



Can clinical presentation predict radiologically confirmed cauda equina syndrome: retrospective case review of 530 cases at a tertiary emergency department

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Abstract

Purpose Cauda equina syndrome (CES) may have significant individual consequences if diagnostic delays occur. Our aim was to evaluate the presenting subjective and objective features of patients with suspected CES in comparison to those with radiologically confirmed cauda equina compression (CEC)..

Methods This was a retrospective analysis of all cases presenting with suspected CES to a tertiary emergency care unit over a two-year period. CEC was defined as radiological confirmation of CEC by Consultant Musculoskeletal (MSK) Radiologist report (MSK-CEC) and by measured canal occupancy due to an acute disc extrusion (> 75%)[measured by a Senior Spinal Surgeon (SP-CEC)]. Routine data collection was compared between categories. Chi square, multivariate regression analyses and ROC analysis of multiple predictors was performed.

Results 530 patients were included in this analysis, 60 (11.3%) had MSK-CEC, and 470 had NO- CEC. Only 43/60 (71.7%) had emergent surgery. Those with MSK-CEC and SP-CEC were statistically more likely to present with bilateral leg pain [(MSK-CEC OR 2.6, 95%CI 1.2, 5.8; $p=0.02$)(SP-CEC OR 4.7, 95%CI 1.7, 12.8; $p=0.003$)]; and absent bilateral ankle reflexes [(MSK-CEC OR 4.3; 95% CI 2.0, 9.6; $p<0.001$)(SP CEC OR 2.5; 95%CI 1.0, 6.19; $p=0.05$)] on multivariate analysis. The ROC curve analysis acceptable diagnostic utility of having SP-CEC when both are present [Area under the curve 0.72 (95%CI 0.61, 0.83); $p<0.0001$].

Conclusion This study suggests that in those presenting with CES symptoms, the presence of both bilateral leg pain and absent ankle reflexes pose an acceptable diagnostic tool to predict a large acute disc herniation on MRI scan..

Highlights

- The most predictive features of radiological cauda equina compression were bilateral leg pain and absent bilateral ankle reflexes when patients present with other features of suspected CES (including any of urinary, bowel, sexual dysfunction and/or perineal sensory change).
- Radiological definitions of cauda equina compression vary across studies making comparisons difficult across existing evidence.
- In cases where there is progression of symptoms, in severity, distribution or laterality of symptoms, we would suggest a low threshold for same-day emergency imaging.

Keywords Cauda equina syndrome · Emergency services · Lower back pain · ROC curve

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Introduction

Cauda equina syndrome (CES) includes any combination of back and/or leg pain with one of the following: altered urinary, bowel or sexual function or sensation; and/or sensory changes to the perineal and perianal region [1]. CES is a clinical syndrome, and if any combination of these symptoms is present in the presence of a radiologically confirmed large intervertebral disc or other compressive cause (cauda equina compression [CEC]), then emergency surgery is recommended [2]. CES, although serious, is a rare condition with estimated incidences of 1 in 100 000 in primary care, and around 19% in those presenting with symptoms of CES [3].

In time and resource pressured emergency settings, clinicians need clear guidance on when same day MRI imaging is most likely to result in CEC diagnosis. Previous studies have sought to determine whether any objective or subjective features of assessment were predictive of CEC on MRI scan [4–6]. One prospective study found post-void residual bladder volume of more than 200mls had a sensitivity of 94.1% and specificity of 66.8% with predicting a large disc on MRI scan [5]. In contrast, Angus et al., found that bilateral leg pain, dermatomal sensory loss and loss of lower limb reflexes was strongly suggestive of a radiological CEC diagnosis [4]. Pooled data from a systematic review found poor predictive value associated with any objective findings [6]. Few studies have explored the predictive values associated with subjective reporting of CES symptoms and conflicting results exist regarding the predictive values of objective signs [4, 5]. A National UK CES pathway was released in February 2023 to guide decisions on when to perform same day imaging [7]. Prior to these standards, there remained a lack of specialism and resource to manage patients with suspected CES on the frontline, with many patients not receiving MRI scans timeously, or having repeated attendances to the emergency department (ED) [8, 9]. Clinicians seek reassurance of when to perform same day imaging given the variability of patient presentation and the significant impact of medico-legal implications.

CES is a clinical syndrome with 17 different descriptions in the literature, [10, 11] which makes differential diagnoses challenging. Recent studies have highlighted the poor inter-rater reliability in defining radiological CEC [12]. In addition, there is a lack of standardisation of how to define radiological CEC, with some studies using Consultant Radiologist report [4] and others using a measure of more than 75% canal occupancy [13].

In 2020, our NHS Trust implemented a physiotherapist-led acute spinal assessment unit (ASAU) [14, 15]. The service relies on input from the on-call spinal surgical team, liaising with the radiology registrars for same-day imaging,

bed managers for admissions, and primary care teams on discharge. When the service was set up, there were no existing pathways or guidance for tertiary care hospitals or emergency departments regarding the management of suspected CES. We developed a clinical pathway using the available evidence from identified literature [4–6, 16] in conjunction with our Consultant Surgeon team, and revised this annually, resulting in this project. Our local pathway continues to evolve informed by our dataset. The aim of this project was to identify clinical predictors of subjective and objective features in patients presenting with suspected CES that might help predict MRI scan findings of an acute large canal occupying disc extrusion.

Methods

Study design

A retrospective analysis of a prospectively collected consecutive dataset between January 2020 and July 2021 at an ASAU of a major trauma and tertiary spinal referral centre in the UK, serving a population of 4.5 million. The evaluation was registered with the hospital audit team (220160-C), as it was an observational study, no ethical approval was required. This project is reported in accordance with the STARD guidelines [17] (See Supplementary material)

Setting

The ASAU unit was implemented in January 2020, and staffed by an advanced spinal practitioner physiotherapist, health care assistant and spinal nurse. All patients seen on the unit were entered into an online database with information regarding referrer, attending diagnosis, discharged diagnosis, MRI requests and overall outcome (admission or discharge). For those with an admitting diagnosis of suspected CES and available MRI scan, electronic notes were pulled to gather the relevant data for this evaluation. Cases with serious pathology were excluded from this analysis.

Patient cohort and reference standard diagnosis

Patients were included in the evaluation if they were over 18 years of age and had undergone MRI due to suspected CES in the acute spinal pathway. All clinical documentation was reviewed from available records, and in most cases was recorded prior to MRI scan. Data was extracted by the study team (LW and ED) to include demographic data, subjective and objective assessment findings, and time to MRI. Please see Table 1 for categories extracted for subjective and objective features. Categorical data (final diagnosis,

Table 1 Data categorisation used in coding

Subjective Features		Objective Features	
Urinary Symptoms	Nil	<i>Sensation Loss</i>	No deficit
	Difficulty Emptying		Dermatoma- l loss
	Incontinence		Global loss
	Other (urgency/ frequency/ other)	<i>Motor Weak- ness (defined as less than 5/5 in recorded notes)</i>	No deficit
Bowel Symptoms	Nil		Unilateral weakness
	Constipation		Bilateral weakness
	Incontinence Other (Sensory changes/ other)	<i>Ankle Reflexes</i>	No deficit Unilateral absent
Saddle Sensation	Nil		Bilateral absent
	Reduced	<i>Perianal Sensation</i>	No deficit
	Altered (pins and needles, tingling)		Unilateral abnormality
Leg Pain	Nil		Bilateral abnormality
	Unilateral Bilateral	<i>DRE</i>	Normal Abnormal
Time of onset	Days (most recent change)		Not recorded
Sexual Dysfunction	Nil	<i>Post-void bladder scan residual urine</i>	Millilitres
	Any reported		

subjective and objective findings) was coded accordingly. This was checked by a member of the research team (FK).

Diagnosis of cauda equina compression

CES diagnosis confirmation was based on the MRI scan findings for the study group. Two approaches to the evaluation of the imaging were utilised: the first was based on the formal report of a consultant musculoskeletal (MSK-CEC) radiologist stating “cauda equina compression” [4]. The second definition was based on the imaging interpretation of two senior spinal surgery fellows (SP-CEC)[ME and CZ] for the presence of an acute large ($\geq 75\%$) canal occupying disc extrusion [13].

Data analysis

Descriptive data (counts, percentages, mean and standard deviation (SD)) for all subjective and objective data categories was used to describe the sample. Data for the final

diagnosis was collapsed into binary values of MSK-CEC or NO-CEC as well as SP-CEC and NO-CEC and for each of the subjective and objective features (e.g. urinary symptoms yes/ no, bilateral absent ankle reflexes yes or no). The following variables were collapsed into dichotomous (yes/no): bilateral leg pain, sexual dysfunction, perineal sensory change, absent bilateral ankle jerks and PVR > 200 ml. These were compared using a χ -square analysis for the binary values. We considered statistically significant p-values < 0.05. Positive and negative predictive values and sensitivity and specificity scores were calculated for the likelihood of detecting MSK-CEC and SP-CEC.

Univariate logistic regression analysis was carried out to obtain the crude (unadjusted) odds ratios (ORs) for subjective and objective risk characteristics associated with a diagnosis of MSK-CEC and repeated with a diagnosis of SP-CEC. Those demonstrating statistically significant results with the univariate analysis were taken forward to a multivariate analysis to evaluate the independent key predictor variables for MSK-CEC and SP-CEC. 95% confidence intervals (CIs) are reported throughout. We then tested the clinical utility of the combined predictive features, by running a ROC curve analysis to assess the ability to diagnose patients with MSK-CEC and SP-CEC. An area under the curve of 0.5 suggests a lack of ability to diagnose patients with and without MSK- and SP-CEC, 0.7 to 0.8 is considered acceptable, 0.8 to 0.9 is considered excellent, and more than 0.9 is considered outstanding as diagnostic utility [18].

We did not calculate a sample size as this was a service evaluation project and used a sample that was pragmatic. Analysis only including cases with data and numbers for each recorded analysis are recorded throughout. SPSS v27.0 was used for all analyses.

Results

Description of sample

Full data sets were obtained for 530 patients (see Fig. 1 for included cases flow chart). Of these, 60 (11.3%) had MSK-CEC, and 470 had NO-CEC. In contrast, when using a definition of SP-CEC, only 24 cases (4.5%) had SP-CEC and 506 had NO-CEC as seen in Tables 2a and 2b. All cases of SP-CEC were also classified as MSK-CEC. Of those that had MSK-CEC only 43/60 (71.7%), and in SP-CEC, 19/24 (79.2%) proceeded to have surgery emergently.

Subjective symptoms

Figure 2 demonstrates the frequency of reported subjective symptoms across all groups of suspected CES with a

Fig. 1 Flow chart to demonstrate eligible cases and diagnostic accuracy cases used at each stage. *Legend* SDEC = Same Day Emergency Care unit; MRI = Magnetic Resonance Image; MSK = musculoskeletal; MSK-CEC = Musculoskeletal Radiologist Cauda Equina Compression; No-CEC = No Cauda Equina Compression; SP-CEC = Spinal Fellow Measured canal occupancy Cauda Equina Compression

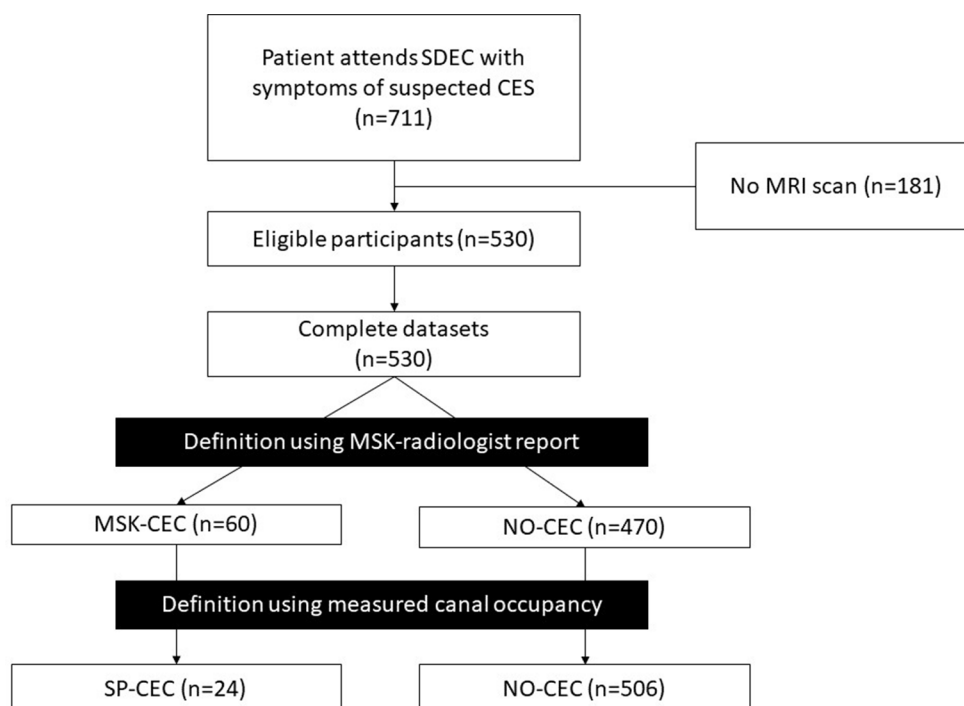


Table 2a Baseline presenting data for all groups using MSK-CEC as definition

	All (n = 530)	MSK-CEC (n = 60)	Spinal Pathology (n = 336)	No Spinal Pathology (n = 134)
Age (mean, SD)	46.2 (14.1)	44.0 (13.6)	48.6 (13.9)	41.2 (14.2)
Sex (n, % female)	390 (73.6%)	29 (48.3%)	245 (72.9%)	116 (86.6%)
<i>Referrer</i>				
ED	212 (40.0%)	26 (43.3%)	127 (37.8%)	59 (44.0%)
Primary Care	129 (24.3%)	13 (21.7%)	79 (23.5%)	37 (27.6%)
Secondary Care/ Unclear	189 (35.7%)	21 (35.0%)	130 (38.7%)	38 (28.4%)
Admissions	58 (10.9%)	24 (40.0%)	24 (7.1%)	10 (7.5%)
Time to MRI (days) (mean, SD)	11.4 (29.8)	-1.4 (9.0)	13.2 (33.1)	11.5 (25.5)
Time onset (days) (mean, SD)	17.0 (32.0)	14.1 (16.6)	17.7 (35.4)	16.6 (28.4)

Table 2b Demographic information of using SP-CEC as case definition

	All (n = 530)	SP-CEC (n = 24)	Spinal Pathology (n = 372)	No Spinal Pathology (n = 134)
Age (mean, SD)	46.2 (14.1)	42.0 (9.6)	48.3 (14.1)	41.2 (14.2)
Sex (n, % female)	390 (73.6%)	12 (50.0%)	262 (70.4%)	116 (86.6%)
<i>Referrer</i>				
ED	212 (40.0%)	11 (45.8%)	142 (38.2%)	59 (44.0%)
Primary Care	129 (24.3%)	5 (20.8%)	87 (23.4%)	37 (27.6%)
Secondary Care/ Unclear	189 (35.7%)	8 (33.3%)	143 (38.4%)	38 (28.4%)
Admissions	58 (10.9%)	11 (45.8%)	37 (9.9%)	10 (7.5%)
Time to MRI (days) (mean, SD)	11.4 (29.8)	0.68 (5.6)	12.4 (32.3)	11.6 (25.7)
Time onset (days) (mean, SD)	17.0 (32.0)	9.1 (9.0)	17.6 (34.1)	16.6 (28.4)

Legend SD = Standard deviation; MSK-CEC = Musculoskeletal Radiologist Cauda Equina Compression; MRI = Magnetic Resonance Image; ED - Emergency Department

diagnosis of MSK-CEC and SP-CEC. Chi-square analysis found statistically significant differences between MSK-CEC and NO-CEC in: bilateral leg pain [MSK-CEC ($n=40/60$,

66.7%), NO-CEC ($n=186/468$, 39.7%)($p < 0.001$) and sexual dysfunction with MSK-CEC ($n=10/35$, 28.6%), and NO-CEC ($n=35/281$, 12.5%)($p=0.01$). When using a

Fig. 2 Frequency of subjectively reported symptoms (%) for MSK-CEC, SP-CEC and NO-CEC. MSK-CEC = Musculoskeletal Radiologist Cauda Equina Compression; SP-CEC = Spinal Surgeon Cauda Equina Compression; No-CEC = No Cauda Equina Compression

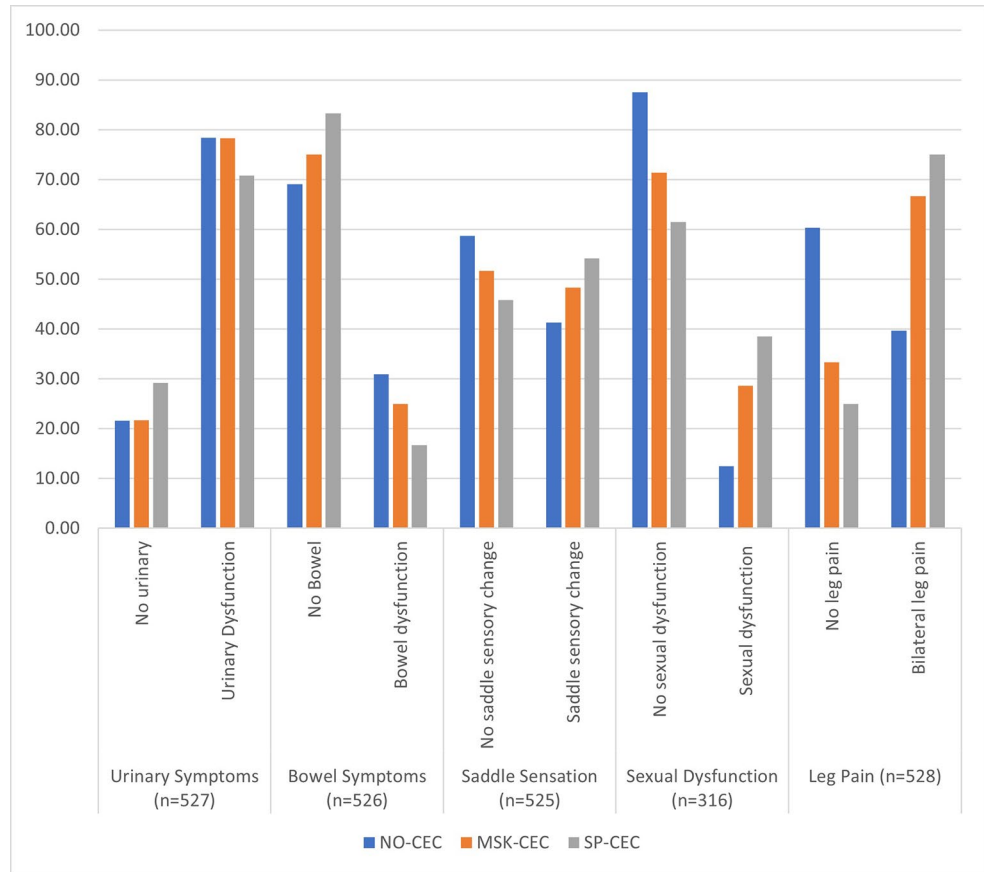


Table 3 Sensitivity and specificity results for subjective and objective assessment findings using MSK-CEC as definition

Assessment Finding	Sensitivity	Specificity	Negative Predictive Value	Positive Predictive Value
Subjective Symptoms				
Urinary Dysfunction	78.3%	21.6%	88.6%	11.4%
Bowel Dysfunction	25.0%	69.1%	87.7%	9.4%
Perineal Sensory Alteration	48.3%	58.7%	89.8%	13.1%
Sexual Dysfunction	24.0%	87.3%	86.7%	25.0%
Bilateral Leg pain	66.7%	60.3%	93.4%	17.7%
Objective Signs				
Dermatomal Sensory Loss	66.7%	39.3%	90.3%	12.3%
Bilateral Motor Weakness	50.8%	57.9%	90.1%	13.6%
Bilateral Ankle Reflex Absent	40.4%	85.6%	91.7%	26.7%
DRE abnormal	17.6%	74.4%	86.9%	8.6%
Abnormal Perianal Sensation	49.1%	50.5%	87.6%	12.2%
PVR > 200mls	17.9%	89.0%	89.8%	16.7%

DRE is digital rectal examination, PVR is post void residual volume measured using bladder scan

definition of SP-CEC, Chi-square analysis similarly found a statistically significant difference between SP-CEC [bilateral leg pain] ($n = 18/24, 75.0\%$) and NO-CEC ($n = 208/504, 41.3\%$) ($p = 0.001$); and those reporting sexual dysfunction [SP-CEC ($n = 5/13, 38.5\%$), and NO-CEC ($n = 40/303, 13.2\%$) ($p = 0.01$)]. See Table 3 for sensitivity and specificity values. Please see Appendix 1 for comparisons of frequency counts across MSK-CEC, SP-CEC and NO-CEC.

Objective signs

Figure 3 demonstrates the reported percentages of objective signs between the NO-CEC and MSK-CEC and SP-CEC groups respectively. Please see Appendix 2 for comparisons of frequency counts across MSK-CEC, SP-CEC and NO-CEC. Chi-square analysis identified the absence of bilateral ankle reflexes

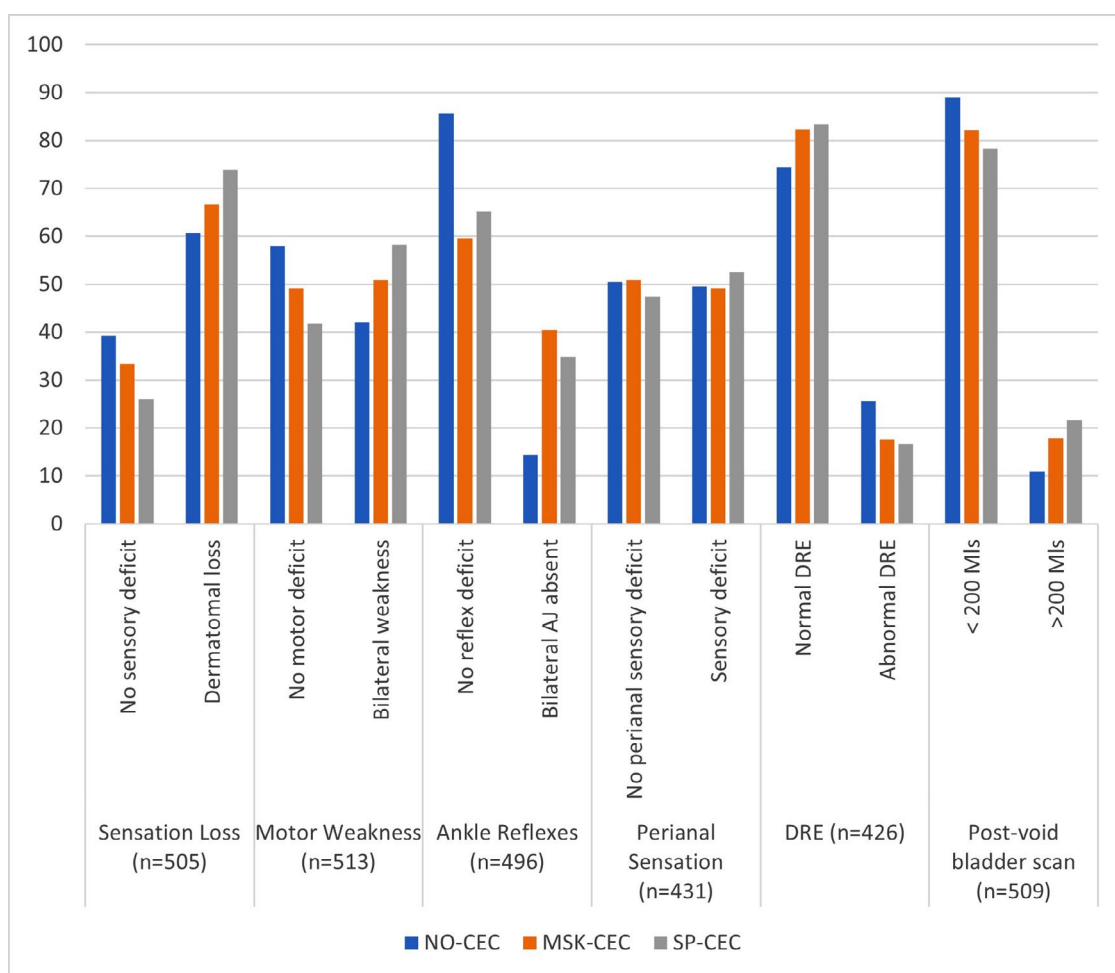


Fig. 3 Frequency of objectively recorded signs (%) for MSK-CEC, SP-CEC and NO-CEC. MSK-CEC=Musculoskeletal Radiologist Cauda Equina Compression; SP-CEC=Spinal Surgeon Cauda Equina

Compression; No-CEC =No Cauda Equina Compression; DRE = Digital Rectal Examination; Mls =millilitres

Table 4 Results of Univariate and Multivariate Analysis

MSK-CEC as case definition	Univariate Analysis		Multivariate Analysis	
	OR (95% CI)	P Value	OR (95% CI)	P Value
Subjective Symptom				
Bilateral leg pain (n= 528)	3.0 (1.7, 5.4)	<0.001	2.6 (1.2, 5.8)	0.02
Sexual dysfunction (n=316)	2.8 (1.2, 6.3)	0.01	2.3 (0.9, 5.7)	0.07
Objective Signs				
Bilateral absent ankle jerks (n=496)	4.0 (2.2, 7.3)	<0.001	4.3 (2.0, 9.6)	<0.001
SP-CEC as case definition				
Subjective Symptom				
Bilateral leg pain (n= 528)	4.3 (1.7, 10.9)	0.002	4.7 (1.7, 12.8)	0.003
Sexual dysfunction (n=316)	4.1 (1.3, 13.2)	0.02	2.7 (0.8, 9.7)	0.1
Objective Signs				
Bilateral absent ankle jerks (n=496)	2.7 (1.1, 6.6)	0.03	2.5 (1.0, 6.19)	0.05

[(MSK-CEC $n = 23/57$, 40.4%; NO-CEC $n = 63/439$, 14.4%; $p < 0.001$); (SP-CEC $n = 8/23$, 34.8%; NO-CEC $n = 78/473$, 16.5%; $p = 0.03$)] as statistically significant. ORs for the association between MSK-CEC and NO-CEC for the significant variables in the univariate analyses are presented in Table 4.

Diagnostic test characteristics - multivariate analysis

Those with MSK-CEC and SP-CEC were statistically more likely to present with subjective features of bilateral leg

pain [MSK-CEC OR 2.6, 95%CI 1.2, 5.8; $p=0.02$]; (SP-CEC OR 4.7, 95%CI 1.7, 12.8; $p=0.003$)] and absent bilateral ankle reflexes [MSK-CEC (OR 4.3; 95% CI 2.0, 9.6; $p<0.001$); SP-CEC (OR 2.5; 95%CI 1.0, 6.19; $p=0.05$)] on multivariate analysis.

The ROC curve analysis (see Fig. 4a and b) demonstrates that when a patient presents with bilateral leg pain and bilateral absent ankle jerks, then the likelihood of having SP-CEC is acceptable [Area under the curve 0.72 (95%CI 0.61, 0.83); $p<0.0001$].

Discussion

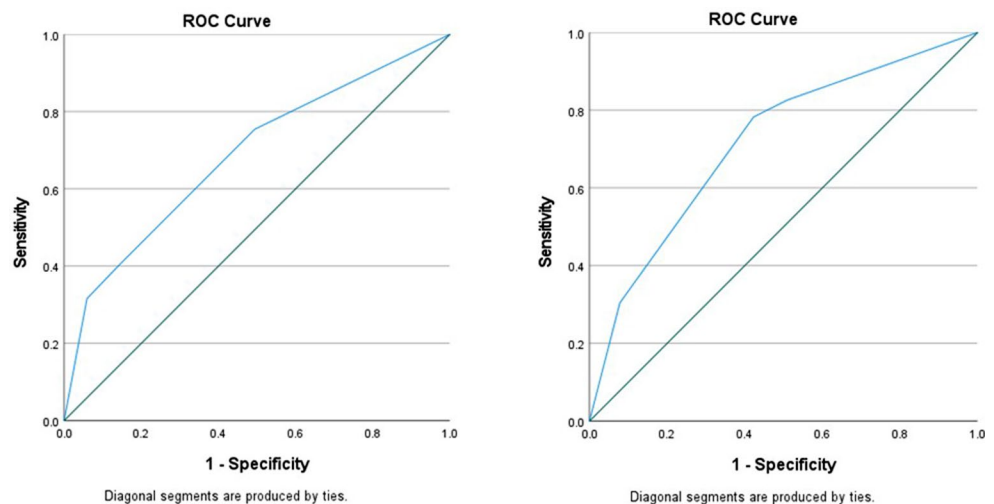
This evaluation found that the most predictive features of both MSK-CEC and SP-CEC were bilateral leg pain and absent bilateral ankle reflexes presenting with other features of suspected CES. There has been much debate about the management of patients presenting to musculoskeletal services with bilateral leg pain and no other symptoms. UK guidance is clear on the need for same-day imaging when patients present with any combination of new bladder, bowel, sexual dysfunction or perineal sensory change [7]. However, sudden onset of bilateral leg pain or progression of unilateral to bilateral leg pain should be considered as a risk factor for progression of CES, and an urgent MRI scan requested (not same day) [7]. The findings of this paper suggest that when patients present with any other CES features in conjunction with bilateral leg pain and absent ankle reflexes, then a higher level of suspicion should be employed.

This study has demonstrated that although clinical definitions of CEC may vary (MSK-CEC vs. SP-CEC) the predictive findings were the same across both groups. There was considerable debate within our author team about the definition used to determine CEC. This demonstrates the

consequences of a radiological definition, as incidence of MSK-CEC and SP-CEC differed, suggesting that an agreed definition is necessary to allow translation into clinical practice. Poor inter-rater reliability between spinal registrars, consultant spinal surgeons and medical students has been recently demonstrated, highlighting the difficulty with diagnosing radiological CEC [12]. Woodfield et al. used a primary definition of more than 50% canal occupancy, and reported 70% of their cohort had more than 75% canal occlusion [19]. Our analysis finds similar results to that of Angus et al. [4] who analysed patient cases from presentation to an emergency village managed by a consultant physiotherapist. They defined CEC using Consultant Radiologist report (as per our MSK-CEC) and found a similar incidence of radiological CEC (111/996, 11%) to our dataset (11.3%), whereas the incidence of SP-CEC was much lower at 4.5%. It is unlikely that patients with 70–75% radiological canal occupancy and symptoms suggestive of CES will not be operated on emergently, and this suggests a need for a working definition based on both radiological and clinical features for more transparent merging of research papers and clinical practice. This may also require additional study to understand the degree of cauda equina nerve compression required to result in symptoms requiring decompressive surgery.

The lower than expected surgical conversion rate between these two groups (MSK-CEC $n=43/60$ [71.7%]; SP-CEC 19/24 [79.2%]) may reflect the variability within current practice. Hoeritzauer et al. [13]. reported a surgical conversion of 87% of their CEC cases. Patients may have subtle or stable symptoms as seen in some of our dataset who had fluctuating stable symptoms over a 2–3/month period. Patients may also choose not to have surgery or trial a course of ‘watch and wait’ when symptoms are again variable or intermittent. This highlights the importance of clear safety-netting and shared decision making, using validated

Fig. 4 ROC curve to demonstrate the clinical utility of the combined presenting features of bilateral leg pain and absent ankle reflexes in predicting MSK-CEC and SP-CEC. ROC analysis on the left used MSK-CEC as definition, ROC analysis on the right used SP-CEC as definition



tools such as the patient consent forms from the UK National CES pathway [7].

We found similar findings to Angus et al. with bilateral leg pain and absent bilateral ankle reflexes; whereas in contrast, they reported the additional association of dermatomal sensory loss [4]. Previous studies have highlighted the importance of bilateral leg symptoms in early MRI scans, and this study provides additional support for this [20]. Other studies have not found any differences between subjective or objective presenting features in predicting diagnosis of CEC [9].

This study is one of the few to incorporate multivariate modelling in a ROC analysis to compare the clinical utility of multiple predictors. When patients present with symptoms of both bilateral leg pain and absent bilateral reflexes and other CES features, then a high degree of suspicion should be employed in clinical practice. The International Federation of Orthopaedic Musculoskeletal and Manual Physical Therapists' framework [16] has provided guidance regarding the clinical reasoning process and index of suspicion for cases of suspected red flag pathology such as CES. In cases where there is progression of symptoms, we would suggest a low threshold for same-day emergency imaging.

Across different international health systems there is a drive to standardise how patients with spinal pathology are managed, and the UK National Getting it Right First Time CES pathway is an example of how services or nations may do this [7]. These pathways aim to reduce delays to diagnosis, in particular MRI scanning, for those with suspected CES symptoms. The findings of this evaluation are in keeping with the national UK pathway, as bilateral symptoms alongside a suspicion of CES features were most predictive of MSK-CEC and SP-CEC, suggesting clinicians should be sensitive to changes in patient presentation. Other studies have demonstrated that early diagnosis of CES such as mild symptoms with bilateral features optimises post-surgical recovery. [20] No other country has produced such comprehensive guidance for the assessment and management of suspected CES. The American Association of Neurological Surgeons [21] and Radiologists [22] both have reference to CES imaging and management, but without clarity on what

symptoms, within what timeframes should trigger imaging or emergency surgery.

Strengths and limitations

This study has included a large cohort of patients that have routinely presented to an emergency care setting either through self-referral, primary care referral or secondary care review. However, this was a tertiary hospital setting, and so it is possible that more CES cases were seen than would be expected in other settings. However, the retrospective nature of the analysis is limited by incomplete data, and does not include participant outcomes, qualitative insights, or patient involvement. Further, there was no standardisation or uniformity in assessment procedures. Missing data was frequently due to clinician non-recording, and it can be assumed that in those with less severe presentation there may have been innate bias to record or assess less.

Clinical and research implications

Clinical assessment should be supported by a clinical reasoning framework using the clinicians' index of suspicion and an overall picture of the patient's general improvement/worsening/ stability to justify emergency referral and imaging. Further prospective cohort studies with patients presenting with CES symptoms, and patient-reported outcome measures may be useful to validate these findings. Consensus on a radiological definition of CEC will be helpful to define what is meant by CEC and what thresholds should be used for future agreement and meta-analysis of studies.

Conclusion

This study suggests that in those presenting with suspected CES, bilateral leg pain and absent bilateral ankle reflexes are an acceptable diagnostic tool to predict a large acute disc herniation on MRI scan. Further research to standardise the radiological definition of CEC is required to improve the quality and comparability across studies.

Appendix

Appendix 1 Table to demonstrate frequency percentiles of subjective symptoms

		NO-CEC	MSK-CEC	SP-CEC
Urinary Symptoms (n = 527)	No urinary	21.60	21.70	29.20
	Urinary Dysfunction	78.40	78.30	70.80
Bowel Symptoms (n = 526)	No Bowel	69.10	75.00	83.30
	Bowel dysfunction	30.90	25.00	16.70
Saddle Sensation (n = 525)	No saddle sensory change	58.70	51.70	45.80
	Saddle sensory change	41.30	48.30	54.20
Sexual Dysfunction (n = 316)	No sexual dysfunction	87.5	71.4	61.5
	Sexual dysfunction	12.5	28.6	38.5
Leg Pain (n = 528)	No leg pain	60.3	33.3	25
	Bilateral leg pain	39.7	66.7	75

Appendix 2 Table to demonstrate frequency percentiles of objective signs

		NO-CEC	MSK-CEC	SP-CEC
Urinary Symptoms (n = 527)	No urinary	21.60	21.70	29.20
	Urinary Dysfunction	78.40	78.30	70.80
Bowel Symptoms (n = 526)	No Bowel	69.10	75.00	83.30
	Bowel dysfunction	30.90	25.00	16.70
Saddle Sensation (n = 525)	No saddle sensory change	58.70	51.70	45.80
	Saddle sensory change	41.30	48.30	54.20
Sexual Dysfunction (n = 316)	No sexual dysfunction	87.5	71.4	61.5
	Sexual dysfunction	12.5	28.6	38.5
Leg Pain (n = 528)	No leg pain	60.3	33.3	25
	Bilateral leg pain	39.7	66.7	75

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s00586-024-08474-5>.

Author contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Lianne Wood, Eleanor Dunstan, Christos Zlatanov, Mohamed Elkazaz and Faris Karouni. The first draft of the manuscript was written by Lianne Wood and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests The authors declare they have no competing or conflicts of interests to disclose.

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