

Whole-body magnetic resonance imaging (WB-MRI) with diffusion-weighted whole-body imaging with background body signal suppression (DWIBS) in prostate cancer: Prevalence and clinical significance of incidental findings

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Abstract

Background

Diffusion-weighted whole-body imaging with background body signal suppression (DWIBS) is now recommended as a first-line staging modality in prostate cancer patients, and the widespread use of DWIBS may lead to an increased frequency of incidental findings. The aim of this study is to evaluate the prevalence and clinical significance of incidental findings detected on whole-body magnetic resonance imaging (WB-MRI) with DWIBS in patients with prostate cancer.

Methods

Data from 124 patients (age, 76.5 ± 5.6 years; range, 60–90) with pathologically confirmed prostate cancer, who underwent WB-MRI between December 2016 and April 2020, were retrospectively analyzed. Findings unrelated to prostate cancer were considered as incidental findings and categorized into two groups based on their clinical implications, as follow: imaging follow-up or additional examinations was required (significant incidental findings) and no need to additional work-up (non-significant incidental findings). A Chi-square test was performed to compare the differences in the prevalence of significant incidental findings based on age (≤ 75 and > 75 years old).

Results

A total of 334 incidental findings were found, with 8.1% ($n = 27$) as significant incidental findings and 91.9% ($n = 307$) as non-significant incidental findings. Significant incidental findings were more frequent in patients over 75 years old than those of 75 years old or younger (28.6% vs 11.1%, $p = 0.018$). Nineteen of the 27 significant incidental findings (70.4%) were observed on non-DWIBS sequences.

Conclusion

Clinically significant incidental findings, which required imaging follow-up or additional examinations, were commonly observed in patients with prostate cancer on WB-MRI/DWIBS.

Background

Recent advances in diagnostic imaging technologies have allowed us to obtain whole-body magnetic resonance imaging (WB-MRI), which provides high-quality anatomical images of the entire human body within reasonable examination times. Diffusion-weighted whole-body imaging with background body signal suppression (DWIBS) was reported as a unique concept for whole-body diffusion-weighted imaging in 2004 [1]. This technique provides high-quality positron emission tomography (PET)-like images without radiation exposure or contrast agent administration [2]. DWIBS is now considered a feasible clinical technique for evaluating primary and metastatic lesions in adult patients with high sensitivity and accuracy [3–7]. In

particular, DWIBS is now recommended as a first-line diagnostic imaging for tumor staging in patients with prostate cancer [8]. However, the widespread use of DWIBS may lead to an increased frequency of incidental findings. Although some of these incidental findings may be beneficial to patients, for example in the case of earlier detection of second primary malignancy, they may lead to increased patient anxiety, radiation exposure, and healthcare costs due to additional examinations required [9–12].

Some studies have reported the prevalence of incidental findings in healthy volunteers on WB-MRI [13–15], but data regarding the prevalence of incidental findings on WB-MRI for cancer patients and its clinical impact remain limited.

The aim of this study was to clarify the prevalence of incidental findings detected on WB-MRI/DWIBS in patients with prostate cancer and their clinical significance.

Methods

Patients

All prostate cancer patients who underwent WB-MRI/DWIBS at our clinic between December 2016 and April 2020 were retrospectively analyzed. Inclusion criteria were: 1) pathologically confirmed prostate cancer; and 2) age > 20 years old. Results from second or subsequent WB-MRI/DWIBS of the same patients were excluded from this study, and only data from the first WB-MRI/DWIBS were analyzed. Since the aim of this study was to assess the incidental findings on WB-MRI/DWIBS in clinical settings, scans with poor image quality due to patient-related factors (e.g., motion artifact, gibbus deformity) were NOT excluded from the analysis.

The institutional review board approved all study protocols. Due to the retrospective nature of the study, informed consent from each patient was waived, and the opt-out method on our hospital website was employed.

WB-MRI/DWIBS protocol

All WB-MRI/DWIBS studies were performed using a 1.5-T MRI scanner (Achieva; Philips Medical Systems, Best, the Netherlands) using a sliding surface coil approach [16]. No contrast agent was used. The WB-MRI/DWIBS protocol was shown in Table 1. Maximum intensity projections (MIPs) of coronal and sagittal images and volumetric view in DWIBS images were reconstructed from axial planes. Fusion images of DWIBS and STIR in three orthogonal directions were also created. Total scan time was about 35 min.

Imaging interpretation and classification of incidental findings

All WB-MRI/DWIBS images were retrospectively reviewed by two board-certified diagnostic radiologists for this study. If the findings detected on WB-MRI/DWIBS were considered unrelated to prostate cancer, they were considered as incidental. If incidental findings were identified, recommendations for management were documented. We categorized incidental findings into two groups based on clinical implication: *non-significant*, if the finding did not require further evaluation, imaging follow-up or treatment (e.g., old brain

infarcts, renal or hepatic cysts, vertebral compression fracture without compression of nervous structures); *significant*, if the finding was considered to be required further evaluation to characterize findings, imaging follow-up or treatment (e.g., cystic lesions of the pancreas, pleural effusion, cardiomegaly, indeterminate masses or nodules in any organs). These significant incidental findings potentially lead to changes in treatment strategy of the patients. In cases of disagreement between two observers, a final consensus was reached through inter-observer discussion.

Statistical analyses

All statistical analyses were performed using SPSS software (IBM SPSS Statistics 25; IBM Japan, Tokyo, Japan). A Chi-square test was performed to compare the differences in the prevalence of significant incidental findings based on age (≤ 75 and > 75 years old). A *p*-value of < 0.05 was considered significant.

Results

A total of 135 WB-MRI/DWIBS scans were performed for 124 consecutive prostate cancer patients during the study period. Eleven examinations were excluded as second scans ($n = 9$), third scans ($n = 1$), or fourth scans ($n = 1$), so 124 cases were included for further analyses (age, 76.5 ± 5.6 years; range, 60–90 years).

All 124 patients showed at least one incidental finding on WB-MRI/DWIBS (Figs. 1–3). A total of 334 incidental findings were identified, with one incidental finding in 36 patients and two or more incidental findings in 88 patients. Of these findings, 27 lesions (8.1%) in 26 patients (21.0%) were considered as significant incidental findings, and further imaging ($n = 21$), echocardiogram and blood test ($n = 3$), urine and blood test ($n = 1$), endoscopy ($n = 1$), or nasopharyngolaryngoscopy ($n = 1$) were recommended. Of these 27 findings, six lesions in six patients (4.8%) were considered highly suspicious for malignancy. Contrast-enhanced computed tomography (CT) ($n = 9$) and magnetic resonance cholangiopancreatography (MRCP) ($n = 8$) were the most frequent imaging modalities recommended for follow-up or further evaluation of significant incidental findings, followed by echocardiogram ($n = 3$), contrast-enhanced MRI ($n = 2$), and unenhanced CT ($n = 2$). The most common incidental findings recommended further work-up were cystic lesions of the pancreas ($n = 8$) (Table 2).

Of these 27 significant incidental findings, 19 lesions (70.4%) were detected on T2-weighted image (T2WI), and eight lesions were detected on DWIBS. These findings were more frequently observed in patients over 75 years old than those of 75 years old or younger (28.6% vs 11.1%, $p = 0.018$). Of the six lesions suspected of malignancy, five lesions were found in patients over 75 years old.

The rest of 307 incidental findings (91.9%) were considered as non-significant. The most common findings were renal cysts (75 patients, 60.5%), hepatic cysts (48 patients, 38.7%), and benign spinal canal stenosis (24 patients, 19.4%).

Discussion

In the current study, the majority of incidental findings on WB-MRI/DWIBS were considered as clinically non-significant. However, some incidental findings were clinically significant with higher prevalence in older

patients, and these may have impacts leading to changes in treatment strategy. It should be emphasized that 19 of the 27 significant incidental findings (70.4%) in 26 patients were found on axial T2WI. We reconfirmed that T2WI plays an important role when reviewing DWI, as a previous study mentioned [17]. Instead of focusing only on DWIBS, T2WI must also be carefully evaluated.

Some previous studies have evaluated incidental findings on WB-MRI [13–15, 18–20]. The prevalence of significant incidental findings in our study (21.0%) was similar to that in previous studies (2.9–36.8%). Of those six previous studies, only three applied DWI/DWIBS in the study protocols, and none of them mentioned the sequences from which incidental findings were identified. In a previous study of WB-MRI with DWIBS in patients with prostate cancer, incidental findings were found in only 31% (31/100) of them [21]. This lower detection rate was probably due to the research focus, comparing DWIBS with bone scintigraphy and CT for the detection of bone metastasis. Actively searching for extraosseous lesions likely increase the detection rate of incidental findings.

In our study, only 1.6% of patients (2/124) showed lung nodule or pulmonary hilar mass, although these findings were reported to be found in 3.8% (4/104) and 4.4% (15/344) of patients on whole-body CT [22, 23]. This is probably due to the limited role of MRI in the detection of lung nodules, given the lower spatial resolution compared to multidetector-row CT and the physiologic noise associated with cardiac and respiratory motions.

The issues regarding incidental findings are not only how often they occur, but also how much impact they have clinically and how to report them. Radiologists should play critical roles in deciding whether a detected lesion is benign or having potential clinical importance. In this study, we categorized the incidental findings into two groups based on the necessity of further work-up—trying to classify the findings according to the most common situations in daily practice. In our study, six patients (4.8%) were considered as having lesions highly suggestive of second malignancy. This result was quite important, since these findings potentially lead to changes in treatment strategy of patients with prostate cancer. Furthermore, additional examinations such as CE-CT were required for further investigation of these findings, they can lead to increased healthcare costs and radiation exposure. Although WB-MRI/DWIBS can provide a comprehensive evaluation of whole-body in cancer patients—detecting metastasis not only in bone marrow, but also in lymph node or other organs—it is not an almighty technique, and additional work-up for evaluation of encountered incidental findings is inevitable. These kinds of suspected malignant lesions were also found in patients with other diseases such as lymphoma (4.4%), neurofibromatosis (1.6%), and multiple myeloma (2.9%) in previous studies with WB-MRI [18–20]. Clinicians should inform patients of these possible incidental findings and the additional examination prior to WB-MRI/DWIBS as part of their informed consent process.

This study had several limitations. First, incidental findings in our study were diagnosed based on MRI features, in the absence of clinical or pathological confirmation. Second, we did not have access to clinical follow-up data for most patients, as all of our patients received primary care in other clinics or hospitals and visited the study site only for imaging consultations.

Conclusion

Our study revealed that clinically significant incidental findings were commonly observed on WB-MRI in patients with prostate cancer, requiring further examination. Checking the entire organ carefully—not only on DWIBS, but also on T2WI—for abnormalities is important. Radiologists should clearly and precisely report any incidental findings detected when reviewing WB-MRI, and clinicians should inform patients of the probability of incidental findings as part of their informed consent process.

Declarations

Ethics approval and consent to participate: Approved by Gunma University Ethical Review Board for Medical Research Involving Human Subjects. HS2020-054, 2020/07/17, retrospectively registered. Due to the retrospective nature of the study, informed consent was carried out using the opt-out method on our hospital website.

Consent to publish: Not applicable

Availability of data and material: The datasets used and/or analyzed during this study are available from the corresponding author on reasonable request.

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Authors' contributions:

SK: Project development, Data collection and management, Data analysis, Manuscript writing

SM: Protocol development, Manuscript editing

YK: Data collection and management, Data analysis

TN: Protocol development, Clinical studies

MO: Protocol development, Clinical studies

YT: Manuscript editing

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Tables

Table 1. MR sequences applied in the WB-MRI study

Parameters	DWIBS	STIR TSE	T1W	In/Out GRE	T2W
			TSE		TSE
Imaged area	neck-pelvis	neck-pelvis	neck-pelvis	neck-pelvis	neck-pelvis
Plane	axial	sagittal, coronal	sagittal	axial, sagittal, coronal	axial
TR/TE (msec)	8461/82	2773/60	642/12	180-216/2.3/4.6	3685/80
Flip angle (deg)		90	90	75	90
FOV (mm)	370×284	330×330/330×411	330×302	370×289/330×330/330×409	370×296
Matrix	112×	224×	336×	256/256/272	256×
Slice thickness (mm)	5.5	5.5/7.0	5.5	5.5/7.0/5.5	5.5
Scan technique	IR	IR	TSE	Dual-FFE	TSE
Fast Imaging	EPI-single shot	TSE-multi shot	TSE-multi shot	-	TSE-multi shot
Fat suppression	STIR	STIR	-	-	-
b-factors (s/mm ²)	0/900	-	-	-	-
NSA	4	2/1	2	1	1
Number of sections	3	3	3	3	3
acquisition time	4min 5sec	1min 57sec/42sec (BH×3)	1min 56sec	35sec/41sec/41sec (BH×4)	59sec

(one
section)

Table 2. Significant incidental findings detected on WB-MRI

Incidental findings	Recommendation	number of the patients (n=124)
cystic lesion of the pancreas	MRCP	8 (6.5%)
cardiac dilation and pleural fusion	echocardiogram and blood test	3 (2.4%)
peripancreatic nodule	CE-CT	2 (1.6%)
carotid gland tumor	CE-MRI	1 (0.8%)
esopharyngeal tumor*	nasopharyngolaryngoscopy	1 (0.8%)
thyroid tumor*	CE-CT	1 (0.8%)
thyroid cystic lesion	CE-MRI	1 (0.8%)
pulmonary hilar mass*	CE-CT	1 (0.8%)
lung nodule*	CE-CT	1 (0.8%)
spinal mass*	CE-CT	1 (0.8%)
gastric-wall mass*	endoscopy	1 (0.8%)
hepatic tumor	CE-CT	1 (0.8%)
small adrenal nodule (1 cm)	Plain-CT	1 (0.8%)
renal mass (2 cm)	CE-CT	1 (0.8%)
pyelonephritis	urine and blood test	1 (0.8%)
intraperitoneal cystic mass	CE-CT	1 (0.8%)
extravertebral mass	CE-CT	1 (0.8%)

B, whole-body; MRI, magnetic resonance imaging; MRCP, magnetic resonance

angiopancreatography; CE, Contrast-enhanced; CT, computed tomography.

*Highly suspicious for malignancy

Figures

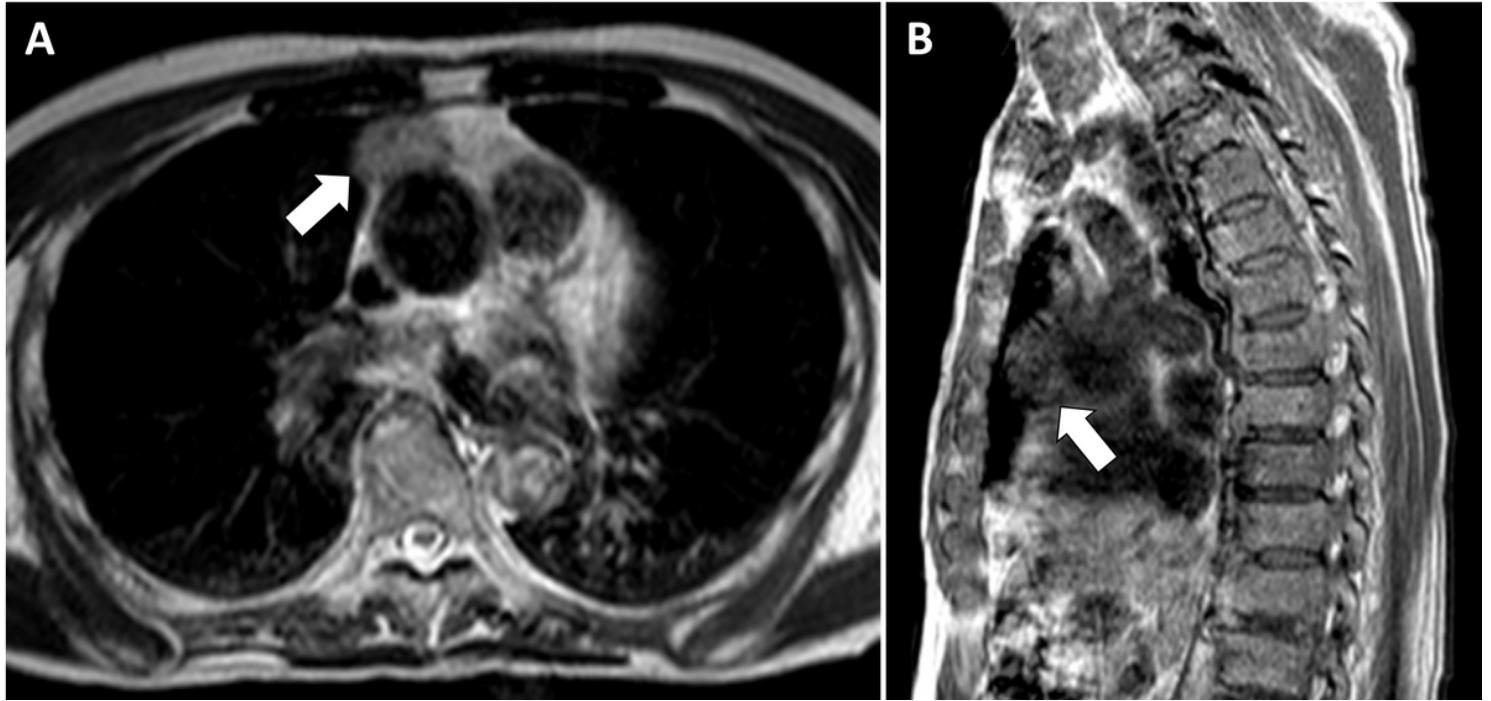


Figure 1

Thymic mass, categorized as a significant incidental finding in a patient in his 70s. Axial T2WI (a) and sagittal T1WI (b) show a mass in the anterior mediastinum (arrows). Contrast-enhanced computed tomography (CT) was recommended as further evaluation.

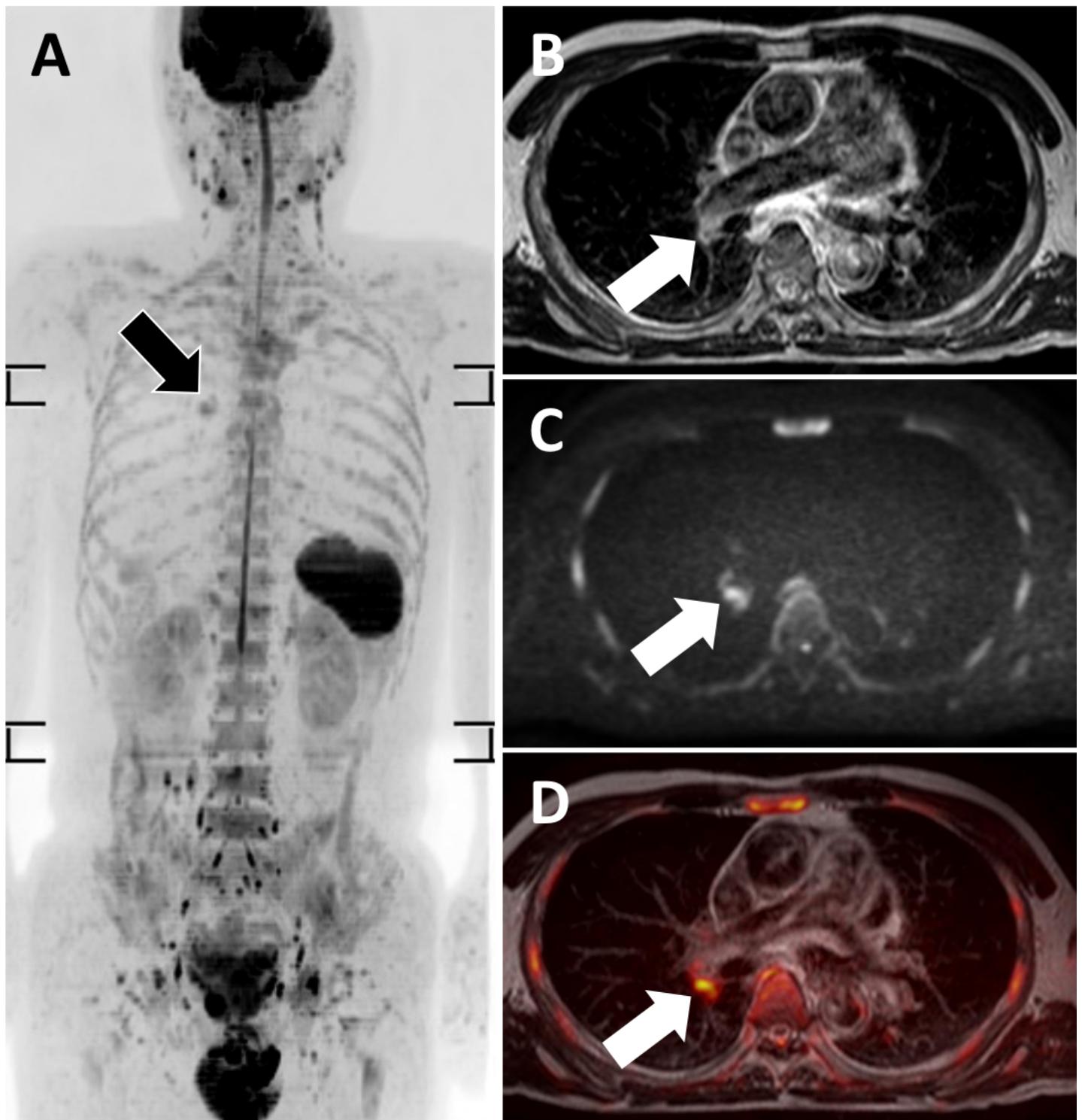


Figure 2

Right pulmonary hilar mass, categorized as a significant incidental finding in a patient in his 70s. DWIBS (a), axial T2WI (b), axial DWI (c), and axial DWI/T2WI fusion image (d) show a mass in the right pulmonary hilum (arrows). Contrast-enhanced CT was recommended as further evaluation.

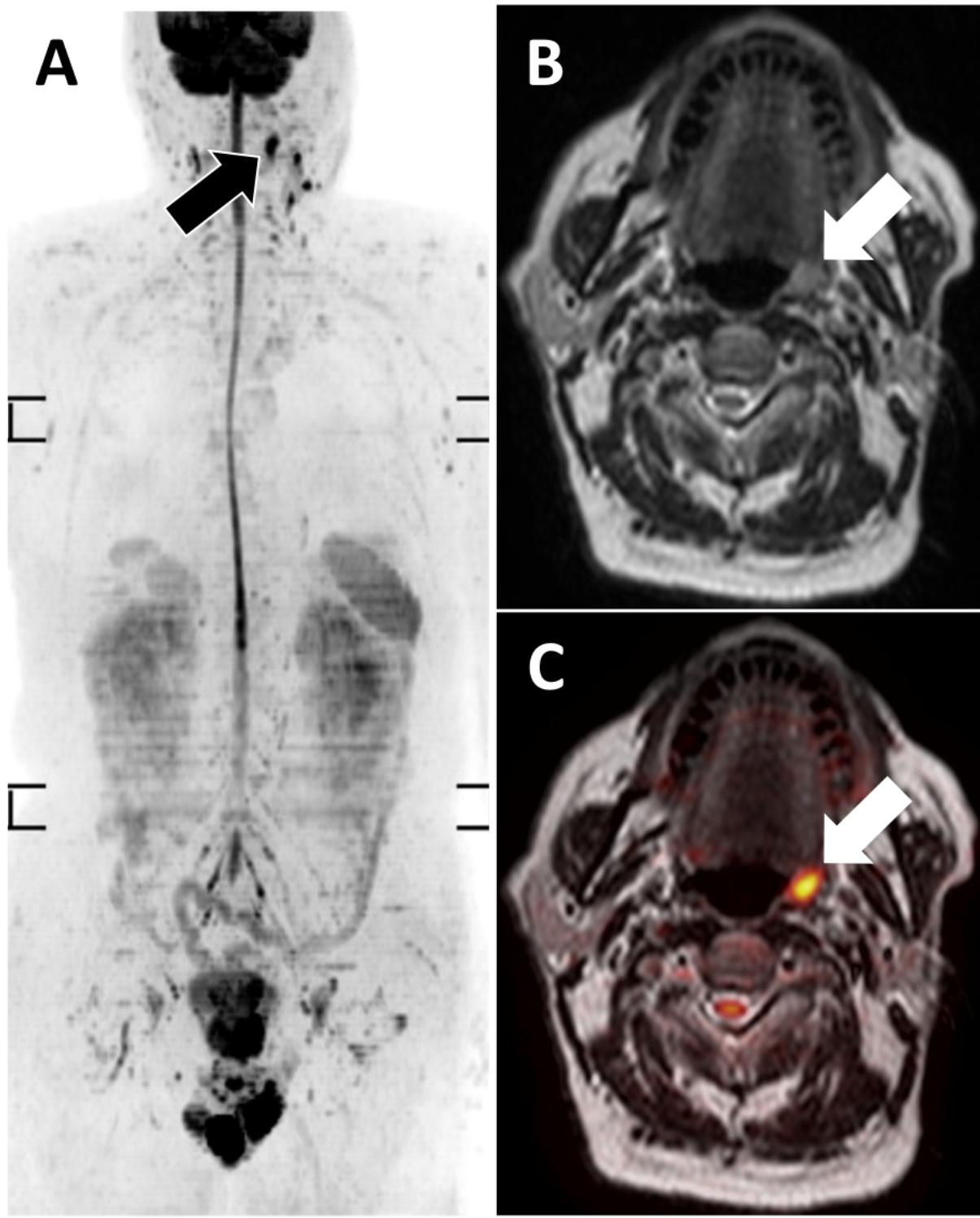


Figure 3

Mesopharyngeal mass, categorized as a significant incidental finding in a patient in his 70s. DWIBS (a), axial T2WI (b), and axial DWI/T2WI fusion image (c) show a mass in the left mesopharynx (arrows). Nasopharyngolaryngoscopy was recommended as further evaluation.