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Clinical Study

Clinical prevalence and population incidence of serious pathologies among patients undergoing magnetic resonance imaging for low back pain

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Abstract

BACKGROUND: In rare cases low back pain may be caused by underlying serious pathology such as fracture, malignancy, cauda equina syndrome, or spinal infection. The lack of evidence regarding either the clinical prevalence or population incidence of serious pathologies in the lumbar spine makes it difficult for clinicians to adequately assess a patient's risk of serious pathology.
PURPOSE: To determine the prevalence of serious pathologies in patients with low back pain who have been referred for a lumbar magnetic resonance imaging (MRI) by a specialist in a private secondary care or public tertiary care setting. The incidence of these serious pathologies in the geographic region of South Auckland, New Zealand was also investigated.
STUDY DESIGN: Retrospective, observational cohort study.
PATIENT SAMPLE: Consecutive patients referred for lumbar MRI over a 10-month period (1st of October 2013–31st of July 2014).
METHOD: Data from all eligible MRI reports was analyzed and any serious pathologies were identified and recorded. Prevalence (along with 95% confidence intervals) was calculated as a percentage of the study population. Prevalence specific to private secondary care and public tertiary care settings was also calculated and prevalence rate ratios were determined to allow comparison between settings. Incidence in the geographic region of South Auckland, New Zealand, was determined using data collected from participants recruited from the regional public hospital. Population incidence with respect to age, gender, and ethnicity for each target condition was calculated and incidence rate ratios were computed to compare groups.
RESULTS: A total of 2,383 participants referred for lumbar MRI scans were included in this study. Prevalence was significantly higher in the public tertiary care setting than in the private secondary care setting for all pathologies investigated in this study. Pathology specific prevalence in secondary care vs tertiary care settings was: malignancy, 0.3%, 4.4% (p<.001); fracture 2.2%, 6.7% (p<.001); cauda equina compression 0.6%, 2.3% (p=.001); infection 0.1%, 3.4% (p<.001). The combined prevalence in secondary care was 3.2% and in tertiary care 14.8% (p<.001). Pathology specific total incidence was: fracture, 13 per 100,000 person-years (p-y); malignancy 8.5 per 100,000 p-y; cauda equina compression 4.4 per 100,000 p-y; spinal infection 6.6 per 100,000 p-y.

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CONCLUSIONS: The prevalence of serious pathologies was significantly higher in tertiary care (public health) than in private secondary care settings. One in every 6.5 patients referred for MRI in tertiary care demonstrated structural abnormalities associated with serious pathology, which raises the question of whether access to MRI should be re-evaluated.

Keywords: Serious pathology; Lumbar spine; Spinal infection; Malignancy; Vertebral fracture; Caudal equina syndrome; Low back pain, Prevalence, Incidence

Introduction

Low back pain (LBP) is a common problem and in rare cases it may be due to underlying serious pathology [1,2]. The most common serious pathologies to affect the lumbar spine are fracture, malignancy, cauda equina syndrome (CES) and spinal infection [3]. Timely diagnosis of these pathologies is crucial as missed or delayed diagnosis can lead to irreversible adverse outcomes such as severe, permanent neurological compromise, and mortality [4,5].

Knowledge of the prevalence of serious pathologies is necessary as it allows calculation of the pretest probability of a patient presenting with a disease and can assist clinical decision making [6]. Similarly, knowing the population incidence permits estimation of the number of new cases of serious pathologies that can be expected each year, within a specific population. These understandings allow a clinician to consider the likelihood of the presence of serious pathology for an individual patient, provided that patient matches the demographic of those included in relevant research [6].

International LBP guidelines strongly emphasize the importance of screening for signs and symptoms of serious pathologies or "red flags" to ensure these pathologies are not missed, due to potential dire outcomes [7−11]. However, guidelines are unable to include an indication of the pretest probability as little is known about the prevalence of these pathologies amongst LBP patients across various clinical settings. Although some studies have investigated the prevalence in primary care [1,2,12−17], few have investigated prevalence in secondary or tertiary care [18−21] and there is no reported data on cauda equina syndrome or spinal infection in either secondary or tertiary care. Despite the recommendation for clinicians to undertake routine red flag screening, we know that these pathologies are commonly missed with one study reporting that up to 70% of vertebral fractures were misdiagnosed on clinical assessment and another found that up to 75% of patients with spinal infection are initially misdiagnosed [22,23,54].

Most LBP guidelines recommend that diagnostic imaging should be reserved for patients where there is suspicion of serious pathology or for those who may require surgical management or other interventional procedures [7,24]. Although routine use of diagnostic imaging has been widely discouraged [7,9−11], many clinicians are either not aware of or do not adhere to these LBP guidelines [25]. Nonadherence to guidelines may be due to a number of reasons including patient expectations, clinician's beliefs or fear of missing serious pathology, and whether or not the patient has health insurance [26]. Despite the high use of diagnostic imaging and evidence that indicates that the use of expensive advanced imaging such as magnetic resonance imaging (MRI) is growing at an unsustainable rate [27−29], several studies have reported that imaging is not being utilized for the correct patients [27−31]. Hence, further research is required to inform clinical guidelines and ensure that advanced imaging is reserved for the patients who really need it.

The dearth of evidence regarding either the clinical prevalence or population incidence of serious pathologies in the lumbar spine makes it difficult for clinicians to adequately assess a patient's risk of serious pathology [32−34]. The current study was undertaken to address this gap in the literature with respect to the four most common serious pathologies that affect the lumbar spine. The primary aim of this study was to determine the prevalence of MRI findings indicative of serious pathology in patients with LBP undergoing lumbar MRI at either a private (secondary) or public (tertiary) health care provider. The secondary aim was to determine the incidence of these serious pathologies in the geographic region of South Auckland, New Zealand. Although infection, malignancy, and fracture can be confidently diagnosed on the basis of MRI findings [35,36], the diagnosis of cauda equina syndrome requires knowledge of clinical signs and symptoms that were not retrievable for the purpose of this study. Consequently, the prevalence of cauda equina compression (CEC) observed on MRI has been reported.

The primary aim of this study was to determine the prevalence of vertebral fracture, malignancy, CEC, and spinal infection in patients with LBP who have been referred for a lumbar MRI from either a private secondary or tertiary public health care provider. The secondary aim was to determine the incidence of these serious pathologies in the geographic region of South Auckland, New Zealand.

Material and methods

The present study was a retrospective, observational cohort study. The study protocol was approved by the Auckland University of Technology Ethics Committee (AUTEC) who provided ethical approval (AUTEC 13/120) to perform a retrospective audit of all lumbar MRI scans during the study

period (1st of October 2013 – 31st of July 2014). The manuscript adheres to the STROBE checklist [37].

Participant demographics

Consecutive patients referred for lumbar MRI over a 10-month period. Data collection took place across two settings: a secondary care private musculoskeletal radiology practice (Specialist Radiology Group) and a tertiary care teaching hospital (Middlemore Hospital). Patients were referred predominantly by orthopedic surgeons and occasionally by sports physicians, general medical physicians, musculoskeletal specialists, or pain specialists. Patients were included if they had received an MRI scan for LBP and were 16 years of age or over. Patients with known serious pathologies or patients undergoing lumbar MRI for reasons other than back pain (eg, for structural or congenital abnormalities not associated with back pain) were excluded. Reported data was deidentified to maintain the privacy and confidentiality of participants.

Target conditions

For the purposes of this study vertebral fractures were defined as "any fracture affecting the vertebral body." Isolated pars interarticularis or pedicle fractures were excluded. Spinal malignancy included any metastatic or malignant spinal tumor with a complaint of LBP on the radiology referral form. CEC was classified as compression of the cauda equina nerves. Spinal infection included vertebral osteomyelitis, discitis, epidural abscess, and paravertebral muscle abscess.

Reference standard

MRI was utilized as the reference standard as it has been shown to be the single best noninvasive test available for the diagnosis of serious pathologies in the lumbar spine [35,38,39]. The MRI scanner at Specialist Radiology Group (SRG) was a 3 Tesla Philips Achieva and the MRI scanner at Middlemore Hospital (MMH) was a 1.5 Tesla Siemens Avanto. The MRI protocol included T1- and T2-weighted sagittal and coronal images, plus Short-T1 Inversion Recovery and/or fat-suppressed images if indicated. Gadolinium contrast was given in limited cases at the radiologist's discretion, if indicated.

Sample size

Sample size was evaluated on the basis of the projected accuracy of the prevalence estimate. A minimum sample size of 1250 was required to allow an expected maximum confidence interval (CI) width ranging between 1.2 percentage points (for a prevalence of 1%) and 2.5 percentage points (for a prevalence of 5%).

Data collection

National health index numbers, age, gender, and ethnicity data for all patients who had received a lumbar MRI scan during the 10-month study period was exported and assessed for eligibility. The primary researcher and research assistant then retrieved the relevant radiology reports.

Data analysis

All participants referred for MRI were screened and any prospective participants that did not meet the eligibility criteria were excluded. Data from individual MRI reports was analyzed and any target conditions were identified and recorded. A random selection of reports was double-read (5%) by a research assistant to ensure there was no error in data extraction or coding.

The total number of participants with each serious pathology was recorded and an overall prevalence (along with 95% CIs) was calculated as a percentage of the study population. Prevalence specific to secondary care and tertiary care was also calculated. The Taylor series method was employed to determine prevalence rate ratios to allow comparisons between secondary and tertiary care settings [40].

Incidence in the geographic region of South Auckland, New Zealand, was determined using data collected from participants recruited from MMH (Counties Manukau District Health Board). The population was subcategorized based on age, gender, and ethnicity to allow comparison between the 2013 South Auckland Census data [41]. Incidence was calculated by determining the number of new cases of serious pathology diagnosed over the study period. Population incidence was based on population estimates with respect to age, gender, and ethnicity for each target condition. Incidence rate ratios were computed to compare groups. CIs was computed using the Clopper-Pearson method [42] for rates and the Taylor series method [40] for rate ratios.

Results

A total of 2,383 participants referred for lumbar MRI scans were included in this study. MRI reports were obtained for all participants. The secondary care private practice SRG contributed 71% (1,681) of these scans and the remaining 29% (702) of the scans were from the tertiary care public hospital MMH. The majority of patients referred to SRG were referred via private spine clinics.

The median age across all participants was 52 years, with an interquartile range of 25 years. Participants referred from private spine clinics were significantly younger ($p<.0001$) than participants referred from the public hospital, with mean ages of 49 and 57 years, respectively (see Table 1). The female to male ratio was even in private. However, there were significantly more females (57%) in the public hospital group ($p=.001$).

Prevalence was significantly higher in the public hospital setting than in the private secondary care setting for all of

Table 1
Baseline characteristics

Participant demographics		Combined	Private clinic	Public hospital	p Value
Age (years)	Mean age (SD)	52	49 (33, 65)	57 (39,75)	0.51
	Median (Interquartile range)	52 (39-64)	49 (37-61)	59(45-71)	
Gender	Female (%)	1,235 (52%)	835 (50%)	400 (57%)	0.001
	Male (%)	1,148 (48%)	846 (50%)	302 (43%)	
	Total	2,383	1,681	702	

Note. SD = Standard deviation.

Table 2
Prevalence of serious pathology in secondary and tertiary care

Target condition	SP total (n)	SP private (n)	SP public (n)	Prevalence total % (95% CI)	Prevalence % private (95% CI)	Prevalence % public (95% CI)	Prevalence rate ratios: public/private (95% CI)	p Value
Malignancy	36	5	31	1.51 (1.06, 2.09)	0.30 (0.097, 0.69)	4.42 (3.02, 6.21)	14.9 (6.12, 43.0)	.00000006
Vertebral fracture	84	37	47	3.52 (2.82, 4.35)	2.20 (1.55, 3.02)	6.70 (4.96, 8.80)	3.04 (1.98, 4.71)	.0000005
CEC	26	10	16	1.09 (0.71, 1.59)	0.59 (0.29, 1.09)	2.28 (1.31, 3.67)	3.81 (1.74, 8.77)	.001
Spinal infection	26	2	24	1.09 (0.71, 1.59)	0.12 (0.014, 0.43)	3.42 (2.20, 5.04)	28.7 (7.94, 180)	.00002
Multiple serious pathologies	15	1	14	0.63 (0.35, 1.04)	0.06 (0.002,0.033)	1.99 (1.09, 3.32)	33.5 (5.94, 716)	.004
Total	157	53	104	6.59 (5.63, 7.66)	3.15 (2.37, 4.10)	14.8 (12.2,17.7)	4.70 (3.39, 6.58)	0

Note. CE, cauda equina compression; SP, serious pathology; n, frequency; 95% CI, 95% confidence interval.

the target conditions investigated in this study (see Table 2). The presence of malignancy in the private group was rare (prevalence of 0.3%). In contrast, the prevalence of this pathology in the public hospital setting (4.4%) was 15 times higher, as indicated by the prevalence rate ratio (PRR) of 14.9 (95% CI [6.12, 43.0]). Similarly, the prevalence of vertebral fracture was significantly higher (PRR=3, 95% CI [2.0,4.7]) in the public hospital. A higher prevalence in hospital setting was also observed with CEC (PRR 3.8, 95% CI [1.7,8.4]). The largest difference in prevalence between settings was for infection which was 29 times more common in the public hospital (PRR 28.7, 95% CI [7.9,180]).

Table 3 provides detail regarding the incidence of serious pathologies across various ethnic, gender, and age groups (pathology-specific tables are provided in the supplement). According to the 2013 New Zealand census [88], 211,038 Europeans, 104,673 Pacific Islanders, 101,520 Asians, and 67,944 Māori live in the South Auckland area. Based on this data and the number of serious pathologies identified in the current study, the overall incidence of such pathologies was 25.8 per 100,000 person-years (p-y). Incidence increased with age, peaking at 249 per 100,000 p-y in the 85 years and over age group. Serious pathologies were slightly, but not significantly, more common in males with a rate ratio (RR) of 1.20 (95% CI [0.80,1.81]). Europeans had the highest risk of developing a serious pathology, followed by Pacific Islanders (RR with respect to Europeans [RR] 0.791, 95% CI [0.471,1.33]), Māori (RR 0.548, 95% CI [0.270,1.113]), and Asians (RR 0.285, 95% CI [0.130,0.623]). In Europeans, incidence peaked at 85 years and over, and at 74−84 years in all other ethnicities.

Overall the serious pathology with the highest incidence was vertebral fracture (12.9/100,000 p-y). The ethnicity-specific highest total incidence was observed in Europeans (20.0/100,000 p-y). Overall incidence increased with older age (see Fig. 1), peaking at 199.2 per 100,000 p-y in the 85 years and over group. There was also a slight peak in incidence for males aged 25−34 years for both European and Pacific populations (12.5 and 20.2/100,000 p-y, respectively). There was no statistically significant difference between total incidence for males and females (RR 1.02, 95% CI [0.57,1.80]). However, all fractures under age 35 were male. Within the Asian population there were no fractures in participants under 55 years of age. Māori males had an incidence of 37.1 per 100,000 p-y in the 45−54 year age group, otherwise Māori males were not affected and all fractures over age 65 years were female (142/100,000 p-y).

With regard to malignancy, risk increased with age with the overall incidence of 4.4 per 100,000 p-y in the 25−34 year age group increasing to 78.4 per 100,000 p-y in the 74−84 years age group (see Fig. 2). Age related risk tripled from age 45−54 years to age 65−74 years, then doubled again by age 74−84 years (10.0/100,000 p-y, 33.5/100,000 p-y, and 78.4/100,000 p-y, respectively). The risk of malignancy was greatest for Māori with a total incidence of 25.6 per 100,000 p-y, and a peak of 495.3 per 100,000 p-y in the 74−84 years age group. Within Māori there was a female predominance in the 25−64 year age group (25.4−47.6/100,000 p-y vs 0.0−37.1/100,000 p-y in males), then a male predominance in the 74−84 year age group (866 vs 263/100,000 p-y in females). The incidence amongst Asians was significantly lower with an overall incidence of 1.2 per 100,000 p-y and the only group affected was males aged

Table 3
Incidence table (per 100,000 person-years) for serious pathologies in Counties Manukau

Age group	European estimate* (95% CI)	Māori estimate* (95% CI)	Pacific estimate * (95% CI)	Asian estimate* (95% CI)	Grand total estimate (95% CI)
16-24 All	5.1 (0.1, 28.2)	0.0 (0.0, 39.9)	19.9 (4.1, 58.1)	8.2 (0.2, 45.7)	10.2 (3.3, 23.7)
Female	10.1 (0.3, 56.2)	0.0 (0.0, 75.5)	12.8 (0.4, 71.6)	0.0 (0.0, 64.6)	8.2 (1.0, 29.6)
Male	0.0 (0.0, 37.4)	0.0 (0.0, 84.7)	27.4 (3.4, 98.9)	15.4 (0.4, 85.9)	12.2 (2.5, 35.6)
25-34 All	5.9 (0.1, 32.6)	29.9 (3.7, 107.8)	36.7 (10.0, 93.9)	6.6 (0.2, 37.0)	17.5 (7.6, 34.5)
Female	0.0 (0.0, 40.5)	25.4 (0.6, 141.5)	16.9 (0.4, 93.9)	0.0 (0.0, 46.6)	8.2 (1.0, 29.6)
Male	12.5 (0.3, 69.9)	36.2 (0.9, 201.7)	60.5 (12.5, 176.6)	14.0 (0.4, 77.9)	28.3 (10.3, 61.5)
35-44 All	12.9 (2.7, 37.6)	14.7 (0.4, 81.9)	20.0 (2.5, 72.3)	0.0 (0.0, 29.9)	12.1 (4.4, 26.4)
Female	24.0 (4.9, 70.2)	25.9 (0.7, 144.3)	0.0 (0.0, 68.1)	0.0 (0.0, 54.6)	15.0 (4.0, 38.5)
Male	0.0 (0.0, 33.9)	0.0 (0.0, 125.2)	43.7 (5.3, 157.8)	0.0 (0.0, 66.0)	8.7 (1.1, 31.6)
45-54 All	15.5 (4.2, 39.6)	33.2 (4.1, 119.9)	11.9 (0.3, 66.5)	8.8 (0.2, 48.8)	18.0 (8.3, 34.2)
Female	22.7 (4.7, 66.3)	0.0 (0.0, 110.8)	22.2 (0.6, 123.9)	0.0 (0.0, 61.5)	19.3 (6.3, 44.9)
Male	7.9 (0.2, 44.0)	74.3 (9.0, 268.0)	0.0 (0.0, 95.0)	18.5 (0.5, 103.0)	16.7 (4.5, 42.7)
55-64 All	38.5 (16.7, 75.9)	26.7 (0.7, 148.8)	97.9 (31.8, 228.3)	25.5 (3.1, 92.0)	48.7 (28.9, 77.0)
Female	28.4 (5.8, 83.0)	47.6 (1.2, 264.8)	75.6 (9.2, 272.8)	47.8 (5.8, 172.5)	47.2 (21.6, 89.5)
Male	48.9 (15.9, 114.1)	0.0 (0.0, 225.3)	121.7 (25.1, 355.4)	0.0 (0.0, 100.6)	50.3 (23.0, 95.5)
65-74 All	77.2 (39.9, 134.9)	0.0 (0.0, 204.5)	70.6 (8.6, 254.8)	26.3 (0.7, 146.6)	67.0 (38.3, 108.8)
Female	62.0 (20.1, 144.7)	0.0 (0.0, 378.5)	0.0 (0.0, 245.4)	51.3 (1.3, 285.7)	48.5 (17.8, 105.6)
Male	93.6 (37.6, 192.7)	0.0 (0.0, 445.4)	150.6 (18.3, 543.0)	0.0 (0.0, 199.3)	87.0 (41.8, 159.9)
74-84 All	142.0 (73.4, 248.0)	495.3 (102.2, 1441.7)	186.5 (22.6, 672.3)	69.8 (1.7, 388.5)	182.8 (113.2, 279.3)
Female	151.1 (60.8, 311.2)	263.3 (6.7, 1459.7)	0.0 (0.0, 572.4)	0.0 (0.0, 489.4)	157.7 (75.7, 289.9)
Male	131.0 (42.6, 305.4)	866.3 (105.1, 3100.3)	465.7 (56.4, 1673.9)	146.5 (3.7, 814.0)	213.7 (106.7, 382.0)
85 & over All	286.9 (137.7, 527.2)	0.0 (0.0, 4420.1)	0.0 (0.0, 1696.0)	0.0 (0.0, 1587.3)	249.0 (119.5, 457.4)
Female	267.7 (98.2, 581.8)	0.0 (0.0, 6035.7)	0.0 (0.0, 2335.8)	0.0 (0.0, 2535.1)	231.5 (85.0, 503.4)
Male	321.6 (87.7, 821.8)	0.0 (0.0, 13982.5)	0.0 (0.0, 5582.3)	0.0 (0.0, 4172.0)	280.7 (76.5, 717.5)
Female total	31.2 (20.8, 45.1)	13.4 (3.6, 34.3)	11.2 (3.6, 26.1)	7.0 (1.5, 20.4)	23.5 (17.1, 31.5)
Male total	27.1 (17.2, 40.6)	19.0 (6.2, 44.3)	35.9 (20.1, 59.2)	9.7 (2.6, 24.9)	28.3 (21.1, 37.4)
Grand Total	29.2 (21.7, 38.4)	16.0 (7.3, 30.4)	23.1 (14.1, 35.7)	8.3 (3.4, 17.1)	25.8 (20.8, 31.7)

Note. All , Male and female combined, 95% CI, Confidence Interval.

* Ethnicity-specific prevalence's are underestimated as the numerator is frequency based on prioritised ethnicity and denominator is population based on total response.

25−34 years. In European and Pacific populations incidence was similar between males and females (RR 1.06, 95% CI [0.42,2.7] in Europeans, RR 1.07, 95% CI [0.14,7.6] in Pacific populations), and incidence was slightly but not significantly lower for males in Māori (RR 0.85, 95% CI [0.19,3.8]).

The overall incidence of CEC was the lowest of all serious pathologies at 4.4 per 100,000 p-y. The highest ethnicity specific total incidence was found in Europeans (5.2/100,00 p-y), followed by Māori (RR with respect to Europeans 0.69, 95% CI [0.15,3.2]), Asians (RR 0.23, 95% CI [0.03,1.8]) and Pacific Islanders (RR 0.22, 95% CI [0.03, 1.8]). The peak incidence by age group varied between ethnicities (see Fig. 3). CEC generally affected older age groups, with incidence peaking in the 74-84-year-old age group for Europeans (35.5/100,000 p-y), and 55−64 year old age group for Māori and Asians (26.7 & 12.7/100,000 p-y). Affected Europeans were generally aged from 55 to 85+ years, with the exception of an incidence of 10.1 per 100,000 p-y in 16−24 year old females. For Asians all cases were within the 55-64 years age group and in Māori 45-64 years. Conversely, Pacific Islanders were younger, with a peak in the 16−24 year old age group (6.6/100,000 p-y). Incidence was higher in males, but not significantly so, in European and Māori populations (RR 1.32, 95% CI [0.35,4.9] for Europeans; 1.13, 95% CI [0.07,18.1] for Māori).

The overall incidence of spinal infection was 6.6 per 100,000 p-y. Incidence of spinal infection was highest in Pacific Islanders at 11.5 per 100,000 p-y and was significantly lower for Europeans at 4 per 100,000 p-y (RR with respect to Pacific Islanders 0.35, 95% CI [0.13,0.91]), but not for Asian populations (RR 0.41, 95% CI [0.13,1.3]) (see Fig. 4). Māori had the lowest incidence of 1.8 per 100,000 p-y (RR with respect to Pacific 0.16, 95% CI [0.02,1.2]). Pacific Island males were the most at-risk group with incidence rising from 60.5 per 100,000 p-y in the 25−34 year old group to 466 per 100,000 p-y in the 74−84 year old age group. Incidence also increased with age for Europeans (9.6−35.5/100,000 p-y from 55 to 84 years), Pacific Islanders 27.5−186/100,00 p-y from 25 to 84 years), and Asians (8.8−26.3/100,000 p-y from 45 to 74 years). However, in Māori the incidence peaked in males at the younger age group of 25−34 years at 36.2 per 100,000 p-y and did not affect any females or other age groups. All cases of spinal infection below age 55 were male and there were no affected Europeans in this group. Overall incidence was significantly higher in males than females (RR 5.3, 95% CI

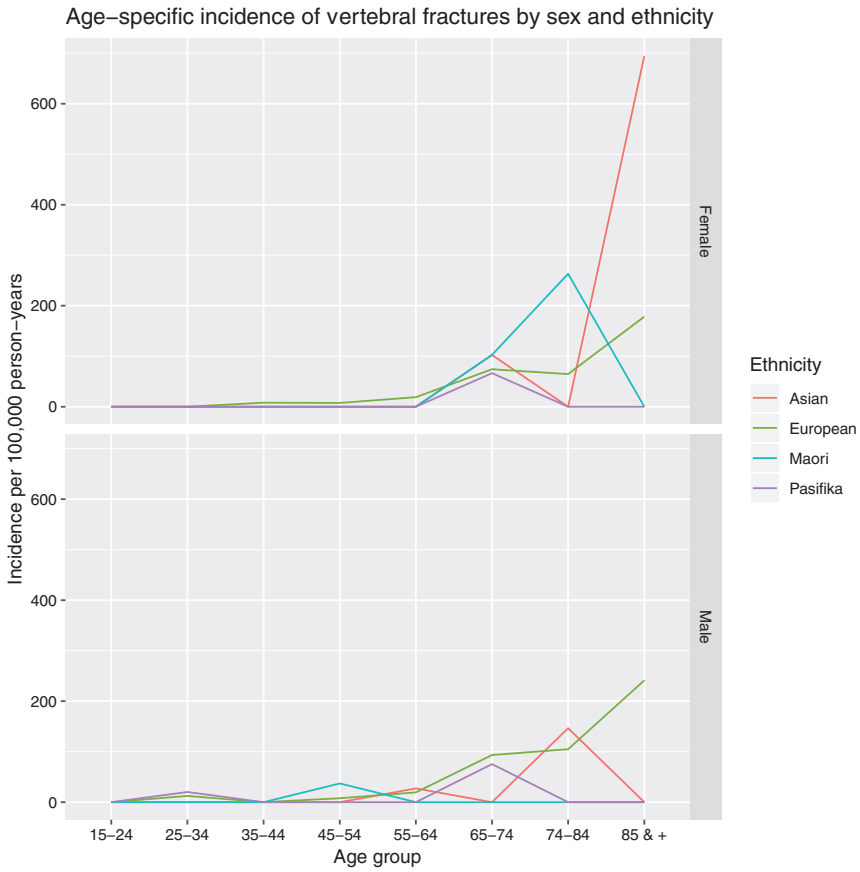

Fig. 1. Incidence of vertebral fractures.

[1.8,15.5]), with the largest gender difference in Pacific Islanders (RR 0.0, 95% CI 0.0,0.33]).

Discussion

This study has provided important new information regarding the prevalence and incidence of MRI findings associated with serious pathologies in people presenting with LBP. The prevalence of all target conditions has been determined in both private secondary and public tertiary care settings, as has incidence, in the geographic region of South Auckland, New Zealand.

Significant differences in the prevalence of serious pathologies were found between private and public health settings, with the overall prevalence of serious pathologies nearly five times higher than our public hospital care setting. Considering the seriousness of a missed or delayed diagnosis of a serious pathology, one in every 6.5 patients undergoing MRI in public health is higher than expected. Considering this, it may be warranted to either reduce the threshold for referral for MRI or improve access to MRI from primary care. At present patients may not be undergoing MRI during the early stages of disease onset due to limited access. MMH services the geographic region of South Auckland and has a large over-representation of people living in deprivation, compared with the national average [43]. This group have lower health literacy and are less likely to seek early medical attention. The South Auckland region has a larger population of Māori and Pacific Islanders than any other region in New Zealand, with the majority living in high deprivation areas [44,45]. Consequently, Māori have the highest rates of avoidable mortality, followed by Pacific Islanders [46]. These groups also have higher rates of comorbidities including diabetes and heart disease, which are often poorly managed and may increase risk of serious pathology [47–49]. Contrariwise, patients attending the private musculoskeletal practice (SRG) are likely to be in higher socioeconomic groups. SRG is located in Greenlane which is one of the highest decile (least deprived) areas in Auckland [43].

Differences between private and public health care prevalence may be partially due to the specialists' threshold for referral. Specialists working in public health care settings may be more likely to adhere to guidelines that recommend that only patients who have suspected serious pathology or neurological deficits and are potential candidates for

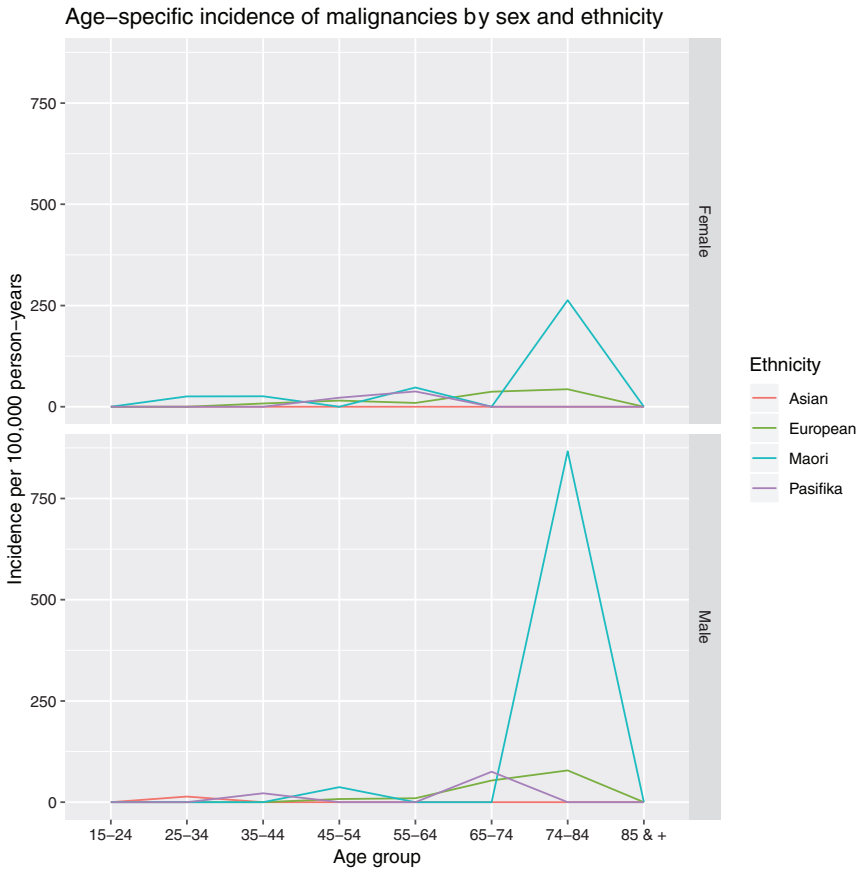

Fig. 2. Incidence of spinal malignancy.

invasive interventions should be referred for MRI [30]. Conversely, despite warnings regarding the potential adverse effects of referring patients for imaging unnecessarily, specialists working in private spine clinics have been shown to be less adherent to such guidelines and continue to refer patients who do not strictly meet these criteria [50,51]. Over-referral for diagnostic imaging may also be influenced by patient expectation, as patients attending private clinics often expect to undergo imaging as part of their management [52]. One study [53] found that only 25% of patients referred for advanced imaging met stated referral criteria. However, this finding could also indicate that the current guidelines are too strict and specialists may be referring patients who do not fit the criteria due to fear of missing a serious pathology [26]. Our study has shown that this fear may be justified and there could be rationale to review the current guidelines and allow improved access at a primary care level to reduce waiting times and encourage early diagnosis.

Education around screening for serious pathologies is useful to improve awareness of red flags and warning signs [9,32–34]. These pathologies are often misdiagnosed, with the majority of vertebral fractures and spinal infections being misdiagnosed initially or completely missed [22,23,54]. One study [55] found that 51% of patients presented to emergency departments two or more times before they were diagnosed with spinal infection, and delayed diagnosis led to a nearly four-fold increase in the likelihood of ongoing motor weakness. In our study the prevalence of spinal infection was low (0.1%) in private spine clinics, but significantly higher in the public hospital with one in every 30 patients referred for MRI having a spinal infection. Previous studies have shown low prevalence of spinal infection in primary care clinics, ranging from 0% amongst patients presenting to primary care clinics with LBP [2], to 0.05% –0.2% if they were referred for plain imaging [14,15], and up to 0.3% if they were referred for MRI by their GP [1]. Other authors have expressed concerns that due to the low prevalence in primary care and variable clinical presentation, spinal infection is difficult to recognize clinically, and more research is required to investigate whether the current guidelines for referral for advanced imaging are robust enough for spinal infection [22,23,56,57]. Our study found that males are more at risk of spinal infection, which is supported by previous studies reporting a predominance in males ranging from 58% to 91% of cases [58–62]. Although risk of infection increased with age, there was a peak at 25–34 years in Māori and Pacific Island males. This could be associated with increased risk-taking

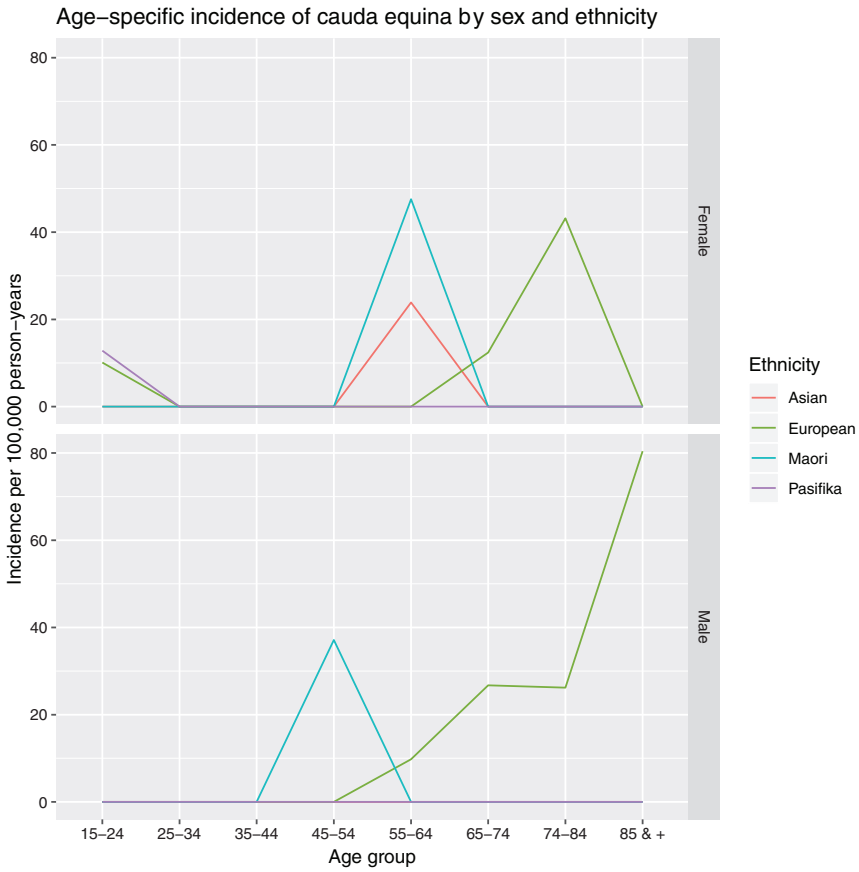

Fig. 3. Incidence of cauda equina compression.

behavior such as IV drug use in this group [63]. The overall incidence of spinal infection in this study was 6.6 per 100,000 p-y, which is higher than reported rates for vertebral osteomyelitis or pyogenic spondylodiscitis in Europe [62,64–66].

Vertebral fracture is relatively common with a prevalence of vertebral fracture internationally is 2.2%–2.6% in secondary care [1,19] and 6.5%–7.2% in tertiary care [18,20]. A‘‘s expected, our study found that the incidence of fracture increased with older age, and interestingly, all fractures in the under 35-year-old age group were male and were traumatic, which may reflect the commonly held belief that young males have increased risk-taking behavior and involvement in adventure sport. With respect to gender, other studies [67] have found that fracture risk is higher in females, however our study did not find any overall difference between gender.

The prevalence of spinal malignancy has been reported to be low (0%–0.7%) amongst LBP patients presenting to primary care [2,12,15,16,68], and up to 5.9% in a tertiary care spine clinic in America [21]. Our public tertiary care prevalence was slightly lower at 4.4%, but still a significantly possibility. The risk of spinal malignancy is known to increase with age and our study found an 18-fold increase in risk from age 25–34 to age 74–84 (see Fig. 2). Māori had a significantly higher risk of spinal malignancy than any other ethnic group. This finding that spinal malignancy was more common in Māori is supported by previous research displaying significantly higher rates of lung cancer mortality and cancer registrations in Māori compared with non-Māori [47]. With the significant increase in risk within this group, a lower threshold for further investigation may be warranted.

CES is known to display varied clinical presentations making it extremely difficult to diagnose without advanced imaging. Missed or delayed diagnosis of CES is likely to result in irreversible neurological damage, reduced quality of life, and huge compensation costs [69]. CES is known to account for 1%–10% of all surgical discectomies [70–74], and in England, the National Health Service spent 25 million Pounds on claims made by individuals with CES between 2010 and 2015 [69]. Clinical guidelines have reinforced that if early signs or symptoms of CES are suspected (ie, back pain and/or sciatica plus the onset of bilateral leg pain, and/or disturbance in bladder or bowel function, and/or saddle or genital sensory disturbance) the patient must be referred for an MRI urgently, even overnight [9]. Hence, improved access at a primary care level would increase the

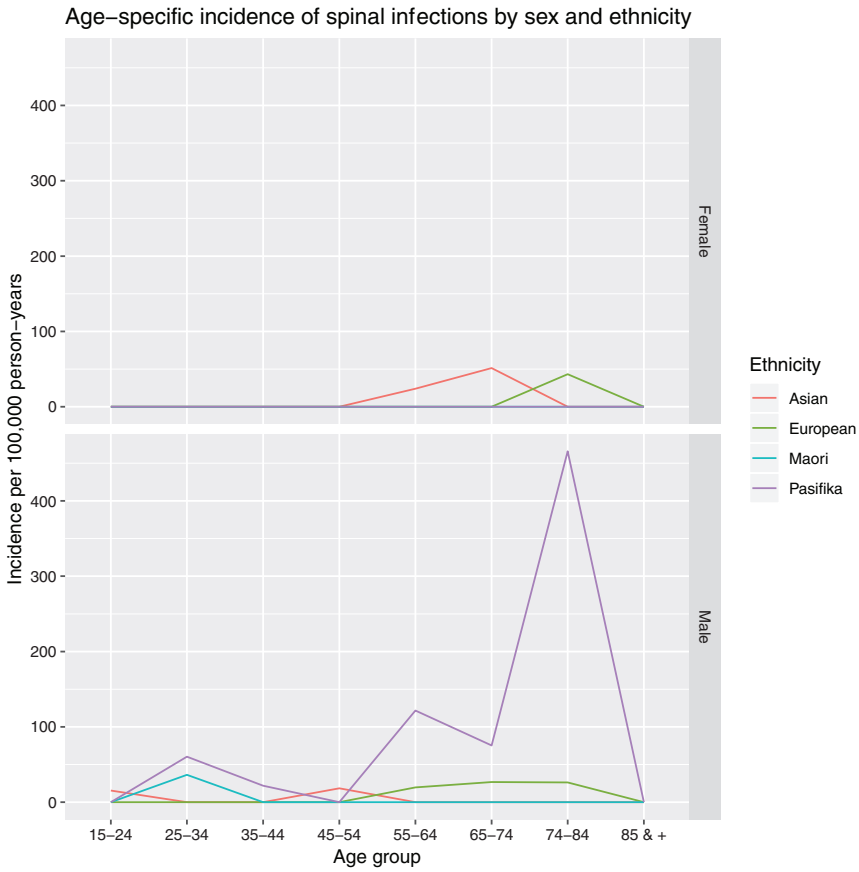

Fig. 4. Incidence of spinal infections.

likelihood of this occurring. In our study one in every 43 (2.3%) patients undergoing MRI in the public hospital had MRI evidence of cauda equina compression, a rate significantly higher than the 0.6% observed in private spine clinics. Only one previous study investigated the prevalence of CES amongst LBP patients in primary care and found a lower prevalence of 0.1% [2]. Our study found that older Europeans had the highest risk of CEC, with peak ages higher than expected. It is known that CES most commonly occurs following a massive disc prolapse, and disc prolapse usually occurs between 30 and 50 years of age [75]. Hence, our findings may indicate reduce tolerance to large disc prolapses with the presence of age related changes such as spondylosis, facet joint arthrosis, or stenosis [40].

Limitations

A potential limitation is that the incidence may be underestimated for fractures. Fractures are commonly identified via plain radiographs or computed tomography. Hence, some patients with previously observed spinal fractures may not have been referred for MRI and would therefore not have been included in our study. However, our study prevalence was similar to other studies that used plain radiographs as their reference standard. The majority of patients with a new diagnosis of malignancy, CEC or infection should have been included in this study as it is standard practice that they would be referred for MRI. Nevertheless, there may be a small number of patients who were unable to undergo MRI due to contraindications.

Conclusions

Knowledge of the prevalence and incidence of serious pathologies is important for clinicians working with patients with LBP to be aware of as it dictates the pretest probability of the presence of a pathology. Our study has found large differences in the prevalence of serious pathologies between private and public health care settings. The high prevalence in the public hospital raises a question of whether access to MRI is too limited and whether referral criteria should be reviewed. Further research is required to investigate the diagnostic accuracy of red flag questions to assist with early diagnosis and to ensure the right patients are referred for MRI at the right time, and that this resource is sustainable.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.spinee.2019.09.002.

References

[1] de Schepper EI, Koes BW, Veldhuizen EF, Oei EH, Bierma-Zeinstra SM, Luijsterburg PA. Prevalence of spinal pathology in patients presenting for lumbar MRI as referred from general practice. Fam Pract 2016;33(1):51–6. https://doi.org/10.1093/fampra/cmv097.

[2] Henschke N, Maher CG, Refshauge KM, Herbert RD, Cumming RG, Bleasel J, et al. Prevalence of and screening for serious spinal pathology in patients presenting to primary care settings with acute low back pain. Arthritis Rheum 2009;60(10):3072–80. https://doi.org/10.1002/art.24853.

[3] Deyo RA, Rainville J, Kent DL. What can the history and physical examination tell us about low back pain? J Am Med Assoc 1992;268(6):760–5. https://doi.org/10.1001/jama.268.6.760.

[4] Cook C, Hegedus E. Orthopedic physical examination tests: An evidence-based approach. 2nd ed. Upper Saddle River, NJ: Pearson; 2012.

[5] Edmond SL, Kiel DP, Samelson EJ, Kelly-Hayes M, Felson DT. Vertebral deformity, back symptoms, and functional limitations among older women: The Framingham Study. Osteoporos Int 2005;16(9):1086–95. https://doi.org/10.1007/s00198-004-1815-y.

[6] Fletcher R, Fletcher S, Fletcher G. Clinical epidemiology: The essentials. 5th ed. Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins; 2014.

[7] Koes BW, van Tulder M, Lin CW, Macedo LG, McAuley J, Maher C. An updated overview of clinical guidelines for the management of non-specific low back pain in primary care. Eur Spine J 2010;19(12):2075–94.

[8] Chou R, Qaseem A, Snow V, Casey D, Cross TJ Jr., Shekelle P, et al. Diagnosis and treatment of low back pain: a joint clinical practice guideline from the American College of Physicians and the American Pain Society. Ann Intern Med 2007;147(7):478-91.

[9] National Institute for Health and Care Excellence. Low back pain in adults: Early management [NICE guidelines CG88] 2016. Available at: www.nice.org.uk/guidance/CG88/chapter/introduction.

[10] Van Tulder M, Becker A, Bekkering T, Breen A, Del Real MTG, Hutchinson A, et al. Chapter 3: European guidelines for the management of acute nonspecific low back pain in primary care. Eur Spine J 2006;15(SUPPL. 2):S169–S91. https://doi.org/10.1007/s00586-006-1071-2.

[11] Accident Compensation Corporation. New Zealand acute low back pain guide. Wellington: New Zealand: Author; 1999.

[12] Donner-Banzhoff N, Roth T, Sönnichsen AC, Luckmann J, Leonhardt C, Chenot JF, et al. Evaluating the accuracy of a simple heuristic to identify serious causes of low back pain. Fam Pract 2006;23(6):682–6. https://doi.org/10.1093/fampra/cml049.

[13] Jacobson AF. Musculoskeletal pain as an indicator of occult malignancy: yield of bone scintigraphy. Arch Intern Med 1997;157(1):105–9.

[14] Khoo LAL, Heron C, Patel U, Given-Wilson R, Grundy A, Khaw KT, et al. The diagnostic contribution of the frontal lumbar spine radiograph in community referred low back pain – A prospective study of 1030 patients. Clin Radiol 2003;58(8):606–9. https://doi.org/10.1016/s0009-9260(03)00173-9.

[15] van den Bosch MAAJ, Hollingworth W, Kinmonth AL, Dixon AK. Evidence against the use of lumbar spine radiography for low back pain. Clin Radiol 2004;59(1):69–76. https://doi.org/10.1016/j.crad.2003.08.012.

[16] Deyo RA, Diehl AK. Lumbar spine films in primary care – Current use and effects of selective ordering criteria. J Gen Intern Med 1986;1(1):20–5. https://doi.org/10.1007/bf02596320.

[17] Deyo RA, Diehl AK. Cancer as a cause of back pain: frequency, clinical presentation, and diagnostic strategies. J Gen Intern Med 1988;3(3):230–8.

[18] Patrick JD, Doris PE, Mills ML, Friedman J, Johnston C. Lumbar spine x-rays: a multihospital study. Ann Emerg Med 1983;12(2):84–7. https://doi.org/10.1016/S0196-0644(83)80378-3.

[19] Roman M, Brown C, Richardson W, Isaacs R, Howes C, Cook C. The development of a clinical decision making algorithm for detection of osteoporotic vertebral compression fracture or wedge deformity. J Man Manip Ther 2010;18(1):44–9. https://doi.org/10.1179/106698110x12595770849641.

[20] Gibson M, Zoltie N. Radiography for back pain presenting to accident and emergency departments. Arch Emerg Med 1992;9(1):28–31.

[21] Cook C, Ross MD, Isaacs R, Hegedus E. Investigation of nonmechanical findings during spinal movement screening for identifying and/or ruling out metastatic cancer. Pain Pract 2012;12(6):426–33. https://doi.org/10.1111/j.1533-2500.2011.00519.x.

[22] Darouiche RO. Spinal epidural abscess. N Engl J Med 2006;355(19):2012–20. https://doi.org/10.1056/NEJMra055111.

[23] Patel AR, Alton TB, Bransford RJ, Lee MJ, Bellabarba CB, Chapman JR. Spinal epidural abscesses: risk factors, medical versus surgical management, a retrospective review of 128 cases. Spine J 2014;14(2):326–30. https://doi.org/10.1016/j.spinee.2013.10.046.

[24] Chou R, Qaseem A, Snow V, Casey D, Cross TJ Jr., Shekelle P, et al. Diagnosis and treatment of low back pain: a joint clinical practice guideline from the American College of Physicians and the American Pain Society. Ann Intern Med 2007;147(7):478-91.

[25] Williams CM, Maher CG, Hancock MJ, et al. Low back pain and best practice care a survey of general practice physicians. Arch Intern Med 2010;170(3):271–7. https://doi.org/10.1001/archinternmed.2009.507.

[26] Deyo RA, Mirza SK. The case for restraint in spinal surgery: does quality management have a role to play? Eur Spine J 2009;18(SUPPL. 3):S331–S7. https://doi.org/10.1007/s00586-009-0908-x.

[27] Oikarinen H, Karttunen A, Pääkkö E, Tervonen O. Survey of inappropriate use of magnetic resonance imaging. Insights Imaging 2013;4(5):729–33. https://doi.org/10.1007/s13244-013-0276-2.

[28] Perez FA, Jarvik JG. Evidence-Based Imaging and Effective Utilization. Lessons in Neuroradiology. Neuroimaging Clin N Am 2012;22(3):467–76. https://doi.org/10.1016/j.nic.2012.05.002.

[29] Dagenais S, Galloway EK, Roffey DM. A systematic review of diagnostic imaging use for low back pain in the United States. Spine J 2014;14(6):1036–48. https://doi.org/10.1016/j.spinee.2013.10.031.

[30] Chou R, Deyo RA, Jarvik JG. Appropriate use of lumbar imaging for evaluation of low back pain. Radiol Clin North Am 2012;50(4):569–85. https://doi.org/10.1016/j.rcl.2012.04.005.

[31] Emery DJ, Shojania KG, Forster AJ, Mojaverian N, Feasby TE. Overuse of magnetic resonance imaging. JAMA Intern Med 2013;173(9):823–5. https://doi.org/10.1001/jamainternmed.2013.3804.

[32] Deyo RA, Jarvik JG, Chou R. Low back pain in primary care. BMJ (Online) 2014;349. https://doi.org/10.1136/bmj.g4266.

[33] Henschke N, Maher CG, Ostelo RW, de Vet HC, Macaskill P, Irwig L. Red flags to screen for malignancy in patients with low-back pain. Cochrane Database Syst Rev 2013;2.

[34] Williams CM, Henschke N, Maher CG, van Tulder MW, Koes BW, Macaskill P, et al. Red flags to screen for vertebral fracture in patients presenting with low-back pain. Cochrane Database Syst Rev 2013;1.

[35] Jarvik JG, Deyo RA. Diagnostic evaluation of low back pain with emphasis on imaging. Ann Intern Med 2002;137(7) Available at: http://www.annals.org/.

[36] Panda P, Das CJ, Baruah U. Imaging of vertebral fractures. Indian J Endocrinol Metab 2014;18(3):295–303. Available at: https://doi.org/10.4103/2230-8210.131140.

[37] von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. J Clin Epidemiol 2008;61(4):344–9. https://doi.org/10.1016/j.jclinepi.2007.11.008.
[38] Joines JD, McNutt RA, Carey TS, Deyo RA, Rouhani R. Finding cancer in primary care outpatients with low back pain a comparison of diagnostic strategies. J Gen Intern Med 2001;16(1):14–23. https://doi.org/10.1046/j.1525-1497.2001.00249.x.
[39] Kosuda S, Kaji T, Yokoyama H, et al. Does bone SPECT actually have lower sensitivity for detecting vertebral metastasis than MRI? J Nucl Med 1996;37(6). Available at: http://jnm.snmjournals.org.
[40] Martin DO, Austin H. Exact estimates for a rate ratio. Epidemiology (Cambridge, Mass) 1996;7(1):29–33.
[41] Zealand SN. Census district health board tables. 2014.
[42] Clopper C, Pearson ES. The use of confidence or fiducial limits illustrated in the case of the bionomial. Biometrika 1934;26(4):404–13. https://doi.org/10.1093/biomet/26.4.404.
[43] Ministry of Health. Cancer: New registrations and deaths. Available at: http://www.health.govt.nz/system/files/documents/publications/cancer-new-registrations-deaths-2010-aug13-v2.pdf.
[44] Health Mo. Independent life expectancy in New Zealand 2013. Wellington: Ministry of Health; 2015. Available at: https://www.health.govt.nz/system/files/documents/publications/independent-life-expectancy-new-zealand-2013-jul15-v2.pdf.
[45] Group HPC. Metro-Auckland Pacific population health profile: Tomorrow's health today. Available at: www.health.govt.nz/system/files/documents/publications/metro-auckland-pacific-population-health-profile-april2103.pdf. Accessed April 10, 2016.
[46] Powell E, Wolfgramm T. Pacific Health Development: Annual Plan 2013/14. Available at: www.countiesmanukau.health.nz/assets/About-CMH/Reports-and-planning/Maori-and-pacific-health/2013-2015-Pacific-health-development-annual-plan.pdf. Accessed April 10, 2016.
[47] Borman B. Health Needs Assessment Counties Manukau District Health Board. Wellington: Ministry of Health; n.d. Available at: https://www.health.govt.nz/system/files/documents/pages/hna-counties-manukau-dhb.pdf.
[48] Coussens LM, Werb Z. Inflammation and cancer. Nature 2002;420(6917):860–7. Available at: https://doi.org/10.1038/nature01322.
[49] Sciubba DM, Gokaslan ZL. Diagnosis and management of metastatic spine disease. Surg Oncol 2006;15(3):141–51. Available at: https://doi.org/10.1016/j.suronc.2006.11.002.
[50] Carey TS, Garrett J. Patterns of ordering diagnostic tests for patients with acute low back Pain. Ann Intern Med 1996;125(10):807–14.
[51] Lurie JD, Birkmeyer NJ, Weinstein JN. Rates of advanced spinal imaging and spine surgery. Spine (Phila Pa 1976) 2003;28(6):616–20. Available at: https://doi.org/10.1097/00007632-200303150-00018.
[52] Verbeek J, Sengers MJ, Riemens L, Haafkens J. Patient expectations of treatment for back pain: a systematic review of qualitative and quantitative studies. Spine (Phila Pa 1976) 2004;29(20):2309–18. Available at: https://doi.org/10.1097/01.brs.0000142007.38256.7f.
[53] Boden SD, Swanson AL. An assessment of the early management of spine problems and appropriateness of diagnostic imaging utilization. Phys Med Rehabil Clin N Am 1998;9(2):411–7.
[54] Grigoryan M, Guermazi A, Roemer FW, Delmas PD, Genant HK. Recognizing and reporting osteoporotic vertebral fractures. Eur Spine J 2003;12(SUPPL. 2):S104–S12. https://doi.org/10.1007/s00586-003-0613-0.
[55] Davis DP, Wold RM, Patel RJ, Tran AJ, Tokhi RN, Chan TC, et al. The clinical presentation and impact of diagnostic delays on emergency department patients with spinal epidural abscess. J Emerg Med 2004;26(3):285–91.
[56] World Health Organisation. Antimicrobial resistance; Global report on surveillance. World Health Organisation; 2014. Available at: http://www.who.int/drugresistance/documents/surveillancereport/en/.
[57] Rees N. 'A pain in the back': psoas abscess and the importance of red and yellow flags. J Paramed Pract 2013;5(1):11–4. 4p.
[58] Nagashima H, Yamane K, Nishi T, Nanjo Y, Teshima R. Recent trends in spinal infections: retrospective analysis of patients treated during the past 50 years. Int Orthop 2010;34(3):395–9. 5p. .https://doi.org/10.1007/s00264-009-0741-1.
[59] Beronius M, Bergman B, Andersson R. Vertebral osteomyelitis in Göteborg, Sweden: a retrospective study of patients during 1990-95. Scand J Infect Dis 2001;33(7):527–32. https://doi.org/10.1080/00365540110026566.
[60] Friedman JA, Maher CO, Quast LM, McClelland RL, Ebersold MJ. Spontaneous disc space infections in adults. Surg Neurol 2002;57(2):81–6. https://doi.org/10.1016/S0090-3019(01)00681-4.
[61] Kemp HBS, Jackson JW, Jeremiah JD, Hall AJ. Pyogenic infections occurring primarily in intervertebral discs. J Bone Joint Surg Series B 1973;55(4):698–714.
[62] Lora-Tamayo J, Euba G, Narváez JA, et al. Changing trends in the epidemiology of pyogenic vertebral osteomyelitis: the impact of cases with no microbiologic diagnosis. Semin Arthritis Rheum 2011;41(2):247–55. https://doi.org/10.1016/j.semarthrit.2011.04.002.
[63] Guglielmi G, De Serio A, Leone A, Agrosì L, Cammisa M. Combined imaging in spondylodiscitis. Rays 2000;25(1):75–88.
[64] Krogsgaard MR, Wagn P, Bengtsson J. Epidemiology of acute vertebral osteomyelitis in Denmark. Acta Orthop Scand 1998;69(5):513–7.
[65] Grammatico L, Baron S, Rusch E, Lepage B, Surer N, Desenclos JC, et al. Epidemiology of vertebral osteomyelitis (VO) in France: analysis of hospital-discharge data 2002-2003. Epidemiol Infect 2008;136(5):653–60. 8p.
[66] Kehrer M, Pedersen C, Jensen TG, Lassen AT. Increasing incidence of pyogenic spondylodiscitis: a 14-year population-based study. J Infect 2014;68(4):313–20. https://doi.org/10.1016/j.jinf.2013.11.011.
[67] Henschke N, Maher CG, Refshauge KM. A systematic review identifies five "red flags" to screen for vertebral fracture in patients with low back pain. J Clin Epidemiol 2008;61(2):110–8. Available at: https://doi.org/10.1016/j.jclinepi.2007.04.013.
[68] Deyo RA, Diehl AK. Cancer as a cause of back pain: Frequency, clinical presentation, and diagnostic strategies. J Gen Intern Med 1988;3(3) Available at: http://www.springer.com/medicine/internal/journal/11606.
[69] Authority NL. Cauda Equina Syndrome. Available at: www.nhsla.nhs.uk. Accessed January 20, 2019.
[70] Choudhury AR, Taylor JC. Cauda equina syndrome in lumbar disc disease. Acta Orthop Scand 1980;51(3):493–9.
[71] Jennett WB. A study of 25 cases of compression of the cauda equina by prolapsed intervertebral discs. J Neurol Neurosurg Psychiatry 1956;19(2):109–16.
[72] Kostuik JP, Harrington I, Alexander D. Cauda equina syndrome and lumbar disc herniation. J Bone Joint Surg Series A 1986;68(3):386–91.
[73] Robinson RG. Massive protrusions of lumbar disks. Br J Surg 1965;52(11):858–65.
[74] Shephard RH. Diagnosis and prognosis of cauda equina syndrome produced by protrusion of lumbar disk. Br Med J 1959;2(5164):1434–9.
[75] Dunsmuir R. (iii) Prolapsed intervertebral discs. Curr Orthop 2004;18(6):434–40. Available at: https://doi.org/10.1016/j.cuor.2005.01.006.