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ORIGINAL ARTICLE

Osteoporosis identification among previously undiagnosed individuals with vertebral fractures

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Abstract

Summary Because osteoporosis is under-recognized in patients with vertebral fractures, we evaluated characteristics associated with osteoporosis identification. Most patients with vertebral fractures did not receive evaluation or treatment for osteoporosis. Black, younger, and male participants were particularly unlikely to have had recognized osteoporosis, which could increase their risk of negative outcomes.

Introduction Vertebral fractures may be identified on imaging but fail to prompt evaluation for osteoporosis. Our objective was to evaluate characteristics associated with clinical osteoporosis recognition in patients who had vertebral fractures detected on their thoracolumbar spine imaging reports.

Methods We prospectively identified individuals who received imaging of the lower spine at primary care clinics in 4 large healthcare systems who were eligible for osteoporosis screening and lacked indications of osteoporosis diagnoses or treatments in the prior year. We evaluated characteristics of participants with identified vertebral fractures that were associated with recognition of osteoporosis (diagnosis code in the health record; receipt of bone mineral density scans; and/or prescriptions for anti-osteoporotic medications). We used mixed models to estimate adjusted odds ratios (ORs) and 95% confidence intervals (95% CIs).

Results A total of 114,005 participants (47% female; mean age 65 (interquartile range: 57–72) years) were evaluated. Of the 8579 (7%) participants with vertebral fractures identified, 3784 (44%) had recognition of osteoporosis within the subsequent year. In adjusted regressions, Black participants (OR (95% CI): 0.74 (0.57, 0.97)), younger participants (age 50–60: 0.48 (0.42, 0.54); age 61–64: 0.70 (0.60, 0.81)), and males (0.39 (0.35, 0.43)) were less likely to have recognized osteoporosis compared to white participants, adults aged 65 + years, or females.

Conclusion Individuals with identified vertebral fractures commonly did not have recognition of osteoporosis within a year, particularly those who were younger, Black, or male. Providers and healthcare systems should consider efforts to improve evaluation of osteoporosis in patients with vertebral fractures.

Keywords Age · Gender · Osteoporosis · race · Thoracolumbar imaging · Vertebral fracture

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Introduction

Osteoporosis is a progressive disease of low bone mass and bone architecture deterioration that increases fracture risk. It is a growing societal problem, affecting over 10% of people over age 50 [1]. Having one or more osteoporotic vertebral fractures is strongly predictive of subsequent osteoporotic fractures, especially hip fractures [2]. Furthermore, patients with osteoporotic vertebral fractures are at increased risk of death relative to non-fractured populations, particularly in the months immediately after the fracture [3], and the increased mortality rate persists for at least the next 10 years [4].

Because bone demineralization causes no symptoms, many patients do not realize they have osteoporosis until significant, symptomatic fractures occur. Early identification of diminishing bone mass can help prevent more severe skeletal injuries. Screening with bone mineral densitometry (BMD) such as dual energy X-ray absorption (DEXA) scans in appropriate age groups can identify individuals with low bone mass and prompt treatment with anti-osteoporotic medications. However, most people at risk for osteoporosis are not screened; a recent study estimated that less than 25% of women age 65 + underwent bone mass measurements over a 2-year study period [5]. Additionally, even though the presence of a vertebral fracture is an indication to strongly consider pharmacotherapy for osteoporosis regardless of BMD [6, 7], recognition/reporting of vertebral fractures on imaging is lacking, particularly when fractures are not present in the areas of the spine that led to the image being ordered [8, 9]. A recent audit of computed tomography (CT) scans performed for reasons other than trauma found that only 60% of vertebral fractures were identified when present and only 2.6% of the patients with vertebral fractures were referred for further treatment [10]. A similar study conducted in Germany found that 30% of patients who had received CT scans mainly for cancer staging and angiography CT imaging had prevalent vertebral fractures, but only a quarter of the fractured patients' imaging reports mentioned the fractures [11].

Our objective was to evaluate the frequency with which vertebral fractures identified on thoracolumbar imaging reports were followed by electronic health record (EHR)-based evidence that patients were evaluated for osteoporosis. We also sought to describe demographic and clinical characteristics associated with osteoporosis assessment, hypothesizing that females and older individuals with vertebral fractures would be most likely to have had osteoporosis that was recognized. A secondary aim was to examine participant and clinical characteristics that were associated with the likelihood of osteoporosis recognition in those without identified vertebral fractures on their thoracolumbar imaging reports to determine whether the same associations existed.

Patients and methods

Study population

This study was registered at ClinicalTrials.gov identifier: NCT02015455.

The parent study for these secondary analyses was the Lumbar Imaging with Reporting of Epidemiology (LIRE) study, which has been described previously [12, 13]. We randomly assigned 98 adult primary care clinics within four health systems [Mayo Clinic (Rochester, MN); Henry Ford (Detroit, MI); Kaiser Permanente Northern California (Oakland, CA); and Kaiser Permanente Washington (Seattle, WA)] to insert text with the epidemiologic benchmark prevalence of common imaging findings among individuals without back pain [13–15] into imaging reports. We automatically enrolled participants ≥ 18 years old who received thoracolumbar spine imaging from October 2013 to September 2016, who had no spine imaging in the past year, and had not opted out of research studies.

For this secondary analysis, we limited the sample to those who were potentially eligible for osteoporotic screening according to guidelines from the National Osteoporosis Foundation (NOF) and who lacked indications of osteoporosis being recognized in the EHR prior to receiving their index spine images. Therefore, we included men who were ≥ 50 years because that was the youngest age that guidelines began to recommend men be screened, if they had additional risk factors [16]. We included women who were ≥ 52 years because the NOF, among others [16], recommends screening postmenopausal women and the average age at which women become postmenopausal is 52 [17, 18]. We excluded those who had (1) International Classification of Diseases, 9th and 10th Revisions, Clinical Modification (ICD-9-CM and ICD-10-CM) codes indicating cancer, osteoporosis, and/or osteopenia (Supplemental Table 1); (2) received BMD scans; and (3) been prescribed osteoporotic medications (Supplemental Table 2) in the year prior to their index thoracolumbar spine images. We also would have excluded participants whose index images were due to acute severe trauma (defined as having had CT scans of ≥ 3 of the following regions: head, chest, abdomen, pelvis, or spine) but did not identify any. We identified participants with vertebral fractures described on their X-ray, magnetic resonance imaging (MRI), or CT scan index imaging reports using an adaptation of a previously validated natural language processing (NLP) methodology [19]. The rules-based algorithm required keywords related to both "spine" AND "fracture" as well as morphologies that could represent fractures (Supplemental Table 3). The algorithm was validated in a sample with all four sites represented of $N = 100$ reports using 2 annotators and 1 adjudicator and was found to have a sensitivity of

96%, specificity of 99%, positive predictive value of 90%, and negative predictive value of 99.7% for identifying vertebral fractures on thoracolumbar imaging reports.

Exposure and outcome variables

We obtained participant characteristics from the EHR and included age (categorized as 50–60, 61–64; 65 + years), sex, imaging modality (X-ray, CT, or MRI), race/ethnicity (mutually exclusive categories included Asian, Black/African American, Native Hawaiian/Pacific Islander, multiracial, Native American/Alaska Native, white, Hispanic (of any race), and unknown), calendar time of the index image (categorized in 6-month intervals), Charlson comorbidity index category (0, 1, 2, and ≥ 3) [20], and participant socioeconomic status (SES). To estimate SES, the study sites mapped participant addresses to Federal Information Processing System codes using geocoding software, which were then mapped to SES indexes derived from the 2010 Census Summary File and the American Community Survey data [21] and categorized into quartiles that were created from this national data [22].

The outcome of interest was evidence in the EHR that clinicians considered the need for evaluation of osteoporosis. We defined this as presence in the EHR from the day of the index image through 365 days later of (1) ICD-9-CM or ICD-10-CM diagnosis codes indicating osteoporosis or osteopenia (see Supplemental Table 1 for codes); (2) written prescription for ≥ 1 anti-osteoporotic medication (Supplemental Table 2); or (3) procedure codes indicating BMD scans (Supplemental Table 1). We investigated this outcome in the cohort of participants who did and did not have vertebral fractures identified on their index imaging reports.

Statistical analysis

We evaluated numbers and percentages for categorical variables and means, medians, and interquartile ranges (IQRs) for continuous variables for the characteristics of participants who did and did not have vertebral fractures identified on their index imaging reports.

We used mixed models (which account for the fact that participants within providers and/or clinics would have been expected to have had correlated osteoporosis recognition patterns) to estimate adjusted odds ratios (ORs) and 95% confidence intervals (95% CIs) for indications of recognition of osteoporosis in the EHR. We included all variables in the same models but separately modeled the cohort that did have vertebral fractures identified on their index imaging reports from the cohort that did not. We also adjusted all models for the participant's health care system and whether the image occurred during the control (i.e., no benchmark text present on the imaging report) or intervention (i.e., benchmark text present on the imaging report) period. We used SAS 9.4 (Cary, NC) for all analyses and two-sided p values < 0.05 were considered significant.

Results

Of the 238,886 participants who were enrolled in the LIRE parent study, 114,055 met our inclusion criteria (Fig. 1). Of these, 8579 (8%) were identified to have vertebral fractures on their index imaging reports. In the subsequent 12 months, 3784 (44%) had received ≥ 1 ICD-9-CM or ICD-10-CM osteoporosis diagnosis code, BMD scans, and/or prescriptions for anti-osteoporotic medications. Among the 105,426 participants who were not identified as having vertebral fractures on their index imaging reports, 13,893 (13%) had osteoporosis recognized within a year (Fig. 1).

About one-fifth of participants with identified vertebral fractures received BMD scans within 12 months of the index image ($n = 1662$; 19%) (Fig. 2) and most ($n = 1556$; 94%) of these had osteoporosis diagnosis codes in their EHRs. However, only 724 participants (8.4%) of those with identified vertebral fractures on their index imaging reports received prescriptions for anti-osteoporotic medications. Of those without identified vertebral fractures on their index imaging reports whose osteoporosis was clinically recognized, $n = 5587$ (5%) received BMD scans within a year and 998 (0.9%) received prescriptions for anti-osteoporotic medications within a year (Fig. 3).

Characteristics of the cohort, stratified by whether vertebral fractures were identified on index imaging reports, are shown in Table 1. Participants with identified vertebral fractures were older than those who were not identified as having fractures (mean (IQR) of 70.3 (61–68) versus 64.9 (57–71) years) and were less likely to have been female (47% of participants with identified vertebral fractures were female compared to 53% of those without identified vertebral fractures). Participants with identified vertebral fractures were more likely to have had X-rays as the index imaging modality (87% versus 79%) and 72% of participants with identified vertebral fractures were white, compared to 64% of those without identified vertebral fractures. Participants with identified vertebral fractures were likely to have more comorbid conditions (12% of participants with identified vertebral fractures had 3 + comorbid conditions versus 7% of participants without identified vertebral fractures).

Results of adjusted models examining the odds of recognition of osteoporosis among participants with identified vertebral fractures are shown in Table 2. We excluded those with missing SES data from multivariate models ($n = 3197$ (2.8%)). Younger participants were less likely to have had osteoporosis documented in their health records compared

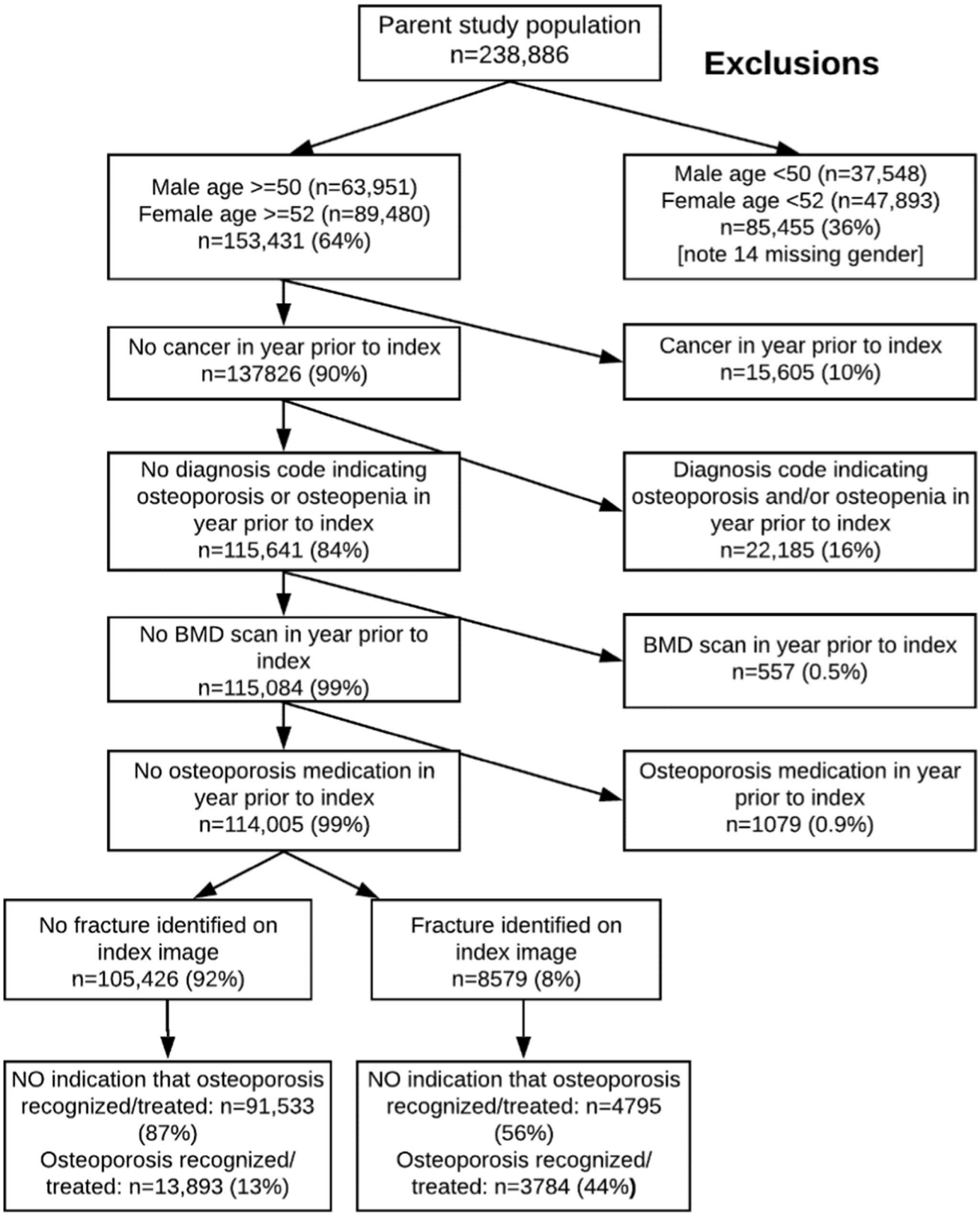

Fig. 1 Flow of participants for analysis

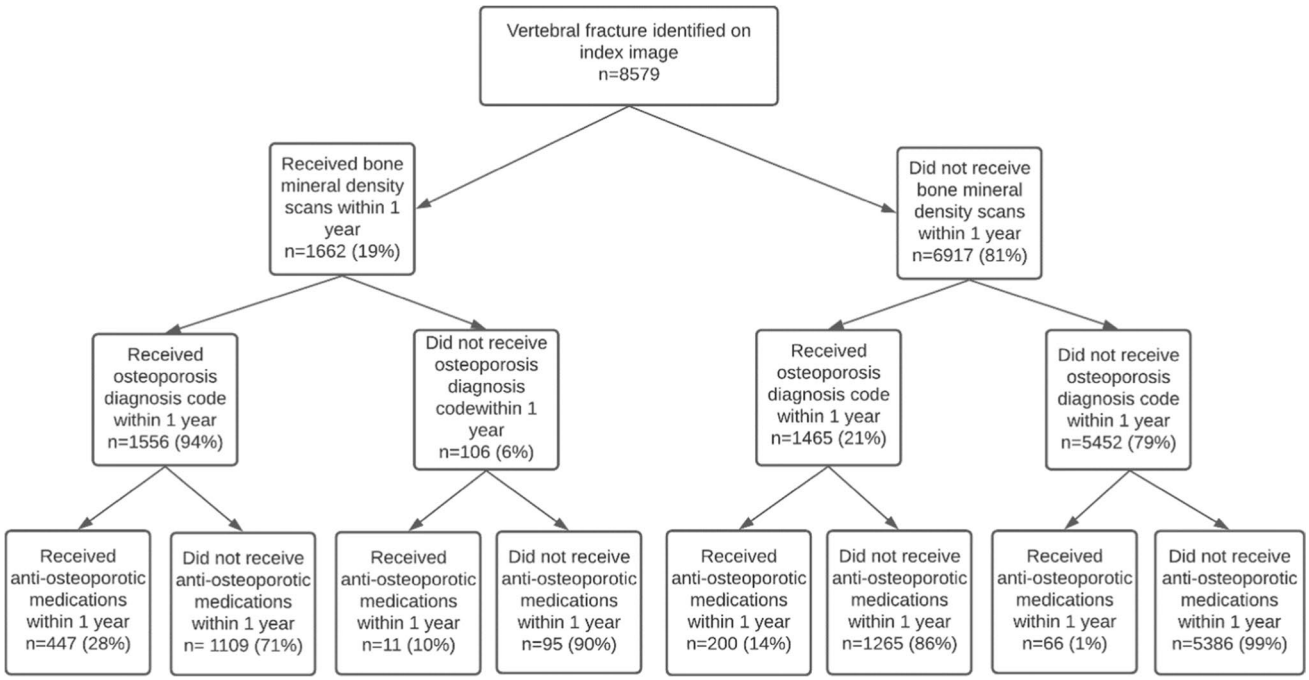

Fig. 2 Proportions of participants with vertebral fractures identified on their index imaging reports who received bone mineral density scans, osteoporosis diagnoses, and anti-osteoporotic medications within 1 year

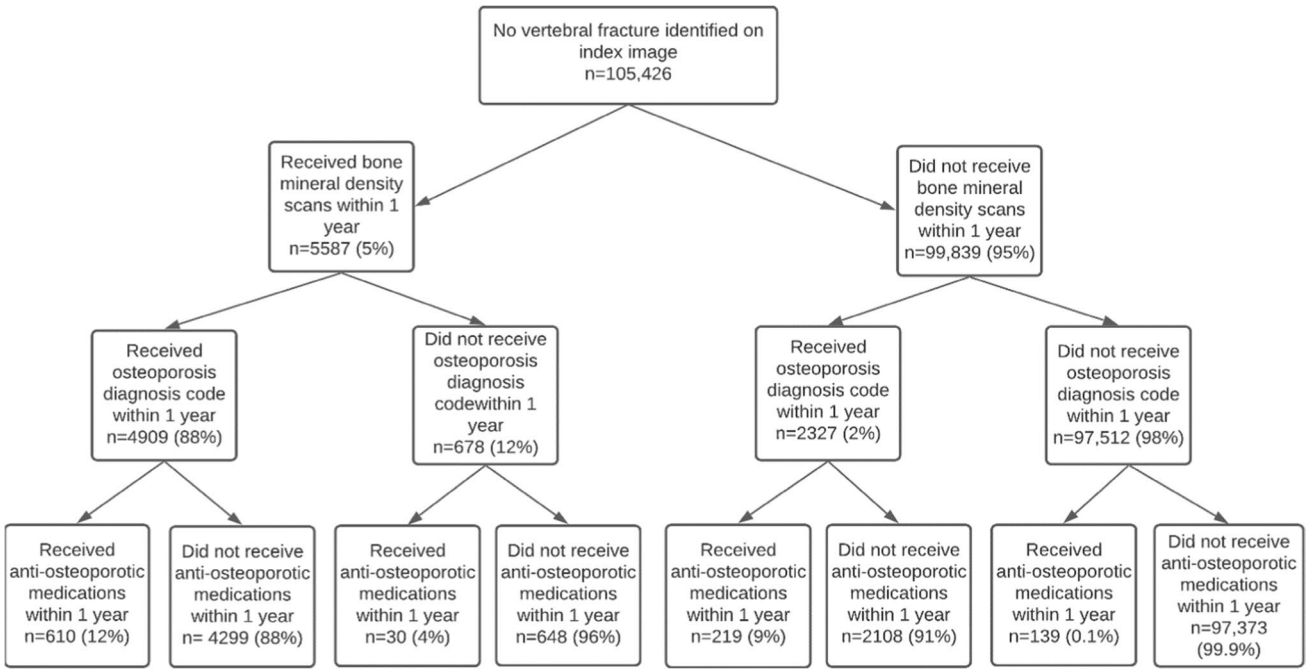

Fig. 3 Proportions of participants without vertebral fractures identified on their index imaging reports who received bone mineral density scans, osteoporosis diagnoses, and anti-osteoporotic medications within 1 year

to older participants (compared to age 65 + , age 50–60 OR (95% CI): 0.48 (0.42, 0.54); age 61–64 0.70 (0.60, 0.81)). Compared with females, males (0.39 (0.35, 0.43)) were less likely to have had recognized osteoporosis, as were participants who received CT (0.24 (0.11–0.50)) or magnetic resonance imaging (MRI) (0.39 (0.34, 0.46)) compared with X-rays. Participants who identified as Black were also less likely to have had documented osteoporosis

Table 1 Characteristics of participants with and without vertebral fractures identified on their index imaging reports who met inclusion criteria

N (column %) or mean (median) interquartile range	Vertebral fracture identified on index imaging report ($n = 8579$)	No vertebral fracture identified on index imaging report ($n = 105,426$)
Age (years)	70.3 (70) 61–80	64.9 (63) 57–71
Age category		
50–60	1998 (23)	41,074 (39)
61–64	1003 (12)	16,045 (15)
65 +	5578 (65)	48,307 (46)
Female	4024 (47)	55,992 (53)
Type of imaging		
X-ray	7480 (87)	83,743 (79)
Computed tomography	63 (1)	469 (0.4)
Magnetic resonance imaging	1036 (12)	21,214 (20)
Race/ethnicity[a]		
Asian	836 (10)	10,042 (10)
Black/African American	454 (5)	10,753 (10)
Native Hawaiian/Other Pacific Islander	37 (0.4)	504 (0.5)
Native American/Alaska Native	50 (0.6)	581 (0.6)
Multiracial	18 (0.2)	268 (0.3)
White	6140 (72)	67,953 (64)
Hispanic	884 (10)	13,004 (12)
Unknown	160 (2)	2321 (2)
Time period		
Oct 2013–Mar 2014	1907 (22)	20,640 (20)
Apr 2014–Sept 2014	1135 (13)	13,409 (13)
Oct 2014–Mar 2015	1470 (17)	16,919 (16)
Apr 2015–Sept 2015	1410 (16)	18,551 (18)
Oct 2015–Mar 2016	1276 (15)	17,481 (17)
Apr 2016–Sept 2016	1381 (16)	18,426 (17)
Charlson comorbidity index		
0	4633 (54)	65,482 (62)
1	1785 (21)	21,179 (20)
2	1122 (13)	10,945 (10)
3 +	1039 (12)	7820 (7)
Socioeconomic status		
Lowest	495 (6)	6500 (6)
Low medium	1035 (12)	12,865 (12)
High medium	1931 (23)	24,229 (23)
Highest	4875 (57)	58,878 (56)
Missing	243 (3)	2954 (3)
Study site		
Kaiser Permanente: Washington	535 (6)	6915 (7)
Kaiser Permanente: Northern California	7058 (82)	86,121 (82)
Henry Ford	645 (8)	7038 (7)
Mayo Clinic	341 (4)	5352 (5)

[a]Categories are mutually exclusive. Hispanic category includes Hispanic ethnicity with any race

relative to those who identified as white (0.74 (0.57, 0.97)). We did not observe significant associations between SES or Charlson comorbidity score and the likelihood of EHR osteoporosis recognition.

Multivariable results were similar when we examined participants who did not have identified vertebral fractures on their index imaging reports (Table 3). Younger participants, males, participants who received MRI, and those who

Table 2 Results of mixed effects model for osteoporosis recognition among participants with vertebral fractures identified on their index imaging reports

Variable	Adjusted[a] odds ratio (95% confidence interval)
Age 50–60 vs 65 +	0.48 (0.42–0.54)
Age 61–64 vs 65 +	0.70 (0.60–0.81)
Participant male vs female	0.39 (0.35–0.43)
Computed tomography vs X-ray	0.24 (0.11–0.50)
Magnetic resonance imaging vs X-ray	0.39 (0.34–0.46)
Asian vs white	1.09 (0.88–1.34)
Black vs white	0.74 (0.57–0.97)
Hawaiian/Pac. Islander vs white	0.79 (0.38–1.64)
Native American/Alaskan vs white	1.48 (0.80–2.75)
Multiracial vs white	0.18 (0.02–1.43)
Hispanic vs white	1.31 (0.90–1.89)
Unknown race/ethnicity vs white	0.93 (0.79–1.08)
Lowest SES vs highest SES	0.94 (0.76–1.17)
Low-medium SES vs highest SES	0.97 (0.83–1.13)
High-medium SES vs highest SES	0.90 (0.80–1.02)
Charlson 1 vs Charlson 0	1.05 (0.93–1.19)
Charlson 2 vs Charlson 0	1.13 (0.98–1.31)
Charlson 3 vs Charlson 0	1.06 (0.92–1.24)
Time April 2014–September 2014 vs October 2013–March 2014	1.00 (0.85–1.18)
Time October 2014–March 2015 vs October 2013–March 2014	1.05 (0.89–1.24)
Time April 2015–Sept 2015 vs October 2013–March 2014	0.70 (0.58–0.84)
Time October 2015–Mar 2016 vs October 2013–March 2014	1.03 (0.84–1.25)
Time April 2016–Sept 2016 vs October 2013–March 2014	0.90 (0.72–1.12)

[a]All variables included in same model, which included random effects for index imaging clinic and image ordering provider. Model was additionally adjusted for study site and whether the intervention text was included in their index imaging reports

Abbreviation: *SES* socioeconomic status

identified as Black were less likely to have had documented osteoporosis relative to those who were older, female, received X-rays, and were white. Participants who identified as Asian were more likely to have had recognized osteoporosis compared to white participants (1.20 (1.10, 1.31)). People with more comorbidities were also more likely to have had osteoporosis documented compared to people who did not have any comorbidities.

Discussion

Among participants whose imaging reports indicated they had vertebral fractures, the majority did not have evidence in the EHR that clinicians considered the need for evaluation of osteoporosis within a year. Only 8% of participants with fractures identified on their imaging reports had EHR evidence of initiating anti-osteoporotic medications. Even among participants whose osteoporosis was recognized in the EHR, only half received prescriptions for anti-osteoporotic medications or received BMD scans. The main characteristics that were associated with lack of recognition of osteoporosis were receiving MRI or CT, male sex, younger age, and identifying as Black. The last three characteristics are all associated with a lower risk of osteoporosis in the general population and clinicians may be biased into discounting the likelihood of osteoporosis in these participants even in the presence of vertebral fractures. Our findings indicate that more direct, less nuanced approaches to alerting clinicians about the possible presence of osteoporosis are needed. These could include machine learning clinical decision support algorithms or radiologists specifically mentioning the presence of vertebral fractures and the need for osteoporosis evaluation in the impression section of imaging reports. These simple steps could improve the recognition and treatment of osteoporosis in patients who are less commonly diagnosed with osteoporosis but remain at risk.

Guidelines from the National Osteoporosis Foundation and Osteoporosis Canada state that patients with histories of spine fractures should receive pharmacologic treatment because vertebral fractures greatly increase the risk of morbidity and mortality [6, 17] as well as increase the

Table 3 Results of mixed effects model for osteoporosis recognition among participants without vertebral fractures identified on their index imaging reports

Variable	Adjusted[a] odds ratio (95% confidence interval)
Age 50–60 vs 65 +	0.24 (0.23–0.25)
Age 61–64 vs 65 +	0.54 (0.51–0.57)
Participant male vs female	0.23 (0.22–0.24)
Computed tomography vs X-ray	0.76 (0.56–1.03)
Magnetic resonance imaging vs X-ray	0.65 (0.62–0.69)
Asian vs white	1.20 (1.10–1.31)
Black vs white	0.70 (0.63–0.76)
Hawaiian/Pac. Islander vs white	0.94 (0.69–1.29)
Native American/Alaskan vs white	1.07 (0.82–1.40)
Multiracial vs white	1.10 (0.72–1.69)
Hispanic vs white	0.98 (0.84–1.14)
Unknown race/ethnicity vs white	1.08 (1.01–1.15)
Lowest SES vs highest SES	0.92 (0.84–1.01)
Low-medium SES vs highest SES	0.98 (0.92–1.05)
High-medium SES vs highest SES	1.02 (0.97–1.07)
Charlson 1 vs Charlson 0	1.05 (1.01–1.11)
Charlson 2 vs Charlson 0	1.09 (1.02–1.16)
Charlson 3 vs Charlson 0	1.25 (1.16–1.34)
Time April 2014–September 2014 vs October 2013–March 2014	0.96 (0.89–1.03)
Time October 2014–March 2015 vs October 2013–March 2014	0.98 (0.91–1.05)
Time April 2015–Sept 2015 vs October 2013–March 2014	0.83 (0.77–0.90)
Time October 2015–Mar 2016 vs October 2013–March 2014	1.00 (0.91–1.08)
Time April 2016–Sept 2016 vs October 2013–March 2014	1.05 (0.96–1.15)

[a]All variables included in same model, which included random effects for index imaging clinic and image ordering provider. Model was additionally adjusted for study site and whether the intervention text was included in their index imaging reports

Abbreviation: *SES* socioeconomic status

likelihood of subsequent future fractures [2]. Osteoporosis screening and treatment are vastly underutilized in populations at risk of fragility fractures as well as those who have sustained fractures already [23, 24]. Previous studies have documented that Black patients were less likely to receive BMD scans or treatment for osteoporosis compared to white patients [25–27]. Similarly, men have been shown to be dramatically less likely to receive BMD screening [28–30] or anti-osteoporotic medications than women, even after adjustment for future hip fracture risk (OR = 0.08 (0.06–0.10)) [25]. Like our study, prior research has shown that patients age < 65 years are less likely than those age 65–74 years to receive BMD scans [27]. Some research has indicated that the likelihood of being treated for osteoporosis among eligible patients has declined over calendar time [31, 32], but we did not observe significant associations with time period and the odds of osteoporosis recognition in the EHR, perhaps because our study took place over only 2.5 years.

We found that participants whose index imaging modality was MRI or CT were less likely to have had indications of osteoporosis recognition in their EHRs compared to participants who received X-rays. We speculate that providers who were concerned that their patients' back pain was due to osteoporotic vertebral fractures may have been more likely to have ordered X-rays than other imaging modalities and thus were also more likely to have recognized the vertebral fractures when they received the imaging reports. Also, participants who received MRI/CT may have had conditions that were more serious than participants whose index images were X-rays, and these other diagnoses took attention away from osteoporosis.

We found similar risk factors for unrecognized osteoporosis among participants without identified vertebral fractures on their index imaging reports as among those with identified vertebral fractures. One difference was that participants with more comorbid conditions who did not have identified vertebral fractures on index were more likely to have had documented osteoporosis. Possibly this is because some comorbidities are associated with increased likelihood of having osteoporosis, including hyperthyroidism, rheumatoid arthritis, and chronic pulmonary disease [33]. Furthermore,

patients with more comorbid conditions may be less able to engage in physical activity which would put them at greater risk of developing osteoporosis [34]. Also, patients with more comorbidities have been shown to have more interactions with their providers [35], so it is likely that they had more opportunities for osteoporosis to be noted.

Another difference comparing participants without identified vertebral fractures on their index imaging reports to those with identified vertebral fractures was that participants who identified as Asian were more likely to have had recognized osteoporosis in their EHRs compared to whites. Compared to non-Hispanic white individuals, some studies have indicated Asian-Americans have lower BMDs [36–38], but Asian individuals have been documented as having lower rates of osteoporotic fractures compared to non-Hispanic white individuals [38, 39]. A recent study conducted in Hawaii found no difference in the likelihood of receiving osteoporosis treatment among Asian-Americans compared to individuals who identified as white or Native Hawaiian/Pacific Islander following adjustment for demographic variables [40]. Further research on associations between racial groups and osteoporotic treatment is needed.

A major strength of our study is the large sample size. Limitations include potential errors in the ascertainment of vertebral fractures on the index images, since we relied on the reports of the imaging studies rather than the actual images. In fact, it is possible that this reliance on imaging reports rather than images resulted in underestimating the vertebral fractures in this population, since vertebral fractures are often not commented upon in imaging reports [10, 11]; it is also possible that vertebral fractures were identified when they were not actually present. We also did not have information about the methods, whether qualitative, quantitative, or simply intuition, that the radiologists used to determine whether vertebral fractures were present. Also, we did not have information for each of the 98 primary care clinics included in our analyses on whether specialists who performed osteoporosis consultations were available onsite or nearby. It is possibly that the presence of such specialists could have affected how readily osteoporosis was recognized. Furthermore, we assumed that the majority of vertebral fractures identified by NLP were osteoporotic because we excluded many non-osteoporotic causes of vertebral fractures such as cancer and severe trauma, but it is possible that some of the identified fractures were not due to osteoporosis and thus osteoporosis was appropriately not clinically recognized. Our study was also limited by our ability to determine whether osteoporosis was recognized using EHR data. For example, we would not have detected whether participants saw providers who diagnosed osteoporosis, ordered BMD scans, or prescribed anti-osteoporotic medications at facilities outside of their healthcare systems, and those would have been misclassified as not having had recognized osteoporosis. However, participants have financial incentive to receive care from within these systems so presumably we captured most healthcare utilization. In addition, our finding that most participants with identified vertebral fractures did not receive prescriptions for anti-osteoporotic medications may have been for appropriate reasons, such as the presence of contraindications, that we were unable to account for in these analyses, but we do not expect contraindications would have applied to most of the participants who were eligible for anti-osteoporotic medications in our sample. We were also unable to account for participants' preferences. A recent survey of postmenopausal women who had recently been diagnosed with osteoporosis found that 65% of the patients chose not to initiate pharmacological treatment because they were concerned about side effects [41]. By definition, patients in our analysis cohort could not have had spine imaging or osteoporosis diagnoses in the year prior to index, but we did not have data from more than 1 year prior to index and thus we were unable to adjust our analyses for whether patients had had previous osteoporotic fractures, an important predictor of future osteoporotic fractures.

We found that participants with vertebral fractures identified on imaging reports often did not have clinically recognized osteoporosis within a year and those who were younger, identified as Black, or male were less likely than those who were older, white, or female to have had their osteoporosis recognized. Our findings suggest that clinicians could heighten their awareness of imaging reports that indicate vertebral fractures and health systems could consider implementing automated interventions that would decrease the impact of clinician bias in the recognition of vertebral fractures and osteoporosis.

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Declarations

Ethics approval All participating institutional review boards determined that the study was minimal risk and granted waivers of both consent and Health Insurance Portability and Accountability Act authorization. All procedures performed in studies involving human participants were performed in accordance with the ethical standards of the institutional committees and with the 1964 Declaration of Helsinki and its later amendments.

Conflicts of interest David F. Kallmes discloses that he has ownership/stock in Kypheze, LLC; patents involved in spine augmentation; and has received research support and royalties from Medtronic. Laura S. Gold, Richard F. Cody, Jr., W. Katherine Tan, Zachary A. Marcum, Eric N. Meier, Karen J. Sherman, Kathryn T. James, Brent Griffith, Andrew L. Avins, Pradeep Suri, Janna L. Friedly, Patrick J. Heagerty, Richard A. Deyo, Patrick H. Luetmer, Sean D. Rundell, David R. Haynor, and Jeffrey G. Jarvik do not have financial or non-financial interests that are directly or indirectly related to this work.

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