European Spine Journal (2019) 28:751–761
https://doi.org/10.1007/s00586-018-5775-x

ORIGINAL ARTICLE

# Predicting the need for surgical intervention in patients with spondylodiscitis: the Brighton Spondylodiscitis Score (BSDS)

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Received: 18 April 2018 / Revised: 3 September 2018 / Accepted: 24 September 2018 / Published online: 13 October 2018


## Abstract

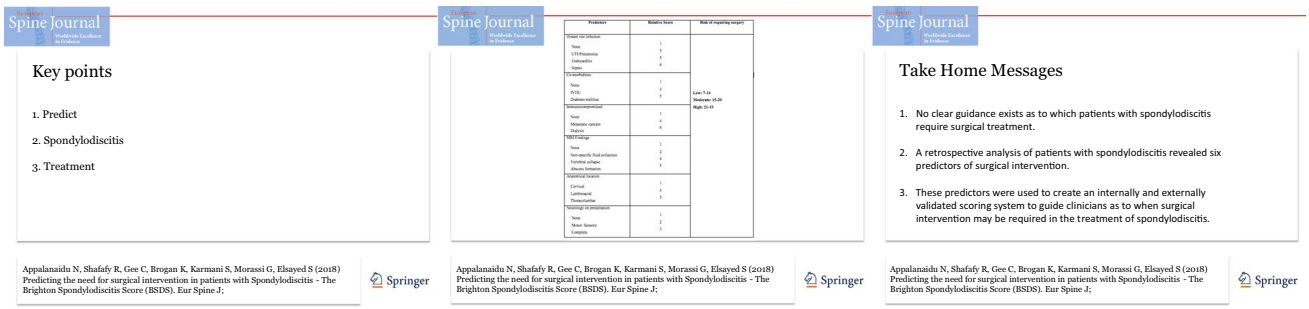
**Purpose** Spondylodiscitis represents a condition with significant heterogeneity. A significant proportion of patients are managed without surgical intervention, but there remains a group where surgery is mandated. The aim of our study was to create a scoring system to guide clinicians as to which patients with spondylodiscitis may require surgery.

**Methods** A retrospective analysis of patients presenting to our institution with a diagnosis of spondylodiscitis between 2005 and 2014 was performed. Data for 35 variables, characterised as potential risk factors for requiring surgical treatment of spondylodiscitis, were collected. Logistic regression analysis was performed to evaluate the predictability of each. A prediction model was constructed, and the model was externally validated using a second series of patients from 2014 to 2015 meeting the same standards as the first population. The predicted odds were calculated for every patient in the data set. Receiver operating characteristic (ROC) curves were created, and the area under curve (AUC) was determined.

**Results** Sixty-five patients were identified. Surgery was deemed necessary in 21 patients. Six predictors: distant site infection, medical comorbidities, the immunocompromised patient, MRI findings, anatomical location and neurology, were found to be the most consistent risk factors for surgical intervention. An internally validated scoring system with an AUC of 0.83 and an Akaike information criterion (AIC) of 115.2 was developed. External validation using a further 20 patients showed an AUC of 0.71 at 95% confidence interval of 0.50–0.88.

**Conclusions** A new scoring system has been developed which can help guide clinicians as to when surgical intervention may be required. Further prospective analyses are required to validate this proposed scoring system.

**Graphical abstract** These slides can be retrieved under Electronic Supplementary Material.




**Keywords** Predict · Spondylodiscitis · Treatment

**Electronic supplementary material** The online version of this article (https://doi.org/10.1007/s00586-018-5775-x) contains supplementary material, which is available to authorized users.

Extended author information available on the last page of the article

## Introduction

Spondylodiscitis describes any infection of the intervertebral disc and or adjacent vertebra and is a potentially life-threatening illness with a mortality rate of 2–20% [1, 2]. It may affect the vertebral bodies, intervertebral discs or posterior elements of the spine including adjacent tissues (e.g. paravertebral and psoas muscles) and spinal canal (e.g. epidural abscesses) [3–5].

The prevalence of spondylodiscitis is on the rise, with an estimated 0.4–2.4 per 100,000 individuals affected in the western population [2, 6]. This may be in part due to a rise in the number of individuals vulnerable to infections (e.g. elderly or immunocompromised) or related to other methods of invasive treatments such as intravenous catheter use for example [2, 3]. Advances in diagnostic imaging may have also led to a previously under-recognised condition being diagnosed more often [4, 7]. The risk factors for spondylodiscitis are: an immunocompromised host, diabetes, advanced age, long-term corticosteroid therapy, renal failure, previous spinal surgery, endocarditis and intravenous drug use [7, 8].

When spondylodiscitis occurs as a complication of distant site infection, bacteraemia or sepsis must occur. Patients may therefore present with a wide range of symptoms, which may or may not be dominated by the primary infective focus and, as a result, a delay in diagnosis is common [9].

The optimum treatment of spondylodiscitis is a challenge, partly due to a lack of a clear consensus on the role of operative treatment. Often the decision is based on clinician preference [10] although medical management frequently forms the basis for treatment, be it alone or in combination with surgery. It normally includes an extended course of antibiotics with optional orthoses and/or bed rest [3] although, as with most musculoskeletal infections, there is debate regarding the optimum route and duration of antibiotic treatment. Some patients may require biopsies when clinical evaluation is unsatisfactory, there is suspicion of an atypical bacteria and if no microorganism has been isolated elsewhere. Failure of conservative management, neural compression, and spinal instability or deformity are the currently accepted indications for surgical intervention [11]. The surgical options are dependent on the site of infection and the indication for surgery. Options include anterior debridement and stabilisation (ideal approach as the anterior spine is usually involved in the pathogenesis of spondylodiscitis [12]); combined anterior–posterior methods; transpedicular curettage and drainage; as well as posterior stabilisation [10, 11].

The lack of evidence to direct surgeons as to which patients require surgery has led to inconsistencies in treatment [1, 2, 7]. Sobottke et al. [10] indicated that when compared to conservative and/or medical management, surgical intervention in patients with uncomplicated spondylodiscitis ensures faster mobilisation and recovery as well as improved short-term quality of life. A recent study by de Graeff et al. [13] identified that diabetes, epidural abscess or concurrent other osteomyelitis were independent factors associated with failure of antibiotic treatment of spondylodiscitis. However, at present, no study has classified a set of predictors into a scoring system to aid the surgeon as which patients with spondylodiscitis would benefit from either medical or surgical management [2, 7]

In this study we aim to:

1. Evaluate the results of the management of spondylodiscitis in our institution and use the data from these patients to identify risk factors for requiring surgery.
2. To produce a scoring system to stratify the risk of patients needing surgery and to then validate the score on a further group of patients.
3. To compare outcomes in those treated operatively and non-operatively with the null hypothesis that surgical intervention does not improve outcome.

## Materials & methods

A literature review was performed to identify potential risk factors for spondylodiscitis and for requiring surgical intervention. These risk factors were then used as the basis for data collection.

A retrospective review of 65 patients with spondylodiscitis treated between 2005 and 2014 at our institution was performed. Patients were identified initially through MRI results and then confirmation through a review of the casenotes, where the treating clinician made a diagnosis of spondylodiscitis. All adult patients who presented with acute bacterial spondylodiscitis were included. Paediatric patients, those with tuberculous or fungal infections and those with post-surgical infections were excluded. Patient and surgical data was then collected using the potential risk factors identified for requiring surgery.

Logistic regression was initially performed onto the training set of data as the pioneer form of modelling. Through this method, the response (i.e. status of surgical intervention) as the outcome of interest was determined and all the other available predictors (i.e. gender, age, health status etc.) were labelled as the original factors to build the model. To produce an exclusive prediction model, a backward (Wald) stepwise predictor was chosen and the process was repeated at a default of 1000 times for each of the data sets (bootstrap). With this, a series of predictive models was produced by classifying the predictors on the number of stages they

occur in the 1000 "bootstrap" resamples. The final prediction model was built based on the previously classified list of predictors which were sequentially added, and the representation with the lowest Akaike information criterion (AIC) was chosen as the final model. The model was internally validated by determining the area under the curve (AUC) using multiple cutoff values on the expected probability of the scoring system.

In order to validate the model externally, further 20 patients treated from 2014 to 2015 from the same organisation (BSUH) were retrospectively reviewed. This group was labelled as the "validation group", and the same inclusion criteria for the initial analysis were used. The probability that signified chances to undergo surgical intervention was produced for each of the patients from the validation group. Then, specificity, sensitivity, negative predictive value (NPV) and positive predictive value (PPV) were determined. Depending on the "probability threshold", these calculated figures were able to alter the predicted outcome of a particular patient. For example, patients with a probability $\leq 0.5$ will obtain medical management only, whereas those $> 0.5$ will undergo surgical intervention as part of their treatment.

Data analysis of the "validation group" was performed to externally validate the prediction model. Based on the set of data obtained, categorical groups were made to facilitate the analysis via SPSS. For example, anatomical locations were divided into cervical, thoracolumbar and lumbosacral. Therefore, an infection at C6-C7 was labelled as cervical. Microbial cultures were clustered into non-MRSA and polymicrobial groups with MRSA/MRSA alone groups to simplify statistical analysis. A pre-analysis briefing was constructed to predict the consistency and validity of the groups. The constructed predictive model in the initial analysis was used on the "validation group" to evaluate predicted probabilities. The "Bootstrap approach" was used, and this method was reiterated at a default of 1000 to form the receiver operating curves (ROC) and to evaluate the AUCs using the resamples from the validation data.

## Results

Table 1 depicts the results used to construct the predictive model for internal validation. Nearly half of patients presented with some degree of neurological compromise, and 35.4% demonstrated vertebral collapse > 30% anterior vertebral height. Only half of patients presented with a fever and in 25% of patients multiple levels were affected. 32% of patients required surgical intervention with the most frequent indication being abscess drainage. 71% of patients were independently mobile prior to the onset of symptoms with 55% maintaining independent mobilisation post-operatively. A third of patients had an improvement in their neurology from initial presentation with over half of the patients requiring rehabilitation after discharge from hospital. The average time to diagnosis from presentation was 4 days and on average patients required an inpatient stay of 35 days. In 32% of patients the infective organism could not be identified and in this group the diagnosis was made on a clinical and radiological basis. 23% of patients had either a UTI, pneumonia or endocarditis and 30% presented with sepsis/bacteraemia.

One or more comorbidities was present in 79% of patients. Diabetes was the most common medical risk factor at 83%, with 35.4% immunocompromised from steroid use, HIV, dialysis or previous organ transplant.

Staphylococcus remained the most common organism (27.7%) followed by coagulase negative staphylococci, gram negative bacilli, polymicrobial cultures and others.

The majority of patients were treated with a 6-week course of antibiotics (90%) with blood results used to monitor response.

Table 2 depicts the logistic regression analysis used to identify the most crucial variables that contributed to increased probability of surgical intervention. Using 'bootstrap' prediction techniques via SPSS, seven grouped predictors were identified to be the most consistent variables to predict the need for surgical intervention.

These risk factors were then analysed as predictors, which are shown in Table 3. The higher the value of the coefficient, the more likely a risk factor is to predict surgical intervention in the group. The *p* value on the other hand implies the impact of each variable to the model entirely. It is said that the higher the p value, the lower its relative significance. Using this analysis, a scoring system was produced (Table 4). The internal validation of this system produced an AIC of 115.20 and an AUC of 0.83. This scoring system was then externally validated using the further 20 patients from 2014 to 2015 with an AUC of 0.71 (95% CI, 0.50–0.88).

Various probability cutoff points were applied to determine the specificity, sensitivity, NPV and PPV. The threshold figures were fixed at a value of 0.35. At this limit value, reliable results were identified as follows: Specificity—0.52; sensitivity—0.75; NPV—0.75; PPV—0.61.

Treatments outcomes of patients categorised as low, medium and high risk by the BSDS are demonstrated in Table 5. Out of 49 patients deemed low risk, 5 required subsequent surgery. Of the 6 patients deemed high risk, all six had surgical intervention.

Outcomes between the two sets of patients in the internal validation group of 65 were assessed and are outlined in Table 6. The results demonstrate more favourable neurological and mobility outcomes in the surgical group. These results also demonstrate a trend towards a quicker improvement in CRP and shorter length of stay although this is not significant.

**Table 1** Results of retrospective casenote analysis of patients presenting with spondylodiscitis

| Variables | Responses | Frequency | Percentage | Mean | Range | Standard deviation |
|---|---|---|---|---|---|---|
| Age (years) | Years | | | 69.22 | 22–93 | 13.331 |
| Gender | Male | 38 | 58.5 | | | |
| | Female | 27 | 41.5 | | | |
| Neurologic status | Intact | 33 | 50.8 | | | |
| | Deficit | 32 | 49.2 | | | |
| | Motor | 22 | 33.8 | | | |
| | Sensory | 5 | 7.7 | | | |
| | Complete | 5 | 7.7 | | | |
| MRI findings | Vertebral collapse | 23 | 35.4 | | | |
| | Abscess formation | 16 | 24.6 | | | |
| | Non-specific fluid collection | 14 | 21.5 | | | |
| | Not specified | 12 | 18.5 | | | |
| Fever | Yes | 33 | 50.8 | | | |
| | No | 32 | 49.2 | | | |
| Levels affected | Single | 49 | 75.4 | | | |
| | Multiple | 16 | 24.6 | | | |
| Affected spinal column | Cervical | 13 | 20.0 | | | |
| | Thoracolumbar | 36 | 55.4 | | | |
| | Lumbar/Sacral | 6 | 9.2 | | | |
| | Widespread | 10 | 15.4 | | | |
| Surgery | Yes | 21 | 32.3 | | | |
| | Abscess drainage | 7 | 10.8 | | | |
| | Decompression | 5 | 7.7 | | | |
| | Stabilisation | 4 | 6.2 | | | |
| | Laminectomy | 3 | 4.6 | | | |
| | Combined | 2 | 3.0 | | | |
| | No | 44 | 67.7 | | | |
| Mobility | Before surgery<br>Independent<br>Non-independent | 46 | 70.8 | | | |
| | After surgery | 19 | 29.2 | | | |
| | Independent | 36 | 55.4 | | | |
| | Non-independent | 29 | 44.6 | | | |
| Improvement in neurology | No changes | 32 | 49.2 | | | |
| | Improved | 22 | 33.8 | | | |
| | Worsening | 10 | 17.0 | | | |
| Post Op complication | DVT | 3 | 4.6 | | | |
| | Infection | 7 | 10.8 | | | |
| | Failure/relapse | 4 | 6.2 | | | |
| | Further surgery | 4 | 6.2 | | | |
| Rehab | Yes | 37 | 56.9 | | | |
| | No | 28 | 43.1 | | | |
| Time to diagnosis (days) | | | | 4.09 | 2–30 | 10.130 |
| Admission duration (days) | | | | 35.08 | 5–130 | 24.989 |

**Table 1** (continued)

| Variables | Responses | Frequency | Percentage | Mean | Range | Standard deviation |
|---|---|---|---|---|---|---|
| Risk factors | Diabetes | | | | | |
| | IDDM | 13 | 20.0 | | | |
| | NIDDM | 39 | 60.0 | | | |
| | Diet controlled DM | 2 | 3.1 | | | |
| | Non-diabetic | 11 | 16.9 | | | |
| | Malignancy | 14 | 21.5 | | | |
| | Immunocompromised | | | | | |
| | LT steroid therapy | 3 | 4.6 | | | |
| | Dialysis | 14 | 21.5 | | | |
| | Transplant | 5 | 7.7 | | | |
| | HIV | 1 | 1.5 | | | |
| | IV Drug users | | | | | |
| | Current | 3 | 4.6 | | | |
| | Ex-IVDU | 3 | 4.6 | | | |
| | Non-IVDU | 59 | 90.8 | | | |
| | Smoking | | | | | |
| | Current | 9 | 13.8 | | | |
| | Ex-smoker | 25 | 38.5 | | | |
| | Non-smoker | 31 | 47.7 | | | |
| Microbial cultures | Positive culture | 44 | 67.7 | | | |
| | Gram positive | | | | | |
| | Gram negative or polymicrobial w/out MRSA | 23 | 35.4 | | | |
| | Polymicrobial with | 11 | 16.9 | | | |
| | MRSA or MRSA alone | 10 | 15.4 | | | |
| | Negative culture | 21 | 32.3 | | | |
| Distant site infection | Present | 35 | 53.8 | | | |
| | UTI/pneumonia | 10 | 15.3 | | | |
| | Endocarditis | 5 | 7.7 | | | |
| | Sepsis/Bacteraemia | 20 | 30.8 | | | |
| | Absent | 30 | 46.2 | | | |

## Discussion

### Managing spondylodiscitis

With an increasingly comorbid and ageing population, spondylodiscitis will become more common and a clear understanding of which patients require surgery is essential. Surgery may include abscess drainage, debridement and stabilisation which may be either anterior or posterior or a combination of all of the above. This study has demonstrated a significantly superior neurological and functional outcome in the surgical group with a trend towards a quicker improvement in CRP and a shorter length of stay. Rossbach et al. [14] have also demonstrated favourable outcomes with surgery. Some evidence suggests prolonged periods of preoperative immobility in the elderly population are associated with greater risk of mortality [15]. The approach and choice of surgery are still up for debate, and a review of the literature pertaining to surgical options is summarised in Table 7 [16–23].

Understanding the microbiology of discitis is important. In this study *Staphylococcus Aureus* remained the most common organism. In the elderly with urinary tract infections *E Coli* infections may be seen, in intravenous drug users *Pseudomonas Aeruginosa* was common, and in patients with diabetes there was an increased prevalence of *Group B haemolytic Streptococcus*. Whilst these were the most common organisms identified in this study, in nearly a third of cases the organism could not be identified. Recent evidence suggests that a microbiological diagnosis is the main predictive factor for a successful treatment outcome [24]. Close liaison with microbiology services, together with an understanding of the common organisms involved, is recommended to guide empirical treatment when no organism is identified.

**Table 2** Logistic regression analysis to identify variables associated with increased probability of surgical intervention

| Test Factors | Outcome | Estimated odds ratio | Lower CI | Upper CI | *p* value |
|---|---|---|---|---|---|
| Age | 5 years incremental | 1.058 | 0.102 | 0.337 | 0.030 |
| Gender | Male vs Female | 2.576 | 0.601 | 8.557 | 0.177 |
| Neurology | Deficit vs Intact | 2.140 | 0.822 | 5.454 | 0.078 |
| MRI findings | Vertebral collapse | 1.867 | 0.520 | 6.485 | 0.657 |
| | Abscess formation | 3.947 | 0.273 | 5.476 | |
| | Non-specific fluid collection | 0.739 | 0.201 | 2.595 | |
| | Not specified | 0.476 | 0.052 | 4.401 | |
| Levels affected | Single vs multiple | 1.430 | 0.199 | 2.897 | 0.641 |
| Affected location | Thoracolumbar vs Cervical | 1.750 | 0.389 | 7.898 | 0.690 |
| | Lumbosacral vs Cervical | 1.780 | 0.468 | 6.789 | |
| | Widespread vs Cervical | 1.003 | 0.221 | 5.998 | |
| Medical co morbidities | Diabetes vs none | 4.346 | 1.269 | 11.883 | 0.109 |
| | IVDU vs none | 1.964 | 0.781 | 2.909 | |
| | Smoking vs none | 1.342 | 0.269 | 2.421 | |
| Immunocompromised | Dialysis vs none | 2.010 | 0.018 | 3.422 | 0.109 |
| | Cancer vs none | 0.711 | 0.189 | 1.123 | |
| | Steroid therapy vs none | 0.611 | 0.426 | 2.230 | |
| | Transplant vs none | 0.310 | 0.233 | 2.033 | |
| Microbial cultures | Gram negative vs gram positive (non-MRSA) | 0.531 | 0.188 | 1.856 | 0.034 |
| | Polymicrobial with MRSA or MRSA alone vs gram positive (non-MRSA) | 2.709 | 0.801 | 8.102 | |
| Distant site infection | Present vs none | 1.072 | 0.761 | 1.005 | 0.037 |
| | Pneumonia/UTI vs none | 2.869 | 0.796 | 10.346 | |
| | Endocarditis alone vs none | 4.999 | 1.234 | 20.239 | |
| | Sepsis alone vs none | 5.856 | 1.673 | 20.5 | |

*CI* confidence interval

**Table 3** Analysis of risk factors for surgical intervention and influence of predictors

| Predictors | Subcategories | Coefficient | *p* value |
|---|---|---|---|
| Distant site infection | None | −1.700 | 0.037 |
| | UTI/pneumonia | −0.301 | |
| | Endocarditis | 1.080 | |
| | Sepsis | 1.555 | |
| Medical comorbidities | Diabetes mellitus | 2.133 | 0.109 |
| | IVDU | 0.888 | |
| | Others | NA | |
| Immunocompromised | Metastatic cancers | 0.551 | 0.106 |
| | Dialysis | 1.988 | |
| | Long term steroid therapy | 0.111 | |
| | HIV positive | −0.133 | |
| MRI findings | Vertebral collapse | 0.122 | 0.257 |
| | Abscess formation | 1.678 | |
| | Non-specific fluid collection | −0.223 | |
| | Not specified | −0.422 | |
| Spine location | Cervical | −1.511 | 0.490 |
| | Thoracolumbar | 1.066 | |
| | Lumbosacral | 0.881 | |
| | Widespread | −1.001 | |
| Neurology on presentation | None | −1.444 | 0.201 |
| | Motor | 0.185 | |
| | Sensory | 0.189 | |
| | Complete deficit | 0.102 | |
| Microbiology | Gram positive | −1.400 | 0.234 |
| | Gram negative or polymicrobial (non-MRSA) | −1.883 | |
| | Polymicrobial with MRSA or MRSA alone | 1.987 | |

**Table 4** Brighton Spondylodiscitis Score (BSDS)

| Predictors | Relative Score | Risk of requiring surgery |
|---|---|---|
| Distant site infection | 1 | Low: 7–14 |
| None | 3 | Moderate: 15–20 |
| UTI/pneumonia | 5 | High: 21–33 |
| Endocarditis<br>Sepsis | 6 | |
| Comorbidities | 1 | |
| None | 3 | |
| IVDU<br>Diabetes mellitus | 5 | |
| Immunocompromised | 1 | |
| None | 4 | |
| Metastatic cancers<br>Dialysis | 6 | |
| MRI Findings | 1 | |
| None | 2 | |
| Non-specific fluid collection | 4 | |
| Vertebral collapse<br>Abscess formation | 5 | |
| Anatomical location | 1 | |
| Cervical | 3 | |
| Lumbosacral<br>Thoracolumbar | 5 | |
| Neurology on presentation | 1 | |
| None | 2 | |
| Motor/sensory<br>Complete | 3 | |

**Table 5** Treatment outcomes of patients categorised as low, moderate and high risk

| | Total | Required surgical intervention |
|---|---|---|
| Low risk | 49 | $n=5$<br>Abscess drainage (5) |
| Moderate risk | 10 | $n=10$<br>Abscess drainage (2)<br>Decompression (6)<br>Stabilisation (2) |
| High risk | 6 | $n=6$<br>Abscess drainage & stabilisation (2)<br>Decompression (2)<br>Stabilisation (2) |

Relapse is potentially problematic in spondylodiscitis. Understandably there is a concern for recurrent infection when implants are used; however, in this study there was no difference in relapse from infection between those treated operatively or with antibiotics alone. However, studies have shown that $\leq 4$ weeks antibiotic treatment is a risk factor for failure of treatment [25]. Patients with more severe vertebral destruction treated with surgery have also been identified as a group at risk of recurrence, but this may represent a more severe or neglected disease processes. Typically medical treatment is advised to continue until resolution of symptoms or normalisation of inflammatory markers (CRP/ESR) with close monitoring of these inflammatory markers after cessation of antibiotic treatment.

In our study advanced age alone was not identified as a risk factor for surgical intervention in spondylodiscitis. This may be due to a trend towards conservative management in older patients or perhaps that age alone does not determine outcome. In their retrospective study of tubercular spondylodiscitis, Shetty et al. [26] felt that the disease process was more severe in elderly patients. Further analysis of their study demonstrates that a significant portion of patients (55%) had limited mobility as well as multiple comorbidities (5 or more in one fifth of patients). Factors such as the presence of comorbidities and mobility may act as surrogate markers of frailty, be a more reliable guide to patient condition and a more important factor in the disease prognosis rather than age alone. A recent large study by Pola et al. [24] did not identify age as a risk factor for poor outcome in spondylodiscitis. There is, however, evidence to suggest that poor pre-operative mobility is a risk factor for mortality in elderly patients undergoing surgery for tubercular spondylodiscitis [15] and frailty scoring may be a useful tool in predicting outcome in these patients [27].

Medical comorbidities remain significant risk factors for spondylodiscitis. Diabetes, malignancy,

**Table 6** Analysis of outcome comparing treatment with antibiotics only and antibiotics with surgery

| Outcomes | Antibiotics only | Antibiotics and surgical intervention | *P* value |
|---|---|---|---|
| Neurology<br>Favourable<br>Unfavourable | 16<br>28 | 17<br>4 | $p = 0.031$ |
| Blood test (mean levels)<br>CRP (presentation)<br>CRP (1/52)<br>CRP (6/52) | 120.85<br>74.08<br>24.99 | 79.97<br>61.45<br>17.87 | $p > 0.05$ |
| Mobility<br>Improved<br>Deteriorated<br>No changes | 16<br>8<br>20 | 17<br>2<br>2 | $p = 0.029$ |
| Relapse/failure | 20 | 5 | $p > 0.05$ |
| Admission duration (mean days) | 39.1 | 30.8 | $p > 0.05$ |
| Rehab (patients) | 23 | 26 | $p > 0.05$ |

immune-compromise from steroids, HIV, dialysis or transplant are all risk factors. Optimising the chronic management of these conditions may have an effect on the incidence of spondylodiscitis and having a lower threshold for spinal MRI in these 'at risk groups' who present with pyrexia of unknown origin or with back pain is advised. Akiyama et al. [28] also identified that mortality rates in these patients were comparatively high compared to those without significant comorbidities.

The site of the infection is an important consideration when managing spondylodiscitis. Thoracolumbar spondylodiscitis is most common and this likely relates to Batsons venous plexus as a conduit for haematogenous innoculation. However, cervical spondylodiscitis occurred in 20% of our patients and in 15% there was a more widespread infection. It was also observed that thoracolumbar spondylodiscitis more commonly required surgery, which may be related to the presence of instability.

## Scoring system

The scoring system presented here is the first of its kind to attempt to aid treating clinicians in identifying patients who may require surgical intervention for spondylodiscitis. The results from our study demonstrate that the scoring system has reasonable clinical value with an internal validation AIC and AUC of 115.20 and 0.83, respectively.

There are, however, weaknesses to our study. As data were collected retrospectively and over a long time period where there were no guidelines in place, treatment will have been variable and based on clinical expertise. This allows for significant variations in care. The scoring system has again been validated based on a retrospective analysis without standardised care. However, this study is the first we are aware of to attempt to provide a scoring system to stratify the risk of surgery and we would suggest further prospective studies to further validate or modify the scoring system.

Our retrospective analysis has also demonstrated an improvement in outcomes with surgery, albeit in a relatively small group of patients treated over a long period of time. Given the suggestion that surgery may improve length of stay and time to normalisation of inflammatory markers without significantly higher rates of relapse, randomised studies are warranted to assess whether early surgical debridement and stabilisation should have a greater role in managing these patients in the future.

## Conclusions

The Brighton Spondylodiscitis Score (BSDS) provides a framework to allow treating clinicians to understand which patients with spondylodiscitis may require surgery. A multidisciplinary approach is advised in these patients to ensure optimum outcomes. Future studies are required to further validate this scoring system. Randomised controlled trials are advised to assess whether surgery should have a greater role and can improve outcomes in these patients.

**Table 7** Summary of literature pertaining to surgical management of spondylodiscitis

| Author/publication year/type of study | Surgical approach | Positive microbial cultures (%) | Period of antibiotic treatment | Further surgical intervention | Failure/relapse | Mortality rate (%) | Conclusion of article |
|---|---|---|---|---|---|---|---|
| Linhardt 2007 [16] (RCT) | Ventral spondylodesis N = 12<br>Ventrodorsal spondylodesis *N* = 10 | ND | 23.8 weeks<br>24.1 weeks | 0%<br>0% | Failure 0%<br>Relapse 9%<br>Failure 0%<br>Relapse 0% | 25%<br>10% | Follow-up: 5.4 years<br>Patients who underwent ventral spondylodesis only felt much better and the area of spinal fusion was less painful compared to those with ventrodorsal fusion |
| Ozturk 2007 [17] (RCos) | Simultaneous anterior and posterior surgery *N* = 29<br>Separate anterior and posterior surgery *N* = 27 | 99 | IV: 6 weeks<br>Oral: 3 months | ND | Failure 0%<br>Relapse ND<br>Failure 0%<br>Relapse ND | ND<br>ND | Follow-up: 6.5 years<br>Simultaneous anterior and posterior surgery was a beneficial substitute method. It resulted fewer complications, shorter operative time and reduced blood loss |
| Pee 2008 [18] (RCoS) | Anterior strut followed by pedicle screw fixation *N* = 37<br>Anterior cage followed by pedicle screw fixation *N* = 23 | 45 | IV: 6 weeks (min)<br>Oral: 6 Weeks (min) | 8.0%<br>4.1% | Failure ND<br>Relapse ND<br>Failure ND<br>Relapse ND | ND<br>ND | Follow-up: 35.8 months<br>Anterior spinal debridement and fusion of cage followed by fixation of pedicle screw may be successful |
| Si 2013 [19] (PCoS) | Anterior debridement and spondylodesis *N* = 11<br>Dorsal spondylodesis and anterior debridement *N* = 12 | ND | ND | 8%<br>0% | Failure 0%<br>Relapse 8%<br>Failure 0%<br>Relapse 0% | ND | Follow-up: 38 months<br>Both approaches were reliable. Patients who underwent fixation of anterior spine attained improved postoperative outcome, including having less pain and significantly improved well-being |
| Lee 2014 [20] (RCos) | Combined anterior and posterior surgery *N* = 10<br>Transpedicular curettage, posterior stabilization and drainage *N* = 26 | 42 | 91.9 days<br>65 days | 0%<br>6% | Failure 0%<br>Relapse 10%<br>Failure 0%<br>Relapse 0% | 0%<br>0% | Follow-up: 57 months<br>Transpedicular drainage and curettage is a useful method to treat patients with pyogenic spondylodiscitis with poor health condition |

**Table 7** (continued)

| Author/publication year/type of study | Surgical approach | Positive microbial cultures (%) | Period of antibiotic treatment | Further surgical intervention | Failure/relapse | Mortality rate (%) | Conclusion of article |
|---|---|---|---|---|---|---|---|
| Lin 2014 [21] (RCoS) | Combined open anterior and posterior<br>*N* = 20<br>Combined percutaneous anterior and posterior<br>*N* = 25 | 80 | 25–80 days | 0%<br>0% | Failure 0%<br>Relapse 5%<br>Failure 0%<br>Relapse 8% | 0%<br>0% | Follow-up: 2 years<br>Anterior interbody fusion and debridement with a bone graft ensued marginally invasive percutaneous posterior instrumentation could be a substitute treatment for pyogenic spondylodiscitis |
| Rossbach 2014 [14] (RCS) | Surgical therapy with antibiotics surgical therapy<br>*N* = 120, extra patients with TLSO<br>N = 46 | 55 | ND | 54.1% | Failure ND<br>Relapse ND | ND | Follow-up: ND<br>Significant improvement in patients (complicated with neurological deficits caused by an epidural abscess) who underwent surgery |
| Schomacher [22] (RCoS) | TTN cage and antibiotic therapy<br>*N* = 21<br>PEEK cage and antibiotic therapy<br>*N* = 16 | 70.1 | IV: 3–6 weeks<br>Oral: 6–10 weeks | 4.5%<br>0% | ND<br>ND | ND<br>ND | Follow-up: 20.4 months<br>The application of PEEK or TTN-cages did not affect the risk of infection or radiological results even with removal of the infected disc in these patients |
| Vcelak 2014 [23] (RCoS) | Two-stage posteroanterior surgery<br>*N* = 23<br>Dorsal transmuscular surgery<br>*N* = 8 | 95 | ND | 8.5%<br>11.2% | Failure 4.0%<br>Relapse 8.1%<br>Failure 0%<br>Relapse 0% | 4.3<br>0% | Follow-up: 1 year<br>The patients who underwent a dorsal transmuscular approach had a greater loss of sagittal stability with no clinical association |

**Conflict of interest** None of the authors has any potential conflict of interest.

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