

Low Back Pain in the Emergency Department: Prevalence of Serious Spinal Pathologies and Diagnostic Accuracy of Red Flags – A Systematic Review

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Abstract

Background: Very little evidence is available on the prevalence of serious spinal pathologies and the diagnostic accuracy of red flags in patients presenting to the emergency department (ED). This systematic review aims to investigate the prevalence of serious spinal pathologies and the diagnostic accuracy of red flags in patients presenting with low back pain to the ED.

Methods: We systematically searched MEDLINE, PUBMED, EMBASE, Cochrane Library, and SCOPUS from inception to January 2019. Two reviewers independently reviewed the references and evaluated methodological quality.

Results: We analyzed 22 studies with a total of 41'320 patients. The prevalence of any serious spinal pathology requiring immediate/urgent treatment was 2.5–5.1% in prospective and 0.7–7.4% in retrospective studies (0.0–7.2% for vertebral fractures, 0.0–2.1% for spinal cancer, 0.0–1.9% for infectious disorders, 0.1–1.9% for pathologies with spinal cord/cauda equina compression, 0.0–0.9% for vascular pathologies). Examples of red flags which increased the likelihood for a serious condition were: suspicion and/or history of cancer (spinal cancer); intravenous drug use, indwelling vascular catheter, other infection site (epidural abscess).

Conclusion: We found a higher prevalence of serious spinal pathologies in the ED compared to the reported prevalence in primary care settings. As the diagnostic accuracy of most red flags was reported only by a single study, further validation in high quality prospective studies is needed.

Introduction

Low back pain is one of the leading complaints in U.S. emergency departments (ED),^{1,2} accounting for 4.4% of all ED visits between 2000 and 2016.^{1,2} The primary goal is to detect a serious pathology that requires urgent treatment.³ In the primary care setting, the prevalence of serious pathologies was found to be less than one percent.⁴ The prevalence in the ED setting is unclear and it is reasonable to assume it to be higher compared to the primary care setting.⁵

Red flags are signs/symptoms that help to identify patients at risk for a serious underlying disease.⁶ However, there is no consensus on which red flags should be screened for: 16 guidelines recommended 46 different red flags.⁶ For example, to identify underlying malignancy, 14 different red flags were suggested and only two red flags were included in all guidelines.⁶ Further, the predictive utility of red flags is unclear. According to two systematic reviews, the only helpful red flag in the primary care setting to detect spinal cancer was a history of cancer,⁷ and the only relevant red flags to detect vertebral fractures were older age, prolonged steroid use, contusion/abrasion, and a history of trauma.⁸

The aim of this systematic review was to summarize the evidence on the prevalence of serious spinal pathologies in patients with low back pain presenting to the ED. We hypothesized that serious conditions are more prevalent in ED compared to primary care settings. Further, we aimed to assess the diagnostic accuracy of red flags to identify patients with a serious spinal pathology in the ED setting.

Methods

Study design

We conducted a systematic review following the recommendation of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).⁹ The development process of the study protocol was described previously.¹⁰

Literature search

We searched the following databases from the inception until January 12, 2019: Medline (Ovid), Embase (Elsevier), Pubmed, Cochrane Library, and Scopus (Elsevier). The search was developed with the help of an experienced librarian (**Appendix 1**). No language restrictions were applied. Further, we screened the reference lists of all included studies and the relevant literature on the topic for potentially eligible references.

Eligibility criteria

We included studies with adult patients presenting with low back pain to an ED that evaluated the prevalence of serious spinal pathologies and/or assessed the diagnostic accuracy of red flags for serious spinal pathologies. We excluded studies with patients aged under 18 years, pregnant women, studies on spine pathologies after high-impact traumatic injuries, and studies in non-clinical settings.

Study selection and data extraction

Two reviewers (GG and DS) independently screened the title and abstract of all references identified by the search strategy and then reviewed the full texts of all potentially relevant references independently. Disagreements between the reviewers were discussed and resolved by consensus. No third-party arbitration was necessary. DS extracted all relevant information in a predefined spreadsheet and a GG confirmed the data. We extracted data on

study specific information, spinal pathologies and patient characteristics (**Appendix 2**). We contacted the author if insufficient details were provided.

Outcome

The primary outcomes were the prevalence of a serious spinal pathology and the accuracy of red flags in patients presenting with low back pain to the ED. As there is no established standard definition for serious spinal pathologies, we assigned each study to four predefined categories: immediate (spinal or paraspinal pathology requiring surgical or non-conservative medical intervention within 48 hours), urgent (surgical or non-conservative medical intervention required within 30 days), non-urgent (conservative treatment or non-urgent surgical intervention), and not specified (no information on the urgency of the condition or treatment available).

Quality assessment

Two reviewers (GG and DS) independently assessed the study quality using a modified checklist of the STROBE statement¹¹ (for prevalence studies) and the Scottish Intercollegiate Guidelines Network (SIGN) Methodology checklist (for diagnostic accuracy studies).¹² Items were rated as met, not met, or unclear. Disagreement between the reviewers were discussed and solved by consensus or by third-party arbitration (MW).

The modified STROBE checklist included 21 items on quality of introduction, methods, results, discussion and funding. The SIGN checklist assessed the risk of bias and the applicability. We classified studies as high quality, acceptable and unacceptable using predefined rules (**Appendix 3**).

Data synthesis and statistical analyses

We reported descriptive statistics with mean and standard deviation (SD) or median and

interquartile range (IQR) for continuous variables, frequencies and percentages for categorical variables. We calculated sensitivity, specificity, positive/negative predictive values (PPV/NPV), and positive/negative likelihood ratio (LR+/LR-).¹³ In case of zero-frequency cells, which prevented us from performing all calculations, 0.5 was added to all cells. The diagnostic accuracy was categorized into: very good (LR+ >10, LR- <0.1); good (LR+ 5–10, LR- 0.1–0.2); fair (LR+ 2–5, LR- 0.2–0.5); or poor (LR+ 1–2, LR- 0.5–1).¹⁴ The confidence intervals (95% CI) of the prevalence, LR+/LR-, and posterior probabilities were computed in R (v3.5.1, R Core Team 2018),¹⁵ using Pearson-Clopper's exact binomial method,¹⁶ Simel's asymptotically normal method,¹⁷ and the objective Bayesian method in 10,000 samples,¹⁸ respectively.

Results

Study selection

Out of 2290 references (**Figure 1**), 208 records were read in full text and 22 studies were included (21 assessed the prevalence, 10 the diagnostic accuracy of red flags).

Study characteristics

Three studies (13.6%, **Table 1**) used a prospective observational, three studies (13.6%) a cross-sectional, and 15 studies (68.2%) a retrospective design (1 case-control study, 14 chart reviews). One study used mixed methods (retrospective chart review followed by a cross-sectional study).¹⁹ The aggregate number of patients included in the reviewed studies was 41,320.

The study quality was acceptable in 12 studies that assessed the prevalence (100%, **Appendix 4**). In studies assessing the diagnostic accuracy of red flags, risk of bias was low in two studies (20%, **Appendix 5**) and acceptable in eight studies (80%). No study had a high risk of bias. One study²⁰ (10%) was considered *directly applicable*, whereas nine studies (90%) were considered *indirectly applicable*.

Prevalence of serious spinal pathologies

Whereas the overall prevalence of any serious spinal pathology requiring immediate/urgent treatment varied substantially (range 0.7–15.5%, **Table 2** and **Appendix 6 and 7**), the prevalence in prospective observational studies was 2.5–5.1% (two studies)^{5, 21} and in cross-sectional studies 3.1–4.5% (three studies).^{19, 22, 23} The prevalence was higher in two studies: 15.3% in a study²⁴ including low back pain patients with a neurological deficit who underwent MRI for exclusion of a cauda equina syndrome, and 15.5% in another study²⁵ including patients with low back pain who warranted a referral to the orthopedic team.

Prevalence of specific spinal pathologies

The prevalence of a cauda equina syndrome or radiculopathy with weakness was 1.9% in one prospective observational study.⁵ In retrospective studies, a cauda equina syndrome was found in 0.3–0.5%,^{26,27} and in patients with neurological deficits in 1.7%.²⁴ One retrospective study reported a higher prevalence of spinal cord/cauda equina compression (15.5%) in patients referred to an orthopedic team because of neurological symptoms.²⁵

Retrospective studies reported a herniated disc requiring immediate treatment in 0.1%,²⁸ a herniated disc requiring urgent treatment in 1.2%,²⁶ and a spinal stenosis requiring urgent treatment in 0.3%.²⁶ In patients with neurological deficits, the prevalence of a severe spinal canal stenosis was higher (11%).²⁴

Underlying infectious disease was found in $\leq 1.9\%$. The prevalence of epidural abscess ranged from 0.0–1.0% (six studies).^{5, 20, 21 26, 29, 30} Other infectious diseases included spondylodiscitis in 0.1–1.9% (three retrospective studies)²⁷⁻²⁹ and osteomyelitis in 0.0–0.9% (two retrospective studies).^{26, 31}

The prevalence of vertebral fracture requiring immediate or urgent treatment was 0.0–1.5% in two prospective observational studies,^{5, 21} 2.1–4.2% in three cross-sectional studies,^{19, 22, 23} and 0.3–7.2% in five retrospective studies.^{19, 24, 31-33}

The prevalence of spinal cancer ranged from 0.0–2.1%.^{5, 21 19, 23 19, 26-29, 31, 33} Other pathologies included aortic rupture (0.6%, one prospective observational study;⁵ 0.0%, one retrospective study),²⁶ acute aortic dissection (0.0%, one retrospective study),³⁴ and retroperitoneal bleeding (0.9%, one retrospective study).²⁶

Diagnostic accuracy of red flags for serious spinal pathologies

Overall, we analyzed the diagnostic accuracy of 84 red flags for 12 serious spinal pathologies based on 10 studies (**Appendix 8**). Red flags showing a good or very good LR+ (LR+; 95% CI) for the diagnosis of any serious outcome (**Figure 2**) were current anticoagulants

use (8.7; 3.1–24.4),²⁶ new urinary retention (7.0; 1.9–26.0),²⁶ bladder/suprapubic fullness in physical examination (40.2; 1.6–979.1),²⁶ hemoglobin <100 g/L (14.0; 2.1–94.4),²⁶ hemoglobin <110 g/L (11.2; 3.2–38.6),²⁶ disturbance of saddle sensation in physical examination (7.0; 1.4–36.0),²⁶ and INR ≥ 1 (6.1; 2.8–13.3).²⁶ No red flag showed at least a good LR- against the diagnosis of any serious outcome.

No red flags with at least a good LR+/LR- were found for a compression of the spinal cord/cauda equina, and severe spinal canal stenosis.

For the diagnosis of epidural abscess (**Figure 3**), a good or very good LR+ was found for intravenous drug use (13.7; 11.4–16.5),²⁰ recent spine fracture (9.5; 5.0–17.8),²⁰ immunocompromised patient (5.1; 3.2–8.0),²⁰ indwelling vascular catheter (15.7; 7.9–31.0),²⁰ other infection site (13.7; 9.4–19.8),²⁰ the classic triad “fever $\geq 38^{\circ}\text{C}$, spine pain, and neurological deficit” (9.9; 1.2–82.2, and 5.7; 1.4–23.2),^{20,35} and systolic blood pressure <90mmHg (9.0; 3.9–20.7).²⁰ A good or very good LR- against an epidural abscess were no risk factor (0.00; 0.0–0.0 and 0.03; 0.0–0.1)^{20, 35} and in case of one or more risk factors a normal erythrocyte sedimentation rate (ESR; 0.00, 0.0–0.0).²⁰

For the diagnosis of a vertebral fracture, a good or very good LR+ was found for a history of trauma with neurological findings (31.1; 5.1–190.2),²² and contusion/abrasion (5.5; 2.2–13.5).³³ The LR- of a history of trauma ranged from very good (0.00; 0.0–0.0)²² to fair (0.4; 0.2–0.7)³³ to poor in a study including minor trauma (0.9; 0.6–1.6).²³

For the diagnosis of cancer, a good or very good LR+ was found for a history of cancer (5.9; 1.9–17.7).²⁷ The combination of a history of cancer and/or the clinical suspicion of cancer resulted in a higher LR+ (27.9; 17.5–44.6).²³ Abnormal neurological findings were associated with a good LR+ (6.0; 2.4–14.9) in one study.²³ Helpful to rule out cancer was no history of cancer and no clinical suspicion of cancer (0.00; 0.0–0.0).²³

Discussion

This systematic review showed a higher prevalence of serious spinal pathologies in patients with low back pain presenting to the ED compared to the prevalence in primary care settings that was reported to be < 1%.⁴ A multicenter cohort study conducted in primary care in Australia, reported that less than 1% of the patients presenting with low back pain to their general practitioner were diagnosed with a serious spinal pathology over a follow-up of 12 months.⁴ The main pathology identified in the primary care setting were vertebral fractures. In our review, the prevalence of serious spinal pathologies requiring immediate or urgent treatment was 2.5–5.1% in prospective and 0.7–7.4% in retrospective studies. The most prevalent conditions were vertebral fractures (0.0–4.2%, in retrospective studies up to 7.2%), cancer (0.5–2.1%), infectious disorders (0.0–0.6%, in retrospective studies up to 1.9%), pathologies with spinal cord/cauda equina compression (1.9%), and vascular pathologies (0.0–0.9%).

Overall, 84 potential red flags for the diagnosis of 12 serious spinal pathologies were investigated. However, almost no red flag was assessed in more than one study. Red flags with a very good diagnostic accuracy (LR+ >10) were *suspicion and/or history of cancer* (for spinal cancer); *intravenous drug use, indwelling vascular catheter, other infection site* (for epidural abscess); *bladder/suprapubic fullness in physical examination, anemia* (for any serious outcome); and *history of trauma plus positive neurological signs* (for vertebral fracture). An epidural abscess was unlikely (LR- <0.1) if the erythrocyte sedimentation rate was normal or in patients with elevated erythrocyte sedimentation rate with no risk factor. Spinal cancer was unlikely if no suspicion and/or no history of cancer was present.

Results in light of existing literature

The choosing wisely initiative of the Canadian Association of Emergency Physicians³⁶ recommends avoiding lumbosacral spinal imaging in patients with non-traumatic low back pain who have no red flags. However, a systematic review of 16 guidelines from different countries

found a wide variety of red flags.⁶ Further, many red flags recommended by clinical guidelines are either not investigated in the ED setting or showed a poor to fair diagnostic accuracy. For example, guidelines from seven different countries recommend the red flags *disturbance of urinary and/or bowel sphincters* and *disturbance of saddle sensation* for the diagnosis of a cauda equine syndrome.⁶ However, the only study that investigated these red flags in the ED setting found a fair diagnostic accuracy (urinary and/or bowel sphincters LR+ 2.1, disturbance of saddle sensation LR+ 3.1).²⁵ One guideline suggested the use of *progressive weakness in lower limbs* to identify patients with a serious spinal pathology.³⁷ We found in three different studies poor diagnostic accuracies of a lower extremity weakness for any serious outcome, vertebral fracture, severe spinal canal stenosis, nerve root impingement, and an intraspinal mass.^{24, 26, 33} Furthermore, in studies that assessed some red flags (e.g. prolonged corticosteroids use, immunosuppressive medications/immunodeficiency) the very low prevalence of serious spinal pathologies (i.e. zero events) resulted in poor likelihood ratios.²⁶ Red flags vary depending on the underlying disease. ED physicians most likely intuitively assess risk factors for various underlying diseases. To date, no prediction rule has been developed to assist ED physicians to assess patients with low back pain. A diagnostic algorithm was recently developed.²⁰ The authors suggested to assess risk factors (e.g. sources for infection) and the clinical presentation (e.g. neurologic deficit or fever) in combination with the erythrocyte sedimentation rate to assist the decision whether an MRI is required. The red flags with the best diagnostic accuracy for the diagnosis of epidural abscess were intravenous drug use, indwelling vascular catheter, and another site of infection. The absence of any risk factor and a normal erythrocyte sedimentation rate could be used in order to exclude an epidural abscess.²⁰ While the prevalence of an epidural abscess was very low in our studies, the prognosis when the diagnosis is delayed is poor.³⁸

Strength and limitations

To the best of our knowledge, this is the first systematic review that provides a comprehensive overview of studies on the prevalence of serious spinal pathologies and the diagnostic accuracy of red flags in patients with low back pain presenting to the ED.¹⁰ We analyzed serious spinal pathologies in the light of the clinical urgency, which provides clinically relevant information. Several limitations need to be discussed. First, due to the lack of high-quality prospective studies, the conclusions drawn from this systematic review should be interpreted with caution. It is likely that high quality studies may change the results. In particular retrospective studies based on imaging studies overestimate the prevalence of conditions which may not be related to the clinical complaint.³⁹ Further, the number of studies investigating red flags for serious spinal pathologies was scarce. For example, there was no study which prospectively evaluated the diagnostic accuracy of red flags for cauda equina syndrome. Furthermore, the red flags were very heterogeneous, which prevented us from conducting a meta-analysis.

Implications for research

Prospective studies of high methodological quality need to assess the prevalence of serious spinal pathologies that absolutely require treatment and therefore, require imaging studies and further investigation in the ED setting. We recommend the use of definitions consistent with current clinical guidelines for the urgency of a treatment. Our analysis showed that many studies did not specify the urgency of a treatment. Further, disc prolapse and spinal stenosis may be overdiagnosed in imaging studies, resulting in overtreatment.^{40, 41} Evidence-based clinical practice guidelines for the management of patients with low back pain in ED settings should be validated in high quality studies and compared to the assessment of experienced clinicians.

Implications for clinical practice

The number of imaging studies (magnetic resonance imaging or computer tomography) in patients with low back pain seeking care increased from 7.4% in 1995 to 11.4% in 2015,⁴² despite guideline recommendations to restrict imaging studies to specific clinical situations⁴³⁻⁴⁵ and the implementation of choosing wisely campaigns in 2012.⁴⁶ The challenge of clinicians is to identify patients with a serious spinal pathology and to perform imaging specifically. This study outlined the evidence on the prevalence of serious spinal pathologies in the ED setting and on red flags used in clinical practice. In particular, the combination of symptoms, patient history and clinical findings could help to identify patients at risk for specific conditions.⁴⁷ For example, the overall prevalence of an epidural abscess was 0.5%.²⁰ When three red flags were present (intravenous drug use, recent spine fracture, and indwelling vascular catheter),²⁰ the post-test probability for an epidural abscess was 90.2%. When no risk factor was present, an epidural abscess was highly unlikely (post-test probability 0%). Further, the presence of a bladder/suprapubic fullness and hemoglobin <100g/L increased the pre-test probability of 2-5.5%^{5,21} to a post-test-probability of 92 - 97% for the presence of any serious spinal pathology. Application of these red flags may potentially help clinicians to avoid overutilization of diagnostic tests and target interventions for patients with low back pain presenting in a ED.

Conclusions

We found a substantially higher prevalence of serious spinal pathologies in the ED compared to that of primary care settings. Red flags may be useful in the clinical assessment. However, their diagnostic accuracy needs to be interpreted with caution as few studies were of high quality and for most red flags, only a single study was available. High quality, prospective studies should validate the diagnostic accuracy of red flags in patients with low back pain presenting to the ED.

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Conflict of interest

None to report.

Authors contribution

MW, GG and DS designed the study. GG and DS independently screened the literature, extracted the data and performed the quality assessment. MW, GG, DS and RLM performed the analysis. All authors interpreted the analysis. MW, DS and GG drafted the first version of the manuscript, which was revised by ERB, MT and RLM. All authors read and approved the final manuscript. GG and DS contributed equally to this study.

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Figure 1: Study flow**Figure 2: Diagnostic accuracy of red flags for any serious spinal pathology**

Abbreviations: CI, confidence interval; INR, international normalized ratio

The grey area shows the range of pre-test prevalence for any serious disease

Figure 3: Diagnostic accuracy of red flags for specific diseases requiring immediate/urgent treatment

Abbreviations: CI, confidence interval; bpm, beats per minute; ESR, erythrocyte sedimentation rate; CRP, C-reactive protein; BMI, body mass index

£, Included diabetes, intravenous drug use, recent spine procedure or indwelling spinal surgical implant, recent spine fracture, indwelling vascular catheter, immunocompromised, other site of infection, chronic liver disease

\$, Included diabetes, intravenous drug use, recent spine procedure, recent spine fracture, indwelling catheter, immunocompromised, distant site of infection, alcohol abuse, chronic renal failure, cancer

φ, Fever $\geq 100.4^\circ$ F, spine pain, and neurological deficit

^, Included patients with a minor trauma (e.g., fall from a standing height or twisting injury)

*, Two or more physical findings (contusion/abrasion, tenderness, spasm, sensory deficit, motor deficit, deep tendon reflex abnormality, or positive straight leg raising)

Tables**Table 1: Baseline characteristics of the included studies**

Author, Year	Study design	Setting	Methods	Inclusion criteria	Exclusion criteria	Patients (n)	Age (years) : mean (SD)
Davis et al., 2011 ²⁰	Mixed prospective and retrospective cohort study	Urban university ED with approximately 45,000 annual visits, San Diego, USA	Prospective: ED patients with spine pain over 9-month period. Retrospective: hospital inpatient records with a	Diagnose of a SEA in the ED during a 14-year period; patients in the ED with spine pain in	None	1101 ^z	SEA patients: 44.8; Non-SEA patients: 44.1

			diagnosis of SEA over 14 years.	a 9-month period.			
Kaplan, 1985 ²¹	Prospective cohort study	ED of Roger Williams General Hospital, Rhode Island, USA	ED patients with a spine-related problem. Analysis of reports for patients with x-rays. Follow-up phone call for patients without x-rays after 2 months.	Age 18 and older, presenting to the ED with any problem related to the spine	None	200	Not reported
Kohns et al., 2017 ⁵	Prospective cohort study	EDs of a level-1 university trauma center, a large community hospital, and a small community hospital, Michigan, USA	Data coders collected data from physicians' and nurses' records on 200 consecutive patients in each center admitted to the ED with a primary diagnosis of LBP. Follow-up care during a 12 months period in patients included in the university hospital were reviewed for serious adverse events.	Patients aged 18 to 80 years, primary diagnosis coded for LBP	Primary reason for admission was not LBP; illegible records; missing documentation of the clinical encounter.	559	43.8
Ala et al., 2012 ⁴⁸	Cross-sectional study	ED of Imam Reza hospital, Mashhad, Iran	Random selection of 100 patients. Lasègue test was conducted for all patients. The patients' MRI was evaluated.	Patients suffering from radiculopathy and acute LBP	History of back surgery; lumbar penetrating or blunt trauma; TB; paravertebral infection; cancer	100	Not reported
Reinus et al., 1998 ²³	Cross-sectional study	Level-2 ED (26'000 cases annually), Washington, USA	Prospective collection of a questionnaire (mandatory to obtain a LSS x-ray). Clinical information extracted from medical charts.	All patients receiving lumbosacral spine radiographs in the ED	None	482	56 (21)
Gibson et al., 1992 ²²	Cross-sectional study	Accident and Emergency Department, Leeds General Infirmary, Leeds, UK	Over a 6-month period, a questionnaire was completed for each patient. In addition, ED records checked for addition visits after the first ED	16-65 years old; complaining of pain in the lumbar region of less than 48h duration.	Patients not meeting inclusion criteria	225	Not reported

			visit				
Tracey et al., 1994 ¹⁹	Prospective cross-sectional part	Accident and ED, Royal Victoria Hospital, Belfast, Ireland	Prospective data collection of medical records over 2 months before implementation of the new guidelines and 6 months after their implementation.	Patients with LBP presenting to the accident and emergency department.	None	312	Not reported
	Retrospective chart review part	Accident and ED, Royal Victoria Hospital, Belfast, Ireland	Retrospective data extraction of medical records over 6 months before implementation of the new guidelines.	Patients with LBP presenting to the accident and ED.	None	445	Not reported
Gallagher et al., 1998 ²⁹	Retrospective chart review	ED, Level I trauma center, Urban teaching hospital, Albert Einstein College of Medicine, Bronx, New York	Restriction of LSS x-rays to three indications. A random sample of patients without x-ray were followed up for >1 year.	Receiving ED LSS radiography during 1992	Pregnant patients and those under 18 years of age	326	41
Friedman et al., 2010 ⁴⁹	Retrospective chart review	Registry data for ED visits representative for the US from the National Hospital Ambulatory Medical Care Survey (NHAMCS) registry of ED visits.	Data were collected by trained data abstractors who use the medical record to gather sociodemographic data as well as specific information about the visit.	Patients ≥ 14 years of age, reason for visit related to and primary ED discharge ICD9 code consistent with LBP	Motor vehicle collision injury, reasons for visit related to leg pain, discharge diagnosis attributable to cervical or thoracic back or spine.	4097	40
Gellhorn et al., 2012 ⁵⁰	Retrospective chart review	Data from Medicare/Medicaid outpatient billing claims database (66 different physician specialties associated with encounters for LBP), USA	Study on representative 20% sample of Medicare/Medicaid patients (2002-2006). Patients with back pain were identified using ICD-9 diagnosis codes and were selected if the primary diagnosis corresponded to LBP.	Patients aged 66 or older who received treatment for LBP	Prior physician visit for LBP; back surgery or lumbar injection in the previous year; visits for postoperative rehabilitation.	25872	76

Thiruganasamban da-moorthy et al., 2014 ²⁶	Retrospective chart review	Two tertiary care EDs of the Ottawa Hospital (>130,000 annual ED visits), Canada	Health records review of consecutive nontraumatic LBP patients. Patient identification by searching The Ottawa Hospital health records database for terms related to LBP in the presenting complaint and the discharge diagnoses. Data extraction from medical records using a predefined standardized data abstraction form.	>16 years old; local residential address; chief complaint of nontraumatic LBP; assessed by an ED physician.	History of nephrolithiasis and typical signs of renal colic; history of back trauma immediately preceding the onset of the symptoms.	329	49.3
Koontz et al., 2017 ²⁴	Retrospective chart review	ED of hospitals affiliated to Indiana University School of Medicine, Indianapolis, USA	In patients who underwent MRI evaluation for exclusion of a CES, the sagittal 3D-T2 SPACE FS pulse sequence was used in addition to the routine LS MRI protocol to identify specific pathologies causing CES. Patient symptoms were extracted from electronic medical records.	>18 years of age; patients with acute LBP and additional symptoms (e.g., lower extremity weakness, bowel/bladder incontinence, perineal numbness, focal neurological deficit).	Significant lumbar spine trauma; known malignancy and intravenous drug use	118	43.3 (13.5)
Ohle et al., 2018 ³⁴	Retrospective chart review	Two tertiary academic care ED, Ottawa, Canada	Patients with a triage diagnosis of truncal pain were identified and included when a CT thorax or thorax/abdomen were performed. Data extraction from medical records.	ED presentation with triage diagnosis of truncal pain (non-traumatic chest, back, abdominal, or flank pain)	Diagnosis without CT, recurrent aortic dissection, patients transferred from other hospitals to rule out aortic dissection.	2833	47 (18.5)
Bellan et al., 2016 ²⁸	Retrospective chart review	ED of University hospital Maggiore della Carità, Novara, Italy	Of all the patients admitted to the ED along one year, information on clinical and	Patients with non-traumatic musculoskeletal complaint	Patients admitted to pediatric (age <14) and obstetrics/gynecology ED	944	51 (17.8)

			laboratory data of the selected patients was collected.				
Davis et al., 2004 ³⁵	Retrospective case-control study	ED, UCSD Medical Centre, large, urban University hospital (45,000 ED annual visits), San Diego, USA	Patients with SEA, analysis of ED medical records (10-year period). A pool of ED patients with back pain was generated using the ED medical record database. Each SEA patient was hand-matched to two controls from this pool. Risk factors were extracted from medical records.	Patients with SEA	Patients not evaluated in the ED for symptoms related to SEA before hospitalization, patients with fungal and tuberculosis abscesses	189	46
Guillen-Astete et al., 2017 ⁵¹	Retrospective chart review	ED, University Hospital Ramón y Cajal, Madrid, Spain	Chart review of medical records from the first assessment in the ED. For each patient, the medical records for the next 3 months were reviewed to identify follow-up visits.	Patients from hospital's referral area; diagnose related to back pain in the ED	Signs of inflammatory back pain; missing data; treatment with buprenorphine, fentanyl, oxycodone, oxycodone/naloxone	732	72.2
Reito et al., 2018 ²⁷	Retrospective chart review	ED, Central Finland Hospital, a level II/III trauma center, Finland	Identification of records using ICD-10 codes of discharge database. Data extraction from the ED discharge summary.	Visit to the ED due to LBP related reason	Cervical or thoracic problem, trauma, age <18 years	900	51.3 (17.0)
Leichtle et al., 2015 ³²	Retrospective chart review	ED, Orthopedic University Clinic of Tübingen, Germany	Over a 32-month period, medical records of all patients were analyzed. Data was collected using a standardized questionnaire.	Acute or chronic pain in the cervical, thoracic, or lumbar back region	None	484	41 (15)
Patrick et al., 1983 ³³	Retrospective chart review	EDs of 2 non-teaching hospitals (St. James Hospital, Illinois; Good Samaritan Hospital, Chicago), 1 teaching	Examination of ED and hospital records and radiological interpretation of LLS x-rays. Extraction of symptoms and physical	Patients having a LS series ordered in one of the EDs	None	552	Not reported

		hospital (William Beaumont Hospital, Michigan), and 1 university center (University Hospital of Jacksonville, Florida)	findings from records.				
Raison et al., 2014 ²⁵	Retrospective chart review	ED St Peter's Hospital, district hospital in London, England	Identification of records with a primary complaint of back pain from the admission records. Chart review of clinical information, imaging reports, and electronic pathology reports.	Back pain that warranted a referral to the orthopedic team.	Patients diagnosed with traumatic or degenerative spinal fractures	206	Not reported
Rao et al., 2015 ³⁰	Retrospective chart review	Massachusetts General Hospital (Level-1 trauma ED), Boston, USA	Random selection of 100 patients. Review of the electronic medical record for clinical context and history.	Patients who presented with a chief complaint of LBP.	A diagnosis related to non-musculoskeletal, non-spinal or upper back pain.	100	48
Weiner et al., 1999 ³¹	Retrospective chart review	The ED of the University of Connecticut Health Center, USA	Review of ED charts for the presence of key findings on patients' history and clinical exam in order to determine the frequency of x-ray obtaining and associated factors.	Evaluation for LBP in the ED between April and September 1995.	Medical records not available, age <16, patients coded inappropriately for musculoskeletal LBP.	214	Not reported

Abbreviations: ED, emergency department; LBP, low/lumbar back pain; LSS, lumbosacral spine; LS, lumbar spine; TB, tuberculosis; ICD, international classification of diseases; SEA, spinal epidural abscess; 3D-T2 SPACE, 3D-T2 Sampling Perfection with Application optimized Contrasts using different flip angle Evolution; FS, fat saturated; CES, cauda equina syndrome; ACR AC, American colleague of Radiology appropriateness criteria; LBP, low back pain

^z Prevalence of epidural abscess was assessed over a 14-year period and was compared to an emergency population with LBP collected over a 9-month period. To calculate the prevalence and the diagnostic accuracy of red flags, we extrapolated the number of the emergency LBP patients to the 14-year study period and thus, the calculated number of all patients was 19033

Table 2: Prevalence of serious spinal pathologies

Spinal pathology, grouped by urgency	Prevalence: %		
	Prospective studies	Cross-sectional studies	Retrospective studies
All spinal pathologies	5.1-5.5 ^{5, 21}	3.1-60.6 ^{19, 22, 23}	1.2-77.1 ^{19, 24 a, 25 f, 26-28, 29 c, 30, 31, 32 d, 33, 49, 50 e, 51}
All pathologies requiring immediate / urgent treatment	2.5-5.1 ^{5, 21}	3.1-4.5 ^{19, 22, 23}	0.7-7.4 ^{19, 26-28, 29 c, 30, 31, 32 d, 33} (15.3 - 15.5) ^{24 a, 25 f}
Immediate treatment			
Epidural abscess and spinal infection	0.0-0.6 ^{5, 20 z, 21}		
Epidural or paraspinal abscess			0.3-1.0 ^{26, 29 c, 30}
Spondylodiscitis			0.1-1.9 ^{27-28, 29 c}
Osteomyelitis			0.0-0.9 ^{26, 31}
Vertebral fracture with dislocation	1.5 ²¹		
Cancer (metastatic deposit, with cord compression)	0.5 ²¹		
Possible Myelopathy	0.5 ²¹		
Cauda equina syndrome and radiculopathy with weakness	1.9 ⁵		
Compression of the spinal cord, conus medullaris, or cauda equina			0.3-15.5 ^{24 a, 25 f, 26, 27}
Herniated disc (cervical disc herniation requiring prompt evaluation and hospital admission) ^d			0.1 ²⁸
Aortic rupture	0.6 ⁵		0.0 ²⁶
Retroperitoneal bleeding			0.6 ²⁶
Acute aortic dissection			0.0 ³⁴
Abdominal aortic aneurysm graft leak			0.3 ²⁶
Immediate/urgent treatment			
Spinal cancer	1.9 ⁵	0.3-1.5 ^{19, 23}	0.0-2.1 ^{19, 26-28, 29 c, 31, 33}
Vertebral fracture	0.0 ⁵	2.1-4.2 ^{19, 22, 23}	0.3-7.2 ^{19, 24 a, 31-33}
Severe spinal canal stenosis			11 ^{24 a}
Spondylolisthesis/instability			3.4 ^{32 d}
Urgent treatment			
Herniated disc			1.2 ²⁶
Spinal stenosis			0.3 ²⁶

Not specified

Vertebral compression fracture (mandating a specific treatment, no detailed information on treatment provided)	1.0 ²¹	
Herniated disc	89.0 ^{48 b}	
Vertebral fracture, indeterminate age	5.0 ²³	
Herniated disc		0.8-9.9 ^{28, 32 d, 49 e, 50}
Nerve root impingement		30.5 ^{24 a}
Intraspinal mass (disc, synovial cyst, hematoma, cerebrospinal fluid leak, or metastases)		31.4 ^{24 a}
Spondylolisthesis		1.8-2.9 ^{19, 33}
Vertebral compression fracture		0.3-4.0 ^{26, 27, 30}

Non-urgent

Vertebral compression fracture	2.0 ²¹	1.1-4.0 ^{28, 30, 51}
Vertebral fracture, chronic age	4.4 ²³	
Spondylosis	47.7 ²³	0.3 ⁴⁹
Axial Spondylarthritis		0.2 ²⁸
Spinal stenosis		0.2-0.5 ^{32 d, 50 e}
Spondylolisthesis grade 1		1.9 ³¹

Abbreviations: SSP, serious spinal pathology; Ref., reference; MRI, magnetic resonance imaging; LBP, low back pain

^a Study participants: acute LBP patients with neurologic deficits who underwent MRI for exclusion of cauda equina syndrome

^f Study participants: back pain patients that warranted a referral to the orthopedic team. Patients showed a high rate of neurologic symptoms

^c Random selection of patients who did not get an X-ray on index visit but were followed-up after >1 year for missed SSP

^d Prevalence calculated based on all spine pain patients

^e Included patients aged 66 or older

^z Prevalence of epidural abscess was assessed over a 14-year period and was compared to an emergency population with LBP collected over a 9-month period. To calculate the prevalence, we extrapolated the number of the emergency LBP patients to the 14-year study period

^b Random selection of patients with acute low back pain and radiculopathy

Appendices

Appendix 1: Database search strategies

Medline search strategy

#	Search terms	References
1	exp Low Back Pain/ or (pain adj3 (lower back or lumb* or spine or spinal or dorsal or vertebral)).ti,ab. or (backache adj3 (low or lower or lumba*)).ti,ab. or (low back adj3 (pain or ache or aching or complain* or disorder*)).ti,ab. or lbp.ti,ab. or lumbago.ti,ab.	44514
2	exp Emergency Service, Hospital/ or exp Emergency Medical Services/ or Emergency Medicine/ or (emergency adj3 (medicine* or service* or department* or room* or ward* or unit* or center* or centre* or clinic* or treatment* or care* or patient* or physician*)).ti,ab. or er.ti. or ed.ti. or eds.ti. or ers.ti. or ems.ti. or accident & emergency.ti. or (accident and emergency).ti. or a&e.ti. or a & e.ti. or emergicenter*.ti. or urgent care.ti. or (trauma adj3 (center* or centre*)).ti,ab. or (triage adj3 (medicine* or service* or department* or room* or ward* or unit* or center* or centre* or clinic* or treatment* or care* or patient* or physician*)).ti,ab. or (urgent care adj3 (medicine* or service* or department* or room* or ward* or unit* or center* or centre* or clinic* or treatment* or care* or patient* or physician*)).ti,ab.	240428
3	1 and 2	622
4	3 not ((exp child/ or exp infant/) not exp adult/) not (accident* or collision* or crash*).ti. not (exp case reports/ or case report.ti.) not (animals not humans).sh.	386

Search date: January 11, 2019

Search platform: Ovid

Embase search strategy

#	Search terms	References
1	'low back pain'/exp OR ((pain NEAR/3 ('lower back' OR lumb* OR spine OR spinal OR dorsal OR vertebral)):ti,ab) OR ((backache NEAR/3 (low OR lower OR lumba*)):ti,ab) OR (('low back' NEAR/3 (pain OR ache OR aching OR complain* OR disorder*)):ti,ab) OR lbp:ti,ab OR lumbago:ti,ab	74481
2	'emergency ward'/exp OR 'emergency care'/exp OR 'emergency medicine'/exp OR 'emergency health service'/exp OR ((emergency NEAR/3 (medicine* OR service* OR department* OR room* OR ward* OR unit* OR center* OR centre* OR clinic* OR treatment* OR care* OR patient* OR physician*)):ti,ab) OR er:ti OR ed:ti OR eds:ti OR ers:ti OR ems:ti OR 'accident & emergency':ti OR 'accident and emergency':ti OR 'a&e':ti OR 'a & e':ti OR emergicenter*:ti OR 'urgent care':ti OR ((trauma NEAR/3 (center* OR centre*)):ti,ab) OR ((triage NEAR/3 (medicine* OR service* OR department* OR room* OR ward* OR unit* OR center* OR centre* OR clinic* OR treatment* OR care* OR patient* OR physician*)):ti,ab) OR (('urgent care' NEAR/3 (medicine* OR service* OR department* OR room* OR ward* OR unit* OR center* OR centre* OR clinic* OR treatment* OR care* OR patient* OR physician*)):ti,ab)	363458
3	1 AND 2	1504
4	1 AND 2 NOT ((([infant]/lim OR [child]/lim OR [adolescent]/lim) NOT ([adult]/lim OR [aged]/lim)) NOT (pediatric*:ti OR paediatric*:ti OR pregnan*:ti) NOT (accident*:ti OR collision*:ti OR crash*:ti) NOT ('case report'/exp OR 'case study'/exp OR 'case report':ti) NOT ([animals]/lim NOT [humans]/lim) NOT [conference abstract]/lim	493

Search date: January 12, 2019

Search platform: Embase

Pubmed search strategy

#	Search terms	References
1	((pain[tiab] AND ("lower back"[tiab] OR lumbar[tiab] OR lumbal[tiab] OR spine[tiab] OR spinal[tiab] OR dorsal[tiab] OR vertebral[tiab])) OR (backache[tiab] AND (low[tiab] OR lower[tiab] OR lumbar[tiab] OR lumbal[tiab])) OR ("low back" [tiab] AND (pain[tiab] OR ache[tiab] OR aching[tiab] OR complain*[tiab] OR disorder*[tiab])) OR lbp[tiab] OR lumbago[tiab])	93050
2	((emergency[tiab] AND (medicine*[tiab] OR service*[tiab] OR department*[tiab] OR room*[tiab] OR ward*[tiab] OR unit*[tiab] OR center*[tiab] OR centre*[tiab] OR clinic*[tiab] OR treatment*[tiab] OR care*[tiab] OR patient*[tiab] OR physician*[tiab])) OR er[ti] OR ed[ti] OR eds[ti] OR ers[ti] OR ems[ti] OR "accident & emergency"[ti] OR "accident and emergency"[ti] OR "a&e"[ti] OR "a & e"[ti] OR emergicenter*[ti] OR "urgent care"[ti] OR (trauma[tiab] AND (center*[tiab] OR centre*[tiab])) OR (triage[tiab] AND (medicine*[tiab] OR service*[tiab] OR department*[tiab] OR room*[tiab] OR ward*[tiab] OR unit*[tiab] OR center*[tiab] OR centre*[tiab] OR clinic*[tiab] OR treatment*[tiab] OR care*[tiab] OR patient*[tiab] OR physician*[tiab])) OR ("urgent care"[tiab] AND (medicine*[tiab] OR service*[tiab] OR department*[tiab] OR room*[tiab] OR ward*[tiab] OR unit*[tiab] OR center*[tiab] OR centre*[tiab] OR clinic*[tiab] OR treatment*[tiab] OR care*[tiab] OR patient*[tiab] OR physician*[tiab])))	250966
3	(((((pain[tiab] AND ("lower back"[tiab] OR lumbar[tiab] OR lumbal[tiab] OR spine[tiab] OR spinal[tiab] OR dorsal[tiab] OR vertebral[tiab])) OR (backache[tiab] AND (low[tiab] OR lower[tiab] OR lumbar[tiab] OR lumbal[tiab])) OR ("low back" [tiab] AND (pain[tiab] OR ache[tiab] OR aching[tiab] OR complain*[tiab] OR disorder*[tiab])) OR lbp[tiab] OR lumbago[tiab]))) AND (((emergency[tiab] AND (medicine*[tiab] OR service*[tiab] OR department*[tiab] OR room*[tiab] OR ward*[tiab] OR unit*[tiab] OR center*[tiab] OR centre*[tiab] OR clinic*[tiab] OR treatment*[tiab] OR care*[tiab] OR patient*[tiab] OR physician*[tiab])) OR er[ti] OR ed[ti] OR eds[ti] OR ers[ti] OR ems[ti] OR "accident & emergency"[ti] OR "accident and emergency"[ti] OR "a&e"[ti] OR "a & e"[ti] OR emergicenter*[ti] OR "urgent care"[ti] OR (trauma[tiab] AND (center*[tiab] OR centre*[tiab])) OR (triage[tiab] AND (medicine*[tiab] OR service*[tiab] OR department*[tiab] OR room*[tiab] OR ward*[tiab] OR unit*[tiab] OR center*[tiab] OR centre*[tiab] OR clinic*[tiab] OR treatment*[tiab] OR care*[tiab] OR patient*[tiab] OR physician*[tiab])) OR ("urgent care"[tiab] AND (medicine*[tiab] OR service*[tiab] OR department*[tiab] OR room*[tiab] OR ward*[tiab] OR unit*[tiab] OR center*[tiab] OR centre*[tiab] OR clinic*[tiab] OR treatment*[tiab] OR care*[tiab] OR patient*[tiab] OR physician*[tiab])))))) NOT (accident*[ti] OR collision*[ti] OR crash*[ti] OR "case report"[ti]))	1681
4	((((((((pain[tiab] AND ("lower back"[tiab] OR lumbar[tiab] OR lumbal[tiab] OR spine[tiab] OR spinal[tiab] OR dorsal[tiab] OR vertebral[tiab])) OR (backache[tiab] AND (low[tiab] OR lower[tiab] OR lumbar[tiab] OR lumbal[tiab])) OR ("low back"[tiab] AND (pain[tiab] OR ache[tiab] OR aching[tiab] OR complain*[tiab] OR disorder*[tiab])) OR lbp[tiab] OR lumbago[tiab]))) AND (((emergency[tiab] AND (medicine*[tiab] OR	

service*[tiab] OR department*[tiab] OR room*[tiab] OR ward*[tiab] OR unit*[tiab] OR center*[tiab] OR centre*[tiab] OR clinic*[tiab] OR treatment*[tiab] OR care*[tiab] OR patient*[tiab] OR physician* [tiab])) OR er[ti] OR ed[ti] OR eds[ti] OR ers[ti] OR ems[ti] OR "accident & emergency"[ti] OR "accident and emergency"[ti] OR "a&e"[ti] OR "a & e"[ti] OR emergicenter*[ti] OR "urgent care"[ti] OR (trauma[tiab] AND (center*[tiab] OR centre*[tiab])) OR (triage[tiab] AND (medicine*[tiab] OR service*[tiab] OR department*[tiab] OR room*[tiab] OR ward*[tiab] OR unit*[tiab] OR center*[tiab] OR centre*[tiab] OR clinic*[tiab] OR treatment*[tiab] OR care*[tiab] OR patient*[tiab] OR physician*[tiab])) OR ("urgent care"[tiab] AND (medicine*[tiab] OR service*[tiab] OR department*[tiab] OR room*[tiab] OR ward*[tiab] OR unit*[tiab] OR center*[tiab] OR centre*[tiab] OR clinic*[tiab] OR treatment*[tiab] OR care*[tiab] OR patient*[tiab] OR physician*[tiab]))) NOT (accident*[ti] OR collision*[ti] OR crash*[ti] OR "case report"[ti])) NOT ((animals[mh] NOT humans[mh])) AND (((inprocess[sb]) OR (publisher[sb] NOT pubstatusnihms NOT pubstatuspmcsd NOT pmcbook)))

110

Search date: January 12. 2019

Search platform: Pubmed

Cochrane Library search strategy

#	Search terms	References
1	((emergency near/3 (medicine* or service* or department* or room* or ward* or unit* or center* or centre* or clinic* or treatment* or care* or patient* or physician*)) or er or ed or eds or ers or ems or "accident & emergency" or "accident and emergency" or "a&e" or "a & e" or emergicenter* or (trauma near/3 (center* or centre*)) or (triage near/3 (medicine* or service* or department* or room* or ward* or unit* or center* or centre* or clinic* or treatment* or care* or patient* or physician*)) or ("urgent care" near/3 (medicine* or service* or department* or room* or ward* or unit* or center* or centre* or clinic* or treatment* or care* or patient* or physician*)):ti,ab,kw and ((pain near/3 ("lower back" or lumb* or spine or spinal or dorsal or vertebral)) or (backache near/3 (low or lower or lumba*)) or ("low back" near/3 (pain or ache or aching or complain* or disorder*)) or lbp or lumbago):ti,ab,kw not (accident* or collision * or crash*):ti not (pediatric* or paediatric* or pregnan*):ti not ("case report" or "case study"):ti (Word variations have been searched)	205

Search date: January 12. 2019

Search platform: Cochrane Library

Scopus search strategy

#	Search terms	References
1	TITLE-ABS-KEY ((emergency W/3 (medicine* OR service* OR department* OR room* OR ward* OR unit* OR center* OR centre* OR clinic* OR treatment* OR care* OR patient* OR physician*)) OR er OR ed OR eds OR ers OR ems OR "accident & emergency" OR "accident and emergency" OR "a&e" OR "a & e" OR emergicenter* OR (trauma W/3 (center* OR centre*)) OR (triage W/3 (medicine* OR service* OR department* OR room* OR ward* OR unit* OR center* OR centre* OR clinic* OR treatment* OR care* OR patient* OR physician*)) OR ("urgent care" W/3 (medicine* OR service* OR department* OR room* OR ward* OR unit* OR center* OR centre* OR clinic* OR treatment* OR care* OR patient* OR physician*)))	849651

2 TITLE-ABS-KEY ((pain W/3 ("lower back" OR lumb* OR spine OR spinal OR dorsal OR vertebral)) OR (backache W/3 (low OR lower OR lumba*)) OR ("low back" W/3 (pain OR ache OR aching OR complain* OR disorder*)) OR lbp OR lumbago)

80987

3 (TITLE-ABS-KEY ((emergency W/3 (medicine* OR service* OR department* OR room* OR ward* OR unit* OR center* OR centre* OR clinic* OR treatment* OR care* OR patient* OR physician*)) OR er OR ed OR eds OR ers OR ems OR "accident & emergency" OR "accident and emergency" OR "a&e" OR "a & e" OR emergicenter* OR (trauma W/3 (center* OR centre*)) OR (triage W/3 (medicine* OR service* OR department* OR room* OR ward* OR unit* OR center* OR centre* OR clinic* OR treatment* OR care* OR patient* OR physician*)) OR ("urgent care" W/3 (medicine* OR service* OR department* OR room* OR ward* OR unit* OR center* OR centre* OR clinic* OR treatment* OR care* OR patient* OR physician*)))) AND (TITLE-ABS-KEY ((pain W/3 ("lower back" OR lumb* OR spine OR spinal OR dorsal OR vertebral)) OR (backache W/3 (low OR lower OR lumba*)) OR ("low back" W/3 (pain OR ache OR aching OR complain* OR disorder*)) OR lbp OR lumbago))

1784

4 (TITLE-ABS-KEY ((emergency W/3 (medicine* OR service* OR department* OR room* OR ward* OR unit* OR center* OR centre* OR clinic* OR treatment* OR care* OR patient* OR physician*)) OR er OR ed OR eds OR ers OR ems OR "accident & emergency" OR "accident and emergency" OR "a&e" OR "a & e" OR emergicenter* OR (trauma W/3 (center* OR centre*)) OR (triage W/3 (medicine* OR service* OR department* OR room* OR ward* OR unit* OR center* OR centre* OR clinic* OR treatment* OR care* OR patient* OR physician*)) OR ("urgent care" W/3 (medicine* OR service* OR department* OR room* OR ward* OR unit* OR center* OR centre* OR clinic* OR treatment* OR care* OR patient* OR physician*)))) AND (TITLE-ABS-KEY ((pain W/3 ("lower back" OR lumb* OR spine OR spinal OR dorsal OR vertebral)) OR (backache W/3 (low OR lower OR lumba*)) OR ("low back" W/3 (pain OR ache OR aching OR complain* OR disorder*)) OR lbp OR lumbago)) AND NOT (TITLE (pediatric* OR paediatric* OR pregnan*)) AND NOT (TITLE (accident* OR collision* OR crash*)) AND NOT (TITLE-ABS-KEY ("case report" OR "case study")) AND NOT (TITLE-ABS-KEY ("erectile dysfunction" OR "lipopolysaccharide-binding protein" OR "local binary pattern*"))

996

5 (TITLE-ABS-KEY((emergency W/3 (medicine* OR service* OR department* OR room* OR ward* OR unit* OR center* OR centre* OR clinic* OR treatment* OR care* OR patient* OR physician*)) OR er OR ed OR eds OR ers OR ems OR "accident & emergency" OR "accident and emergency" OR emergicenter* OR (trauma W/3 (center* OR centre*)) OR (triage W/3 (medicine* OR service* OR department* OR room* OR ward* OR unit* OR center* OR centre* OR clinic* OR treatment* OR care* OR patient* OR physician*)) OR ("urgent care" W/3 (medicine* OR service* OR department* OR room* OR ward* OR unit* OR center* OR centre* OR clinic* OR treatment* OR care* OR patient* OR physician*)))) AND (TITLE-ABS-KEY((pain W/3 ("lower back" OR lumb* OR spine OR spinal OR dorsal OR vertebral)) OR (backache W/3 (low OR lower OR lumba*)) OR ("low back" W/3 (pain OR ache OR aching OR complain* OR disorder*)) OR lbp OR lumbago)) AND NOT (TITLE(pediatric* OR paediatric* OR pregnan*)) AND NOT (TITLE(accident* OR collision* OR crash*)) AND NOT (TITLE-ABS-KEY("case report" OR "case study")) AND NOT (TITLE-ABS-KEY("erectile dysfunction" OR "lipopolysaccharide-binding protein" OR "local binary pattern")))

1037

Search date: January 12, 2019

Search platform: Scopus

Appendix 2: Extracted information in the data extraction process

<i>Study specific information</i>	author, year of publication, study design, setting, aim of the study, follow-up duration
<i>Methods</i>	eligibility criteria, sample size calculation, statistical analysis
<i>Definition of the disease</i>	definition of low back pain, diagnostic procedures, diagnostic tests, and if applicable, reference test(s)
<i>Serious spinal pathologies</i>	operationalization, number of events
<i>Patient characteristics</i>	number of patients, age, gender, comorbidities, risk factors for a serious spinal pathology

Appendix 3: Rules for the quality classification of studies

Modified STROBE checklist¹¹	
high quality (++)	≥12 of 21 items were rated as “yes” and no item was rated as “no”
acceptable (+)	<12 items were rated as “yes” and <12 items were rated as “no”
unacceptable (-)	≥12 of 21 items were rated as “no”

SIGN checklist¹²	
<i>Risk of bias</i>	
high quality (++) , low risk of bias	≥6 of 10 items were rated as “yes” and no item was rated as “no”
acceptable (+) , moderate risk of bias	<6 items were rated as “yes” but <6 items were rated as “no”
unacceptable (-) , high risk of bias	≥6 items were rated “no”
<i>Applicability</i>	
directly applicable (++)	3 of 3 criteria were met
“some indirectness”	at least 1 criterion was rated as “no” or “can’t say”

Appendix 4: Quality assessment based on the modified STROBE checklist for observational and cross-sectional studies

Ref.	Author	Year	Introduction		Methods										Results				Discussion			Other	Overall assessment	
			Background	Objectives	Study design	Setting	Participants	Variables	Data sources/ measurement	Bias	Study size	Statistical methods		Participants	Descriptive data		Outcome data	Main results	Limitations	Interpretation	Generalizability	Funding		
			1	2	3	4	5	6	7.1	7.2	8	9	10	10	11	12	12	13	14	15	16	17	18	
²⁸	Bellan et al.	2016	Y	Y	Y	N	Y	Y	Y	C	N	N	N	N	Y	Y	N	Y	N	Y	Y	Y	Y	+
⁴⁹	Friedman et al.	2010	Y	Y	Y	Y	Y	N	Y	C	N	Y	Y	N	Y	Y	N	Y	N	Y	Y	Y	Y	+
²⁹	Gallagher et al.	1998	Y	Y	Y	Y	Y	Y	Y	C	N	Y	Y	N	Y	N	Y	Y	N	Y	Y	Y	N	+
⁵⁰	Gellhorn et al.	2012	Y	Y	Y	Y	Y	N	Y	C	N	N	Y	N	Y	Y	N	N	N	Y	Y	Y	Y	+
⁵¹	Guillen-Astete et al.	2017	Y	Y	Y	Y	Y	N	Y	C	N	Y	Y	Y	Y	Y	C	Y	Y	Y	Y	N	Y	+
²¹	Kaplan	1985	Y	Y	N	N	N	N	Y	C	Y	N	N	C	Y	Y	N	Y	N	N	Y	N	N	+
⁵	Kohns et al.	2017	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	C	Y	N	Y	Y	Y	Y	+
³²	Leichtle et al.	2015	Y	Y	Y	N	Y	N	Y	N	N	N	Y	N	Y	Y	N	Y	Y	N	Y	N	Y	+
³⁰	Rao et al.	2015	Y	Y	Y	Y	Y	N	Y	C	N	N	Y	N	Y	Y	N	Y	N	Y	Y	Y	N	+
³¹	Weiner et al.	1999	Y	Y	Y	Y	Y	Y	Y	C	N	N	Y	Y	Y	N	N	Y	N	Y	Y	Y	N	+
¹⁹	Tracey et al.	1994	Y	Y	Y	Y	Y	N	Y	Y	N	N	N	N	Y	N	N	Y	N	N	Y	N	N	+
³⁴	Ohle et al.	2018	Y	Y	N	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y	N	Y	Y	Y	Y	Y	N	+

Ref., reference; Y, "yes"; N, "no"; C, "can't say"; +, acceptable quality

- 1: The scientific background and rationale for the investigation is explained
- 2: Specific objectives and prespecified hypotheses are stated
- 3: Key elements of the study design are stated
- 4: The setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection are described
- 5: The eligibility criteria, and the sources and methods of selection of participants are provided
- 6: All outcomes (serious spinal pathologies) are clearly defined and have a high quality of reference standard

- 7.1: For each variable of interest, source of data is given
- 7.2: Details of methods of assessment are given (blinding, reviewers)
- 8: Efforts to address potential sources of bias are described or risk of bias is low due to prospective study design
- 9: It is explained how the study size was arrived at
- 10.1: All statistical methods, including those used to control for confounding, are described
- 10.2: It is explained how missing data were addressed
- 11: Numbers of individuals at each stage of study are reported
- 12.1: Characteristics of study participants are provided, at least sex category and mean age of participants
- 12.2: Number of participants with missing data for each variable of interest is indicated
- 13: Numbers of serious spinal pathologies are reported
- 14: Category boundaries are reported when continuous variables were categorized (including standard deviation and range)
- 15: Limitations of the study are discussed
- 16: A cautious overall interpretation of results considering objectives, multiplicity of analyses, results from similar studies, and other relevant evidence is given
- 17: The generalizability (external validity) of the study results is discussed
- 18: The source of funding is declared

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Appendix 5: Quality assessment based on the Scottish Intercollegiate Guidelines Network (SIGN) Methodology checklist for diagnostic studies

Ref.	Author	Year	Patient selection				Index test			Reference standard			Flow and timing			Overall assessment	
			Risk of bias			Appli-cability	Risk of bias		Appli-cability	Risk of bias		Appli-cability	Risk of bias			Risk of bias	Appli-cability
			1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1	3.2	3.3	4.1	4.2	4.3	5.1	5.2
⁴⁸	Ala et al.	2012	C	Y	C	C	Y	N	C	Y	C	Y	C	N	Y	+	+
²⁰	Davis et al.	2011	Y	Y	Y	Y	C	N	Y	Y	C	Y	C	N	Y	+	++
³⁵	Davis et al.	2004	Y	N	Y	Y	C	Y	C	Y	C	C	C	N	N	+	+
²²	Gibson et al.	1992	Y	Y	C	Y	C	C	C	Y	C	Y	C	N	C	+	+
²⁴	Koontz et al.	2017	Y	Y	Y	N	C	Y	C	Y	Y	Y	C	Y	Y	++	+
³³	Patrick et al.	1983	Y	Y	Y	N	C	C	C	Y	C	Y	C	C	Y	+	+
²⁵	Raison et al.	2014	C	Y	N	N	C	C	C	Y	C	Y	C	N	C	+	+
²³	Reinus et al.	1998	Y	Y	Y	N	Y	C	Y	Y	Y	Y	C	N	Y	+	+
²⁶	Thiruganasamban-damoorthy et al.	2014	Y	Y	Y	Y	Y	Y	Y	Y	C	C	C	C	Y	++	+
²⁷	Reito et al.	2018	Y	Y	Y	Y	C	Y	C	Y	C	Y	C	N	Y	+	+

Ref., reference; Y, "yes"; N, "no"; C, "can't say"; Risk of bias: ++, high quality; +, acceptable quality; -, unacceptable; Applicability: ++, directly applicable; +, some indirectness

1.1: A consecutive sequence or random selection of patients is enrolled

1.2: Case-control methods are not used

1.3: Inappropriate exclusions are avoided

1.4: The included patients and settings match the key question

2.1: The index test results are interpreted without knowledge of the results of the reference standard

2.2: If a threshold is used, it is pre-specified

2.3: The index test, its conduct, and its interpretation is similar to that used in practice with the target population of the guideline

3.1: The reference standard is likely to correctly identify the target condition

3.2: Reference standard results are interpreted without knowledge of the results of the index test

3.3: The target condition as defined by the reference standard matches that found in the target population of the guideline

4.1: There is an appropriate interval between the index test and reference standard

4.2: All patients receive the same reference standard

4.3: All patients recruited into the study are included in the analysis

5.1: Risk of bias: Overall quality

5.2: Applicability: overall quality

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Appendix 6: Prevalence of serious spinal pathologies (SSP)

Author, Year	Any SSP %	Urgency (prevalence %)	Serious spinal pathology (prevalence %, patients with serious spinal pathologies/total of patients in the study)
Prospective studies with follow-up			
Kaplan, 1985 ²¹	5.5	Immediate (2.5)	Vertebral fracture with dislocation (1.5, 3/200), cancer with cord compression (0.5, 1/200), possible myelopathy (0.5, 1/200), spine infection (0.0, 0/200)
		Not specified (1.0)	Vertebral compression fracture mandating a specific treatment, with no details on treatment provided (1.0, 2/200)
		Non-urgent (2.0)	Vertebral compression fracture with conservative treatment (2.0, 4/200)
Davis et al., 2011 ²⁰	n.i.	Immediate (n.i.)	Epidural abscess (0.5, 86/19033) ²
Kohns et al., 2017 ⁵	5.1	Immediate (3.2)	Epidural abscess (0.6, 1/158), aortic rupture (0.6, 1/158), conditions with progressive neurologic change including cauda equina and radiculopathy with weakness (1.9, 3/158)
		Immediate / urgent (1.9)	Spinal cancer (1.9, 3/158), vertebral fracture (0.0, 0/158)
Cross-sectional studies, prospective			
Ala et al., 2012 ^{48,b}	n.i.	Not specified (n.i.)	Herniated disc (89.0, 89/100)
Reinus et al., 1998 ²³	60.6	Immediate / urgent (3.5)	Acute vertebral fracture (2.1, 10/482), spinal cancer (1.5, 7/482)
		Not specified (5.0)	Vertebral fracture of indeterminate age (5.0, 24/482)
		Non-urgent (52.1)	Vertebral fracture of chronic age (4.4, 21/482), spondylosis (47.7, 230/482)
Gibson et al., 1992 ²²	3.1	Immediate / urgent (3.1)	Vertebral fracture (3.1, 7/225)
Tracey et al., 1994 ¹⁹	4.5	Immediate / urgent (4.5)	Vertebral fracture (4.2, 13/312), spinal cancer (0.3, 1/312)
Retrospective studies			
Gallagher et al., 1998 ^{29,c}	1.2	Immediate (0.9)	Epidural abscess (0.3, 1/326), paraspinal abscess (0.3, 1/326), spondylodiscitis (0.3, 1/326)
		Immediate / urgent (0.3)	Paraspinal sarcoma/ lymphoma (0.3, 1/326)
Friedman et al., 2010 ⁴⁹	2.3	Not specified (2.0)	Herniated disc (2.0, 80/4097)
		Non-urgent (0.3)	Spondylosis (0.3, 12/4097)
Gellhorn et al., 2012 ^{50,e}	1.3	Not specified (0.8)	Herniated disc (0.8, 207/25872)
		Non-urgent (0.5)	Spinal stenosis (0.5, 129/25872)
Bellan et al., 2016 ²⁸	11.8	Immediate (0.3)	Spondylodiscitis (0.1, 1/802), herniated cervical disc requiring prompt evaluation and hospital admission (0.1, 1/802) ^d
		Immediate / urgent (0.4)	Spinal cancer (0.4, 4/944)
		Not specified (9.9)	Herniated disc (9.9, 93/944)
		Non-urgent (1.3)	Vertebral compression fracture without neurologic involvement (1.1, 10/944), axial spondyloarthritis (0.2, 2/944)
Guillen-Astete, 2017 ⁵¹	4.0	Non-urgent (4.0)	Vertebral compression fracture as a comorbidity (4.0, 29/732)
Leichtle et al., 2015 ³²	8.6	Immediate / urgent (3.7)	Vertebral fracture (0.3, 1/327), spondylolisthesis/instability (3.4, 11/327)

		Not specified (4.8)	Herniated disc (4.8, 23/484) ^d
		Non-urgent (0.2)	Spinal stenosis (0.2, 1/484) ^d
Ohle et al., 2018 ³⁴	n.i.	Immediate (n.i.)	Acute aortic dissection (0.0, 0/2833)
Patrick et al., 1983 ³³	10.3	Immediate / urgent (7.4)	Vertebral fracture (7.2, 40/552), spinal cancer (0.2, 1/552)
		Not specified (2.9)	Spondylolisthesis (2.9, 16/552)
Raison et al., 2014 ^{25,1}	15.5	Immediate (15.5)	Compression of the spinal cord and cauda equina on MRI (15.5, 32/206)
Rao et al., 2015 ³⁰	5.0	Immediate (1.0)	Epidural abscess (1.0, 1/100)
		Not specified (4.0)	Vertebral compression fracture (4.0, 4/100)
Reito et al., 2018 ²⁷	3.6	Immediate (2.4)	Cauda equina syndrome (0.5, 4/737), spondylodiscitis (1.9, 14/737)
		Immediate / urgent (0.7)	Spinal cancer (0.7, 5/737)
		Not specified (1.1)	Vertebral compression fracture (1.1, 8/737)
Thiruganasambandamoorthy et al., 2014 ²⁶	6.4	Immediate (2.4)	Epidural abscess (0.3, 1/329), osteomyelitis (0.9, 3/329), cauda equina syndrome (0.3, 1/729), retroperitoneal bleeding (0.6, 2/329), abdominal aortic aneurysm graft leak (0.3, 1/329), aortic rupture (0.0, 0/329)
		Immediate / urgent (2.1)	Spinal cancer (2.1, 7/329)
		Urgent (1.5)	Herniated disc requiring surgery within 30 days (1.2, 4/329), spinal stenosis requiring surgery within 30 days (0.3, 1/329)
		Not specified (0.3)	Vertebral compression fracture (0.3, 1/329)
Tracey et al., 1994 ¹⁹	8.5	Immediate / urgent (6.7)	Vertebral fracture (5.8, 26/445), spinal cancer (0.9, 4/445)
		Not specified (1.8)	Spondylolisthesis (1.8, 8/445)
Weiner et al., 1999 ³¹	2.8	Immediate (0.0)	Osteomyelitis (0.0, 0/214)
		Immediate / urgent (0.9)	Vertebral fracture (0.9, 2/214), spinal cancer (0.0, 0/214)
		Non-urgent (1.9)	Spondylolisthesis grade 1 (1.9, 4/214)
Koontz et al., 2017 ^{24,a}	77.1	Immediate (1.7)	Cord/conus medullaris compression (1.7, 2/118)
		Immediate / urgent (13.6)	Severe spinal canal stenosis (11.0, 13/118), acute vertebral fracture (2.5, 3/118)
		Not specified (61.9)	Nerve root impingement (30.5, 36/118), intraspinal mass including disc, synovial cyst, hematoma, cerebrospinal fluid leak, or metastases (31.4, 37/118)

Abbreviations: SSP, serious spinal pathology; No., number; n.i., not investigated; LBP, low back pain; MRI, magnetic resonance imaging

^z Prevalence of epidural abscess was assessed over a 14-year period and was compared to an emergency population with LBP collected over a 9-month period. To calculate the prevalence, we extrapolated the number of the emergency LBP patients to the 14-year study period

^b Random selection of patients with acute low back pain and radiculopathy

^c Random selection of patients who did not get an X-ray on index visit but were followed-up after >1 year for missed SSP

^e Only patients aged 66 or older included

^d Prevalence calculated based on all spine pain patients

^f Study participants: back pain patients that warranted a referral to the orthopedic team. Patients showed a high rate of neurologic symptoms

^a Study participants: acute LBP patients with neurologic deficits who underwent MRI for exclusion of cauda equina syndrome

Appendix 7: Prevalence of serious spinal pathologies

Urgency	Serious spinal pathology (SSP)	Prevalence: % (No. of all)	Ref.
Prospective observational studies			
All studies with any SSP: range		5.1 - 5.5	5, 21
All studies with any immediate/urgent SSP: range		2.5 - 5.1	5, 21
Immediate	Epidural abscess / spinal infection	0.0 (0/200)	21
		0.5 ² (86/19033)	20
		0.6 (1/158)	5
		1.5 (3/200)	21
		0.5 (1/200)	21
		0.5 (1/200)	21
		1.9 (3/158)	5
		0.6 (1/158)	5
Immediate/urgent	Spinal cancer	1.9 (3/158)	5
	Vertebral fracture	0.0 (0/158)	5
Not specified	Vertebral compression fracture (mandating a specific treatment, no detailed information on treatment provided)	1.0 (2/200)	21
Non-urgent	Vertebral compression fracture (conservative treatment)	2.0 (4/200)	21
Cross-sectional studies, prospective			
All studies with any SSP: range		3.1 - 60.6	19, 22, 23
All studies with any immediate/urgent SSP: range		3.1 - 4.5	19, 22, 23
Immediate/urgent	Vertebral fracture	2.1 (10/482)	23
		3.1 (7/225)	22
		4.2 (13/312)	19
		0.3 (1/312)	19
		1.5 (7/482)	23
Not specified	Herniated disc	89.0 ⁰ (89/100)	48
	Vertebral fracture, indeterminate age	5.0 (24/482)	23
Non-urgent	Vertebral fracture, chronic age	4.4 (21/482)	23
	Spondylosis	47.7 (230/482)	23
Retrospective studies			
All studies with any SSP: range		1.2 - 77.1	19, 24-33, 49-51
All studies with any immediate/urgent SSP: range	Studies without particular patient selection	0.7 - 7.4	19, 26-33
	Studies with high rate of neurologic symptoms ^{a,1}	15.3 - 15.5	24, 25
Immediate	Epidural or paraspinal abscess	0.3 (1/329)	26
		0.6 ^c (2/326)	29
		1.0 (1/100)	30
		0.1 (1/802)	28
	Spondylodiscitis	0.3 ^c (1/326)	29
		1.9 (14/737)	27
		0.0 (0/214)	31
	Osteomyelitis	0.9 (3/329)	26
		0.3 (1/329)	26
	Compression of the spinal cord, conus medullaris, or cauda equina	0.5 (4/737)	27
		1.7 ^a (2/118)	24
15.5 ¹ (32/206)		25	

	Herniated disc (cervical disc herniation requiring prompt evaluation and hospital admission) ^d	0.1 (1/802)	28
	Retroperitoneal bleeding	0.6 (2/329)	26
	Abdominal aortic aneurysm graft leak	0.3 (1/329)	26
	Aortic rupture	0.0 (0/329)	26
	Acute aortic dissection	0.0 (0/2833)	34
Immediate/urgent	Vertebral fracture	0.3 (1/327)	32
		0.9 (2/214)	31
		2.5 ^a (3/118)	24
		5.8 (26/445)	19
		7.2 (40/552)	33
	Spinal cancer	0.0 (0/214)	31
		0.2 (1/552)	33
		0.3 ^c (1/326)	29
		0.4 (4/944)	28
		0.7 (5/737)	27
	0.9 (4/445)	19	
	2.1 (7/329)	26	
	Severe spinal canal stenosis	11.0 ^a (13/118)	24
	Spondylolisthesis/instability	3.4 (11/327)	32
Urgent	Herniated disc (requiring surgery within 30 days)	1.2 (4/329)	26
	Spinal stenosis (requiring surgery within 30 days)	0.3 (1/329)	26
Not specified	Herniated disc	0.8 ^e	50
		(207/25872)	
		2.0 (80/4097)	49
		4.8 ^d (23/484)	32
		9.9 (93/944)	28
	Nerve root impingement	30.5 ^a (36/118)	24
		31.4 ^a (37/118)	24
	Intraspinal mass (disc, synovial cyst, hematoma, cerebrospinal fluid leak, or metastases)		
	Spondylolisthesis	1.8 (8/445)	19
		2.9 (16/552)	33
	Vertebral compression fracture (no information about urgency)	0.3 (1/329)	26
		1.1 (8/737)	27
		4.0 (4/100)	30
	Non-urgent	Vertebral compression fracture (requiring non-urgent treatment)	1.1 (10/944)
4.0 (29/732)			30, 51
Axial spondylarthritis		0.2 (2/944)	28
Spondylosis		0.3 (12/4097)	49
Spinal stenosis		0.2 ^d (1/484)	32
		0.5 ^e	50
	(129/25872)		
	Spondylolisthesis grade 1	1.9 (4/214)	31

Abbreviations: SSP, serious spinal pathology; No., number; Ref., reference; LBP, low back pain; MRI, magnetic resonance imaging

^z Prevalence of epidural abscess was assessed over a 14-year period and was compared to an emergency population with LBP collected over a 9-month period. To calculate the prevalence, we extrapolated the number of the emergency LBP patients to the 14-year study period

^b Random selection of patients with acute low back pain and radiculopathy

^c Random selection of patients who did not get an X-ray on index visit but were followed-up after >1 year for missed SSP

^a Study participants: acute LBP patients with neurologic deficits who underwent MRI for exclusion of cauda equina syndrome

^f Study participants: back pain patients that warranted a referral to the orthopedic team. Patients showed a high rate of

neurologic symptoms

^e Included patients aged 66 or older

^d Prevalence calculated based on all spine pain patients

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Appendix 8: Diagnostic accuracy of red flags for serious spinal pathologies (classified into urgency group)

Serious spinal pathology	Red flag	TP	FN	FP	TN	Sens %	Spec %	LR+	LR-	PPV %	NPV %	Ref.
Immediate												
Epidural abscess	History/symptoms											
	Any risk factor ^z	86	0	4424	14523	100.0	76.7	4.3	0.00	1.9	100.0	20,z
	Any risk factor ^s	62	1	27	99	98.0	78.6	4.6	0.03	**	**	35
	Immunocompromised	15	71	663	18284	17.7	96.5	5.1	0.85	2.2	99.6	20,z
	Diabetes mellitus	14	72	1421	17526	16.7	92.5	2.2	0.90	1.0	99.6	20,z
	Intravenous drug abuse	52	34	834	18113	60.4	95.6	13.7	0.41	5.9	99.8	20,z
	Liver disease	12	74	853	18094	13.5	95.5	3.0	0.91	1.3	99.6	20,z
	Renal disease	2	84	189	18757	2.1	99.0	2.1	0.99	0.9	99.6	20,z
	Recent spine procedure/surgical implants	15	71	909	18037	17.7	95.2	3.7	0.86	1.6	99.6	20,z
	Recent spine fracture	9	77	208	18738	10.4	98.9	9.5	0.91	4.1	99.6	20,z
	Clinical findings											
	Classic triad (fever (temperature $\geq 38^{\circ}\text{C}$, 100.4°F), spine pain, and neurological deficit)	2	84	76	18871	2.3	99.6	5.7	0.98	2.5	99.6	20,z
		5	58	1	125	7.9	99.2	9.9	0.93	**	**	35
	Temperature $\geq 100.4^{\circ}\text{F}$	6	80	379	18568	7.3	98.0	3.7	0.95	1.6	99.6	20,z
	Systolic Blood Pressure < 90 mmHg	5	81	133	18814	6.3	99.3	9.0	0.94	3.9	99.6	20,z
	Heart rate > 100 bpm	32	54	3107	15839	37.5	83.6	2.3	0.75	1.0	99.7	20,z
	Abnormal neurological exam	21	65	1743	17204	24.0	90.8	2.6	0.84	1.2	99.6	20,z
	Indwelling vascular catheter	8	78	114	18833	9.4	99.4	15.7	0.91	6.6	99.6	20,z
	Other site of infection	22	64	360	18587	26.0	98.1	13.7	0.75	5.8	99.7	20,z
	Elevated ESR (> 20 mm/hour) plus a risk factor ^z	86	0	6252	12694	100.0	67.0	3.0	0.00	1.4	100.0	20,z
Elevated CRP (> 1.0) plus a risk factor ^z	75	11	9473	9473	87.0	50.0	1.7	0.26	0.8	99.9	20,z	
Compression of the spinal cord or cauda equina												
Clinical findings												
Obesity (BMI $\geq 30 \text{ kg/m}^2$)	1	1	26	90	50.0	77.6	2.2	0.64	3.7	98.9	24,a	
Disturbance of saddle sensation in physical examination	11	21	19	155	34.4	89.1	3.1	0.74	36.7	88.1	25,1	
Disturbance of urinary and/or bowel sphincters	18	14	47	127	56.3	73.0	2.1	0.60	27.7	90.1	25,1	
Profound lower limb neurological dysfunction	9	23	30	144	28.1	82.8	1.6	0.87	23.1	86.2	25,1	
Immediate/urgent												
Any serious outcome^s	History/symptoms											
	Radiation of pain to the leg	8	14	145	162	36.4	52.8	0.8	1.21	5.2	92.0	26
	Duration of pain > 365 days	2	20	9	298	9.1	97.1	3.1	0.94	18.2	93.7	26
	Duration of present illness < 1 day	3	19	83	224	13.6	73.0	0.5	1.18	3.5	92.2	26
	History of insidious onset of present illness	11	11	120	187	50.0	60.9	1.3	0.82	8.4	94.4	26
	Pain in the middle of lumbar vertebrae	0	22	11	296	0.0	96.4	0.0	1.04	0.0	93.1	26
	Pain persistent despite appropriate analgesia	13	9	114	193	59.1	62.9	1.6	0.65	10.2	95.5	26
	Pain that awakens patient	3	19	19	288	13.6	93.8	2.2	0.92	13.6	93.8	26

at night											
Pain that is worse at night	3	19	13	294	13.6	95.8	3.2	0.90	18.8	93.9	²⁶
Pain that is worse at rest	1	21	9	298	4.5	97.1	1.6	0.98	10.0	93.4	²⁶
Radiation to the leg below the knee	6	16	90	217	27.3	70.7	0.9	1.03	6.3	93.1	²⁶
Progressive/worsening symptoms in anamnesis of present illness	7	15	123	184	31.8	59.9	0.8	1.14	5.4	92.5	²⁶
Motor symptoms (weakness/ paralysis) in anamnesis of present illness	6	16	44	263	27.3	85.7	1.9	0.85	12.0	94.3	²⁶
Sensory symptoms in anamnesis of present illness	8	14	55	252	36.4	82.1	2.0	0.78	12.7	94.7	²⁶
Fever in anamnesis of present illness	0	22	8	299	0.0	97.4	0.0	1.03	0.0	93.1	²⁶
Urinary retention in anamnesis of present illness	3	19	6	301	13.6	98.0	7.0	0.88	33.3	94.1	²⁶
Urinary incontinence in anamnesis of present illness	0	22	6	301	0.0	98.0	0.0	1.02	0.0	93.2	²⁶
Fecal incontinence in anamnesis of present illness	1	21	3	304	4.5	99.0	4.7	0.96	25.0	93.5	²⁶
Recent bacteremia procedures ^a	2	20	8	299	9.1	97.4	3.5	0.93	20.0	93.7	²⁶
History of cancer	3	19	17	290	13.6	94.5	2.5	0.91	15.0	93.9	²⁶
History of HIV	0	22	2	305	0.0	99.3	0.0	1.01	0.0	93.3	²⁶
History of osteoporosis	1	21	5	302	4.5	98.4	2.8	0.97	16.7	93.5	²⁶
On anticoagulants	5	17	8	299	22.7	97.4	8.7	0.79	38.5	94.6	²⁶
On immunosuppressive medication	0	22	6	301	0.0	98.0	0.0	1.02	0.0	93.2	²⁶
Prolonged steroids use (\geq 90 days)	0	22	3	304	0.0	99.0	0.0	1.01	0.0	93.3	²⁶
Age > 65 years	12	10	52	255	54.5	83.1	3.2	0.55	18.8	96.2	²⁶
Age > 75 years	9	13	34	273	40.9	88.9	3.7	0.66	20.9	95.5	²⁶
Clinical findings											
Fever (\geq 38°C)	1	21	9	298	4.5	97.1	1.6	0.98	10.0	93.4	²⁶
Disturbance of saddle sensation in physical examination	2	20	4	303	9.1	98.7	7.0	0.92	33.3	93.8	²⁶
Decreased sensation in physical examination	6	16	21	286	27.3	93.2	4.0	0.78	22.2	94.7	²⁶
Decreased anal sphincter tone in physical examination	0	22	3	304	0.0	99.0	0.0	1.01	0.0	93.3	²⁶
Bladder/suprapubic fullness in physical examination	1	21	0	307	6.5	99.8	40.2	0.94	75.0	93.5	²⁶
Motor weakness in physical examination	3	19	49	258	13.6	84.0	0.9	1.03	5.8	93.1	²⁶
Inability to walk in physical examination	2	20	29	278	9.1	90.6	1.0	1.00	6.5	93.3	²⁶
Deep tendon reflex abnormality	8	14	138	169	36.4	55.0	0.8	1.16	5.5	92.3	²⁶
Tenderness in physical examination	3	19	66	241	13.6	78.5	0.6	1.10	4.3	92.7	²⁶
Hemoglobin < 100 g/L	2	20	2	305	9.1	99.3	14.0	0.92	50.0	93.8	²⁶
Hemoglobin < 110 g/L	4	18	5	302	18.2	98.4	11.2	0.83	44.4	94.4	²⁶
INR \geq 1	7	15	16	291	31.8	94.8	6.1	0.72	30.4	95.1	²⁶
Any serious History/symptoms											

outcome°	Most recent spinal operation	0	31	148	558	0.0	79.0	0.0	1.27	0.0	94.7	²⁷
	Referral from general practitioner	30	3	633	234	90.9	27.0	1.2	0.34	4.5	98.7	²⁷
	Referral from private sector	0	33	42	825	0.0	95.2	0.0	1.05	0.0	96.2	²⁷
	Referral from a consultant	2	31	23	844	6.1	97.3	2.3	0.96	8.0	96.5	²⁷
	Direct referral	1	32	169	698	3.0	80.5	0.2	1.20	0.6	95.6	²⁷
	History of cancer	2	29	50	656	6.5	92.9	0.9	1.01	3.8	95.8	²⁷
	Vertebral fracture	History/symptoms										
	Hip/leg pain	9	31	118	394	22.5	77.0	1.0	1.01	7.1	92.7	³³
	Radiation of pain to the leg	9	31	124	388	22.5	75.8	0.9	1.02	6.8	92.6	³³
	No radiation	30	10	387	125	75.0	24.4	1.0	1.02	7.2	92.6	³³
	History of trauma	7	0	75	143	100.0	65.6	2.9	0.00	8.5	100.0	²²
	History of trauma	32	8	231	281	80.0	54.9	1.8	0.36	12.2	97.2	³³
	History of trauma [^]	4	6	169	303	40.0	64.2	1.1	0.93	2.3	98.1	²³
	Clinical findings											
	History of trauma plus positive neurological signs	2	5	2	216	28.6	99.1	31.1	0.72	50.0	97.7	²²
	Obesity (BMI \geq 30 kg/m ²)	2	1	25	90	66.7	78.3	3.1	0.43	7.4	98.9	^{24,a}
	Non-obesity (BMI < 30 kg/m ²)	1	2	90	25	33.3	21.7	0.4	3.07	1.1	92.6	^{24,a}
	Contusion/abrasion	6	34	14	498	15.0	97.3	5.5	0.87	30.0	93.6	³³
	Spasm	10	30	87	425	25.0	83.0	1.5	0.90	10.3	93.4	³³
	Tenderness in physical examination	29	11	211	301	72.5	58.8	1.8	0.47	12.1	96.5	³³
	Abnormal neurological exam	2	5	15	203	28.6	93.1	4.2	0.80	11.8	97.6	²²
	Incontinence (bladder and/or bowel)	1	2	55	60	33.3	52.2	0.7	1.28	1.8	96.8	^{24,a}
	Lower extremity weakness	1	2	67	48	33.3	41.7	0.6	1.60	1.5	96.0	^{24,a}
	Motor weakness in physical examination	0	40	4	508	0.0	99.2	0.0	1.01	0.0	92.7	³³
	Decreased sensation in physical examination	1	39	9	503	2.5	98.2	1.4	0.99	10.0	92.8	³³
	Deep tendon reflex abnormality	3	37	25	487	7.5	95.1	1.5	0.97	10.7	92.9	³³
	Positive straight leg raising test (SLR)	7	33	88	424	17.5	82.8	1.0	1.00	7.4	92.8	³³
	Multiple signs*	17	23	106	406	42.5	79.3	2.1	0.73	13.8	94.6	³³
Spinal cancer	History/symptoms											
	History of cancer or clinical suspicion of cancer	7	0	17	458	100.0	96.4	27.9	0.00	29.2	100.0	²³
	History of cancer	2	3	50	682	40.0	93.2	5.9	0.64	3.8	99.6	²⁷
	Clinical findings											
	Abnormal neurological exam	3	4	34	441	42.9	92.8	6.0	0.62	8.1	99.1	²³
Severe spinal canal stenosis	Clinical findings											
	Obesity (BMI \geq 30 kg/m ²)	10	3	17	88	76.9	84.2	4.9	0.27	37.7	96.7	^{24,a}
	Non-obesity (BMI < 30 kg/m ²)	3	10	88	17	23.1	15.8	0.3	4.88	3.3	62.3	^{24,a}
	Focal neurologic deficit	2	11	7	98	15.4	93.3	2.3	0.91	22.2	89.9	^{24,a}
	Incontinence (bladder and/or bowel)	6	7	50	55	46.2	52.4	1.0	1.03	10.7	88.7	^{24,a}
	Lower extremity weakness	9	4	59	46	69.2	43.8	1.2	0.70	13.2	92.0	^{24,a}
	Perineal anesthesia	1	12	22	83	7.7	79.0	0.4	1.17	4.3	87.4	^{24,a}
Not specified												
Herniated disc	Clinical findings											
	Positive straight leg raising	69	20	7	4	77.6	36.5	1.2	0.61	90.8	16.7	^{48,b}

test (SLR)												
Reverse SLR	79	10	10	1	88.9	10.9	1.0	1.02	89.0	10.8	48, ^b	
Cross SLR	26	63	1	10	29.2	90.9	3.2	0.78	96.3	13.7	48, ^b	
Associating the description of the patient's conditions with positive SLR	80	9	0	11	89.5	95.8	21.5	0.11	99.4	54.8	48, ^b	
Nerve root impingement	Clinical findings											
Obesity (BMI \geq 30 kg/m ²)	17	19	10	72	47.2	87.8	3.9	0.60	63.0	79.1	24, ^a	
Non-obesity (BMI < 30 kg/m ²)	19	17	72	10	52.8	12.2	0.6	3.87	20.9	37.0	24, ^a	
Focal neurologic deficit	4	32	5	77	11.1	93.9	1.8	0.95	44.4	70.6	24, ^a	
Incontinence (bladder and/or bowel)	16	20	40	42	44.4	51.2	0.9	1.08	28.6	67.7	24, ^a	
Lower extremity weakness	25	11	43	39	69.4	47.6	1.3	0.64	36.8	78.0	24, ^a	
Perineal anesthesia	7	29	16	66	19.4	80.5	1.0	1.00	30.4	69.5	24, ^a	
Intraspinal mass^{**}	Clinical findings											
Obesity (BMI \geq 30 kg/m ²)	21	16	6	75	56.8	92.6	7.7	0.47	77.8	82.4	24, ^a	
Non-obesity (BMI < 30 kg/m ²)	16	21	75	6	43.2	7.4	0.5	7.66	17.6	22.2	24, ^a	
Lower extremity weakness	23	14	45	36	62.2	44.4	1.1	0.85	33.8	72.0	24, ^a	
Incontinence (bladder and/or bowel)	14	23	42	39	37.8	48.1	0.7	1.29	25.0	62.9	24, ^a	
Perineal anesthesia	4	33	19	62	10.8	76.5	0.5	1.17	17.4	65.3	24, ^a	
Focal neurologic deficit	4	33	5	76	10.8	93.8	1.8	0.95	44.4	69.7	24, ^a	
Vertebral fracture of acute, chronic and indeterminate age	Clinical findings											
Neurological deficit consistent with lumbar plexus distribution	3	52	34	393	5.5	92.0	0.7	1.03	8.1	88.3	23	
Non-urgent Spondylosis	Clinical findings											
Neurological deficit consistent with lumbar plexus distribution	24	206	13	239	10.4	94.8	2.0	0.94	64.9	53.7	23	

TP, true positive; FN, false negative; FP, false positive; TN, true negative; Sens, sensitivity; Spec, specificity; LR+, positive likelihood ratio; LR-, negative likelihood ratio; PPV, positive predictive value; NPV, negative predictive value; Ref., reference; bpm, beats per minute; ESR, erythrocyte sedimentation rate; CRP, C-reactive protein; BMI, body mass index; MRI, magnetic resonance imaging; LBP, low/lumbar back pain; INR, international normalized ratio; HIV, human immunodeficiency virus; SLR, straight leg raising

LR+/LR-: very good (LR+ >10, LR- <0.1); good (LR+ 5 to 10, LR- 0.1 to 0.2); fair (LR+ 2 to 5, LR- 0.2 to 0.5); poor (LR+ <2, LR- >0.5)

[£] Included diabetes, intravenous drug use, recent spine procedure or indwelling spinal surgical implant, recent spine fracture, indwelling vascular catheter, immunocompromised, other site of infection, chronic liver disease

^z Prevalence of epidural abscess was assessed over a 14-year period and was compared to an emergency population with LBP collected over a 9-month period. To calculate the prevalence and the diagnostic accuracy of red flags, we extrapolated the number of the emergency LBP patients to the 14-year study period

[§] Included diabetes, intravenous drug use, recent spine procedure, recent spine fracture, indwelling catheter, immunocompromised, distant site of infection, alcohol abuse, chronic renal failure, cancer

^{**} Calculation not reasonable due to study design (case-control study)

^a Study participants: acute LBP patients with neurologic deficits who underwent MRI for exclusion of CES

^f Study participants: back pain patients that warranted a referral to the orthopedic team. Patients showed a high rate of neurologic symptoms

[§] Included the following pathologies: osteomyelitis (n=3), epidural abscess (n=1), cancer (n=7), cauda equina syndrome (n=1), severe disc prolapse requiring surgery within 30 days (n=4), retroperitoneal bleeding (n=2), spinal stenosis requiring surgery within 30 days (n=1), abdominal aortic aneurysm graft leak (n=1), and compression fracture

(n=1)

& Recent (within the past 8 weeks) procedure known to cause bacteremia – any genitourinary or gastrointestinal procedure; or recent spinal injections such as lumbar puncture, epidural injections or spinal steroid injections

° Included the following pathologies: cauda equina syndrome (n=4), spondylodiscitis (n=14), cancer (n=5), vertebral compression fracture (n=8)

^ Included patients with a minor trauma (e.g., fall from a standing height or twisting injury)

* Two or more physical findings (contusion/abrasion, tenderness, spasm, sensory deficit, motor deficit, deep tendon reflex abnormality, or positive straight leg raising)

^b Random selection of patients with acute low back pain and radiculopathy

Included disc (n=30), synovial cyst (n=3), hematoma (n=2), cerebrospinal fluid leak (n=1), metastases (n=1)

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Clinical Significance

- The prevalence of serious spinal pathologies at the ED was 2.5–5.1%.
- Red flags with a very good diagnostic accuracy were suspicion/history of cancer for spinal cancer; intravenous drug use, indwelling vascular catheter, and other infection site for epidural abscess.
- Situations with decreased likelihood: no risk factor, normal ESR (for epidural abscess), no suspicion/history of cancer (for spinal cancer).
- Out of 84 red flags, only 2 were investigated in more than one study.

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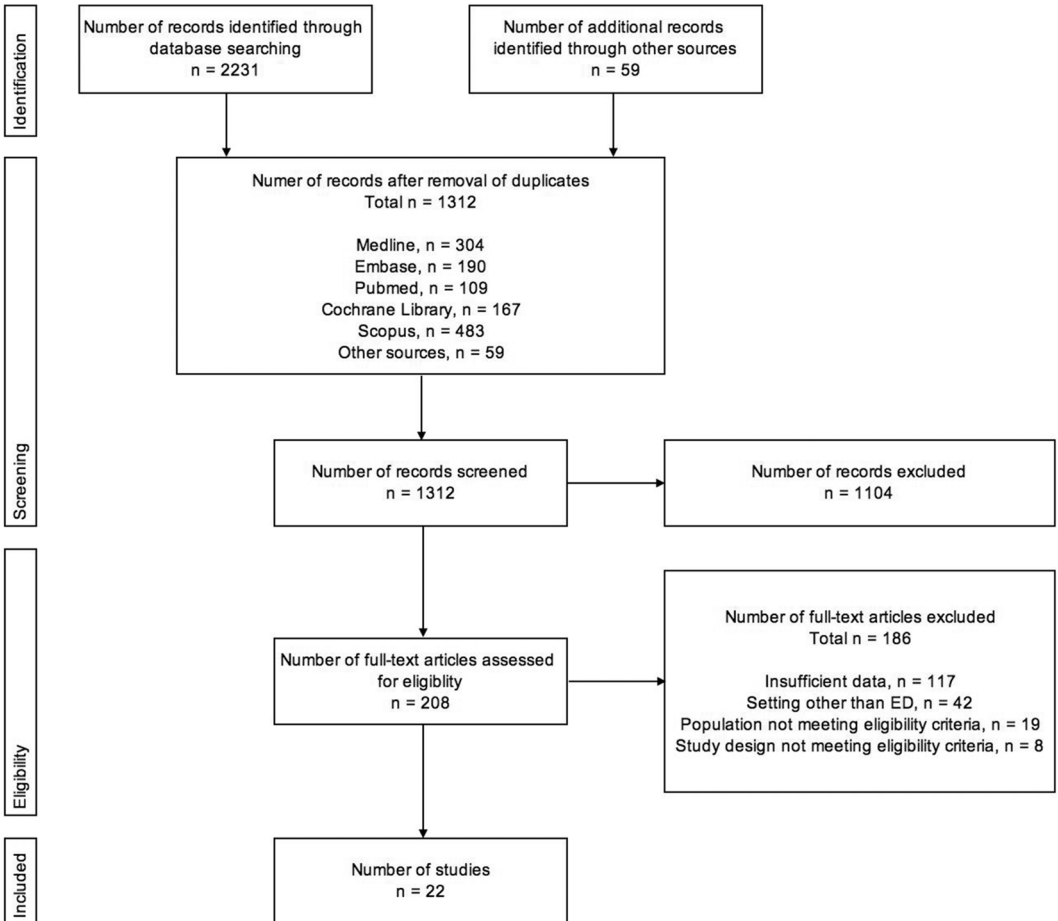


Figure 1

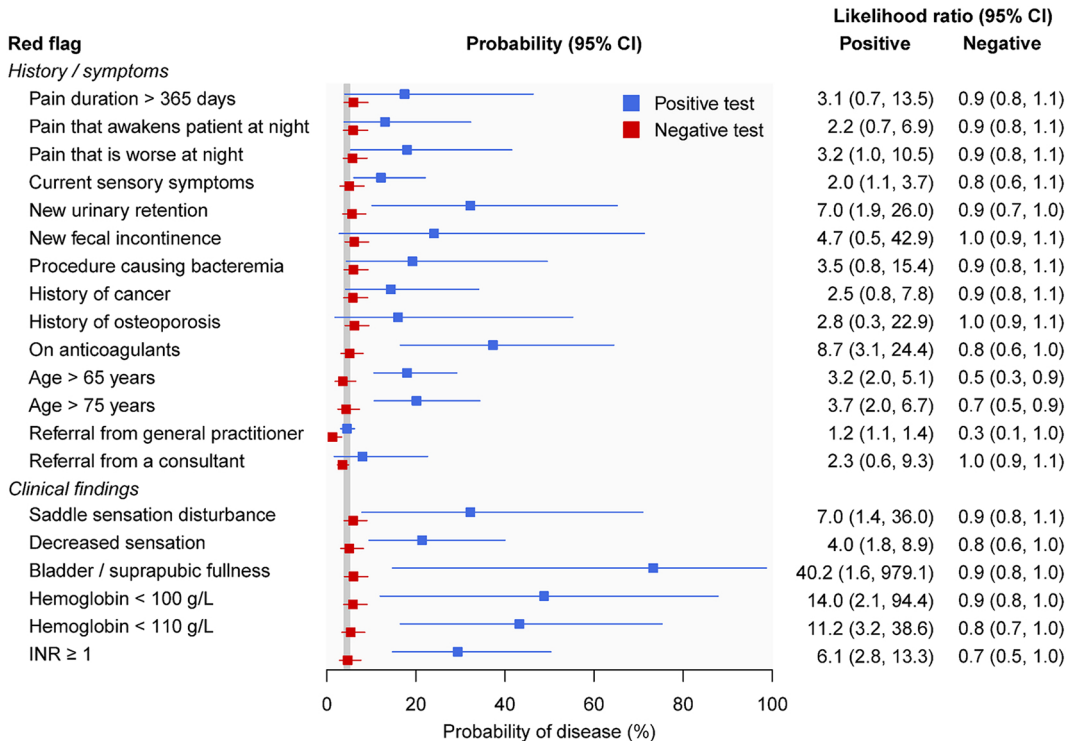


Figure 2

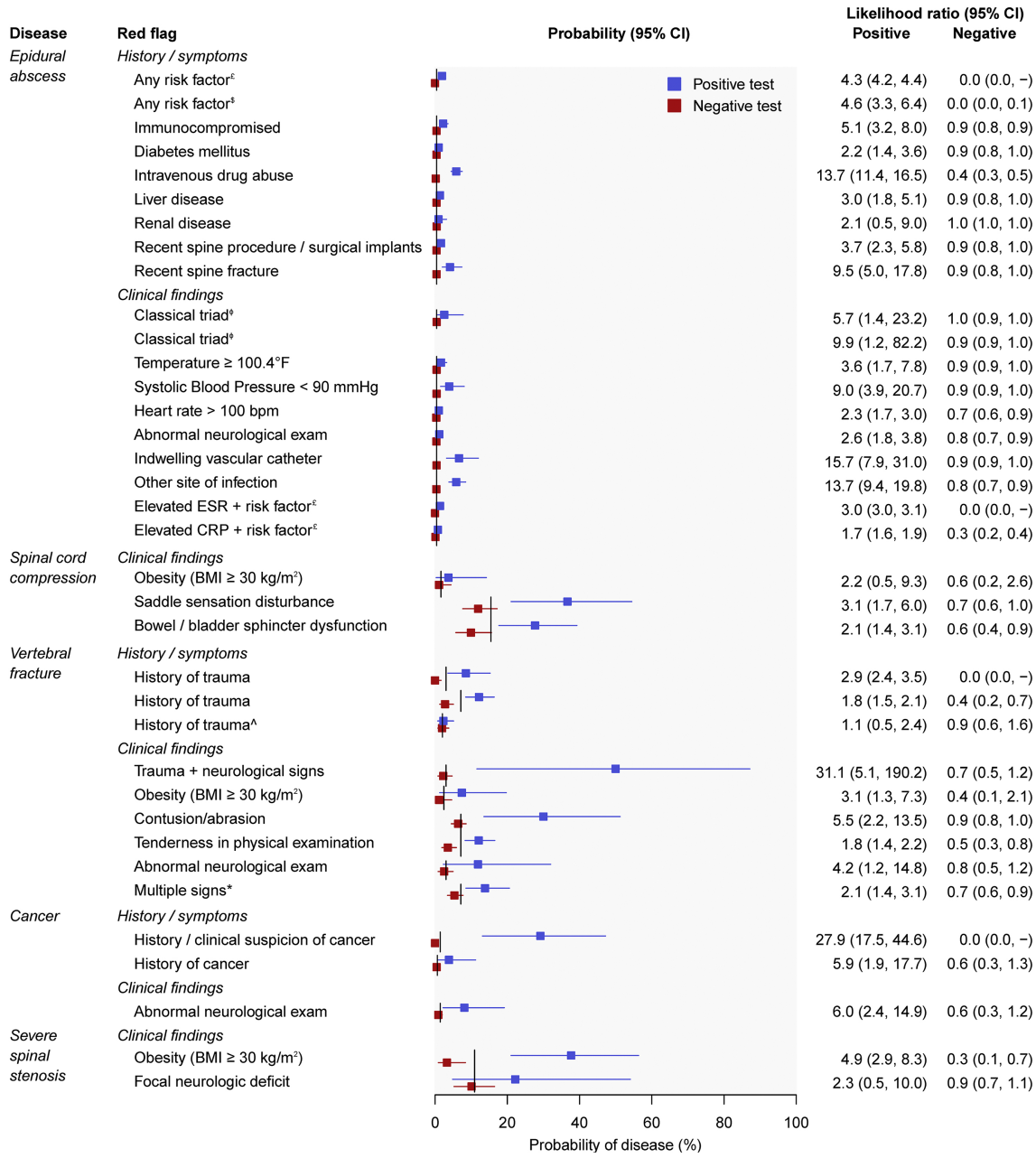


Figure 3