prostat* tumor”]) AND ([bone] OR [skeletal]) AND ([“magnetic resonance imaging”] OR [“MR imaging”] OR [MRI] OR [MR]) AND ([detection] OR [detectability] OR [positivity] OR [sensitivity] OR [specificity] OR [diagnosis] OR [diagnostic] OR [accuracy] OR [performance]). Bibliographies of identified articles were screened to identify additional relevant studies. The search was limited to studies on “humans” using the “English” language.

2.2. Study selection

2.2.1. Inclusion criteria

We included studies that met the following PICOS criteria (10): (1) patients diagnosed with prostate cancer, (2) MRI used as the index test for detection of bone metastasis, (3) histopathology or BVC as the reference standard for comparison, (4) sufficient information to reconstruct 2×2 contingency tables regarding sensitivity and specificity, and (5) publication type of original articles.

2.2.2. Exclusion criteria

The exclusion criteria were as follows: (1) study population of $<$10 patients; (2) study population comprising patients with tumors other than prostate cancer (however, studies were included if the diagnostic performance was separately provided for each type of tumor); (3) review articles, guidelines, consensus statements, letters, editorials, and conference abstracts; (4) MRI with a magnetic field strength of $<$1.5 T; (5) MRI used for the detection of bone metastasis in prostate tumor, but focusing on topics rather than on diagnostic accuracy; (6) overlapping patient population; and (7) insufficient data for the reconstruction of 2×2 tables. In case of an overlapping study population, the study with the largest study population was included. Authors of the studies were contacted for provision of further information when 2×2 tables could not be reconstructed.

The literature search and study selection process was independently performed by two reviewers (S.W. and C.H.S., with 4 yr of experience in performing systematic reviews and meta-analyses) with consultation from a third reviewer (S.Y.K.) for reaching a consensus when disagreement was present.

2.3. Data extraction and quality assessment

The following data were extracted from the selected studies using a standardized form: (1) patient characteristics—number of patients, number of patients with bone metastasis, clinical setting (newly diagnosed vs treated and risk stratification of bone metastasis according to clinical criteria), median age and range of patients, prostate-specific antigen (PSA) level, PSA doubling time, Gleason score (based on biopsy and radical prostatectomy [RP] specimens in primary and treated prostate cancer, respectively), and clinical T stage (pathological T stage in post-RP patients); (2) study characteristics—origin of study (authors, institution, and duration of patient recruitment), publication year, study design (prospective vs retrospective, multicenter vs single center, and consecutive vs nonconsecutive enrollment), reference standard, interval between MRI and reference standard, blinding to reference standard, and characteristics of readers (number and experience); and (3) MRI characteristics—magnet field strength; scanner model and manufacturer; coverage of MRI (whole body, axial skeleton or pelvis [as included in routine prostate multiparametric MRI]); type of MRI sequences used among diffusion-weighted imaging (DWI), contrast-enhanced (CE)

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