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# Development of a validated search filter for Ovid Embase for degenerative cervical myelopathy

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**Abstract**

**Background:** Degenerative cervical myelopathy (DCM) is a recently proposed umbrella term for symptomatic cervical spinal cord compression secondary to degeneration of the spine. Currently literature searching for DCM is challenged by the inconsistent uptake of the term 'DCM' with many overlapping keywords and numerous synonyms.

**Objectives:** Here, we adapt our previous Ovid MEDLINE search filter for the Ovid EMBASE database, to support comprehensive literature searching. Both EMBASE and MEDLINE are recommended as a minimum for systematic reviews.

**Methods:** References contained within EMBASE identified in our prior study formed a 'development gold standard' reference database ($N = 220$). The search filter was adapted for EMBASE and checked against the reference database. The filter was then validated against the 'validation gold standard'.

**Results:** A direct translation was not possible, as MEDLINE indexing for DCM and the keywords search field were not available in EMBASE. We also used the 'focus' function to improve precision. The resulting search filter has 100% sensitivity in testing.

**Discussion and Conclusion:** We have developed a validated search filter capable of retrieving DCM references in EMBASE with high sensitivity. In the absence of consistent terminology and indexing, this will support more efficient and robust evidence synthesis in the field.

**KEYWORDS**
data mining, EMBASE, indexing, information retrieval, literature searching, MEDLINE, review and systematic search, review systematic, search strategies

# INTRODUCTION

Degenerative Cervical Myelopathy (DCM) is a recently proposed umbrella term for symptomatic cervical spinal cord compression secondary to degeneration of the spine (Nouri et al., 2015). It was proposed to overcome inconsistencies and limitations in the use and application of existing terms, such as cervical spondylotic myelopathy and ossification of the posterior longitudinal ligament (OPLL; Nouri et al., 2020), and numerous synonyms (e.g. 'cervical spondylotic myelopathy' or 'cervical stenosis with myelopathy'). The term 'Degenerative Cervical Myelopathy' has become increasingly adopted, including for the first international guidelines (Fehlings et al., 2017), but not by all (Zileli, 2019).

Consequently, literature searching, which is essential for research and evidence-based practice, is challenging in this field. The inconsistent terminology has precluded the establishment of index classifiers, such as a Medical Subject Heading (MeSH) or an International Classification of Disease (ICD) code. Moreover, key search terms are not specific (e.g. 'cervical' also relates to the cervix uteri; Khan et al., 2020).

To address this, we previously developed and validated a standardised search filter for finding DCM references in the Ovid MEDLINE database (Davies et al., 2018). This was developed to be 100% sensitive for primary human research references, assessing a sample exclusively with DCM. The high level of sensitivity was chosen in order to form a foundation for researchers to customise (Pope et al., 2020). This filter has already been used in published research (Khan et al., 2020).

It is widely recognised that searching MEDLINE alone may not be sufficient for systematic reviews (Bramer et al., 2016). In studies comparing MEDLINE and EMBASE retrieval, whilst MEDLINE typically outperforms EMBASE, studies have consistently demonstrated their combined superiority to searching either in isolation (Bramer et al., 2016; McDonald et al., 1999). EMBASE provides greater coverage of European, non-English language publications, pharmaceutical journals and conference abstracts (Wong et al., 2006). Consequently, their use together is generally recommended as the minimum for systematic reviews (Suarez-Almazor et al., 2000). The aim of this study was to develop and validate a translation for use in Ovid EMBASE.

# METHODS

A search filter is a reusable set of search terms designed to retrieve specific types of study (e.g. a study employing a certain type of methodology or pertaining to a specific disease) from a database (Lee et al., 2012). We followed

## Key messages

- Literature searching for systematic reviews of conditions with newly coined clinical terminology (such as Degenerative Cervical Myelopathy, DCM) is difficult, as the associated conditions may be indexed under a variety of search terms, particularly if there is not yet a direct MeSH term.
- Development of a MEDLINE search filter for DCM may form the basis of an EMBASE search filter for DCM, using development and validation gold standard databases.
- Such search filters (with high recall) will require further monitoring, as the changes in clinical terminology become more widely accepted and used.

previously described strategies of formulating search filters (Glanville et al., 2019; Sampson et al., 2006). Here, a 'development gold standard' set of relevant references on the topic of the filter is formulated, and the filter is tested against this reference set. Sensitivity is defined as the proportion of relevant records in the 'development gold standard' that are retrieved by the search filter (Glanville et al., 2019; Jenkins, 2004).

In this study, our objective was to adapt our previous MEDLINE search filter into an EMBASE search filter with 100% sensitivity for finding DCM references in the EMBASE database. The filter was developed in two stages: (1) filter development and (2) filter validation.

## Filter development

The full list of references used previously was collected to form a 'global database' of 250 important DCM articles. This reference set was chosen as it comprised articles from both surgical and non-surgical journals and included articles that had been hand-searched for and assessed for relevance to DCM.

EMBASE does not index the same references. Hence, each reference in this 'global database' of references was searched for manually and individually in EMBASE to confirm whether it was indexed in EMBASE. Thirty references were not indexed by EMBASE; these references were removed from the 'global database' to form an updated 'development gold standard' list of 220 references for filter development (Figure 1).

When formulating our previous MEDLINE filter, we analysed the results of our own previous published systematic

reviews as well as those conducted by others related to this field, and also examined the MEDLINE MeSH taxonomy. We identified two necessary components: (1) 'pertaining to the cervical spine' AND (2) 'pertaining to spinal cord compression (i.e. myelopathy)'. We then used the NOT Boolean operator to exclude conditions that may fit these criteria but were not DCM, such as motor neurone disease, metastatic cancer, autoimmune conditions or genetic disorders. See Data 2 for the complete filter.

This MEDLINE search filter was directly translated and used in EMBASE. Initially, a direct transfer was attempted, but only a few search terms were equivalent, and modifications were required. This included simple grammar differences between the terms (e.g. MEDLINE used 'exp Cervical Vertebrae/' whilst EMBASE used 'exp cervical vertebra/') but also synonym differences (e.g. MEDLINE used 'exp Cervical Cord/' whilst EMBASE used 'exp cervical spinal cord/' and 'exp cervical spine/'). Additionally, whilst the 'explode' function on MEDLINE and EMBASE is used to incorporate related search terms and increase sensitivity, MEDLINE and EMBASE use different terms. Each MEDLINE term was searched on EMBASE in isolation without the explode function. This output proposed a list of possible explode terms. From this output, the appropriate explode terms were selected.
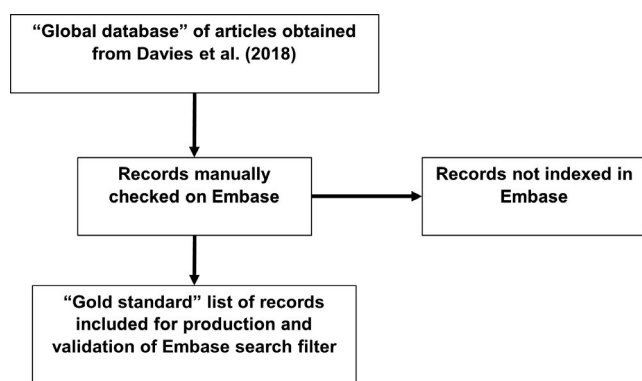
In cases where multiple explode terms were appropriate, all were included.

The explode dictionary in EMBASE is larger than MEDLINE, and consequently, all keywords from the MEDLINE filter, if possible, were used in this manner to increase sensitivity (e.g. 'exp cervical myelopathy/' or 'exp cervical spondylotic myelopathy/', or 'exp Japanese Orthopaedic Association score/').

Precision is defined as the proportion of records retrieved by the filter that are relevant (Jenkins, 2004). The 'focus' function finds references that have a particular subject heading as their main topic. This feature increases the precision of the output and makes it more manageable for the user. However, a risk of using 'focus' is that relevant references can be missed due to poor heading assignments. MEDLINE has fewer subject headings than EMBASE and consequently it was felt a greater risk of losing relevant references with the operator 'focus'. Hence, 'focus' was not a feature in our previous MEDLINE filter. However, as EMBASE has many more subject headings than MEDLINE, this was considered acceptable. Therefore, we initially used 'focus' for each included explode term. However, during the iterative refinement stage, we removed some instances of 'focus' to achieve 100% sensitivity.

During filter development, if a relevant article is missed by the filter, it is analysed to determine the cause of exclusion and the filter is modified so that it is included. This step happens iteratively until an acceptable level of sensitivity has been established (Glanville et al., 2019). Our initial direct transfer did not retrieve 100% of the references from the 'development gold standard' database. Each non-included reference was searched manually on MEDLINE and EMBASE. The title, abstract, subject headings and keywords of the indexed reference in both databases were analysed to determine why that reference had been included in the MEDLINE filter but missed by the proposed EMBASE filter. The causes were grouped, and each line of the proposed



FIGURE 1 Production of 'gold standard' database

TABLE 1 An example of the iterative refinement of line #4 of the filter

| Iteration | Search filter (line #4) | Articles returned | Relevant articles included (out of 52) | % sensitivity |
|---|---|---|---|---|
| 1 | "ossification of posterior longitudinal ligament".ti,ab. or exp *ligament calcinosis/ | 1232 | 42 | 80.8 |
| 2 | "ossification of posterior longitudinal ligament".ti,ab. or exp *ligament calcinosis/ **or (exp *posterior longitudinal ligament/ and exp *ossification/)** | 1426 | 50 | 96.2 |
| 3 | "ossification of posterior longitudinal ligament".ti,ab. or exp *ligament calcinosis/ or (**exp posterior longitudinal ligament/** and (exp *ossification/ **or ossif*.ti,ab.**)) | 1777 | 52 | 100.0 |

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┌─────────────────────────────────────────────────────────────┐
│  Direct transfer of Davies et al. (2018) MEDLINE terms to Embase │
└─────────────────────────────────────────────────────────────┘
                              │
                              ▼
┌─────────────────────────────────────────────────────────────┐
│  MEDLINE-specific explode terms converted to Embase-specific │
└─────────────────────────────────────────────────────────────┘
                              │
                              ▼
┌─────────────────────────────────────────────────────────────┐
│  Keywords from Davies et al. (2018) MEDLINE identified as potential │
└─────────────────────────────────────────────────────────────┘
                              │
                              ▼
┌─────────────────────────────────────────────────────────────┐
│  Focus feature added to all exploded Embase terms │
└─────────────────────────────────────────────────────────────┘
                              │
                              ▼
┌─────────────────────────────────────────────────────────────┐
│  Filter tested against "gold standard" list and articles not found with filter identified │
└─────────────────────────────────────────────────────────────┘
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                              ▼
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│  Title, abstract, subject headings and keywords screened as possible sources │
└─────────────────────────────────────────────────────────────┘
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│  Filter for validation │
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│  "Included articles" of three recent systematic reviews identified │
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│  Articles checked whether indexed by MEDLINE and Embase │
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│  Indexed articles verified if found by search filters │
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│  Validated filter │
└─────────────────────────────────────────────────────────────┘
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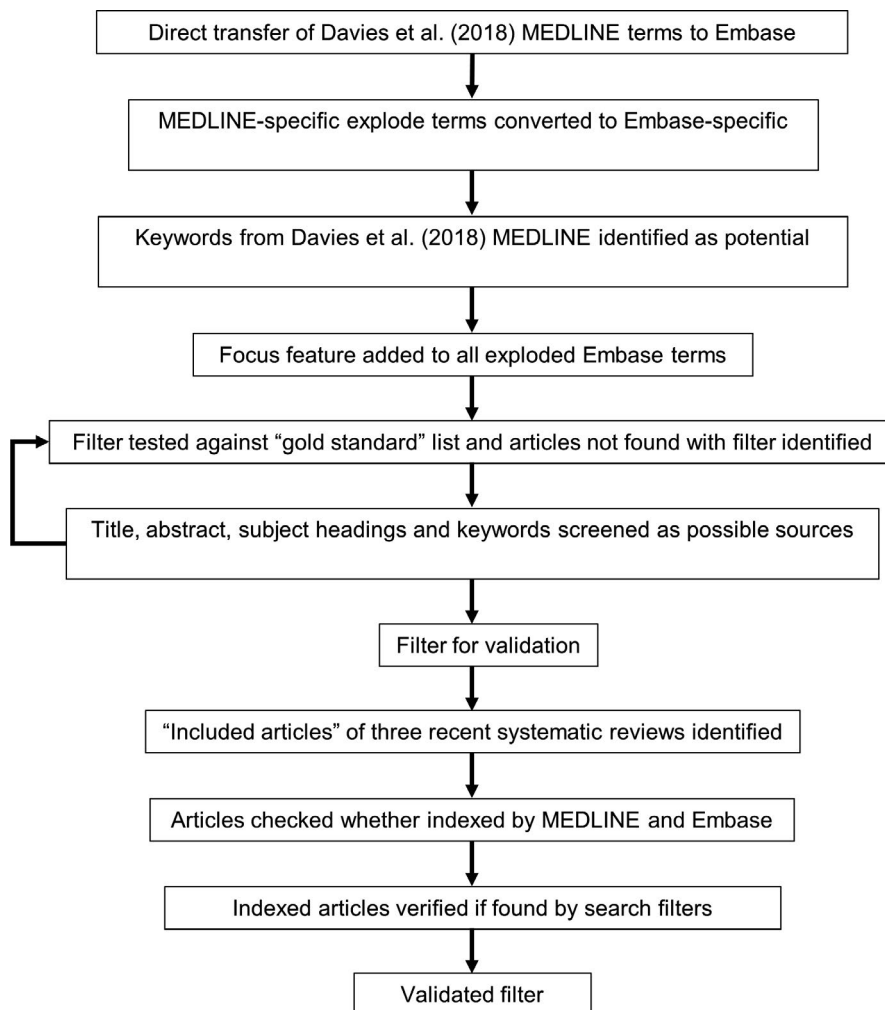
**FIGURE 2**  Development and validation of search filter

search filter was iteratively refined until all references were included.

An example of the iterative refinement of the filter for line #4 is shown in Table 1. Fifty-two references from the 'development gold standard' list were expected to be found by this search line. Initially, only 42 references were found (80.7% sensitivity) but with each iteration, there was a progressive increase in sensitivity to 100%. In bold are the modifications from the previous iteration. See Data 1 for commentary.

This iterative process was repeated for all lines of the search filter until 100% of 'development gold standard' references were retrieved.

## Filter validation

'Filter validation' is the process by which a search filter is tested against a 'validation gold standard' list of references that is different to the 'development gold standard' used for filter development (Jenkins, 2004). When developing

a filter based on one reference set, there is always a risk of overfitting to that specific reference set and not being generalisable to other reference sets (Wagner et al., 2020). Hence, we validated both filters using reference sets that other researchers have deemed appropriate.

Three systematic reviews were identified in MED-LINE. Database records containing 'Degenerative Cervical Myelopathy' in their title were searched and the results were filtered using the MEDLINE filter by publication type: systematic review. The results were sorted by year of publication and the top three systematic reviews that were not co-authored by any of the co-authors in this study were chosen for filter validation (Fogarty et al., 2018; Tetreault et al., 2016; Wang et al., 2019). A total of seventy-seven references were identified from the systematic reviews, and their full texts were analysed to confirm eligibility. Seventy-five references were eligible and formed the validation reference set.

The development and validation process is summarised in Figure 2.

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**TABLE 2** Filter validation

| Systematic review | Articles included in systematic review | Eligible articles | Articles indexed in MEDLINE | Articles returned by MEDLINE filter | Articles indexed in EMBASE | Articles returned by EMBASE filter |
|---|---|---|---|---|---|---|
| Fogarty et al. (2018) | 3 | 3 | 3 | 3 | 3 | 3 |
| Wang et al. (2019) | 14 | 14 | 13 | 13 | 14 | 14 |
| Tetreault et al. (2016) | 60 | 58 | 58 | 58 | 58 | 58 |
| Total | 77 | 75 | 74 | 74 | 75 | 75 |

**TABLE 3** Final validated DCM filter for EMBASE with 100% sensitivity of the key articles identified by Davies et al. (2018)

| # | EMBASE |
|---|---|
| 1 | exp *cervical vertebra/ or exp *cervical spinal cord/ or cervical.ti,ab. or exp *cervical spine/ or (phrenic nucleus or accessory nucleus).ti,ab. or exp *Japanese Orthopaedic Association score/ or Japanese Orthop?edic Association.ti,ab. or ("Japanese Orthop?edic Association" adj2 scor*).ti,ab. or (joa adj2 scor*).ti,ab. |
| 2 | myelopath*.mp. or exp cervical myelopathy/ or exp *cervical spondylotic myelopathy/ or spondylotic cervical myelopathy. mp. or exp *spinal cord disease/ or "cervical spinal cord injury".ti,ab. or exp *myelography/ or exp *myeloradiculopathy/ or myeloradiculopath*.ti,ab. or exp *cervical spondylosis/ or (spinal cord adj3 (diseas* or disorder*)).ti,ab. or spondylomyelopath*. ti,ab. or (Spinal Cord adj3 Compress*).ti,ab. or exp *spinal cord compression/ |
| 3 | 1 and 2 |
| 4 | "ossification of posterior longitudinal ligament".ti,ab. or exp *ligament calcinosis/ or (exp posterior longitudinal ligament/ and (exp *ossification/ or ossifi*.ti,ab.)) |
| 5 | 3 or 4 |
| 6 | exp atlantooccipital joint/ or exp arteriovenous fistula/ or exp radiotherapy/ or exp cyanocobalamin/ or exp radiation injury repair/ or exp radiation injury/ or exp *radiation/ or exp re-irradiation/ or exp irradiation/ or exp craniospinal irradiation/ or exp whole body radiation/ or exp *motor neuron disease/ or exp *amyotrophic lateral sclerosis/ or neoplasm metastasis.mp. or exp metastasis/ or exp *neoplasm/ or exp malignant neoplasm/ or exp radiation induced neoplasm/ or exp myeloproliferative neoplasm/ or exp vertebra hemangioma/ or exp hemangioma/ or exp nervous system malformation/ or autoimmune diseases of the nervous system.mp. or autoimmune nervous system.mp. or (congenital, hereditary, and neonatal diseases and abnormalities).mp. or "congenital disorder".mp. or exp genetic disorder/ or "newborn disease".mp. or exp virus infection/ |
| 7 | 5 not 6 |

# RESULTS

## Filter development

Direct transfer and iterative refinement of each line of the new filter, resulted in 100% of references in the 'development gold standard' database being retrieved.

## Filter validation

All references in the validation reference set were indexed in EMBASE, and all but one of the references were also indexed in MEDLINE [the article by Badhiwala et al. (2019) from the Wang et al. (2019) systematic review was not indexed]. Both filters were able to retrieve all

indexed references (Table 2). A total of 77 articles were included in the three systematic reviews. Seventy-five references were eligible and formed the 'validation gold standard'. Of these, 74 were indexed in MEDLINE, whilst EMBASE indexed all 75. Each filter returned 100% of indexed articles.

The final, validated filter is shown in Table 3. See Data 2 for a comparison against the MEDLINE filter.

# DISCUSSION

We have adapted and validated a highly sensitive search filter for retrieving DCM references in the EMBASE database (Table 3). This should be used alongside our previous MEDLINE filter for systematic literature searches

on DCM. The filter is designed to have high sensitivity and hence the final number of search results returned is large. This is considered desirable, in order to allow researchers to build on these foundations with additional criteria relevant to their hypothesis.

## Limitations

It should be acknowledged our validation process used the included articles from recent and external systematic reviews, without prior power calculation. This approach was taken on the basis that DCM articles are relatively infrequent within general literature repositories, and to ensure incorporation of current DCM literature. However, given the relatively recent introduction of DCM, and gradual global uptake, there are few reviews conducted thus far external to our group. Consequently, whilst the list of references for validation reference is perhaps lower than used in other studies (see Sampson et al., 2006), it represents the current yield for the topic. Regardless we have taken a rigorous approach building on the performance of our MEDLINE filter, and feel confident of its performance.

All search filters are likely to retrieve some irrelevant results due to a certain degree of ambiguity of terms in the filters and the way in which they are combined. This is also the case for our proposed search filter, and a necessary compromise. For example, the Japanese Orthopaedic Association Score is mainly used for the assessment of cervical myelopathy (Kato et al., 2015). Hence, it was included in line #1 of our search filter. However, it is possible that an article uses this scoring system to assess a different spinal level, as is apparent in the case series by Okada et al. (2010), which describes surgical outcomes in patients with OPLL of the lumbar spine; our search filter would retrieve this reference. In addition, it is possible that the article contains words referring to DCM but is focused on a different spinal level. For example, the article by Glassman et al. (2019) investigated whether neurologic disorders were risk factors for revision after lumbar spine surgery. They used a prior diagnosis of 'cervical spondylotic myelopathy' as a covariate in their analysis; our search filter retrieves this reference.

Furthermore, in our desire to take a maximally sensitive approach with this filter, article returns are high (18,779 references currently). Whilst this may limit its day to day uptake, as the research priorities and focus for DCM move away from surgical technique (Davies et al., 2019), its predominant theme for the last 20 years (Mowforth et al., 2019), it is likely broader search strategies will hold value: it is intended that in the absence of consistent terminology and indexing, this filter will offer the foundations to support more efficient and robust evidence synthesis in the field.

This aligns with the broader scope and aims of AOSpine RECODE-DCM, an international multi-stakeholder consortium, to develop a research toolkit to advance knowledge discovery that can improve outcomes for people with DCM (www.aospine.org/recode).

## CONCLUSIONS

We have developed a search filter capable of identifying primary clinical research on DCM in the EMBASE database with high sensitivity. The EMBASE filter, when used alongside our previous MEDLINE filter, will serve as a useful foundation for systematic search strategies in this field.

## CONFLICT OF INTEREST
None.

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## APPENDIX

## Data 1

*The first iteration was simply a direct translation of the MEDLINE search. In this example, the explode term "Ossification of Posterior Longitudinal Ligament" existed in MEDLINE but not in Embase, so an appropriate transformation was required. The keyword search suggested a related explode term, "ligament calcinosis", might be relevant – this was used with a focus model. The original MEDLINE explode term was also included as a keyword search, "ossification of posterior longitudinal ligament". These two search terms were combined to produce the first iteration of the line #4 of the Embase filter. This returned 1232 articles, 320 more than the 912 yielded from the MEDLINE search. Once all lines of the search had been formulated, the entire search was run*

*The articles missed by this first iteration were identified, and the titles, abstracts, subject headings and keywords were screened to determine why the article had been included in the MEDLINE filter but missed by the first iteration of the Embase filter. The analysis indicated that, out of the total 220 "gold standard" list of articles, 52 articles were supposed to be found by line #4, but only 42 were actually discovered (80.7% sensitivity). We predicted that an explode of "posterior longitudinal ligament" with a logical conjunct explode of "ossification", both in focus mode, may be sufficient to find the remaining 10 "gold standard" articles. This hypothesis was tested in the second iteration. This yielded a further 194 articles, which included 8 out of the 10 "gold standard" articles that were initially missed (overall sensitivity 96.2%). We realised that not all missed "gold standard" articles had "ossification" in explode and focus mode. Hence, in the third iteration, we sought to include "ossification" as a keyword that could be used alongside the modifications from the previous iteration. However, some studies may use slightly different suffixes of "ossification", e.g. "ossified" or "ossify". Hence, we used the wildcard symbol (\*) with the prefix "ossif" to include suffixes. We also removed the focus mode restriction from the "posterior longitudinal ligament" explode. We evaluated this amendment in the third iteration and successfully brought the sensitivity to 100% of finding "gold standard" articles expected from line #4*

## Data 2

Final, validated filter for Embase with 100% sensitivity of the key articles identified by Davies et al. (2018).

| # | MEDLINE (Davies et al. (2018)) | Hits | Embase | Hits |
|---|---|---|---|---|
| 1 | exp Cervical Vertebrae/ or exp Cervical Cord/ or cervical.mp. or (phrenic nucleus or accessory nucleus).mp. or (("Japanese Orthop?edic Association" adj2 score\*) or (joa adj2 score\*)).mp. | 231347 | exp \*cervical vertebra/ or exp \*cervical spinal cord/ or cervical.ti,ab. or exp \*cervical spine/ or (phrenic nucleus or accessory nucleus).ti,ab. or exp \*Japanese Orthopaedic Association score/ or Japanese Orthop?edic Association.ti,ab. or ("Japanese Orthop?edic Association" adj2 scor\*).ti,ab. or (joa adj2 scor\*).ti,ab. | 277666 |
| 2 | myelopath\*.mp. or exp Spinal Cord Diseases/ or (spinal cord adj3 (diseas\* or disorder\*)).mp. or myeloradiculopath\*.mp. or spondylomyelopath\*.mp. or spondylomyeloradiculopath\*.mp. or (Spinal Cord adj3 Compress\*).mp. or exp Spinal Cord Compression/ | 135824 | myelopath\*.mp. or exp cervical myelopathy/ or exp \*cervical spondylotic myelopathy/ or spondylotic cervical myelopathy.mp. or exp \*spinal cord disease/ or "cervical spinal cord injury".ti,ab. or exp \*myelography/ or exp \*myeloradiculopathy/ or myeloradiculopath\*.ti,ab. or exp \*cervical spondylosis/ or (spinal cord adj3 (diseas\* or disorder\*)).ti,ab. or spondylomyelopath\*.ti,ab. or (Spinal Cord adj3 Compress\*).ti,ab. or exp \*spinal cord compression/ | 172911 |
| 3 | 1 and 2 | 17641 | 1 and 2 | 22689 |

| # | MEDLINE (Davies et al. (2018)) | Hits | Embase | Hits |
|---|---|---|---|---|
| 4 | exp "Ossification of Posterior Longitudinal Ligament"/ | 912 | "ossification of posterior longitudinal ligament".ti,ab. or exp *ligament calcinosis/ or (exp posterior longitudinal ligament/ and (exp *ossification/ or ossifi*.ti,ab.)) | 1777 |
| 5 | 3 or 4 | 18094 | 3 or 4 | 23851 |
| 6 | exp Atlanto-Occipital Joint/ or exp Arteriovenous Fistula/ or exp Radiotherapy/ or exp Vitamin B 12/ or exp Radiation/ or exp Radiation Injuries/ or exp Re-Irradiation/ or exp Craniospinal Irradiation/ or exp Whole-Body Irradiation/ or exp Motor Neuron Disease/ or exp Amyotrophic Lateral Sclerosis/ or exp Neoplasm Metastasis/ or exp Hemangioma/ or exp neoplasm/ or exp metastasis/ or exp Nervous System Malformations/ or exp "autoimmune diseases of the nervous system"/ or exp "congenital, hereditary, and neonatal diseases and abnormalities"/ or exp virus diseases/ | 5634818 | exp atlantooccipital joint/ or exp arteriovenous fistula/ or exp radiotherapy/ or exp cyanocobalamin/ or exp radiation injury repair/ or exp radiation injury/ or exp *radiation/ or exp re-irradiation/ or exp irradiation/ or exp craniospinal irradiation/ or exp whole body radiation/ or exp *motor neuron disease/ or exp *amyotrophic lateral sclerosis/ or neoplasm metastasis.mp. or exp metastasis/ or exp *neoplasm/ or exp malignant neoplasm/ or exp radiation induced neoplasm/ or exp myeloproliferative neoplasm/ or exp vertebra hemangioma/ or exp hemangioma/ or exp nervous system malformation/ or autoimmune diseases of the nervous system.mp. or autoimmune nervous system.mp. or (congenital, hereditary, and neonatal diseases and abnormalities).mp. or "congenital disorder".mp. or exp genetic disorder/ or "newborn disease".mp. or exp virus infection/ | 6472182 |
| 7 | 5 not 6 | 12992 | 5 not 6 | 18779 |