Spine

DIAGNOSTICS

Bladder Scans and Postvoid Residual Volume Measurement Improve Diagnostic Accuracy of Cauda Equina Syndrome

Muralidharan Venkatesan, MRCS, MCh(Orth), FRCS(Orth), Luigi Nasto, MD, PhD,
Magnum Tsegaye, MD, FRCSEd, (Neuro Surg), and Michael Grevitt, BSc, FRCS, FRCS(Orth)

Study Design. A prospective, observational cohort study.
Objective. The aim of this study was to determine the role of pre and postvoid bladder scan in predicting cauda equina syndrome (CES). The thesis was that bladder scanning [specifically postvoid residual (PVR) volume] would have higher diagnostic accuracy than physical examination alone.
Summary of Background Data. CES is an ill-defined condition with a spectrum of presenting symptoms. There is neither a combination of clinical symptoms and/or signs that reliably predicts cauda equina compression nor single defining clinical criterion that has 100% predictive value to confirm or exclude CES.
Methods. Patients with suspected CES admitted over a 6-month period at a single institution were prospectively assessed by physical examination (including digital rectal examination and pin prick perianal sensation) and bladder ultrasound scanning (recording pre- and PVR volume). These results were compared with the subsequent magnetic resonance imaging (MRI) scans and those patients who had emergent surgery for CES.
Results. Ninety-two patients were included in the study (52 women) with a mean age of 44.9 years.
An MRI scan demonstrating causing compression of the cauda equina was present in only 18% (17/92).
The sensitivity of anal tone to predict CES was 52.9%. Peri-anal numbness (either unilateral or bilateral) had sensitivity of 82.3% and negative predictive value of 92%.

For nonoperated group (without CES), mean PVR was 199 mL (95% confidence interval ± 59 mL). On the basis of receiver operating curves, the optimal bladder volume cut-off for predicting CES was ≥200 mL for PVR volume. A PVR of <200 mL gave CES probability of 3.6%. If >200 mL, then the probability of having CES is 43% ($P < 0.000003$). A PVR <200 mL had a negative predictive value of 97%.
Conclusion. Bladder scanning was a useful adjunct in the diagnosis of CES. It had a better negative predictive value than physical examination.
Key words: accuracy, bladder scan, cauda equina syndrome, diagnosis, postvoid residual volume, predictive value.
Level of Evidence: 3
Spine 2019;44:1303–1308

Cauda equina syndrome (CES) is a neurological emergency and prompt diagnosis is imperative to prevent significant morbidity.[1] Diagnostic delay can result in irreversible motor, sphincter, and sexual dysfunction.[1–3]

A significant problem is the fact that it is an ill-defined condition with a spectrum of presenting symptoms.[4] Clinical signs include perianal numbness, absence of voluntary anal sphincteric contraction, or reduced anal tone. These clinical features are commonly quoted "red flags" that should raise suspicion of CES. However, a review of literature suggests there is no combination of clinical symptoms and/or signs that reliably predict cauda equina (CE) compression.[5–8] A recent study suggests that digital rectal examination (DRE) cannot be used as a discriminator between the presence or absence of CES.[9]

It is a *sine qua non* of CES that there must be functional compromise of the CE nerves. A demonstrable end-point of this process is "loss of executive control" of the bladder (cf. Gleave and Macfarlane[2]) with urinary retention and overflow incontinence. However, delaying diagnosis to this point is undesirable in prognostic terms[3] and is a significant contributor to alleged clinical negligence.

Given the daily frequency of urination, it is the function of the bladder that gives the most useful assessment of CE

integrity. Formal urodynamic assessment is impractical in the most clinical settings where CES is suspected, hence the dearth of related data in the CES literature. However, ultrasound bladder scan devices are cheap and available in most family practices and emergency departments (EDs). These devices have high accuracy in measuring pre- and postvoid residual (PVR) volumes. The utility of bladder scanning would be supporting the earlier diagnosis of CESI when there was incomplete voiding of urine but still detrusor activity and sphincteric control.

We therefore set out to determine the role of pre and postvoid bladder scan in predicting CES.

Our thesis was that bladder scanning and specifically PVR volume would have higher diagnostic accuracy than physical examination alone.

MATERIALS AND METHODS

We analyzed our prospective spinal on-call electronic database specifying CES referrals over a 6-month period from November 1, 2015, to April 30, 2016. The unit is the regional tertiary spinal service serving a catchment population of 4.7 million. We included patients referred to our emergency service with suspected CES on clinical grounds alone and requiring MRI evaluation before intervention if appropriate. This includes patients referred from our ED (circa 200,000 new patient attendances per year), direct referral from General practitioners, and those patients transferred from peripheral district general hospitals for specialist spinal on-call assessment and MRI service. We excluded patients who had undergone emergency surgery after being referred with an MRI scan that confirmed a large lumbosacral disc prolapse and CE compression. Electronic case records were reviewed, and information collated include demographics, presenting symptoms and signs, pre- and postvoid bladder scan volumes, and outcome of MRI. Our unit policy is that every suspected CES patient has prevoid volume and PVR bladder volume measured by transabdominal ultrasound after adequate analgesia and before MRI. The bladder scans were performed as part of the initial clinical assessment on admission to the spinal unit. Only patients with a complete data set of bladder scans, MRI, and documented outcome were included in this study.

All patients referred to our unit had been initially assessed by at least one doctor whose seniority level ranged from senior practitioner (in the case of family medicine referrals) or at least junior resident status (ED or other hospital specialties). On admission to the unit, the patients were reassessed by senior Board-eligible clinical fellows; where there were potential incongruous physical findings from the chart review, the fellows' elicited signs were preferred. The bladder scanner used was a Bardscan IIs Real Time Ultrasound Bladder Scanner (www.bardmedical.co.uk)

Statistical Methods

Categorical variables were compared using Chi-squared tests with Yates correction where small numbers existed. Sensitivity, specificity, positive predictive value, and negative predictive value were calculated using standard techniques. The 95% confidence interval (95% CI) of these values was determined using the Newcombe method.[11] Logistic regression was used to determine the odds ratio (OR) values ($P < 0.05$). A receiver operator curve was constructed to determine the optimum cuff-off point of post-micturition bladder volume to maximize the specificity and sensitivity for PVR volume. The area under the receiver operator curve was calculated and determined the accuracy of using this cut-off.

RESULTS

Ninety-two patients were admitted with suspected CES through the on-call service during the 6-month study period. There were 52 women; the mean age of the cohort was 44.9 years (14–89 years). Table 1 summarizes proportion of patients presented with loss of perianal pin prick sensation and absent or reduced anal tone on DRE.

The range and proportion of specialties making these referrals are summarized in Figure 1.

A positive MRI scan (i.e., a large lumbosacral disc prolapse occupying the majority of the canal cross-sectional area sufficient to compress the CE) was present in only 18% (17/92) of clinically suspected cases. All MRI scans were independently reported by senior (attending status) musculoskeletal radiologists and verified by the operating surgeon during the decompression procedure. All underwent emergent surgical intervention in the form of discectomy and decompression. Table 1 compares the prevalence of the physical signs in the nonoperated group compared with those who had surgery.

Given the subjective nature of DRE, we defined a positive result for assessing anal tone as either reduced or absent. Negative was when tone was deemed normal. Give these definitions sensitivity of anal tone to predict CES in our series was 52.9%. Perianal numbness either unilateral or bilateral has sensitivity of 82.3% and negative predictive value of 92%.

TABLE 1. Prevalence of the Physical Signs in the Nonoperated Group Compared with Those who had Surgery

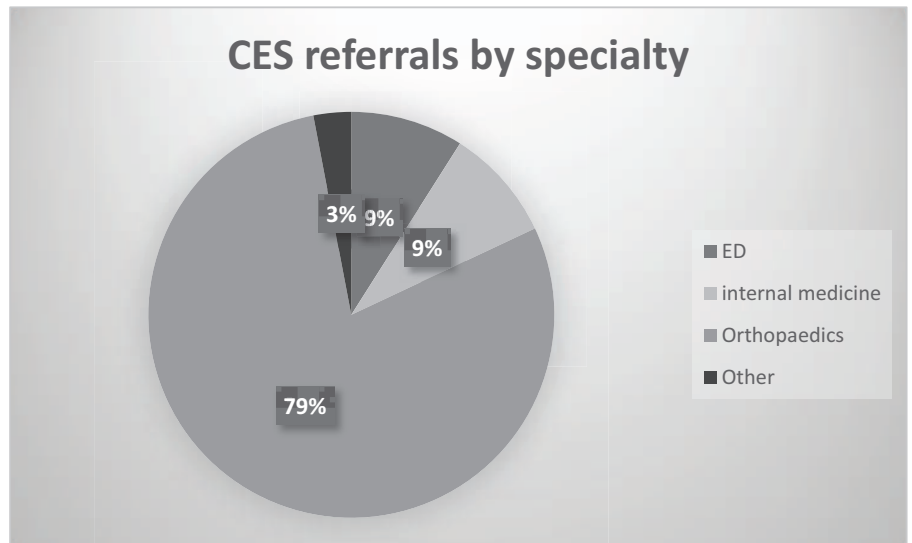| Signs	Nonoperative	Operated
Reduced perianal sensation	(42/75) 56%	(12/17) 82%
Reduced anal tone	(25/75) 33%	(4/17) 24%
Absent anal tone	(3/75) 4%	(5/17) 29%
Loss of voluntary anal "squeeze"	(3/75) 4%	(5/17) 29%

Figure 1. Range of specialties referring to spinal unit.

For the whole group, the mean (± 95% CI) prevoid volume was 470 mL (±61 mL) and the mean PVR volume was 248 mL (±59 mL). Mean postvoid for patients with CES with 95% CI was 466 mL (±48 mL).

For nonoperated group (without CES), mean postvoid with 95% CI was 199 mL (±59 mL). PVR volume for patients with CES *versus* patients without CES: $P = 0.002$.

With regards to prevoid volume, mean prevoid for patients with CES was 672 mL (±138 95% CI) and the respective value for patients without CES was 424 mL (±64 95% CI). Prevoid volume for patients with CES *versus* patients without CES: $P = 0.002$.

Receiver operating characteristic (ROC) curves were constructed for prevoid and postvoid bladder volume to determine cut-off points to predict CES. On the basis of ROC, the optimal bladder volume cut-offs for predicting the CES were ≥400 mL for prevoid scan and ≥200 mL for postvoid scan.

For pre-micturition scan volume of <400 mL, probability of CES is 4.5% and for ≥400 mL, probability is 35% ($P = 0.0006$, Chi-square).

For postvoid scan, a residual volume of <200 mL has probability of 3.6%, and if greater than 200 mL, then the probability of having CES is 43% ($P < 0.000003$). ROC for postvoid volumes demonstrates area under curve of 0.81 for cut-off >200 mL (Figures 2 and 3).

Logistic regression analysis revealed that the odds of having cauda equine syndrome is 20.7 times higher given PVR bladder scan is ≥200 mL (OR 20.7).

Table 2 outlines the sensitivity, specificity, and probability of CES for the observed bladder scan cut-off volumes.

Table 3 summarizes that PVR volume has higher sensitivity, specificity, and predictive value than perianal numbness in the evaluation of suspected CES.

DISCUSSION

The diagnosis of CES remains problematic; published studies have shown that physical examination and elicited signs alone are unreliable.[5–10,12]

Bell et al[6] in their prospective study concluded that no clinical characteristics correlated predicted CE compression on MRI.

Balasubramanian et al[5] reported that no single clinical symptom or sign has absolute predictive value in establishing diagnosis of CES; only 18.8% of the suspected patients had CE compressive lesion seen in MRI.
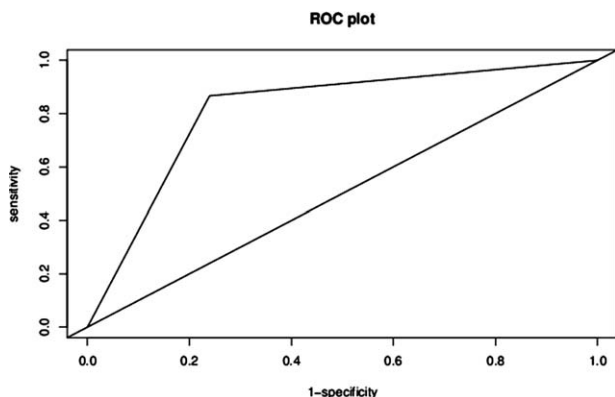

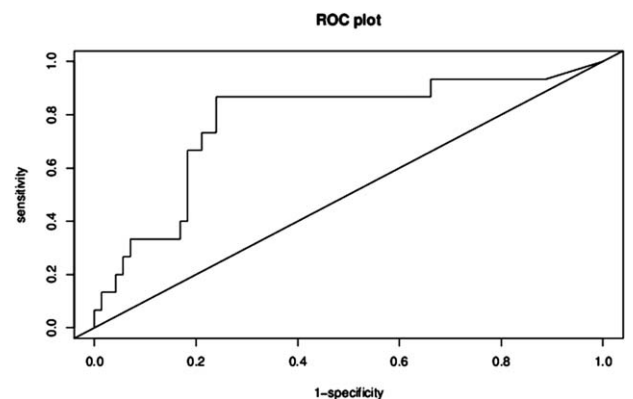**Figure 2.** ROC for postvoid bladder scan volume.

Figure 3. ROC postvoid as a continuous variable.

TABLE 2. Proportion of Patients with Perianal Numbness and Impaired Anal Tone at Presentation

Sign	No. of Patients (n = 92)	% of Patients
Perianal numbness	56	61%
Unilateral	22	24%
Bilateral	34	37%
Impaired/reduced anal tone	37	40%

Similarly, Ahad et al[8] confirmed that no clinical features were able to predict the presence of established CES on MRI.

The reasons for the poor predictive value of physical examination are complex and multifactorial. DRE has been an established requisite for adequate assessment of the suspected CES. Gooding et al[9] in their retrospective study observed that DRE had no significant value in evaluation of suspected CES. Sherlock et al[12] evaluated the reliability and accuracy of DRE on a model anus using pressure transduce; accuracy in assessing anal tone using is limited and not useful in suspected with CES.

In summary, assessment of anal tone in suspected CES is associated with significant interobserver variance. Absence of contraction or a patulous anus are late signs in the progression of CES, and more likely indicate CESR. Therefore, reliance on this sign is unhelpful in trying to establish an earlier diagnosis.

The other element of physical examination that receives considerable attention is the integrity of perianal or perineal sensation. Using sharp-touch or pin prick sensation as a test modality has obvious attraction in view of the dichotomous nature of the response (present or absent).

Unfortunately, there is considerable anatomical uncertainty regarding the relative positions of the S1 and S2 dermatomes. Figure 4 is a composite of dermatomal maps taken from internet sources. The S1 dermatome can either be confined to below the knee or extend toward the buttock. Alternatively, the S2 dermatome can either extend to the perianal region or be limited to below the buttock creases. Thus, a complaint of "saddle anaesthesia" may not be specific to CES, as a large lumbosacral disc herniation causing S1 nerve root compression may produce this symptomatic hypoaesthesia. Alternatively, reduced perianal sensation may be due to S1 rather than S2 compression, especially if testing is not carried out to the anal margin (i.e., S3/4).

Given the frequency of urination, it is urinary dysfunction that is the most common and self-evident symptom of CE compression. It is arguably the most important proxy in lieu of any direct measurement of intracanal pressure. Therefore, some form of urodynamic assessment of detrusor muscle and bladder sphincteric function is potentially advantageous.

In this study, the proportion of patients with MRI-confirmed CES was 18% out of 92 clinically suspected cases and this is like previously published observed rate.[5,6,8] This confirms that the population studied was typical of most groups of suspected CES. Therefore, this study is both generalizable to most health care systems and the results are applicable in diverse clinical settings.

Measurement of PVR (the amount of residual urine in the bladder after a voluntary void) is a screening test for voiding dysfunction. In-and-out catheterization can be done after asking the patient to void but at the expense of discomfort for patients and carries a risk of urinary tract infection and trauma.[13] Portable three-dimensional ultrasound scanning is an alternative noninvasive bedside method shown to provide highly accurate measurement of bladder volume. Coombes and Millard[14] compared the Bladder Scan BVI 2500 series (Diagnostic Ultrasound, Bothell, WA) with catheterization for the measurement of bladder volume. Study results demonstrated no significant difference between estimates made with the bladder scan and catheter estimates of true volume.

Threshold values delineating what constitutes an abnormal PVR are poorly defined. Most urologists agree that volumes of 50 to 100 mL constitute the lower threshold to define an abnormal PVR. A PVR volume of less than 50 mL is considered adequate bladder emptying in young adult; in the elderly, between 50 and 100 mL is considered normal.[15]

Analysis of the CE receiver operator characteristic (ROC) curve revealed PVR cut-off value of 200 mL as a strong predictor of CE compression in suspected cases with better sensitivity of 94%, specificity of 72%, and negative predictive value of 98%. The area under the ROC curve for the cut-off value of >200 mL was 0.81 and indicates that the discriminative power of the PVR cut-off is good, justifying its clinical utility in evaluation patients with suspected CES.

PVR of more than 200 mL was the most important predictor of MRI-confirmed cauda compression. Regression analysis revealed that odds of having CE compressive lesion in MRI is 20.7 times higher if PVR is more than 200 mL. PVR volume above 200 mL also had higher sensitivity, specificity, and predictive value as compared with perianal numbness (Table 4).

It has been argued that there should be a low threshold for requesting MRI scans in suspected CES.[16] However, MRI scans indicate the size of the disc herniation and probable

TABLE 3. Sensitivity, Specificity, and Probability of CES for Pre/Postvoid Volumes

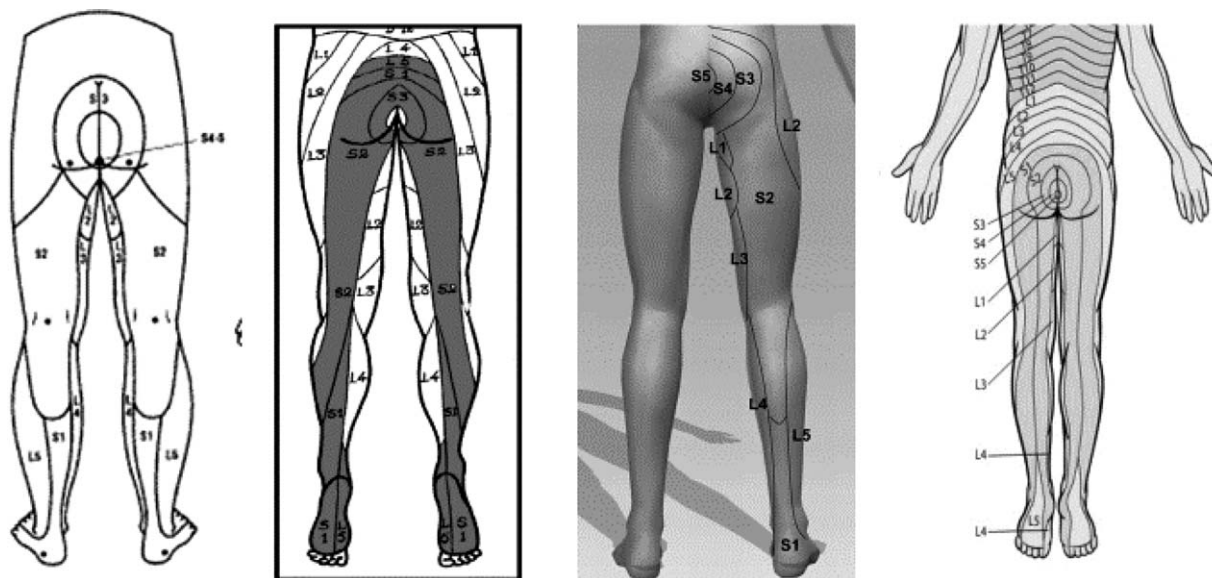| Residual Volume, mL	CES Probability	Sensitivity (95% CI)	Specificity (95% CI)	P (LR)
Prevoid ≥400	34%	85% (57–97)	67% (54–77)	0.004
Postvoid ≥200	43%	94% (73–99)	72% (61–81)	0.005

Figure 4. Published variation in sacral dermatomes.

compression. The latter may not cause CE dysfunction as experienced surgeons will attest.[17] Several studies have shown that patients with sciatica due to large disc herniations resolve naturally if there is no sphincter dysfunction. A nonoperative "watchful-wait" approach despite a massive disc herniation without sphincter involvement was both safe and efficacious with no emergency decompressions for CES.[18,19]

In our series, one patient had no urinary dysfunction or sphincteric disturbance but had documented bilateral sciatica and bilateral perianal numbness. His PVR was less than 200 mL and MRI scan demonstrated a large disc herniation with reported CE compression. The patient was counselled regarding the low risk of CES notwithstanding the MRI result. Nonetheless, he elected to have surgery due to severe pain. Although he did not have CES, it was decided to include him in the "false-negative" category of calculating specificity. Had he been omitted, then PVR <200 mL specificity would be 71% and the negative predictive value would rise to 100%.

Domen *et al*[20] reported that urinary retention of more than 500 mL alone or in combination with two or more specific clinical characteristics were the most important predictors of MRI-confirmed cauda compression. Given our data, this higher PVR threshold of 500 mL in our opinion would potentially miss definite CES cases.

The trajectory of ordering MRI scans in the majority of suspected CES will have some substantial cost implications in terms of negative scans and inpatient bed-days and transport costs. It must be questioned whether this trend is affordable or proper where most health budgets are shrinking in relative terms.

No one would dispute the need for timely diagnosis and surgical intervention to reduce the long-term disability of CES. Unfortunately, conventional physical signs have low sensitivity and specificity, which creates clinical uncertainty. In this paper, we are suggesting that bladder scanning and PVR is a useful adjunct to and better than conventional physical examination. Use of PVR threshold gives an objective measurement of voiding function and potential CE dysfunction. Its use allows reasonable risk stratification; where there is normal perianal sensation and a PVR <200 mL, then the risk of CES is negligible. That individual does not require an urgent, often out-of-hours MRI scan; rather, the associated radiculopathy should be treated according to local protocols and practice. A PVR of <200 mL allows the assessing physician confidence to defer a scan till normal working hours

Conversely, a PVR >200 mL should be leverage for an urgent scan. Severe back and sciatic pain may prevent complete bladder voiding. These may give instances of "negative scans," that is, disc herniations that do not compress the CE. However, it is our opinion that the selected threshold is a reasonable balance between avoidable scanning in the majority *versus* potential early diagnosis of CES.

TABLE 4. Sensitivity, Specificity, Positive Predictive Value (PPV), and Negative Predictive Value (NPV) of Perianal Numbness *versus* Postvoid Residual Volume ≥200 mL

Sign	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)
Perianal numbness	82.3% (59–94)	42% (32–53)	25% (16–38)	92% (78–97)
Postvoid residual (PVR) ≥200 mL	94% (73–99)	72% (61–81)	43% (29–59)	98% (90–100)

In conclusion, bedside ultrasound measurement of PVR volume is a useful objective adjunct in the evaluation of patients with suspected CES. Our data demonstrate that PVR of more than 200 mL is a strong predictor of CE compression seen on subsequent MRI and authors recommend expedited MRI evaluation in suspected CES. Conversely, a PVR of <200 mL has a very high negative predictive value for CES.

➢ Key Points

- ❑ Physical examination alone has low sensitivity and specificity in predicting CES.
- ❑ PVR volume of <200 mL has increased accuracy in predicting CES and a 98% negative predictive value.
- ❑ A PVR ≥200 mL increased the odds of CES 20-fold.
- ❑ Bladder scan is a useful adjunct in diagnosing CES and aids in decision-making.

References

1. Kohles SS, Kohles DA, Karp AP, et al. Time-dependent surgical outcomes following cauda equina syndrome diagnosis: comments on a meta-analysis. *Spine (Phila Pa 1976)* 2004;29:1281–7.
2. Gleave JR, Macfarlane R. Cauda equina Syndrome: what is the relationship between timing of surgery and outcome?. *Br J Neurosurg* 2002;16:325–8.
3. DeLong WB, Polissar N, Neradilek B. Timing of surgery in cauda equina syndrome with urinary retention: meta-analysis of observational studies. *J Neurosurg Spine* 2008;8:305–20.
4. Spector LR, Madigan L, Rhyne A, et al. Cauda equina syndrome. *J Am Acad Orthop Surg* 2008;16:471–9.
5. Balasubramanian K, Kalsi P, Greenough CG, et al. Reliability of clinical assessment in diagnosing cauda equina syndrome. *Br J Neurosurg* 2010;24:383–6.
6. Bell DA, Collie D, Statham PF. Cauda equina syndrome: what is the correlation between clinical assessment and MRI scanning?. *Br J Neurosurg* 2007;21:201–3.
7. Fraser S, Roberts L, Murphy E. Cauda equina syndrome: a literature review of its definition and clinical presentation. *Arch Phys Med Rehabil* 2009;90:1964–8.
8. Ahad A, Elsayed M, Tohid H. The accuracy of clinical symptoms in detecting cauda equina syndrome in patients undergoing acute MRI of the spine. *Neuroradiol J* 2015;28:438–42.
9. Gooding BW, Higgins MA, Calthorpe DA. Does rectal examination have any value in the clinical diagnosis of cauda equine syndrome?. *Br J Neurosurg* 2013;27:156–9.
10. Gardner A, Gardner E, Morley T. Cauda equine syndrome: a review of the current clinical and medico-legal position. *Eur Spine J* 2011;20:690–7.
11. Newcombe RG. Two-sided confidence intervals for the single proportion: comparison of seven methods. *Stat Med* 1998;17:857–72.
12. Sherlock KE, Turner W, Elsayed S, et al. The evaluation of digital rectal examination for assessment of anal tone in suspected cauda equina syndrome. *Spine (Phila Pa 1976)* 2015;40:1213–8.
13. Schaeffer AJ, Chmiel J. Urethral meatal colonisation in the pathogenesis of catheter associated bacteriuria. *J Urol* 1983;130:1096–9.
14. Coombes GM, Millard RJ. The accuracy of portable ultrasound scanning in the measurement of residual urine volume. *J Urol* 1994;152:2083–5.
15. Kelly CE. Evaluation of voiding dysfunction and measurement of bladder volume. *Rev Urol* 2004;6:S32–7.
16. Germon T, Ahuja S, Casey AT, et al. British Association of Spine Surgeons standards of care for cauda equina syndrome. *Spine J* 2015;15 (3 suppl):S2–4.
17. Postacchini F. Results of surgery compared with conservative management for lumbar disc herniations. *Spine (Phila Pa 1976)* 1996;21:1383–7.
18. Benson RT, Tavares SP, Robertson SC, et al. Conservatively treated massive prolapsed discs. *Ann R Coll Surg Engl* 2010;92:147–53.
19. Cribb GL, Jaffray DC, Cassar-Pullicino VN. Observations on the natural history of massive lumbar disc herniation. *J Bone Joint Surg Br* 2007;89:782–4.
20. Domen PM, Hofman PA, van Santbrink H, et al. Predictive value of clinical characteristics in patients with suspected cauda equina syndrome. *Eur J Neurol* 2009;16:416–9.