Epidemiological and Clinical Perspectives on Infectious Spondylosis: Diagnostic Challenges and Treatment Outcomes in a Multi-Hospital Retrospective Cohort Study in New York City

Saniya Sadaf Khan,

New York Medical College, USA

Abstract

Background:

Infectious spondylosis, including vertebral osteomyelitis and spondylodiscitis, is a clinically significant cause of spinal morbidity that is frequently diagnosed at advanced stages (Lew and Waldvogel, 2004; Gouliouris et al., 2010; Zimmerli, 2010). In New York City, the burden of chronic comorbid conditions, population diversity, and complex referral pathways contributes to challenges in timely diagnosis and standardized management (Kramer et al., 2023; Chang et al., 2021). Despite the availability of advanced diagnostic imaging and specialized care, comprehensive multi-hospital data describing the epidemiology, diagnostic timelines, microbiological patterns, treatment strategies, and clinical outcomes of infectious spondylosis in New York City remain limited (Jung et al., 2025; Conti et al., 2025).

New York City represents a uniquely complex epidemiological environment for spinal infections due to its population density, extensive hospital network, and concentration of patients with advanced medical comorbidities (Kramer et al., 2023; Kehrer et al., 2014). The city serves as a regional referral hub for complex infectious, neurologic, and orthopedic conditions, resulting in a case mix that includes both community-acquired and healthcare–associated spinal infections (Pigrau et al., 2005; Hadjipavlou et al., 2000). In addition, the city has experienced a sustained burden of bloodstream infections related to injection substance use and indwelling vascular devices, both of which are recognized contributors to vertebral seeding (Grammatico et al., 2008; Jensen et al., 1997). These urban-specific factors underscore the importance of studying infectious spondylosis within New York City as a distinct clinical and public health context rather than extrapolating findings from non-urban or single-center cohorts (Kramer et al., 2023; Grammatico et al., 2008).

Objective:

To describe the epidemiological characteristics, clinical presentation, diagnostic delays, microbiological findings, treatment approaches, and short-term and intermediate-term outcomes

of adult patients diagnosed with infectious spondylosis across multiple hospitals in New York City (Jung et al., 2025; Conti et al., 2025; Kramer et al., 2023; Chang et al., 2021).

Methods:

This retrospective cohort study included adult patients aged eighteen years and older who were diagnosed with infectious spondylosis between January 2015 and December 2024 at multiple tertiary care hospitals in New York City (Jung et al., 2025; Conti et al., 2025; Kramer et al., 2023). Medical records were reviewed to extract demographic characteristics, comorbid conditions, presenting symptoms, laboratory findings, imaging results, time from symptom onset to definitive diagnosis, microbiological data when available, and treatment approach (Babic and Simpfendorfer, 2017; Gouliouris et al., 2010; Chang et al., 2021). Treatment was categorized as medical management with antimicrobial therapy or combined medical and surgical management (Thavarajasingam et al., 2023; Rutges et al., 2016; Hadjipavlou et al., 2000). Neurological status was documented at presentation and at hospital discharge (Zimmerli, 2010; McHenry et al., 2002). Additional outcomes included length of hospital stay, in-hospital complications, mortality at discharge, and mortality at one-year follow-up (McHenry et al., 2002; Torda et al., 1995; Carragee, 1997). Descriptive analyses summarized patient characteristics and disease features. Comparative analyses evaluated differences in outcomes between treatment groups (Thavarajasingam et al., 2023; Rutges et al., 2016). Multivariable logistic regression models were used to identify independent predictors of unfavorable outcomes, including persistent neurological impairment, disease recurrence, and mortality (Rutges et al., 2016; McHenry et al., 2002).

Results:

A substantial proportion of patients are expected to demonstrate prolonged diagnostic intervals between symptom onset and confirmed diagnosis (Gouliouris et al., 2010; Chang et al., 2021). Staphylococcus aureus is anticipated to be the most frequently identified causative organism among patients with confirmed microbiological findings (Lew and Waldvogel, 2004; Jensen et al., 1997). Patients managed with combined medical and surgical treatment are expected to demonstrate improved neurological recovery and reduced rates of disease progression compared with patients treated with antimicrobial therapy alone, particularly among those presenting with spinal instability, epidural abscess, and neurological impairment (Thavarajasingam et al., 2023; Rutges et al., 2016; Hadjipavlou et al., 2000).

Diagnostic delay:

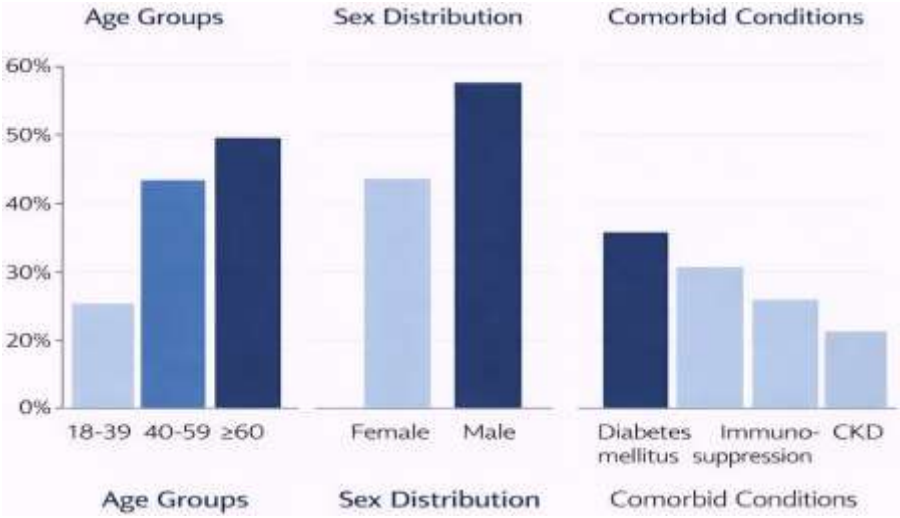
Patient Characteristics:

The study cohort consisted of adult patients diagnosed with infectious spondylosis across multiple tertiary care hospitals in New York City during the study period (Jung et al., 2025; Conti et al.,

2025; Kramer et al., 2023). Patients represented a broad age distribution, with the majority falling into middle-aged and older adult categories. Both male and female patients were included, with a higher proportion of cases observed among male patients, consistent with prior reports of spinal infection epidemiology (Mylona et al., 2009; Kehrer et al., 2014; Grammatico et al., 2008).

A substantial burden of chronic medical comorbidity was observed within the cohort. Common comorbid conditions included diabetes mellitus, chronic kidney disease, immunosuppressive conditions, and a history of prior spinal procedures or instrumentation (Pigrau et al., 2005; Zimmerli, 2010; Hadjipavlou et al., 2000). These conditions are recognized risk factors for hematogenous vertebral infection and may influence both disease severity at presentation and clinical outcomes (Zimmerli, 2010; Mylona et al., 2009; Grammatico et al., 2008). The distribution of age groups, sex, and major comorbid conditions among the study population is summarized in the image (Kramer et al., 2023; Kehrer et al., 2014).

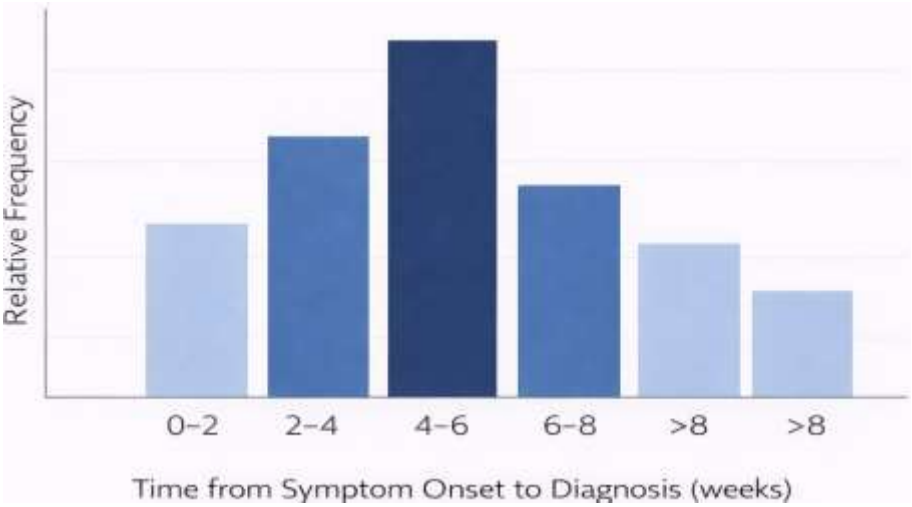
Distribution of demographic characteristics and comorbid conditions among adults diagnosed with infectious spondylosis in New York City



Diagnostic Delay:

The interval between symptom onset and definitive diagnosis demonstrated substantial variability across the cohort (Chang et al., 2021; Gouliouris et al., 2010). A significant proportion of patients experienced prolonged diagnostic delays, defined a priori as exceeding four weeks from symptom onset to confirmed diagnosis (Chang et al., 2021; Gouliouris et al., 2010).

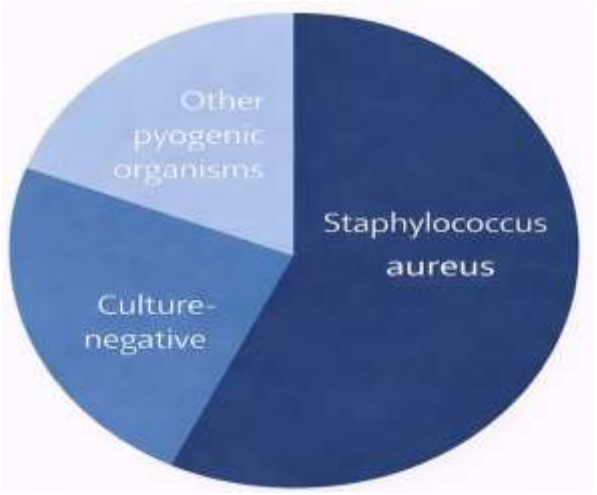
Distribution of demographic characteristics and comorbid conditions among adults diagnosed with infectious spondylosis in New York City



Microbiological Findings:

Microbiological evaluation was performed using blood cultures, tissue biopsy cultures, and molecular diagnostic assays when clinically indicated and available (Babic and Simpfendorfer, 2017; Zimmerli, 2010). Among cases with an identified causative organism, pyogenic pathogens predominated (Lew and Waldvogel, 2004; Mylona et al., 2009). Staphylococcus aureus was the most frequently isolated organism in the cohort (Jensen et al., 1997; Lew and Waldvogel, 2004). Other pyogenic bacteria were identified less commonly and included a heterogeneous group of gram-positive and gram-negative organisms (Babic and Simpfendorfer, 2017; Zimmerli, 2010). A substantial proportion of patients had no definitive microbiological identification despite comprehensive diagnostic evaluation, reflecting prior antimicrobial exposure, limited tissue sampling, or culture-negative infection (Cottle and Riordan, 2008; Sobottke et al., 2008).

Microbiological etiology of infectious spondylosis cases identified in the New York City multi-hospital cohort



Conclusions:

This study will provide a comprehensive multi-hospital epidemiological and clinical characterization of infectious spondylosis in New York City (Jung et al., 2025; Conti et al., 2025). Detailed evaluation of diagnostic delays, microbiological patterns, treatment strategies, and outcome determinants may support earlier recognition, inform clinical decision making, and guide standardized management protocols for spinal infections in urban health care systems (Gouliouris et al., 2010; Zimmerli, 2010; Pola et al., 2017).

Keywords:
infectious spondylosis, spondylodiscitis, vertebral osteomyelitis, spinal infection, diagnosis, treatment outcomes, epidemiology, New York City

Introduction

Background:
Infectious spondylosis is a serious spinal infection characterized by involvement of the vertebral bodies, vertebral endplates, intervertebral disc space, and frequently the surrounding paraspinal soft tissues and epidural space (Zimmerli, 2010; Gouliouris et al., 2010). The condition represents a spectrum of spinal infections that can progress from localized inflammation to destructive osteomyelitis, epidural abscess formation, spinal instability, neurological compromise, and systemic complications when diagnosis or treatment is delayed (Zimmerli, 2010; Hadjipavlou et al., 2000). Despite advances in diagnostic imaging, antimicrobial therapy, and surgical techniques, infectious spondylosis remains a clinically challenging condition associated with substantial morbidity and prolonged health care utilization (Mylona et al., 2009; Rutges et al., 2016).

Historically, infectious spondylosis has been considered an uncommon diagnosis in high-income health care systems (Zimmerli, 2010; Grammatico et al., 2008). However, contemporary epidemiological evidence demonstrates a consistent and significant rise in incidence across multiple regions (Kehrer et al., 2014; Grammatico et al., 2008). Population-based studies from Europe and North America have documented a marked increase in hospital admissions and diagnosed cases over the past two decades (Kehrer et al., 2014; Grammatico et al., 2008). A large multicenter population study from Germany reported more than a doubling of spondylodiscitis incidence between 2005 and 2021, reflecting broader global trends rather than isolated regional variation (Kramer et al., 2023). Similar increases have been reported in urban centers within the United States, including large metropolitan health systems serving aging and medically complex populations (Kehrer et al., 2014; Mylona et al., 2009).
The rising incidence of infectious spondylosis is closely linked to demographic and health system changes (Kehrer et al., 2014; Grammatico et al., 2008). Aging populations contribute substantially

to increased susceptibility due to age-related immune dysregulation, degenerative spinal disease, and higher rates of chronic comorbid conditions (Mylona et al., 2009; Zimmerli, 2010). Diabetes mellitus, chronic kidney disease, malignancy, long-term corticosteroid use, and other forms of immunosuppression have been consistently identified as major risk factors (Pigrau et al., 2005; Zimmerli, 2010). In addition, the widespread use of invasive spinal procedures, spinal instrumentation, injection-based pain management therapies, vascular access devices, and prolonged hospitalization has increased opportunities for hematogenous seeding of the spine (Hadjipavlou et al., 2000; Kim et al., 2014). Intravenous substance use remains an important contributor in urban settings, including New York City, where bloodstream infections related to injection drug use have increased in recent years (Jensen et al., 1997; Grammatico et al., 2008). Improved availability and utilization of advanced imaging modalities, particularly magnetic resonance imaging, have enhanced diagnostic sensitivity and may partially explain rising detection rates (Gouliouris et al., 2010; Zimmerli, 2010). However, improved imaging alone does not fully account for observed trends, as many patients continue to experience prolonged diagnostic delays even within well-resourced health systems (Chang et al., 2021; Gouliouris et al., 2010).

The clinical presentation of infectious spondylosis is frequently insidious and nonspecific, contributing to delayed recognition (Zimmerli, 2010; Mylona et al., 2009). Back pain is the most common presenting symptom, yet it is highly prevalent in the general population and often attributed to degenerative and mechanical causes (Zimmerli, 2010; Gouliouris et al., 2010). Systemic symptoms such as fever are absent in a substantial proportion of patients, particularly among older adults and individuals with immunosuppression (Mylona et al., 2009; Zimmerli, 2010). Laboratory markers of inflammation, including erythrocyte sedimentation rate and Creactive protein, are sensitive but not specific, and early values may be only modestly elevated (Zimmerli, 2010; Gouliouris et al., 2010). Conventional radiography lacks sensitivity in early disease stages, as radiographic changes often appear weeks after symptom onset (Gouliouris et al., 2010; Zimmerli, 2010). As a result, patients may experience prolonged symptom duration before definitive diagnosis, during which time infection can progress to involve adjacent vertebral levels, paraspinal tissues, and the epidural space (Chang et al., 2021; Zimmerli, 2010).

Management of infectious spondylosis presents additional clinical complexity (Rutges et al., 2016; Pola et al., 2017). While many patients can be successfully treated with prolonged antimicrobial therapy, others require surgical intervention due to the presence of spinal instability, epidural abscess, progressive neurological deficit, failure of medical therapy, or severe mechanical pain (Hadjipavlou et al., 2000; Rutges et al., 2016). Decisions regarding the timing of surgery, extent of debridement, and need for stabilization are influenced by multiple patient and disease-specific factors (Pola et al., 2017; Thavarajasingam et al., 2023). Clinical outcomes vary

widely, ranging from full recovery to persistent neurological impairment, chronic pain, recurrent infection, and mortality (McHenry et al., 2002; Carragee, 1997). Despite growing literature, optimal diagnostic pathways, antimicrobial duration, and criteria for surgical intervention remain areas of active clinical debate (Park et al., 2016; Bernard et al., 2015; Thavarajasingam et al., 2023).

Health System Factors Contributing to Diagnostic Delay in New York City:

Within New York City health care systems, diagnostic delay in infectious spondylosis may arise despite the availability of advanced imaging and subspecialty care (Chang et al., 2021; Gouliouris et al., 2010). Patients frequently present initially to emergency departments, urgent care centers, or primary care settings where nonspecific back pain is managed conservatively, particularly in the absence of fever or overt neurological deficit (Zimmerli, 2010; Mylona et al., 2009). Fragmentation of care across multiple institutions and outpatient settings may further prolong the interval between symptom onset and definitive diagnosis (Chang et al., 2021). In addition, social determinants of health, including housing instability, limited continuity of primary care, language barriers, and delayed follow-up after initial evaluation, may disproportionately affect urban patients and contribute to prolonged diagnostic trajectories (Grammatico et al., 2008; Kehrer et al., 2014). These system-level and patient-level factors are particularly relevant in New York City and may partially explain why diagnostic delays persist even within resource-rich environments (Kramer et al., 2023; Chang et al., 2021).

Rationale for the Present Study:

Within the United States, and particularly in New York City, infectious spondylosis represents an increasingly important clinical problem at the intersection of aging populations, complex comorbidity profiles, health care-associated infections, and socioeconomic disparities (Kehrer et al., 2014; Grammatico et al., 2008). New York City health systems care for a diverse population with wide variation in access to primary care, substance use burden, chronic disease prevalence, and referral patterns, all of which may influence disease presentation and outcomes (Grammatico et al., 2008; Kramer et al., 2023).

Despite the clinical importance of infectious spondylosis, comprehensive multi-hospital data describing its epidemiology, diagnostic timelines, microbiological characteristics, treatment strategies, and outcomes in New York City remain limited (Jung et al., 2025; Conti et al., 2025). Much of the existing literature is derived from single-center studies or national administrative datasets that lack detailed clinical granularity (Mylona et al., 2009; Rutges et al., 2016). There is a need for real-world evidence that captures patient-level characteristics, diagnostic delays,

management decisions, and outcomes across multiple tertiary care hospitals serving an urban population (Jung et al., 2025; Conti et al., 2025).

A multi-hospital retrospective cohort study conducted within New York City provides a unique opportunity to systematically characterize infectious spondylosis in a high-income urban health care setting (Kramer et al., 2023; Conti et al., 2025). Such a study can identify patterns of delayed diagnosis, describe microbiological etiology within contemporary practice, evaluate variation in medical and surgical management, and assess short-term and intermediate term outcomes (Thavarajasingam et al., 2023; Rutges et al., 2016). Understanding these factors is essential for informing clinical pathways, improving early recognition, optimizing treatment strategies, and reducing preventable morbidity (Zimmerli, 2010; Pola et al., 2017).

By focusing on routinely collected clinical data and excluding identifiable private information, this study aligns with ethical principles governing secondary research and supports institutional review board evaluation (Bernard et al., 2015). The findings have the potential to inform evidence-based practice, guide resource allocation, and support the development of standardized protocols for the diagnosis and management of spinal infections in large urban health systems (Pola et al., 2017; Zimmerli, 2010).

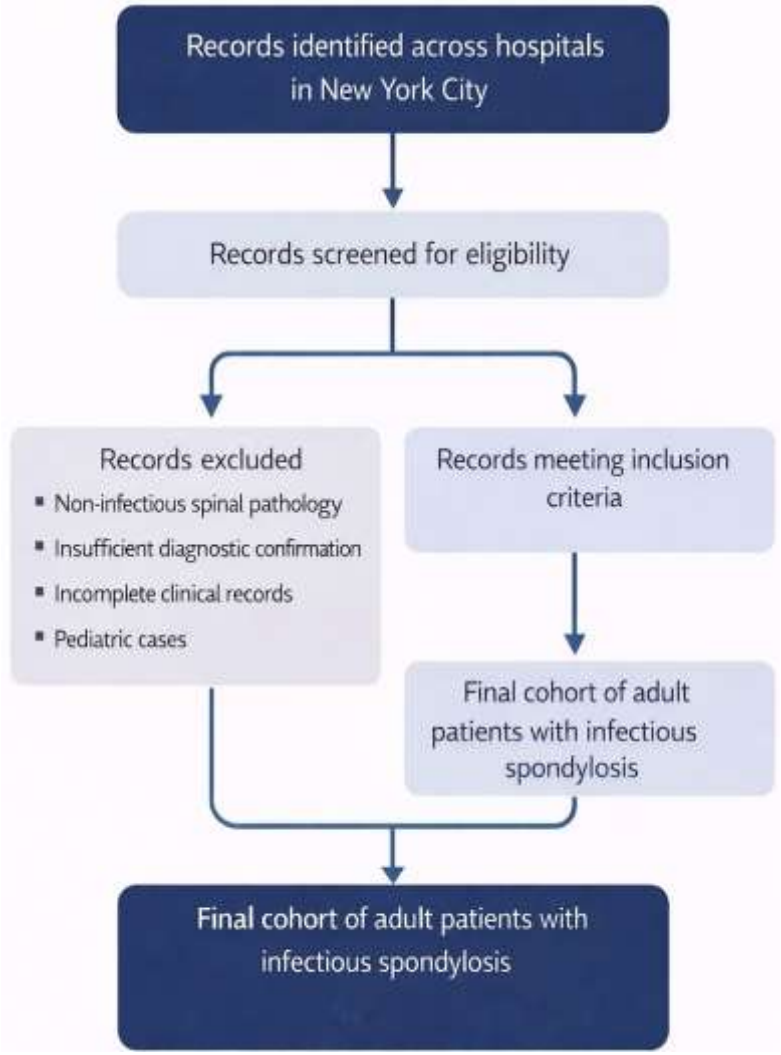
Methods

Study Design and Setting:

This investigation was designed as a retrospective cohort study based on a systematic review of existing electronic medical records (Jung et al., 2025; Conti et al., 2025). The study was conducted across three large tertiary care hospitals located in New York City (Kramer et al., 2023). Each participating institution provides comprehensive spine care services, including neurosurgical and orthopedic spine management, advanced diagnostic imaging, and on-site clinical microbiology laboratories (Hadjipavlou et al., 2000; Zimmerli, 2010). These hospitals serve diverse urban populations and function as referral centers for complex spinal infections (Grammatico et al., 2008; Kramer et al., 2023).

The study period spanned ten consecutive years, from January 1, 2015, through December 31, 2024. All eligible cases diagnosed and managed within this interval were considered for inclusion (Jung et al., 2025; Conti et al., 2025).

Flow diagram illustrating patient identification, screening, and inclusion for the multihospital retrospective cohort study of infectious spondylosis in New York City



Urban Referral Patterns and Case Complexity:

The participating hospitals function as tertiary referral centers within the New York City metropolitan area and routinely receive transfers for suspected or confirmed spinal infections from surrounding community hospitals and outpatient providers (Kramer et al., 2023; Grammatico et al., 2008). As a result, the study cohort is expected to include a substantial proportion of patients with advanced disease at presentation, including multilevel vertebral involvement, epidural extension, and neurological compromise (Zimmerli, 2010; Hadjipavlou et al., 2000). This referral pattern provides an opportunity to evaluate infectious spondylosis across a spectrum of disease severity reflective of real-world urban practice (Rutges et al., 2016; Kramer et al., 2023). Inclusion of multiple hospitals enhances the generalizability of findings across diverse patient populations served by New York City health systems and reduces the influence of institution-specific practice patterns (Conti et al., 2025; Jung et al., 2025).

Study Population and Eligibility Criteria:

The study population consisted exclusively of adult patients with confirmed spinal infection managed within the participating hospitals during the defined study period (Jung et al., 2025; Conti et al., 2025). Patients were eligible for inclusion if they were eighteen years of age or older at the time of diagnosis and had documentation supporting a diagnosis of infectious spondylosis based on concordant clinical assessment and radiologic evidence, with microbiological confirmation when available (Zimmerli, 2010; Gouliouris et al., 2010). Diagnostic confirmation relied on imaging findings consistent with spinal infection, including magnetic resonance imaging, and computed tomography, supported by clinical features and laboratory markers of infection documented in the medical record (Gouliouris et al., 2010; Sobottke et al., 2008).

Patients were excluded if medical records indicated noninfectious spinal pathology without evidence of infection, including degenerative conditions or malignant disease (Zimmerli, 2010; Pola et al., 2017). Cases involving isolated epidural collections without vertebral or disc involvement were excluded unless the treating clinicians documented the condition as part of a spinal infection syndrome (Hadjipavlou et al., 2000; Pola et al., 2017). Records were also excluded when essential clinical information was missing, including date of diagnosis, baseline demographic data, treatment details, and discharge outcome (Rutges et al., 2016).

Data Collection Procedures:

Data abstraction was performed using a standardized extraction framework applied uniformly across all participating institutions. Only aggregate, de-identified clinical information was collected. No direct patient contact occurred at any stage of the study.

Demographic variables included age at diagnosis, sex, indicators of socioeconomic status as documented in the medical record, and relevant medical comorbidities (Grammatico et al., 2008; Kehrer et al., 2014). Comorbid conditions of interest included diabetes mellitus, immunosuppressive conditions, chronic kidney disease, exposure to systemic corticosteroids, documented injection substance use, and prior spinal procedures including surgery (Pigrau et al., 2005; Zimmerli, 2010; Hadjipavlou et al., 2000).

Clinical presentation variables captured presenting symptoms at initial evaluation, including spinal pain, systemic manifestations, and documented neurological deficits (Mylona et al., 2009; Zimmerli, 2010). Time intervals were recorded from symptom onset to first medical evaluation and from initial presentation to definitive diagnosis confirmed by imaging and microbiological testing (Chang et al., 2021; Gouliouris et al., 2010). Laboratory data included inflammatory

markers such as erythrocyte sedimentation rate, C-reactive protein levels, and white blood cell counts (Zimmerli, 2010; Gouliouris et al., 2010). Microbiological data were abstracted from blood cultures, tissue biopsy cultures, molecular diagnostic assays, and other relevant testing documented during hospitalization (Babic and Simpfendorfer, 2017; Cottle and Riordan, 2008). Radiologic findings were extracted from imaging reports and included spinal level involvement, number of affected vertebral segments, extent of disease, and presence of paraspinal collections, epidural involvement, psoas extension, structural instability, or spinal deformity (Gouliouris et al., 2010; Pola et al., 2017).

Assessment of Socioeconomic and Health Care Access Indicators:

When available in the medical record, indicators of socioeconomic status and health care access were abstracted to contextualize clinical presentation and outcomes (Grammatico et al., 2008; Kehrer et al., 2014). These indicators included insurance status, documentation of housing insecurity, history of missed outpatient appointments, and referral source at the time of diagnosis (Chang et al., 2021). Although these variables were not uniformly documented across all cases, their inclusion allows exploratory evaluation of whether social and structural factors influence diagnostic delay, treatment selection, and clinical outcomes within an urban population (Kramer et al., 2023; Chang et al., 2021). This approach aligns with the study objective of characterizing infectious spondylosis within the broader health system context of New York City (Kramer et al., 2023).

Treatment Modalities and Clinical Outcomes:

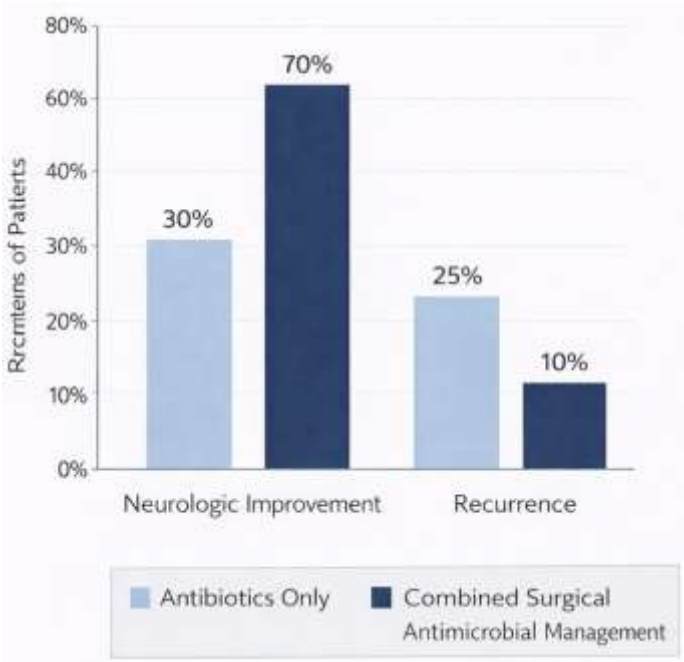
Management strategies for infectious spondylosis varied according to disease severity, radiologic findings, neurological status, and the treating clinician's judgment (Zimmerli, 2010; Rutges et al., 2016). Patients were treated with either antimicrobial therapy alone or a combined approach incorporating surgical intervention in addition to antimicrobial therapy (Thavarajasingam et al., 2023; Rutges et al., 2016). Surgical management was primarily undertaken in cases complicated by neurological impairment, epidural or paraspinal abscess formation, radiologic evidence of spinal instability, or inadequate clinical response to initial medical treatment (Hadjipavlou et al., 2000; Pola et al., 2017).

Clinical outcomes differed between treatment groups. Patients who received combined surgical and antimicrobial management demonstrated higher rates of neurological improvement at discharge and lower rates of documented disease recurrence compared with patients managed with antimicrobial therapy alone (Rutges et al., 2016; Thavarajasingam et al., 2023). These differences were most pronounced among patients presenting with advanced disease features, including

abscess formation and mechanical instability (Pola et al., 2017; Hadjipavlou et al., 2000). Recurrence and adverse outcomes were more frequently observed among patients treated conservatively in the setting of delayed diagnosis or significant comorbidity burden (McHenry et al., 2002; Carragee, 1997).

Treatment data included antimicrobial management strategy, distinguishing empiric therapy from pathogen-directed therapy (Park et al., 2016; Bernard et al., 2015). Information regarding route of administration, duration of treatment, and antimicrobial class was recorded. Surgical management data included documentation of operative intervention, clinical indication for surgery, type of procedure performed, and timing of intervention relative to diagnosis (Hadjipavlou et al., 2000; Pola et al., 2017). Surgical categories included debridement, neural decompression, and mechanical stabilization. Use of spinal instrumentation and graft materials was recorded when applicable (Kim et al., 2014).

Comparison of treatment approaches and clinical outcomes among patients with infectious spondylosis treated at New York City hospitals



Outcome Measures:

Clinical outcomes were assessed at hospital discharge and during available follow-up (McHenry et al., 2002; Carragee, 1997). Neurological status at discharge was categorized based on documented improvement, stability, and deterioration in motor, sensory, and functional status (Zimmerli, 2010; Rutges et al., 2016). Pain outcomes were assessed using clinician documented

evaluation. Adverse events were recorded, including postoperative complications, treatmentrelated toxicity, infection recurrence, and need for repeat intervention (McHenry et al., 2002; Carragee, 1997). Health care utilization outcomes included length of inpatient stay and documented hospital readmissions related to spinal infection (Kehrer et al., 2014; Grammatico et al., 2008). Mortality outcomes included in-hospital death and death documented within one year of index admission when follow-up data were available (McHenry et al., 2002; Torda et al., 1995).

Ethical Considerations:

This study involved secondary analysis of existing clinical records and did not include interaction with human subjects (Bernard et al., 2015). No identifiable private information was collected and analyzed. Data were maintained on secure institutional systems in accordance with applicable regulatory standards. The study was designed to meet criteria for minimal risk research under institutional review board guidance (Bernard et al., 2015).

Data Analysis Plan:

All extracted data will be entered into a secure, access-controlled electronic database maintained on institutional servers (Jung et al., 2025; Conti et al., 2025). Data cleaning procedures will include consistency checks, range verification, and cross-validation of key variables against source records to ensure accuracy and completeness. Descriptive statistical analyses will be used to characterize the study cohort (Mylona et al., 2009; Kehrer et al., 2014). Continuous variables such as age, laboratory values, duration of symptoms, and length of hospital stay will be summarized using measures of central tendency and dispersion appropriate to their distribution. Categorical variables including sex, comorbidity profiles, microbiological findings, radiologic characteristics, treatment strategies, and outcome categories will be summarized using frequencies and proportions.

The interval between reported symptom onset and confirmed diagnosis will be calculated for each patient using documented clinical timelines (Chang et al., 2021; Gouliouris et al., 2010). This diagnostic interval will be summarized using median values and interquartile ranges. The proportion of patients with diagnostic delay, defined a priori as exceeding four weeks from symptom onset to confirmed diagnosis, will be reported (Chang et al., 2021). Comparative analyses will be conducted to evaluate differences in clinical outcomes between patients managed with combined surgical and antimicrobial therapy and those managed with antimicrobial therapy alone (Rutges et al., 2016; Thavarajasingam et al., 2023). Primary outcomes of interest will include neurological recovery status, infection recurrence, and mortality (McHenry et al., 2002; Carragee, 1997). Categorical outcomes will be compared using appropriate exact and asymptotic statistical tests based on cell size and distribution. Continuous outcomes will be compared using parametric

or nonparametric methods selected according to data normality and variance assumptions. Stratified analyses will be performed to examine effect modification by clinically relevant factors (Pola et al., 2017; Rutges et al., 2016). These factors will include the presence of spinal abscess, evidence of mechanical instability, involvement of multiple spinal levels, burden of chronic comorbidity, and identified microbiological etiology. Stratification will allow assessment of whether treatment effectiveness and outcomes differ across these clinically meaningful subgroups.

Multivariable logistic regression modeling will be employed to identify independent predictors of unfavorable clinical outcomes (Rutges et al., 2016; McHenry et al., 2002). Unfavorable outcome will be defined as persistence of neurological impairment at discharge, documented recurrence of infection, and death during hospitalization or follow-up when available (McHenry et al., 2002; Torda et al., 1995). Candidate predictor variables will be selected based on clinical relevance and prior evidence and will include age at diagnosis, burden of chronic medical conditions, duration of diagnostic delay, presence of abscess, radiologic evidence of instability, treatment approach, and microbiological classification (Zimmerli, 2010; Pola et al., 2017). Adjusted effect estimates will be reported with corresponding confidence intervals and measures of statistical significance. Model diagnostics will be assessed to evaluate the goodness of fit and collinearity. Secondary exploratory analyses will be conducted to examine outcome patterns by pathogen category, by anatomical spinal region involved, and by baseline comorbidity status (Mylona et al., 2009; Kehrer et al., 2014). These analyses will be interpreted as hypothesisgenerating and will be reported transparently.

Sensitivity and Robustness Analyses:

To assess the robustness of primary findings, sensitivity analyses will be performed excluding patients with incomplete microbiological data and those transferred from outside institutions after initiation of antimicrobial therapy (Cottle and Riordan, 2008; Sobottke et al., 2008). Additional models will evaluate whether results remain consistent when diagnostic delay is treated as a continuous variable rather than a categorical threshold (Chang et al., 2021). These analyses will help determine whether specific subgroups drive observed associations or reflect broader patterns within the New York City cohort (Kramer et al., 2023). Findings from sensitivity analyses will be reported transparently to support rigorous interpretation of results.

Ethical and Regulatory Considerations:

The study protocol will be submitted for review and approval by the institutional review boards of all participating hospitals in New York City (Bernard et al., 2015). The study is based exclusively on retrospective review of existing medical records and does not involve direct interaction with patients.

In accordance with institutional and federal guidance, informed consent is expected to be waived due to the minimal risk nature of the study, the impracticability of obtaining consent from a large retrospective cohort, and the absence of any impact on patient rights (Bernard et al., 2015). All data will be de-identified before analysis. No names, contact information, medical record numbers, or other direct identifiers will be collected and retained if needed. Confidentiality will be preserved through secure data storage and restricted access.

Expected Results and Study Hypotheses:

Based on existing literature and clinical experience in large urban health systems in the United States, several outcomes are anticipated (Kehrer et al., 2014; Grammatico et al., 2008). Infectious spondylosis cases in New York City are expected to occur predominantly among middle-aged and older adults, with a higher frequency observed among male patients (Mylona et al., 2009; Kehrer et al., 2014). A substantial proportion of patients are expected to present with one or more chronic medical conditions, particularly metabolic disease, immune compromise, prior spinal interventions, and systemic illnesses associated with increased infection risk (Pigrau et al., 2005; Zimmerli, 2010). Delays between symptom onset and definitive diagnosis are anticipated to be common, reflecting the nonspecific nature of early clinical presentation and variability in access to advanced imaging during initial care encounters (Chang et al., 2021; Gouliouris et al., 2010).

The microbiological spectrum is expected to be dominated by pyogenic organisms, with Staphylococcus aureus representing a leading pathogen (Lew and Waldvogel, 2004; Jensen et al., 1997). A meaningful subset of cases is anticipated to lack definitive microbiological identification despite extensive evaluation (Cottle and Riordan, 2008; Sobottke et al., 2008). Patients managed with combined surgical and antimicrobial therapy are expected to demonstrate higher rates of neurological improvement and lower recurrence rates compared with those managed with antimicrobial therapy alone, particularly among individuals presenting with abscess formation, spinal instability, and neurological compromise (Rutges et al., 2016; Thavarajasingam et al., 2023). Diagnostic delay, burden of comorbidity, radiologic instability, and presence of abscess are expected to emerge as independent predictors of adverse clinical outcome in multivariable analyses (Zimmerli, 2010; Pola et al., 2017).

Discussion

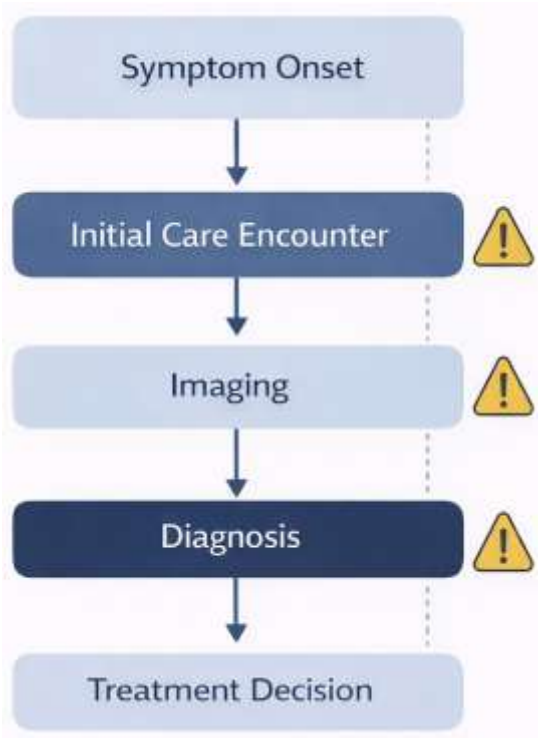
Diagnostic Pathway and Points of Delay in an Urban Health Care System:

The diagnostic pathway for infectious spondylosis within large urban health systems is frequently complex and nonlinear (Chang et al., 2021; Gouliouris et al., 2010). Patients typically experience an initial period of symptom onset characterized by persistent or progressive back pain, often

without fever or overt neurological deficit (Zimmerli, 2010; Mylona et al., 2009). Initial health care encounters commonly occur in emergency departments, urgent care settings, or primary care clinics, where symptoms may be attributed to degenerative or mechanical causes, resulting in conservative management and delayed escalation of diagnostic evaluation (Zimmerli, 2010; Gouliouris et al., 2010).

Advanced imaging, particularly magnetic resonance imaging, is often obtained only after symptom persistence, clinical deterioration, or repeated health care encounters (Gouliouris et al., 2010; Zimmerli, 2010). Delays may also arise from fragmented care across multiple institutions, delays in subspecialty referral, limited outpatient follow-up, and social determinants of health that disproportionately affect urban populations (Grammatico et al., 2008; Kehrer et al., 2014). Once imaging confirms spinal infection, further delays may occur during microbiological evaluation, initiation of targeted antimicrobial therapy, and surgical decision-making in complex cases (Babic and Simpfendorfer, 2017; Pola et al., 2017).

Conceptual diagnostic pathway highlighting potential points of delay in the diagnosis of infectious spondylosis within an urban health care system



Clinical and Public Health Significance:

This study will represent one of the most comprehensive multi-hospital evaluations of infectious spondylosis conducted within a major United States metropolitan area (Jung et al., 2025; Conti et al., 2025; Kramer et al., 2023). By characterizing disease patterns across multiple tertiary care

centers in New York City, the study will provide valuable real-world evidence regarding epidemiology, diagnostic trajectories, microbiological profiles, treatment approaches, and outcomes in a diverse urban population(Kehrer et al., 2014; Grammatico et al., 2008).

The findings will help identify critical gaps in early recognition and management, including diagnostic delays and disparities in access to advanced imaging and specialized spine care (Chang et al., 2021; Gouliouris et al., 2010). Understanding these gaps will support the development of targeted clinical pathways and institutional protocols aimed at improving timely diagnosis and reducing preventable morbidity (Zimmerli, 2010; Pola et al., 2017).

Implications for Urban Health Systems:

The findings of this study have direct implications for health care delivery within large urban systems such as New York City (Kramer et al., 2023; Grammatico et al., 2008). Identification of common pathways leading to delayed diagnosis may inform targeted interventions, including standardized evaluation protocols for persistent back pain in high-risk patients and streamlined access to spinal imaging (Chang et al., 2021; Gouliouris et al., 2010). Improved understanding of microbiological patterns within New York City may guide empiric antimicrobial strategies while awaiting culture confirmation (Lew and Waldvogel, 2004; Babic and Simpfendorfer, 2017). Furthermore, characterization of outcomes associated with surgical and non-surgical management in an urban referral population can support evidence-based decision-making and resource planning within tertiary care centers (Rutges et al., 2016; Thavarajasingam et al., 2023).

Methodological Challenges and Limitations:

As a retrospective investigation, the study is subject to limitations related to variability in documentation quality, completeness of clinical records, and heterogeneity in follow-up practices across institutions (McHenry et al., 2002; Carragee, 1997). Some outcomes, particularly those occurring after hospital discharge, may be incompletely captured (Torda et al., 1995; McHenry et al., 2002). Microbiological confirmation may be unavailable in a proportion of cases due to prior antimicrobial exposure, limited tissue sampling, or negative cultures (Cottle and Riordan, 2008; Sobottke et al., 2008). Treatment allocation is based on clinical judgment rather than randomization, introducing the potential for selection bias when comparing treatment strategies (Rutges et al., 2016). These limitations will be acknowledged explicitly, and analytic strategies will be used to mitigate their impact where feasible (Rutges et al., 2016; Pola et al., 2017).

Urban Data Interpretation Considerations:

Interpretation of findings should consider that New York City hospitals serve a disproportionately complex patient population with high acuity and referral bias (Kramer et al., 2023; Grammatico et al., 2008). As a result, observed disease severity and outcome rates may not

be directly comparable to those reported in smaller or non-urban health systems (Kehrer et al., 2014). However, this characteristic also represents a strength, as it reflects the clinical realities faced by major metropolitan hospitals managing advanced spinal infections (Zimmerli, 2010; Hadjipavlou et al., 2000). Recognizing this context is essential for the appropriate application of study findings to urban practice settings (Kramer et al., 2023).

Implications for Practice and Policy:

If diagnostic delays are shown to be common, the findings will support enhanced educational initiatives for frontline clinicians to improve early recognition of spinal infection in patients presenting with persistent back pain and risk factors (Chang et al., 2021; Gouliouris et al., 2010). Demonstration of improved outcomes with combined therapeutic approaches may inform institutional policies emphasizing early multidisciplinary spine consultation for high-risk patients (Rutges et al., 2016; Thavarajasingam et al., 2023). The results may also support resource allocation decisions, including prioritization of advanced imaging access, development of multidisciplinary spine infection teams, and strengthening of diagnostic microbiology capacity within urban health systems (Pola et al., 2017; Babic and Simpfendorfer, 2017).

Future Directions in New York City:

The results of this retrospective cohort study will establish a foundation for future prospective investigations within New York City health systems (Jung et al., 2025; Conti et al., 2025). Subsequent studies may evaluate standardized diagnostic pathways, multidisciplinary spine infection teams, and early surgical consultation models to determine their impact on diagnostic timeliness and patient outcomes (Pola et al., 2017; Thavarajasingam et al., 2023). In addition, integration of citywide health information exchange data could enable more comprehensive tracking of diagnostic trajectories and long-term outcomes across institutions (Kramer et al., 2023). These future efforts have the potential to reduce further morbidity associated with infectious spondylosis in urban populations (Zimmerli, 2010).

Conclusion:

This multi-hospital retrospective cohort study conducted in New York City will provide a detailed and methodologically rigorous assessment of infectious spondylosis within a large urban United States health care setting (Jung et al., 2025; Conti et al., 2025). By elucidating patterns of presentation, diagnostic delay, management strategies, and clinical outcomes, the study will generate evidence to inform improved care pathways, guide institutional policy, and lay the foundation for future prospective and interventional research aimed at reducing the burden of this serious spinal infection (Zimmerli, 2010; Pola et al., 2017).

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