**Outcomes reported after surgery for Cauda Equina Syndrome: A Systematic Literature Review**

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**ABSTRACT**

OBJECTIVE

To assess the outcomes reported in trials and observational studies of surgery for cauda equina syndrome, to inform the development of a core outcome set.

METHODS

Ovid Medline, Embase and CINAHL Plus were searched from 01/01/1990 to 30/9/2016 with the term “Cauda Equina Syndrome.” Inclusion and exclusion criteria were applied according to study design, diagnosis, procedure, publication date, language and patient age. Data Extracted included demographics, study design, the outcomes reported, and their definition. We also assessed variation in the use of terminology for each outcome domain.

RESULTS

1,873 articles were identified, of which 61 met the inclusion criteria. 737 outcomes reported verbatim were categorised into 20 core outcome domains and 12 subdomains with a range of 1 to 141 outcomes per outcome domain or subdomain. The most commonly reported outcomes were Bladder Function (70.5%), Motor Function (63.9%) and Sensation (50.8%). Significant variation in the terms used for each outcome was documented e.g. Bladder Function outcome domain had 141 different terms.

CONCLUSION

There is significant heterogeneity in outcomes reported for studies after surgery for CES patients. This indicates a clear need for the development of a core outcome set.

**COMET (Core Outcome Measure in Effectiveness Trials) registration number**: 824

**INTRODUCTION**

Cauda Equina Syndrome (CES) is mainly due to compression of the lumbosacral nerve roots below the conus medullaris. Clinically, symptoms and signs include low back pain, saddle anaesthesia, unilateral or bilateral sciatica, and motor weakness of the lower extremities with bladder and bowel dysfunction (Kostuick et al, 1993; Gardner et al, 2011). However, CES is a clinical-radiological diagnosis as clinical signs are not particularly sensitive to a CES diagnosis (Balasubramanium et al, 2010; Bell et al, 2007). A lumbro-sacral MRI is required for diagnosis. Gleave and McFarlane, 2002 stressed the importance of categorizing CES into CES incomplete (CESI) and CES complete with urinary retention (CESR) (**Figure 1**). It is deemed a surgical emergency and there have been numerous publications and debates relating to the ideal timing for surgery (Ahn et al, 2000; Kohles et al, 2004; Todd et al, 2005; Srikandarajah et al 2015). It can result in permanent damage to nerve roots resulting in long lasting or permanent disabling symptoms (Gardner et al, 2011)

**Figure 1**. Symptoms relating to CESI and CESR.

|  |  |
| --- | --- |
| **CESI** | **CESR** |
| Lumbar +/- leg pain | Lumbar +/- leg pain |
| Motor or sensory deficit in lower limbs | Motor or sensory deficit in lower limbs |
| Urinary issues of neurogenic origin including loss of desire to void, altered urinary sensation, and hesitancy | Painless urinary retention with overflow incontinence |
| Partial saddle anaesthesia | Complete perianal sensory loss |
| Anal sphincter tone reduced | Faecal incontinence |

There is no consultation with patients in the literature regarding outcomes for CES. In addition, there is little known about the long-term outcomes, which was highlighted by Korse et al, 2013 who independently decided to focus on outcomes of micturition, defecation and sexual function. Bias in studies, lack of universal definitions and incomplete follow up data was seen in this systematic review.

The problems with not having a core outcome set includes:

1. Patients are not included so important outcomes to them may not be measured. This has been witnessed in other healthcare areas such as childhood asthma and oesophageal cancer (Sinha et al, 2009; Sinha et al, 2011; Avery et al, 2015; Korse et al, 2015; Williamson et al, 2012).

2. Lack of a consistent approach makes individual studies difficult to interpret and put into context of other studies.

3. Possibility for synthesizing evidence in a systematic review and meta-analysis are diminished (Jones and Hunter, 1995).

4. Waste and inefficiency. It is reported that 85% of research funding is wasted across the research cycle with key sources related to outcomes; important outcomes are not assessed, published research fails to set its position when compared to all previous similar research and 50% of planned study outcomes are not reported (Chalmers et al, 2009).

At present, there is no core outcome set for CES, which is to the detriment of patients and health services. The aim of this systematic literature review is to inform the future development of a COS by identifying all documented outcomes for patients following surgery in CES, identify if they are defined and to assess what variability there is. The systematic literature review is the first step to inform the development of a core outcome set (Williamson et al, 2012) for patients who have undergone surgery for CES to be used in research and in practice.

**METHODS**

This study has been registered as 824 on the COMET (Core Outcome Measures in Effectiveness Trials) website (<http://www.comet-initiative.org/studies/details/824)>. **Table 1** lists the inclusion criteria applied to the search strategy.

**Table 1.** Inclusion criteria for the systematic literature review.

|  |
| --- |
| **Inclusion criteria** |
| Diagnosis of Cauda Equina Syndrome |
| Patients have undergone surgery for the pathology causing Cauda Equina Syndrome |
| Randomised controlled trials, non-randomised controlled trials, prospective and retrospective cohort studies and case series |
| Human studies |
| English language |
| 5 or more patients |
| Published between 1990 to 30/9/16 |
| Adult patients aged 16 and above |

Search Strategy

We searched Medline, Embase and CINAHL Plus (Cumulative Index to Nursing and Allied Health Literature). The search strategy for each database is available in **Appendix 1**. Online trial registries included Clinical Trials.gov, EU clinical trials registry and ISRCTN (International Standard Randomised Controlled Trials Number) registry. The trial registries were searched for any completed or on-going trials in surgery for cauda equina syndrome and no relevant studies were found. Only case reports and abstracts were excluded in the initial search term as we wanted studies with 5 or more patients. We only included studies published after 01/01/1990 to keep investigation (post MRI era) and surgical management of CES in line with current medical practice. Citations were collated with Endnote X7 referencing programme (Thomson Reuters, New York, NY, USA) and duplicates removed.

Data Extraction

Titles and abstract were initially screened by NS to identify potential studies for inclusion, for which full text articles were obtained for further assessment. 10% of included papers were randomly checked for suitability by clinical supervisors and any discussion regarding uncertainty of eligibility criteria applied to the search results was discussed with them (SC, MW, AM). A Data Extraction form was used to collect data on study design and location, patient demographics, timing of operation, definition of CES, diagnosis, aetiology, surgical procedure, follow up duration, outcome terminology, outcome definition and assessment tool.

Terminology

Below are the definitions for the main terms used in the analysis of this systematic literature review.

1. Core outcome domain- The overall category to which similar subdomains and outcomes are listed under. The outcome domains that we have used in this paper have been linked to the high level set of outcome categories used for annotation of Cochrane reviews (<http://linkeddata.cochrane.org/linked-data-project/metadata-and-vocabularies/outcomes>; Davey et al, 2011) and through discussion with the COMET initiative team. These are listed in bold in **Table 3.**

2. Subdomain- A subcategory of a Core outcome domain to which similar outcomes are listed under. These are listed in normal script in **Table 3**.

3. Outcome- An outcome documented in an article after a patient has had an operation for CES.

For example, Nervous system (core outcome domain)> Bladder function (subdomain)> Urinary incontinence (outcome).

4. Variations- Variations were also documented, which means the number of different terms used to define a core outcome domain or subdomain. An example of a variation is given in the superscript of **Table 4**.

5. Outcome definition- this was categorised as “no definition” or “definition present.” If a definition was present it could be subjectively a complete or partial definition but was recorded as “definition present”. “No Definition” indicates the outcome domain was mentioned with no accompanying definition in the article or assessment tool. An example of how outcome definition was done is given in the superscript of **Table 4**.

**RESULTS**

A total of 1,873 articles were identified by electronic database searches.

1. Medline (650)

2. Embase (949)

3. CINAHL Plus (239)

4. Registries (35) included Clinical Trials.gov (5), EU clinical trials registry (12) and ISRCTN (International Standard Randomised Controlled Trials Number) registry (18).

The Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) flowchart in **Figure 1** shows the process during the systematic literature review. Following inclusion criteria in **Table 1** resulted in 1,838 articles plus the 35 studies from the online registry search giving a total of 1,873 studies. 10% of included studies were reviewed by a supervisor (MW and SC) to assess if inclusion and exclusion criteria had been applied adequately and agreement was achieved after discussion amongst us. Uncertainty regarding eligibility of certain full text articles for inclusion were discussed with the clinical supervisory team (MW, SC, TM) and settled leading to 61 included articles. 34 articles were excluded after the full text was obtained and the reasons for this were given as in **Figure 2**.

**Figure 2**. PRISMA flowchart for online databases.

Additional records identified through other sources  
(n = 35)

Records identified through database searching  
(n = 1838)

## Identification

Records after duplicates removed  
(n = 1633)

## Screening

Records excluded  
(n =1538)

Records screened  
(n = 1633)

Less than 5 patients operated: 14

Unable to retrieve: 9

Outcomes not after surgery: 8

Incorrect diagnosis: 1

Not adults: 1

Qualitative: 1

Full-text articles assessed for eligibility  
(n = 95)

Studies included in quantitative synthesis   
(n = 61)

## Included

## Eligibility

Summary details, patient demographics and how many studies they were reported in out of the 61 included studies are detailed in **Table 2**. Most studies (90.2%) were retrospective. CES was not defined in 20 studies (32.8%). Even in the articles where CES is defined there were many differing definitions. The most common definition was CESI and CESR as described in **Figure 1**.

**Table 2. Summary characteristics and demographics of included studies**

|  |  |
| --- | --- |
| **Characteristic (number of studies reported)** | **Value** |
| **Study design (61)** |  |
| Retrospective cohort | 55 |
| Prospective cohort | 6 |
| **Location (61)** |  |
| Europe | 32 |
| North America | 15 |
| South America | 1 |
| Asia | 13 |
| **Single Centre** | 57 |
| **Year of publication (61)** |  |
| 1990-1995 | 5 |
| 1996-2000 | 4 |
| 2001-2005 | 10 |
| 2006-2010 | 16 |
| 2011-2016 | 26 |
| **Mean follow up period post surgery (54)** | 8.4 yrs |
| Range | 1-38 yrs |
| **Median number of CES patients (61)** | 14 |
| Range | 5 to 11,207 |
| **Mean age (53)** | 45.5 |
| Range | 20.5-70 |
| **Median follow up (43)** | 31 months |
| Range | post op-29yrs |
| **CES definition (61)** |  |
| Defined | 41 |
| Not defined | 20 |
| **Diagnostic Main Investigation (54)** |  |
| MRI | 44 |
| CT | 9 |
| Myelogram | 1 |
| **Aetiology (59)** |  |
| Disc Herniation | 34 |
| Degenerative | 4 |
| Post op complication | 3 |
| Trauma | 7 |
| Tumour | 6 |
| Other | 2 |
| **Main Surgical Method (51)** |  |
| Laminectomy & Discectomy | 15 |
| Laminectomy | 14 |
| Laminectomy & Instrumentation | 12 |
| Microdiscectomy | 8 |
| Other | 2 |

A total of 737 outcomes were reported in the 61 included articles. For ease of analysis in this study, these reported outcomes have been categorised to one of the 20 core outcome domains (**Table 3**). The nervous system core outcome domain had 10 subdomains, and the physical functioning has two subdomains (**Table 3)**. All different variations in the description of outcomes can be seen in **Appendix 2** linked to the outcome domains.

**Figure 3** shows the number of articles in which specific outcomes were reported. Bladder function, Motor, Sensation, Bowel function, Leg pain and Lower back pain were the most commonly reported in descending order. They are all within the Nervous System core outcome domain. Also, for each outcome, the number of articles where it is defined and not defined is documented. **Figure 3** also shows the number of articles where the reported outcome had an assessment tool or not.

**Table 3. Core outcome Domains (in bold) and subdomains**

|  |  |
| --- | --- |
| Mortality | Role Functioning |
| General Disorders | **Social Functioning** |
| Nervous System Outcomes | **Emotional Functioning** |
| Bladder Function | **Global Quality of Life** |
| Motor Function | **Hospital Use** |
| Sensation | **Need for Intervention** |
| General Neurology | **Adverse Events** |
| Lower Back Pain | **Infection** |
| Leg Pain | **Skin and Subcutaneous Tissue** |
| Bowel Function | **Vascular** |
| Perianal sensation | **Outcomes related to neoplasms** |
| Perianal Tone | **Urological and Renal** |
| Reflexes | **Cardiac** |
| Physical Functioning | **Blood and Lymphatic** |
| Sexual Function | **Respiratory** |
| Walking | **Gastrointestinal** |

**Figure 3.** Stacked bar chart showing total number of articles where the outcome was reported and the proportion of those defined (blue) and those not defined (red). Also for each outcome the number of articles which have used an assessment tool for a reported outcome (green) and the number that have not (orange). Outcomes are listed from most to least reported.

**Table 4** shows the raw data for each outcome showing how many studies each outcome is reported in, the total number of outcomes, the number of variations in the description of the outcome if a definition is present or not in the reported studies and the number of assessment tools for the reported outcome. **Table 5** shows the various assessment tools used for each outcome.

**Table 4.** Raw data for each outcome showing how many studies each outcome is reported in, the total number of outcomes, the variations for each outcome, if a definition is present or not in the reported studies and the number of assessment tools for reported outcomes. Outcomes are listed in order of decreasing frequency of reported studies.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Outcome Domain** | **Reported/ 61 studies N (%)** | **Total number of outcomes** | **Number of Variations** | **Definition present in reported studies (%)** | **Assessment tool in reported studies (%)** |
| Bladder Function **(Nervous System)** | 43 (70.5) | 141 | 87[[1]](#footnote-1) | 25 (58.1)[[2]](#footnote-2) | 13 (30.2) |
| Motor Function **(Nervous System)** | 39 (63.9) | 62 | 36 | 9 (23.1) | 16 (41) |
| Sensation **(Nervous System)** | 31 (50.8) | 53 | 26 | 6 (19.4) | 6 (19.4) |
| Bowel Function **(Nervous System)** | 28 (45.9) | 60 | 47 | 7 (25) | 8 (28.6) |
| Leg Pain **(Nervous System)** | 27 (44.3) | 32 | 16 | 5 (18.5) | 7 (25.9) |
| Lower Back Pain **(Nervous System)** | 26 (42.6) | 31 | 13 | 4 (15.4) | 9 (34.6) |
| General Neurology **(Nervous System)** | 22 (36.1) | 31 | 21 | 3 (13.6) | 8 (36.4) |
| **Skin and Subcutaneous Tissue** | 19 (31.1) | 22 | 15 | 5 (26.3) | 0 (0) |
| **General disorders** | 19 (31.1) | 44 | 36 | 6 (31.6) | 6 (31.6) |
| **Mortality** | 18 (29.5) | 25 | 13 | 6 (33.3) | 0 (0) |
| Perianal Sensation **(Nervous System)** | 17 (27.9) | 23 | 16 | 5 (29.4) | 0 (0) |
| Sexual Function **(Physical Functioning)** | 16 (26.2) | 46 | 41 | 6 (37.5) | 6 (37.5) |
| Walking **(Physical Functioning)** | 16 (26.2) | 28 | 25 | 3 (18.8) | 5 (31.3) |
| **Adverse Events** | 12 (19.7) | 16 | 12 | 8 (66.7) | 0 (0) |
| **Role Functioning** | 11 (18) | 20 | 20 | 3 (27.3) | 7 (63.6) |
| Perianal Tone **(Nervous System)** | 11 (18) | 16 | 13 | 2 (18.2) | 0 (0) |
| **Need for Intervention** | 10 (16.4) | 13 | 13 | 6 (60) | 0 (0) |
| **Infection** | 10 (16.4) | 11 | 8 | 1 (10) | 0 (0) |
| **Vascular** | 8 (13.1) | 13 | 5 | 0 (0) | 0 (0) |
| **Hospital Use** | 5 (8.2) | 8 | 6 | 0 (0) | 0 (0) |
| **Global Quality of Life** | 5 (8.2) | 8 | 6 | 3 (60) | 4 (80) |
| Reflexes **(Nervous System)** | 4 (6.6) | 7 | 7 | 0 (0) | 0 (0) |
| **Emotional Functioning** | 4 (6.6) | 7 | 7 | 1 (25) | 3 (75) |
| **Respiratory** | 4 (6.6) | 4 | 5 | 0 (0) | 0 (0) |
| **Outcomes relating to neoplasms** | 3 (4.9) | 5 | 3 | 0 (0) | 0 (0) |
| **Urological and Renal** | 3 (4.9) | 3 | 3 | 0 (0) | 0 (0) |
| **Cardiac** | 3 (4.9) | 3 | 2 | 0 (0) | 0 (0) |
| **Social Functioning** | 2 (3.3) | 2 | 2 | 0 (0) | 2 (100) |
| **Blood and Lymphatic** | 2 (3.3) | 2 | 2 | 0 (0) | 0 (0) |
| **Gastrointestinal** | 1 (1.6) | 1 | 1 | 0 (0) | 0 (0) |

**Table 5.** Assessment tools are listed in alphabetical order for the corresponding reported outcomes.

|  |  |
| --- | --- |
| **OUTCOME DOMAIN** | **ASSESSMENT TOOLS** |
| Bladder Function **(Nervous System)** | 25 item questionnaire (Fukui et al, 2011)/ Bristol Female Lower Urinary Tract/ Cystometry/ Functional Independence Measurement/ Gibbon’s criteria/ Gleave and McFarland, 1990/ Hannover pelvic scoring system/ International Continence Society male questionnaire/ Japanese Orthopaedic Association score / Modified Odom's criteria/ Short Form Incontinence Questionnaire/ Urodynamics |
| Motor Function **(Nervous System)** | American Spinal Injury Association Score/ Frankel grading/ Gibbon’s criteria / McCormick scale/ MRC grading/ Modified Odom's criteria |
| Sensation  **(Nervous System)** | American Spinal Injury Association Score/ Frankel grading/ Gibbon’s criteria / McCormick scale/ Modified Odom’s criteria/ Nanko evaluation system |
| Bowel Function **(Nervous System)** | 25 item questionnaire (Fukui et al, 2011)/ Chronic idiopathic constipation index / Faecal incontinence questionnaire (Jorge et al 1993)/ Functional Independence Measurement/ Hannover pelvic scoring system/ Modified Odom’s criteria/ Nanko evaluation system/ Short Form Incontinence Questionnaire/ |
| Leg Pain  **(Nervous System)** | Benoist et al 1993/ Japanese Orthopaedic Association score/ Visual Assessment Score |
| Lower Back Pain **(Nervous System)** | Low Back Outcome Score/ Oswestry Disability Index/ Short Form Health Survey 36/ Visual Assessment Score |
| General Neurology **(Nervous System)** | American Spinal Injury Association Score/ Baba et al, 1995 study questionnaire/ Frankel grading/ Gibbon’s criteria/ Japanese Orthopaedic Association score/ McCormick's scale |
| **General disorders** | Epstein & Hood/ Nanko evaluation system/ Prolo economic and functional scale/ Short Form Health Survey 36/ Spengler classification/ Visual Assessment Score |
| Sexual Function **(Physical Functioning)** | International index of erectile function/ Male sexual health inventory/ McCormick scale/ Modified Odom’s criteria/ Nogueira et al. 1990/ Sheffield Female pelvic floor questionnaire/ Japanese Orthopaedic Association score |
| Walking  **(Physical Functioning)** | Baba et al 1995/ Functional Independence Measurement/ Japanese Orthopaedic Association score/ McCormick scale/ Short Form Health Survey 36 |
| **Role Functioning** | Chronic idiopathic constipation index/ Kirkaldy Willis classification/ Nanko evaluation system/ Oswestry Disability Index/ Prolo economic and functional scale/ Short Form Incontinence Questionnaire |
| **Global Quality of Life** | 25 item questionnaire (Fukui et al, 2011)/ Oswestry Disability Index/ Short Form Health Survey 36 |
| **Emotional Functioning** | Functional Independence Measurement/ Kelleher et al 1997 questionnaire/ Short Form Health Survey 36 |
| **Social Functioning** | Kelleher et al 1997 questionnaire/ Short Form Health Survey 36 |

**DISCUSSION**

This systematic review shows that there is significant heterogeneity in the outcomes measured for patients who have undergone surgery for CES with no consensus.

Most of the evidence regarding outcomes for CES patients after surgery is derived from level 4 evidence, namely single centre retrospective cohort review studies. The average data collection period was over 8 years with a median number of 14 patients per study, which highlights the rare nature of the condition and difficulty in collecting meaningful data retrospectively. This feeling is also echoed by Todd and Dickson, 2016. Since 1990 the number of publications analysing outcomes after an operation for CES have increased with the most being produced in the last 5-year period (43.5%). Median follow up was at 31 months reflecting the deficiency in the literature for any long-term outcomes.

The main investigation is MRI, which reflects the systematic literature review focusing on studies from 1990 onwards. Before this there may have been a reliance on myelography and CT to radiologically identify CES compression. The main aetiology is disc herniation. There are no studies in the literature documenting the exact distribution of CES aetiology but the most common cause is believed to be due to disc herniation.

Poor definition of CES has been previously highlighted in a systematic review of the literature (Fraser et al, 2009). 20 studies (32.8%) did not define this and of the 41 studies where a definition was present, there was significant heterogeneity in the definitions. The most common definition for CES in this review was CESI and CESR (Gleaves and McFarland, 2002). If a study fails to define CES then we are unsure of the condition to which the outcomes of the study belong to.

Most common surgical method in studies was a laminectomy and discectomy as seen in **Table 2** but there were other studies that predominantly performed surgery via a microdiscectomy. Laminectomy alone, or with instrumentation was also mentioned for CES patients. In fact, now there is an increase in the popularity of endoscopic lumbar discectomy procedure (Li et al, 2016), which adds to the range of procedures available when dealing with CES secondary to disc herniation. There is no consensus in the literature as to a specific decompressive procedure to be used for CES secondary to compressive pathology. This is also another factor that may affect outcomes for these patients.

In total, there were 737 outcomes reported verbatim and categorised into 20 core outcome domains and 12 subdomains. Instead of the same term being used for each outcome there exists 507 variations in terminology (**Table 4**). In addition, most of the outcomes in the included articles have no definition. Except Bladder Function, Adverse Events, Need for Intervention and Global quality of Life, all other outcomes had no definition in the majority of the included articles (**Figure 3**). This highlights that there is significant heterogeneity in not only the outcome terminology used but the level to which it is defined in the literature. Except Global Quality of Life, Emotional Functioning, Role Functioning and Social Functioning, most outcomes did not have an assessment tool in most of the articles (**Figure 3**). 14 of the outcome domains/ subdomains we categorised had multiple different assessment tools used for each of them as seen in **Table 5**. There is a lack of uniformity over which assessment tool is best suited for each outcome in the literature. If outcomes are being measured with different scales, scoring systems and questionnaires then it would be difficult to synthesise these results for meaningful analyses.

There is significant heterogeneity of the outcomes for patients who have undergone an operation for CES, how they are defined and measured in the literature. Bladder Function, Motor Function, Sensation, Bowel Function, Leg Pain and Lower Back Pain outcomes are the most reported. They are all physiological core domains, which have been prioritised in the literature over the other core domains that relate to life impact, mortality, resource use and adverse events. However, there has not been consultation with key stakeholders regarding what outcomes are the most important to be justifying this practice. Involvement of key stakeholders through an iterative process has been employed in Rheumatology through OMERACT (Outcome MEasures in Rheumatology) and in Women’s Health through the CROWN (CoRe Outcomes in Women’s and Newborns health) initiative (Kirkham et al, 2013; Tugwell et al, 2007; <http://www.omeract.org/>; http://www.crown-initiative.org). They have come a long way since developing core outcome sets to achieving a level of homogeneity among similar studies to increase the quality and yield of their research. This needs to be achieved for patients who have undergone surgery for CES.

Limitations

The systematic literature review was carried out by the main author (NS). Uncertainties and discrepancies were discussed with the research team (PRW, TM, MW, SC, AN). Only English language articles were included. It would have been beneficial to have another independent group conduct the search strategy and data extract independently and to compare the results achieved. Due to limitation of resources this was not performed.

Conclusions

There is significant heterogeneity in outcomes reported for studies after surgery for CES patients and the methods by which they are measured. This indicates a clear need for the development of a core outcome set and the results of this systematic literature will be combined with the results of outcomes sourced from CES patients in qualitative interviews. All outcomes will then be prioritised through a Delphi process and consensus meeting to develop a core list of outcomes determined to be of most importance by key stakeholders.

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**Appendix 1**: Database Search Strategy.

**Appendix 2:** Variation in Terminology (Excel)

**REFERENCES**

(1-89)

1. Ahn UM, Ahn NU, Buchowski JM, Garrett ES, Sieber AN, Kostuik JP. Cauda equina syndrome secondary to lumbar disc herniation: a meta-analysis of surgical outcomes. Spine. 2000;25(12):1515-22.

2. Akbar A, Mahar A. Lumbar disc prolapse: management and outcome analysis of 96 surgically treated patients. JOURNAL-PAKISTAN MEDICAL ASSOCIATION. 2002;52(2):62-5.

3. Albert R, Lange M, Brawanski A, Schebesch KM. Urgent discectomy: Clinical features and neurological outcome. Surgical Neurology International. 2016;7 (1) (no pagination)(17).

4. Allegretti L, Mavilio N, Fiaschi P, Bragazzi R, Pacetti M, Castelletti L, et al. Intra-Operative Vertebroplasty Combined with Posterior Cord Decompression A Report of Twelve Cases. Interventional Neuroradiology. 2014;20(5):583-90.

5. Aly TA, Aboramadan MO. Efficacy of delayed decompression of lumbar disk herniation causing cauda equina syndrome. Orthopedics. 2014;37(2):e153-6.

6. Amitendu S, Mak SKD, Ling JM, Ng WH. A single institution experience of the incidence of extracranial metastasis in glioma. Journal of Clinical Neuroscience. 2012;19(11):1511-5.

7. Arrigo RT, Kalanithi P, Boakye M. Is cauda equina syndrome being treated within the recommended time frame? Neurosurgery. 2011;68(6):1520-6.

8. Avery K, Chalmers K, Whale K, Blencowe N, Macefield R, Brookes S, et al. The importance of stakeholder selection in core outcome set development: how surveying different health professionals may influence outcome selection. Trials. 2015;16(2):P47.

9. Ayoub MA. Displaced spinopelvic dissociation with sacral cauda equina syndrome: outcome of surgical decompression with a preliminary management algorithm. Eur Spine J. 2012;21(9):1815-25.

10. Baba H, Maezawa Y, Furusawa N, Imura S, Tomita K. The role of calcium deposition in the ligamentum flavum causing a cauda equina syndrome and lumbar radiculopathy. Spinal Cord. 1995;33(4):219-23.

11. Balasubramanian K, Kalsi P, Greenough CG, Kuskoor Seetharam MP. Reliability of clinical assessment in diagnosing cauda equina syndrome. Br J Neurosurg. 2010;24(4):383-6.

12. Bejia I, Younes M, Zrour S, Touzi M, Bergaoui N. Factors predicting outcomes of mechanical sciatica: a review of 1092 cases. Joint Bone Spine. 2004;71(6):567-71.

13. Bell D, Collie D, Statham P. Cauda equina syndrome–What is the correlation between clinical assessment and MRI scanning? Br J Neurosurg. 2007;21(2):201-3.

14. Bellabarba C, Schildhauer TA, Vaccaro AR, Chapman JR. Complications associated with surgical stabilization of high-grade sacral fracture dislocations with spino-pelvic instability. Spine. 2006;31(11S):S80-S8.

15. Božić B, Kogler A, Negovetić L, Sajko T, Kudelić N. Sequestred extrusion of lumbar disc: experimental model, clinical picture, diagnosis and treatment. Acta Clin Croat. 2003;42(3):213.

16. Buchner M, Schiltenwolf M. Cauda equina syndrome caused by intervertebral lumbar disk prolapse: Mid-term results of 22 patients and literature review. Orthopedics. 2002;25(7):727-31.

17. Busse JW, Bhandari M, Schnittker JB, Reddy K, Dunlop RB. Delayed presentation of cauda equina syndrome secondary to lumbar disc herniation: functional outcomes and health-related quality of life. CJEM. 2001;3(04):285-91.

18. Chalmers I, Glasziou P. Avoidable waste in the production and reporting of research evidence. Obstetrics & Gynecology. 2009;114(6):1341-5.

19. Crocker M, Fraser G, Boyd E, Wilson J, Chitnavis BP, Thomas NW. The value of interhospital transfer and emergency MRI for suspected cauda equina syndrome: a 2-year retrospective study. Ann R Coll Surg Engl. 2008;90(6):513-6.

20. Daniels EW, Gordon Z, French K, Ahn UM, Ahn NU. Review of medicolegal cases for cauda equina syndrome: what factors lead to an adverse outcome for the provider? Orthopedics. 2012;35(3):e414-e9.

21. Davey J, Turner RM, Clarke MJ, Higgins JP. Characteristics of meta-analyses and their component studies in the Cochrane Database of Systematic Reviews: a cross-sectional, descriptive analysis. BMC medical research methodology. 2011;11(1):160.

22. Dhatt S, Tahasildar N, Tripathy SK, Bahadur R, Dhillon M. Outcome of spinal decompression in cauda equina syndrome presenting late in developing countries: case series of 50 cases. Eur Spine J. 2011;20(12):2235-9.

23. Dindo D, Demartines N, Clavien P-A. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Annals of surgery. 2004;240(2):205-13.

24. Domen P, Hofman P, Van Santbrink H, Weber W. Predictive value of clinical characteristics in patients with suspected cauda equina syndrome. Eur J Neurol. 2009;16(3):416-9.

25. Duncan JW, Bailey RA. Cauda equina syndrome following decompression for spinal stenosis. Global spine journal. 2011;1(01):015-8.

26. Ea H-K, Lioté F, Lot G, Bardin T. Cauda equina syndrome in ankylosing spondylitis: successful treatment with lumboperitoneal shunting. Spine. 2010;35(24):E1423-E9.

27. Foruria X, de Gopegui KR, García-Sánchez I, Moreta J, Aguirre U, Martínez-de Los Mozos J. Cauda equina syndrome secondary to lumbar disc herniation: Surgical delay and its relationship with prognosis. Revista Española de Cirugía Ortopédica y Traumatología (English Edition). 2016;60(3):153-9.

28. Fraser S, Roberts L, Murphy E. Cauda equina syndrome: a literature review of its definition and clinical presentation. Archives of physical medicine and rehabilitation. 2009;90(11):1964-8.

29. Fukui J, Ohotsuka K, Asagai Y. Improved symptoms and lifestyle more than 20 years after untethering surgery for primary tethered cord syndrome. Neurourology and urodynamics. 2011;30(7):1333-7.

30. Fuso FAF, Dias ALN, Letaif OB, Cristante AF, Marcon RM, de Barros TEP. EPIDEMIOLOGICAL STUDY OF CAUDA EQUINA SYNDROME. Acta Ortop Bras. 2013;21(3):159-62.

31. Galasko C. Spinal instability secondary to metastatic cancer. Bone & Joint Journal. 1991;73(1):104-8.

32. Galvin J, Freedman B, Schoenfeld A, Cap A, Mok J. Morbidity of early spine surgery in the multiply injured patient. Archives of orthopaedic and trauma surgery. 2014;134(9):1211-7.

33. Gardner A, Gardner E, Morley T. Cauda equina syndrome: a review of the current clinical and medico-legal position. Eur Spine J. 2011;20(5):690-7.

34. Gitelman A, Hishmeh S, Morelli BN, Joseph Jr SA, Casden A, Kuflik P, et al. Cauda equina syndrome: a comprehensive review. Am J Orthop (Belle Mead NJ). 2008;37(11):556-62.

35. Gleave J, Macfarlane R. Cauda equina syndrome: what is the relationship between timing of surgery and outcome? Br J Neurosurg. 2002;16(4):325-8.

36. Gleave JR, MacFarlane R. Prognosis for recovery of bladder function following lumbar central disc prolapse. Br J Neurosurg. 1990;4(3):205-9.

37. Gleave JR, Macfarlane R. Prognosis for recovery of bladder function following lumbar central disc prolapse. Br J Neurosurg. 1990;4(3):205-9.

38. Gooding BW, Higgins MA, Calthorpe DA. Does rectal examination have any value in the clinical diagnosis of cauda equina syndrome? Br J Neurosurg. 2013;27(2):156-9.

39. Henriques T, Olerud C, Petren-Mallmin M, Ahl T. Cauda equina syndrome as a postoperative complication in five patients operated for lumbar disc herniation. Spine. 2001;26(3):293-7.

40. Hussain S, Gullan R, Chitnavis B. Cauda equina syndrome: outcome and implications for management. Br J Neurosurg. 2003;17(2):164-7.

41. Jones J, Hunter D. Consensus methods for medical and health services research. BMJ: British Medical Journal. 1995;311(7001):376.

42. Kennedy JG, Soffe KE, McGrath A, Stephens MM, Walsh MG, McManus F. Predictors of outcome in cauda equina syndrome. Eur Spine J. 1999;8(4):317-22.

43. Kirkham JJ, Gargon E, Clarke M, Williamson PR. Can a core outcome set improve the quality of systematic reviews?–a survey of the Co-ordinating Editors of Cochrane Review Groups. Trials. 2013;14(1):21.

44. Kohles SS, Kohles DA, Karp AP, Erlich VM, Polissar NL. Time-dependent surgical outcomes following cauda equina syndrome diagnosis: comments on a meta-analysis. Spine. 2004;29(11):1281-7.

45. Korse N, Jacobs W, Elzevier H, Vleggeert-Lankamp C. Complaints of micturition, defecation and sexual function in cauda equina syndrome due to lumbar disk herniation: a systematic review. Eur Spine J. 2013;22(5):1019-29.

46. Kostuik JP. Controversies in cauda equina syndrome and lumbar disk herniation. Current Opinion in Orthopaedics. 1993;4(2):125-8.

47. KOTİL K, ERAS M, AKÇETİN M, ACAR C, BİLGE T. Do the Spinal Pathologies that Accompany Lumbar Disc Disease Affect Surgical Prognosis? Turkish Neurosurgery. 2006;16(4).

48. Li X, Dou Q, Hu S, Liu J, Kong Q, Zeng J, et al. Treatment of cauda equina syndrome caused by lumbar disc herniation with percutaneous endoscopic lumbar discectomy. Acta Neurologica Belgica. 2016;116(2):185-90.

49. Lich Ng LC, Tafazal S, Longworth S, Sell P. Cauda Equina Syndrome: An Audit. Can We Do Better? Journal of Orthopaedic Medicine. 2004;26(3):98-101.

50. Lyons MK, Atkinson JL, Wharen RE, Deen HG, Zimmerman RS, Lemens SM. Surgical evaluation and management of lumbar synovial cysts: the Mayo Clinic experience. Journal of Neurosurgery: Spine. 2000;93(1):53-7.

51. Marascalchi BJ, Passias PG, Goz V, Weinreb JH, Joo L, Errico TJ. Comparative Analysis of Patients With Cauda Equina Syndrome Versus an Unaffected Population Undergoing Spinal Surgery. Spine. 2014;39(6):482-90.

52. McCarthy MJH, Aylott CEW, Grevitt MP, Hegarty J. Cauda equina syndrome - Factors affecting long-term functional and sphincteric outcome. Spine. 2007;32(2):207-16.

53. McKinley WO, Tellis AA, Cifu DX, Johnson MA, Kubal WS, Keyser-Marcus L, et al. Rehabilitation outcome of individuals with nontraumatic myelopathy resulting from spinal stenosis. The journal of spinal cord medicine. 1998;21(2):131-6.

54. Morita M, Miyauchi A, Okuda S, Oda T, Aono H, Iwasaki M. Intraspinal epidermoid tumor of the cauda equina region: seven cases and a review of the literature. Clinical Spine Surgery. 2012;25(5):292-8.

55. Ökten AI, Özsoy KM, Gezercan Y, Ates T, Menekse G, Çapraz M, et al. Analysis of Clinical and Surgical Outcomes of Upper Lumbar Disk Herniations. Neurosurgery Quarterly. 2015;25(3):349-54.

56. Olivero WC, Wang HA, Hanigan WC, Henderson JP, Tracy PT, Elwood PW, et al. Cauda Equina Syndrome (CES) From Lumbar Disc Herniations. J Spinal Disord Tech. 2009;22(3):202-6.

57. Podnar S. Cauda equina lesions as a complication of spinal surgery. Eur Spine J. 2010;19(3):451-7.

58. Qureshi A, Sell P. Cauda equina syndrome treated by surgical decompression: the influence of timing on surgical outcome. Eur Spine J. 2007;16(12):2143-51.

59. Raj D, Coleman N. Cauda Equina Syndrome secondary to lumbar disc herniation. Acta Orthop Belg. 2008;74(4):522-7.

60. Ronen J, Goldin D, Itzkovich M, Bluvshtein V, Gelernter I, Livshitz A, et al. Outcomes in patients admitted for rehabilitation with spinal cord or cauda equina lesions following degenerative spinal stenosis. Disabil Rehabil. 2005;27(15):884-9.

61. Sakai Y, Matsuyama Y, Katayama Y, Imagama S, Ito Z, Wakao N, et al. Spinal myxopapillary ependymoma: neurological deterioration in patients treated with surgery. Spine. 2009;34(15):1619-24.

62. Sapkas GS, Mavrogenis AF, Papagelopoulos PJ. Transverse sacral fractures with anterior displacement. Eur Spine J. 2008;17(3):342-7.

63. Schebesch K-M, Albert R, Brawanski A, Lange M. Urgent discectomy: Clinical features and neurological outcome. Surgical Neurology International. 2016;2016(7):17.

64. Schildhauer TA, Bellabarba C, Nork SE, Barei DP, Routt Jr MLC, Chapman JR. Decompression and lumbopelvic fixation for sacral fracture-dislocations with spino-pelvic dissociation. J Orthop Trauma. 2006;20(7):447-57.

65. Sengoz A, Kotil K, Tasdemiroglu E. Posterior epidural migration of herniated lumbar disc fragment Clinical article. J Neurosurg-Spine. 2011;14(3):313-7.

66. Shapiro S. Cauda equina syndrome secondary to lumbar disc herniation. Neurosurgery. 1993;32(5):743-7.

67. Shapiro S. Medical realities of cauda equina syndrome secondary to lumbar disc herniation. Spine. 2000;25(3):348-51.

68. Shen L, Fang L, Qiu Y, Xing S, Chen D, He X, et al. Study on different surgical approaches for acute Lumber disk protrusion combined with Cauda Equina Syndrome. International journal of clinical and experimental pathology. 2014;7(12):8875.

69. Shi JG, Jia LS, Yuan W, Shi GD, Ma B, Wang B, et al. Clinical classification of cauda equina syndrome for proper treatment A retrospective analysis of 39 patients. Acta Orthop. 2010;81(3):391-5.

70. Shih P, Smith TR, Fessler RG, Song JK. Minimally invasive discectomy for the treatment of disc herniation causing cauda equina syndrome. Journal of Clinical Neuroscience. 2011;18(9):1219-23.

71. Sinha IP, Smyth RL, Williamson PR. Using the Delphi technique to determine which outcomes to measure in clinical trials: recommendations for the future based on a systematic review of existing studies. PLoS Med. 2011;8(1):e1000393.

72. Sinha IP, Williamson PR, Smyth RL. Outcomes in clinical trials of inhaled corticosteroids for children with asthma are narrowly focussed on short term disease activity. PLoS One. 2009;4(7):e6276.

73. Smith MD, Bohlman H. Spondylolisthesis treated by a single-stage operation combining decompression with in situ posterolateral and anterior fusion. An analysis of eleven patients who had long-term follow-up. The Journal of Bone & Joint Surgery. 1990;72(3):415-21.

74. Sokolowski MJ, Garvey TA, Perl J, Sokolowski MS, Akesen B, Mehbod AA, et al. Postoperative lumbar epidural hematoma - Does size really matter? Spine. 2008;33(1):114-9.

75. Sorbie C. Cauda equina syndrome. Orthopedics. 2009;32(6).

76. Srikandarajah N, Boissaud-Cooke MA, Clark S, Wilby MJ. Does early surgical decompression in cauda equina syndrome improve bladder outcome? Spine. 2015;40(8):580-3.

77. Sun T, Liu Z, Liu S, Xu S. The clinical study of repairing cauda equina fibres with fibrin glue after lumbar fracture and dislocation. Spinal Cord. 2010;48(8):633-7.

78. Szövérfi Z, Lazary A, Bozsódi Á, Klemencsics I, Éltes PE, Varga PP. Primary Spinal Tumor Mortality Score (PSTMS): a novel scoring system for predicting poor survival. The Spine Journal. 2014;14(11):2691-700.

79. Takahashi T, Hanakita J, Kawaoka T, Ohtake Y, Adachi H, Shimizu K. Indication for Partial Vertebral Osteotomy and Realignment in Posterior Spinal Fixation for Osteoporotic Thoracolumbar Vertebral Collapse with Neurological Deficits. Neurologia medico-chirurgica. 2016;56(8):485-92.

80. Tamburrelli F, Genitiempo M, Bochicchio M, Donisi L, Ratto C. Cauda equina syndrome: evaluation of the clinical outcome. Eur Rev Med Pharmacol Sci. 2014;18(7):1098-105.

81. Tan G-q, He J-l, Fu B-s, Li L-x, Wang B-m, Zhou D-s. Lumbopelvic fixation for multiplanar sacral fractures with spinopelvic instability. Injury. 2012;43(8):1318-25.

82. Todd N. Cauda equina syndrome: the timing of surgery probably does influence outcome. Br J Neurosurg. 2005;19(4):301-6.

83. Todd N, Dickson R. Standards of care in cauda equina syndrome. Br J Neurosurg. 2016;30(5):518-22.

84. Todd NV. Causes and outcomes of cauda equina syndrome in medico-legal practice: a single neurosurgical experience of 40 consecutive cases. Br J Neurosurg. 2011;25(4):503-8.

85. Tugwell P, Boers M, Brooks P, Simon L, Strand V, Idzerda L. OMERACT: an international initiative to improve outcome measurement in rheumatology. Trials. 2007;8(1):38.

86. Walker JL, Schulak D, Murtagh R. Midline disk herniations of the lumbar spine. South Med J. 1993;86(1):13-7.

87. Williamson PR, Altman DG, Blazeby JM, Clarke M, Devane D, Gargon E, et al. Developing core outcome sets for clinical trials: issues to consider. Trials. 2012;13(1):132.

88. Wostrack M, Shiban E, Obermueller T, Gempt J, Meyer B, Ringel F. Conus medullaris and cauda equina tumors: Clinical presentation, prognosis, and outcome after surgical treatment: Clinical article. Journal of Neurosurgery: Spine. 2014;20(3):335-43.

89. Yamanishi T, Yasuda K, Yuki T, Sakakibara R, Uchiyama T, Kamai T, et al. Urodynamic evaluation of surgical outcome in patients with urinary retention due to central lumbar disc prolapse. Neurourology and urodynamics. 2003;22(7):670-5.

1. An example of analysing the variation of terminology used for Bladder Function outcome domain: “Urinary incontinence” “Bladder dysfunction” and “Urinary retention” are 3 variations of the way this outcome domain is described. [↑](#footnote-ref-1)
2. 2 examples of how Bladder Function outcome domain was classified with definition present: 1) Retention of Urine *–* “the inability to pass urine necessitating urinary catheterization”. This study was retrospective and relied upon adequate documentation in the patients’ clinical notes. Residual urine volumes were only available in 11 patients (all greater than 300millilitres) whereas 24 patients were documented to be in urinary retention. Urinary retention at follow-up comprised those patients requiring catheterisation to enable them to empty their bladder and also those patients who reported incomplete bladder emptying. (McCarthy et al, 2007). 2) Urine retention diagnosis was clinical (a bladder that required catheterisation). (Foruria et al, 2016) [↑](#footnote-ref-2)