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Systematic Review/Meta-Analysis

A critical appraisal of clinical practice guidelines for diagnostic imaging in the spinal cord injury

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Abstract

BACKGROUND CONTEXT: Spinal cord injury (SCI) is a serious health problem which carries a heavy economic burden. Imaging technologies play an important role in the diagnosis of SCI. Although several organizations have developed guidelines for diagnostic imaging of SCI, their quality has not yet been systematically assessed.

PURPOSE: We aim to conduct a systematic review to appraise SCI guidelines and summarize their recommendations for diagnostic imaging of SCI.

STUDY DESIGN: Systematic review.

METHODS: We searched Embase, Medline, Web of Science, Cochrane, some guideline-specific databases (eg, Scottish Intercollegiate Guidelines Network) and Google Scholar from January 2000 to January 2022. We included guidelines developed by nationally recognized organizations. If multiple versions could be obtained, we included the latest one. We appraised included guidelines using the Appraisal of Guidelines for Research and Evaluation, 2nd edition instrument which contains six domains (eg, scope and purpose). We also extracted recommendations and assessed their supporting evidence using levels of evidence (LOE). The evidence was categorized as A (the best quality), B, C, and D (the worst quality).

RESULTS: Seven guidelines (2008–2020) were included. They all received the lowest scores in the domain of applicability. All guidelines (7/7, 100%) recommended magnetic resonance imaging (MRI) in patients with SCI or SCI without radiographic abnormality (SCIWORA). A total of 12 recommendations involving patient age (eg, adult and child patients), timing of MRI (eg, as soon as possible and in the acute period), symptoms indicated for MRI (eg, a stiff spine and midline tenderness, suspected disc and posterior ligamentous complex injury, and neurological deficit), and

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types of MRI (eg, T2-weighted imaging and diffusion tensor imaging) were extracted. Among them, the LOE was C in nine (75%) recommendations and D in three (25%) recommendations.
CONCLUSIONS: Seven guidelines were included in the present systematic review, and all of them showed the worst applicability scores in the Appraisal of Guidelines for Research and Evaluation, 2nd edition instrument. They all weakly recommended MRI for patients with suspected SCI or SCIWORA based on a low LOE.

Keywords: AGREE II; Clinical practice guidelines; Diagnostic imaging; Level of evidence; MRI; Spinal cord injury

Introduction

In recent years, spinal cord injury (SCI), which carries a heavy economic burden, has become increasingly common [1,2]. According to the Global Burden of Disease Study, there were 20.64 million (95% uncertainty interval: 18.93 −23.61 million) prevalent cases of SCI recorded globally in 2019 [3]. According to the National Spinal Cord Injury Statistical Center, the average yearly expenses for patients with SCI ranged from $0.04 million to $1.08 million in the United States [2].

Diagnostic imaging plays important roles in the evaluation of patients with suspected SCI [4]. Computed tomography (CT) is regarded as an initial imaging examination after spinal trauma for its clear radiographic image of the spinal column [5]. Magnetic resonance imaging (MRI) is effective in detecting slight changes in soft tissues, supporting a better diagnosis of SCI and proper management [6]. This makes it crucial in the evaluation of damage to neurological structures [7].

High-quality guidelines can promote efficient practices for health conditions [8]. However, without information regarding the quality of existing guidelines, it is difficult for clinicians to choose high-quality guidelines [9]. Furthermore, a critical appraisal of relevant guidelines greatly benefits future work in this field, as more evidence is added by researchers [10]. Although clinical practice guidelines for the diagnostic imaging of SCI have been published by some authoritative organizations, the consistency of the recommendations and the overall quality of the guidelines remain unclear. In 2021, Liang et al. [11] appraised the guidelines for SCI published in the Paralyzed Veterans of America; however, not all available guidelines were included or focused on diagnostic imaging.

Therefore, the purpose of this study is to critically appraise existing guidelines on diagnostic imaging of SCI, and to present recommendations based on an assessment of the supporting evidence.

Methods

Study design

According to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [12], we conducted a systematic review and registered it on PROSPERO (CRD42022350091). The systematic review team consisted of two attendings, one epidemiologist, one guideline methodologist, two interns, and two medical students.

Search strategy

Guidelines developed in the past may not apply to current clinical practice. Based on the recommendations of a study published in *Annals of Internal Medicine* [13], the publication time of clinical practice guidelines was limited to January 2000 to January 2022. Using search strategies (Appendix 1) formulated by a professional librarian, we searched Embase, Medline, Cochrane, and Web of Science for clinical practice guidelines related to SCI. We also searched Google Scholar and some guideline-specific databases (eg, Scottish Intercollegiate Guidelines Network, Congress of Neurological Surgeons, National Institute for Health and Care Excellence, etc.) (Appendix 2) to supplement the results. We restricted the results to English-language.

Selection of guidelines

After the removal of duplicates, the titles and abstracts of the literature were reviewed independently by three reviewers to exclude documents which were not guidelines or were not related to SCI. Before reviewing full-text articles, we increased consistency by selecting 5% of the selected documents as a pilot test [14]. Differences were resolved through discussion. If differences persisted, senior scientists were available for consultation.

Based on the recommendations of a study published in *Annals of Internal Medicine* [13], our inclusion criteria were as follows: (1) developed by nationally recognized committees, medical societies, or publicly funded institutions that formulated recommendations on SCI; (2) included specific methodological sections (for example, literature review, review of the evidence, and the methodology of the forming recommendations); and (3) was the latest version if several versions were available.

Quality assessment of guidelines

The included guidelines were appraised by three reviewers independently according to the Appraisal of Guidelines for Research and Evaluation, 2nd edition

(AGREE II) instrument (www. agreetrust. org). The AGREE II instrument contains 23 items split into six different domains: scope and purpose (regarding aims, target population, and health problems of guidelines), stakeholder involvement (regarding appropriate stakeholders and intended users in the process of the guideline development), rigor of development (regarding the gathering of evidence and formulation or revisions of recommendations), clarity of presentation (regarding organizations and formats of guidelines and language), applicability (regarding potential barriers to, facilitators factors of, and possible resource impact of the practical application of guidelines), and editorial independence (regarding conflicts of interest in the process of formulating recommendations) [15]. Further, the AGREE II instrument contains an overall rating item that indicates the general quality of appraised guidelines.

We scored each item on a scale of 1 to 7 to indicate the degree of agreement between the criteria of AGREE II instrument and the content of the guidelines [15]. One indicates strong disagreement, and 7 indicates strong agreement. We calculated the score for each domain as follows: (obtained score-minimum possible score)/(maximum possible score-minimum possible score) [15]. We also calculated the overall rating score by averaging the scores of all 23 items [16,17]. Considering that the AGREE II instrument did not define a specific minimum threshold for the scores of each domain [15], we set it to 50% in our study, referring to a prior study [8]. If the scores of most domains (5−6 domains) were above 50%, the guideline would be evaluated as "recommended"; if the scores of some domains (1−4 domains) were above 50%, the guideline would be evaluated as "recommended with modifications"; if the scores of all domains were below 50%, the guideline would be evaluated as "not recommended" [18].

To enhance consistency among the three reviewers, we selected two guidelines from all included guidelines as a pilot before the formal appraisal [14]. The interquartile range (IQR) and the median score of each domain were calculated. We also calculated the interrater agreement by the intraclass correlation coefficient with a corresponding 95% confidence interval (CI) to measure the reliability of the results. A score of 0.01 to 0.20 indicates poor agreement; a score of 0.21 to 0.40 indicates fair agreement; a score of 0.41 to 0.60 indicates moderate agreement; a score of 0.61 to 0.80 indicates substantial agreement; a score of 0.81 to 1.00 indicates very good agreement [13]. Differences of three points or fewer in the item rating among raters were accepted [13]. Any discrepancy was discussed. If necessary, senior scientists were available for consultation. All calculations in our study were performed by IBM SPSS Statistics 25.0 and Microsoft Excel 2016.

Recommendations on diagnostic imaging

One reviewer extracted recommendations on diagnostic imaging of SCI with supporting evidence from guidelines which were evaluated as "recommended with modification" and "recommended." Two reviewers checked the work. Any differences were resolved through discussion [19].

Appraisal of levels of evidence

Given the lack of high-quality supporting evidence such as randomized controlled trials (RCTs), we evaluated the quality of supporting evidence of extracted recommendations by levels of evidence (LOE) based on a prior study whose quality of included supporting evidence was similar to ours [20]. LOE was categorized as A, B, C or D. Grade A refers to individual RCTs and systematic reviews of RCTs; Grade B refers to systematic reviews of cohort/case-control studies, case-control studies, and cohort studies; Grade C refers to case report/series and poor-quality case-control studies or cohort studies; Grade D refers to troublingly inconsistent or inconclusive studies. Additionally, LOE will be assessed as D if one recommendation is an expert opinion formulated without explicit critical appraisal of evidence (Appendix 3).

Results

Selection of guidelines

In total, 12,017 articles were available after the removal of duplicates. Seven guidelines from 2008 to 2020 were included after reviewing titles, abstracts, and full texts (Fig. 1). They were developed by AO Spine [21], Paralyzed Veterans of America [22], French Society of Anesthesia and Intensive Care Medicine [23], American Association of Neurological Surgeons and Congress of Neurological Surgeons Joint Guidelines Committee [24], World Federation of Neurosurgical Societies Spine Committee [25,26], and Chinese Association of Spine and Spine Cord Injury [27]. Table 1 provides detailed information.

Quality assessment of guidelines

For all included guidelines, the scores for each domain were as follows: scope and purpose (range: 51.3%−86.7%, IQR: 56.9%−69.3%, median: 57.2%), stakeholder involvement (range: 17.9%−84.1%, IQR: 25.0%−53.9%, median: 34.3%), rigor of development (range: 41.3%−75.7%, IQR: 45.1%−61.8%, median: 55.1%), clarity of presentation (range: 77.8%−91.2%, IQR: 84.1%−88.0%, median: 87.0%), applicability (range: 5.8%−38.3%, IQR: 7.7%−15.7%, median: 9.7%), editorial independence (range: 22.2%−100%, IQR: 46.7%−84.4%, median: 50.0%), and overall rating (range: 3.5−5.4, IQR: 3.7−4.5, median: 3.7; Table 2, Fig. 2). The range of intraclass correlation coefficients was between 0.838 (95% CI: 0.707−0.921) and 0.975 (95% CI: 0.951−0.988), indicating that the consistency among the three raters was very good. Two guidelines [21,23] scored over 50% in 5 to 6 domains and were evaluated as "recommended"; five guidelines [22,24−27] scored

over 50% in 1 to 4 domains and were evaluated as "recommended with modification." Therefore, we extracted recommendations from all included guidelines.

Diagnostic imaging

Twelve recommendations were extracted from the included guidelines. We described all included recommendations in detail in Appendix 4 and summarized them in Table 3. LOE was C in nine recommendations and D in three recommendations.

Magnetic resonance imaging

All guidelines (7/7, 100%) recommended MRI in the diagnosis of SCI or SCI without radiographic abnormality (SCIWORA). Specifically, two guidelines [21,26], two guidelines [21,23], three guidelines [22,23,27], and one guideline [25] made recommendations on patient age, timing of MRI, symptoms indicated for MRI, and types of MRI, respectively.

Patient age

For patient age, one guideline [26] (1/2, 50%) recommended MRI for child patients (LOE: C), and one guideline [21] (1/2, 50%) for adult patients (LOE: C).

Timing of MRI

Regarding the timing of MRI, one guideline [23] (1/2, 50%) recommended MRI as soon as possible once SCI was suspected (LOE: C), and one guideline [21] (1/2, 50%) in the acute period (LOE: C).

Symptoms indicated for MRI

For the symptoms indicated for MRI, two guidelines [23,27] (2/3, 66.7%) recommended MRI for patients who had a neurological deficit (LOE: C [n=1] and D [n=1]), one guideline [22] (1/3, 33.3%) for patients with a stiff spine and midline tenderness (LOE: C), and one guideline [27] (1/3, 33.3%) for patients with suspected disc and posterior ligamentous complex injury (LOE: D).

Types of MRI

Regarding the types of MRI, one guideline [25] (1/1, 100%) recommended that T2-weighted imaging (T2WI) was an acceptable method for the diagnosis of SCI (LOE: C) and diffusion tensor imaging (DTI) might be used to predict outcomes of patients with SCI (LOE: C).

Discussion

Seven guidelines regarding diagnostic imaging for patients with SCI were included in the systematic review. In the domains of clarity of presentation, scope and purpose, all included guidelines were above the minimum threshold. Over half of included guidelines were above the minimum threshold in the domains of rigor of development and editorial independence. In the domain of applicability, no guidelines reached the minimum threshold.

The following accounted for the low scores of the domain of applicability of the included guidelines: (1) Advice and tools for the application of the recommendations were lacking; (2) potential facilitators of and barriers to the application of the recommendations were not discussed; and (3) potential cost implications of the application of the recommendations were not considered. In the future, guideline developers should describe potential factors that may promote or hinder the application of the recommendations, such as advice and tools for the application (eg, a quick reference guide), potential barriers to the application (eg, insufficient skills of practitioners), potential facilitators of the application (eg, sufficient imaging equipment for diagnosis), and potential cost implications of the application (eg, imaging acquisition costs), to improve the applicability of the guidelines [28].

Regarding patient age, one guideline [26] recommended MRI for child patients because it was a guideline for pediatric SCI. Another guideline [21] recommended MRI for adult patients because the target population of most of the supporting evidence was adult patients. Notably, both recommendations were based on a low LOE. The other guidelines [22–25,27] did not describe the patient age in the recommendations. To some extent, these data indicates that there is no high-level evidence to prove that there is an age limit for the use of MRI. One possible reason is that MRI is a safe imaging modality with the use of non-ionizing electromagnetic radiation. With proper management and care, MRI can be performed safely for patients of all ages [29,30].

Regarding the timing of MRI, one guideline [23] recommended that MRI should be performed as soon as possible once SCI was suspected but did not describe a specific time. Another guideline [21] recommended MRI in the "acute period", which was defined as "within a week of injury." Both guidelines lacked high-quality evidence to prove their reliability, which made their recommendations weak. Although the quality of the supporting evidence was low, the consistency of recommendations was high. One possible reason is that MRI performed in the acute setting can play an important role in the evaluation of patients with suspected SCI for an earlier diagnosis and a timely treatment, which are beneficial to the prognosis of neurological function [1,4]. Therefore, although the quality of the supporting evidence was low, the guidelines arrived at the consistent conclusions leading to the high consistency of the recommendations.

One guideline [25] recommended that T2WI was an acceptable method for the diagnosis of SCI and DTI might be used to predict outcomes of patients with SCI. In clinical practice, T2WI is the most important method for the detection of SCI [31]. It can depict the pathology of most tissues

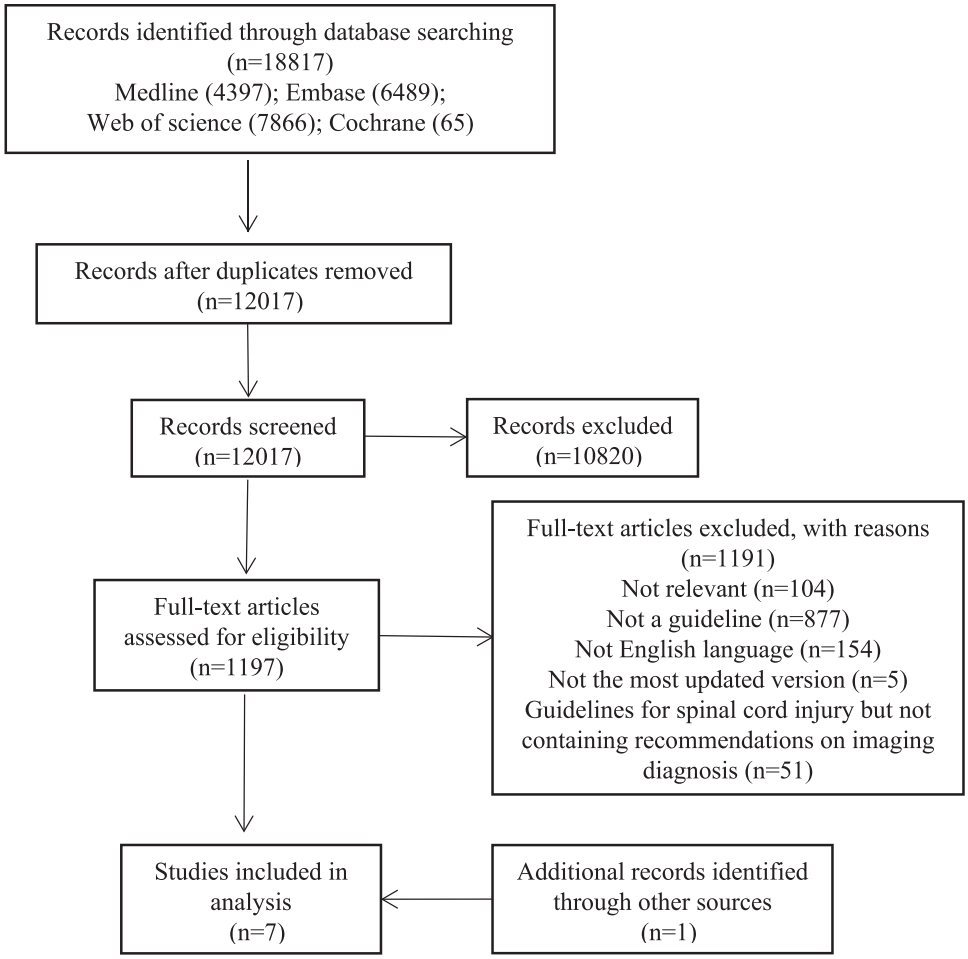

Fig. 1. PRISMA flow chart showing the process in the systematic review.

well and have a high sensitivity to spinal cord edema and hemorrhage [32,33]. DTI is a useful imaging method for detecting the microstructure of spinal cord, which is based on diffusion of water molecules in biological tissues [34,35]. It can evaluate the extent of spinal cord damage and monitor the effects of regeneration-inducing treatment [36]. However, the clinical utility of DTI is limited because susceptibility artifacts caused by cardiac and respiratory motions can affect its accuracy [4]. The acquisition methods, data processing, and interpretation of DTI are also limiting factors [37]. Further, DTI metrics varies with age and signal quality [38]. These may be reasons why DTI was not widely recommended in the other included guidelines. The limited availability of relevant clinical studies with a long-term follow-up might also contribute to the weak recommendation for DTI.

Two guidelines [24,26] recommended for MRI in the diagnosis of SCIWORA. SCIWORA is defined as the presence of clinical symptoms of traumatic myelopathy with no radiographic or computed tomographic features of spinal fracture or instability [39]. For this reason, MRI can be utilized to detect some characteristic pathomorphological changes in soft tissues of patients with SCIWORA, such as spinal cord hematomas and edema [40].

Referring to the suggestions of reviewers, this study did not include recommendations relevant to CT. CT is regarded as a first-line imaging modality after spinal trauma because it is sensitive to osseous abnormalities and can be performed rapidly [4]. However, CT is less able to detect ongoing spinal cord edema and hemorrhage than MRI [21,41].

In the future, more high-quality evidence (eg, data from RCTs) is expected to formulate strong recommendations. However, considering the particularity of studies for diagnostic strategies, this could be difficult and challenging. With synthesis of existing evidence, clinical experience, and expert opinions, the Appropriate Use Criteria (AUC) methodology could be expected to be utilized by a rating panel to determine the appropriateness of MRI in various clinical scenarios [42]. Additionally, more types of MRI for the diagnosis of SCI such as diffusion-weighted imaging and susceptibility-weighted imaging are expected to be studied and gradually introduced into future guidelines [43,44].

Table 1
Characteristics of included guidelines

Guideline	Author	Year	Target population	Development committees/ agencies/associations	Methods used in recommendation development	Recommendation on MRI
A clinical practice guideline for the management of patients with acute spinal cord injury: recommendations on the role of baseline magnetic resonance imaging in clinical decision making and outcome prediction	Fehlings et al.	2017	Spinal cord injury	AO Spine	GRADE system	For
Early acute management in adults with spinal cord injury: a clinical practice guideline for health-care providers	Paralyzed Veterans of America	2008	Spinal cord injury	Paralyzed Veterans of America	Guidance from Canadian Medical Association	For
French recommendations for the management of patients with spinal cord injury or at risk of spinal cord injury	Roquilly et al.	2020	Spinal cord injury	French Society of Anesthesia and Intensive Care Medicine	GRADE system	For
Outcomes of spinal cord injury: WFNS Spine Committee Recommendations	Parthiban et al.	2020	Cervical spinal cord injury	WFNS Spine Committee	Delphi method	For
An expert consensus on the evaluation and treatment of acute thoracolumbar spine and spinal cord injury in China	Zhang et al.	2013	Thoracolumbar spine cord injury	Chinese Association of Spine and Spinal Cord Injury	Delphi method	For
Pediatric cervical spine injuries and SCIWORA: WFNS Spine Committee Recommendations	Konovalov et al.	2020	Pediatric cervical spinal cord injury/ SCIWORA	WFNS Spine Committee	Delphi method	For
Spinal cord injury without radiographic abnormality (SCIWORA)	Rozzelle et al.	2013	SCIWORA	AANS/CNS Joint Guidelines Committee	Modified North American Spine Society criteria	For

AANS/CNS, American Association of Neurological Surgeons and Congress of Neurological Surgeons; GRADE, Grading of Recommendations Assessment, Development and Evaluation; MRI, magnetic resonance imaging; SCIWORA, Spinal Cord Injury Without Radiographic Abnormality; WFNS, World Federation of Neurosurgical Societies.

The characteristics of all seven guidelines are outlined in Table 1. This includes their names, authors, edition years, target population, development committees/ agencies/ associations, methods used in recommendation development, recommendation on MRI respectively.

Table 2
Appraisal of guidelines through AGREE II instrument

Guideline	Intraclass correlation coefficient (95% CI)	Scope and purpose (%)	Stakeholder involvement (%)	Rigor of development (%)	Clarity of presentation (%)	Applicability (%)	Editorial independence (%)	Overall rating
Fehlings et al. 2017	0.838 (0.707–0.921)	86.7	84.1	68.3	91.2	38.3	100.0	5.4
Paralyzed Veterans of America 2008	0.890 (0.795–0.948)	63.7	54.8	75.7	83.0	13.9	22.2	4.4
Roquilly et al. 2020	0.900 (0.812–0.952)	74.8	53.0	55.1	87.0	17.5	96.7	4.5
Parthiban et al. 2020	0.939 (0.883–0.972)	51.3	17.9	55.3	88.9	7.9	50.0	3.7
Zhang et al. 2013	0.894 (0.802–0.950)	56.7	34.3	43.2	77.8	7.5	72.2	3.7
Konovalov et al. 2020	0.868 (0.756–0.937)	57.2	18.0	46.9	85.2	5.8	43.3	3.5
Curtis et al. 2013	0.975 (0.951–0.988)	57.0	32.0	41.3	87.0	9.7	50.0	3.6

95% CI, 95% confidence interval; AGREE II, Appraisal of Guidelines for Research and Evaluation, 2nd edition.

The results of appraisals of all seven guidelines through the AGREE II instrument are outlined in Table 2. This includes six domains: scope and purpose, stakeholder involvement, rigor of development, clarity of presentation, applicability, and editorial independence, and overall rating with intraclass correlation coefficient companied with 95% CI.

There were some strengths in our study. First, this study included seven available clinical practice guidelines on diagnostic imaging of SCI from 2008 to 2020 through a systematic search and critically appraised their qualities using the AGREE II instrument [15]. This strategy enabled an intuitive presentation of the qualities of existing available guidelines, which can help clinicians in selecting high-quality guidelines to facilitate consistent, efficient, and evidence-based practices in clinical conditions and provide guidance for future work for guideline developers. Second, to our knowledge, this study is the first time to summarize and analyze the recommendations on diagnostic imaging for SCI from existing available guidelines and evaluate the level of their supporting evidence by a unified evidence assessment system. The findings can help clinicians intuitively acquire similarities and differences of the recommendations in current existing guidelines and the quality of their supporting evidence.

Our study also had some limitations. First, considering that the AGREE II instrument has not defined a specific minimum threshold for the scores of each domain and defined the method for evaluating the overall quality of appraised guidelines, the minimum threshold (50%) set for each domain and evaluation methods of the overall quality

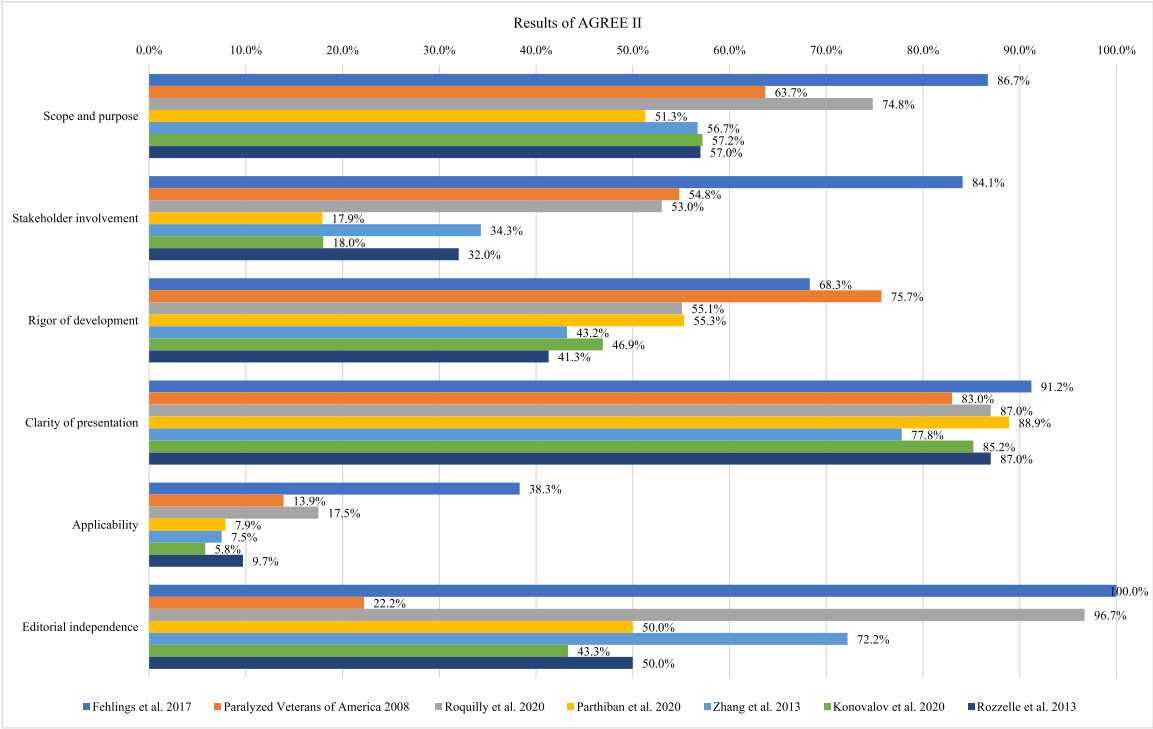

Fig. 2. Appraisal of guidelines through AGREE II instrument.

Table 3
Recommendations on MRI in the diagnosis of spinal cord injury from guidelines and LOE of recommendations

			Fehlings et al. 2017	Paralyzed Veterans of America 2008	Roquilly et al. 2020	Parthiban et al. 2020	Zhang et al. 2013	Konovalov et al. 2020	Rozzelle et al. 2013
SCI	Patient age	Adult	++						
		Children						++	
	Timing of MRI	As soon as possible			++				
		Acute period	++						
	Symptoms indicated for MRI	Neurological deficit			++		+		
		Suspected disc and posterior ligamentous complex injury					+		
		A stiff spine and midline tenderness		++					
	Types of MRI	T2WI				++			
		DTI				++*			
SCIWORA								++	+

DTI, diffusion tensor imaging; SCI, Spinal cord injury; SCIWORA, spinal cord injury without radiographic abnormality; T2WI, T2 weight imaging.

* DTI sequences may be promising to predict outcome in both acute and chronic SCI patients. +, recommended for with LOE D; ++, recommended for with LOE C; +++, recommended for with LOE B; ++++, recommended for with LOE A. Grade A refers to individual RCTs and systematic reviews of RCTs; Grade B refers to systematic reviews of cohort/case-control studies, case-control studies, and cohort studies; Grade C refers to case report/series and poor-quality case-control studies or cohort studies; Grade D refers to troublingly inconsistent or inconclusive studies. LOE will also be assessed as D if one recommendation is an expert opinion formulated without explicit critical appraisal of evidence.

might be limitations. However, we evaluated the overall quality of the included guidelines based on two commonly used methods: 1) number of domains reaching the minimum threshold and 2) overall rating score. The results were similar, indicating that the set minimum threshold and evaluation methods did not significantly affect the appraisal results of the overall quality of the included guidelines and the subsequent extraction results of the recommendations. Second, the inclusion criterion that literature must be published in English may have caused several available guidelines to be omitted.

In conclusion, seven guidelines were included in the present systematic review, and all of them showed the worst applicability scores in the AGREE II instrument. They all weakly recommended MRI for patients with suspected SCI or SCIWORA based on a low LOE.

Declarations of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.spinee.2023.03.003.

References

[1] Ahuja CS, Wilson JR, Nori S, Kotter MRN, Druschel C, Curt A, et al. Traumatic spinal cord injury. Nat Rev Dis Primers 2017;3:17018. https://doi.org/10.1038/nrdp.2017.18.
[2] SCI facts and figures. J Spinal Cord Med 2017;40(6):872–3. https://doi.org/10.1080/10790268.2017.1379938.
[3] Global Burden of Disease Collaborative Network. Global burden of disease study 2019 (GBD 2019) results. Seattle, United States: Institute for Health Metrics and Evaluation (IHME); 2020 http://ghdx.healthdata.org/gbd-results-tool.
[4] Shabani S, Meyer BP, Budde MD, Wang MC. Diagnostic imaging in spinal cord injury. Neurosurg Clin N Am 2021;32(3):323–31. https://doi.org/10.1016/j.nec.2021.03.004.
[5] Eli I, Lerner DP, Ghogawala Z. Acute traumatic spinal cord injury. Neurol Clin 2021;39(2):471–88. https://doi.org/10.1016/j.ncl.2021.02.004.
[6] Sharif S, Jazaib Ali MY. Outcome prediction in spinal cord injury: myth or reality. World Neurosurg 2020;140:574–90. https://doi.org/10.1016/j.wneu.2020.05.043.
[7] Kumar Y, Hayashi D. Role of magnetic resonance imaging in acute spinal trauma: a pictorial review. BMC Musculoskelet Disord 2016;17:310. https://doi.org/10.1186/s12891-016-1169-6.

[8] Anderson DB, Luca K, Jensen RK, Eyles JP, Van Gelder JM, Friedly JL, et al. A critical appraisal of clinical practice guidelines for the treatment of lumbar spinal stenosis. Spine J 2021;21(3):455–64. https://doi.org/10.1016/j.spinee.2020.10.022.

[9] Montero-Odasso MM, Kamkar N, Pieruccini-Faria F, Osman A, Sarquis-Adamson Y, Close J, et al. Evaluation of clinical practice guidelines on fall prevention and management for older adults: a systematic review. JAMA Netw Open 2021;4(12):e2138911. https://doi.org/10.1001/jamanetworkopen.2021.38911.

[10] Lee JL, Matthias MS, Menachemi N, Frankel RM, Weiner M. A critical appraisal of guidelines for electronic communication between patients and clinicians: the need to modernize current recommendations. J Am Med Inform Assoc 2018;25(4):413–8. https://doi.org/10.1093/jamia/ocx089.

[11] Liang N, Wu S, Roberts S, Makaram N, Ngwayi JRM, Porter DE. Critical appraisal of paralyzed veterans of America Guidelines in spinal cord injury: an International Collaborative Study Using the Appraisal of Guidelines for Research and Evaluation II Instrument (AGREE II). Mil Med 2021. https://doi.org/10.1093/milmed/usab465.

[12] Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. BMJ 2009;339:b2535. https://doi.org/10.1136/bmj.b2535.

[13] Erickson J, Sadeghirad B, Lytvyn L, Slavin J, Johnston BC. The scientific basis of guideline recommendations on sugar intake: a systematic review. Ann Intern Med 2017;166(4):257–67. https://doi.org/10.7326/m16-2020.

[14] van Teijlingen E, Hundley V. The importance of pilot studies. Nurs Stand 2002;16(40):33–6. https://doi.org/10.7748/ns2002.06.16.40.33.c3214.

[15] Brouwers MC, Kho ME, Browman GP, Burgers JS, Cluzeau F, Feder G, et al. AGREE II: advancing guideline development, reporting and evaluation in health care. CMAJ 2010;182(18):E839–42. https://doi.org/10.1503/cmaj.090449.

[16] Guan B, Fan Y, Zheng R, Fu R, Yao L, Wang W, et al. A critical appraisal of clinical practice guidelines on pharmacological treatments for spinal cord injury. Spine J 2023;23(3):392–402. https://doi.org/10.1016/j.spinee.2022.09.009.

[17] Zheng R, Guan B, Fan Y, Fu R, Yao L, Wang W, et al. A critical appraisal of clinical practice guidelines for management of four common complications after spinal cord injury. Spine J 2022. https://doi.org/10.1016/j.spinee.2022.12.001.

[18] Simon A, Pratt M, Hutton B, Skidmore B, Fakhraei R, Rybak N, et al. Guidelines for the management of pregnant women with obesity: a systematic review. Obes Rev 2020;21(3):e12972. https://doi.org/10.1111/obr.12972.

[19] Khanji MY, Bicalho VV, van Waardhuizen CN, Ferket BS, Petersen SE, Hunink MG. Cardiovascular risk assessment: a systematic review of guidelines. Ann Intern Med 2016;165(10):713–22. https://doi.org/10.7326/m16-1110.

[20] Acuna SA, Huang JW, Scott AL, Micic S, Daly C, Brezden-Masley C, et al. Cancer screening recommendations for solid organ transplant recipients: a systematic review of clinical practice guidelines. Am J Transplant 2017;17(1):103–14. https://doi.org/10.1111/ajt.13978.

[21] Fehlings MG, Martin AR, Tetreault LA, Aarabi B, Anderson P, Arnold PM, et al. A clinical practice guideline for the management of patients with acute spinal cord injury: recommendations on the role of baseline magnetic resonance imaging in clinical decision making and outcome prediction. Global Spine J 2017;7(Suppl. 3):221S–30S. https://doi.org/10.1177/2192568217703089.

[22] Early acute management in adults with spinal cord injury: a clinical practice guideline for health-care providers. J Spinal Cord Med 2016;31(4):403–79. https://doi.org/10.1080/10790268.2008.11760744.

[23] Roquilly A, Vigue B, Boutonnet M, Bouzat P, Buffenoir K, Cesareo E, et al. French recommendations for the management of patients with spinal cord injury or at risk of spinal cord injury. Anaesth Crit Care Pain Med 2020;39(2):279–89. https://doi.org/10.1016/j.accpm.2020.02.003.

[24] Rozzelle CJ, Aarabi B, Dhall SS, Gelb DE, Hurlbert RJ, Ryken TC, et al. Spinal cord injury without radiographic abnormality (SCIWORA). Neurosurgery 2013;72(Suppl. 2):227–33. https://doi.org/10.1227/NEU.0b013e3182770ebc.

[25] Parthiban J, Zileli M, Sharif SY. Outcomes of spinal cord injury: WFNS Spine Committee Recommendations. Neurospine 2020;17(4):809–19. https://doi.org/10.14245/ns.2040490.245.

[26] Konovalov N, Peev N, Zileli M, Sharif S, Kaprovoy S, Timonin S. Pediatric cervical spine injuries and SCIWORA: WFNS Spine Committee Recommendations. Neurospine 2020;17(4):797–808. https://doi.org/10.14245/ns.2040404.202.

[27] Zhang Z, Li F, Sun T. An expert consensus on the evaluation and treatment of acute thoracolumbar spine and spinal cord injury in China. Neural Regen Res 2013;8(33):3077–86. https://doi.org/10.3969/j.issn.1673-5374.2013.33.001.

[28] The Appraisal of guidelines for research and evaluation (AGREE) II instrument: introduction, user's manual and AGREE II instrument. 2017.

[29] Yousaf T, Dervenoulas G, Politis M. Advances in MRI Methodology. Int Rev Neurobiol 2018;141:31–76. https://doi.org/10.1016/bs.irn.2018.08.008.

[30] Panych LP, Madore B. The physics of MRI safety. J Magn Reson Imaging 2018;47(1):28–43. https://doi.org/10.1002/jmri.25761.

[31] Talbott JF, Huie JR, Ferguson AR, Bresnahan JC, Beattie MS. Dhall SS. MR imaging for assessing injury severity and prognosis in acute traumatic spinal cord injury. Radiol Clin North Am 2019;57(2):319–39. https://doi.org/10.1016/j.rcl.2018.09.004.

[32] Kulkarni MV, McArdle CB, Kopanicky D, Miner M, Cotler HB, Lee KF, et al. Acute spinal cord injury: MR imaging at 1.5 T. Radiology 1987;164(3):837–43. https://doi.org/10.1148/radiology.164.3.3615885.

[33] Bitar R, Leung G, Perng R, Tadros S, Moody AR, Sarrazin J, et al. MR pulse sequences: what every radiologist wants to know but is afraid to ask. Radiographics 2006;26(2):513–37. https://doi.org/10.1148/rg.262055063.

[34] Kaushal M, Shabani S, Budde M, Kurpad S. Diffusion tensor imaging in acute spinal cord injury: a review of animal and human studies. J Neurotrauma 2019;36(15):2279–86. https://doi.org/10.1089/neu.2019.6379.

[35] Clark CA, Werring DJ. Diffusion tensor imaging in spinal cord: methods and applications - a review. NMR Biomed 2002;15(7-8):578–86. https://doi.org/10.1002/nbm.788.

[36] Petersen JA, Wilm BJ, von Meyenburg J, Schubert M, Seifert B, Najafi Y, et al. Chronic cervical spinal cord injury: DTI correlates with clinical and electrophysiological measures. J Neurotrauma 2012;29(8):1556–66. https://doi.org/10.1089/neu.2011.2027.

[37] Martin AR, Aleksanderek I, Cohen-Adad J, Tarmohamed Z, Tetreault L, Smith N, et al. Translating state-of-the-art spinal cord MRI techniques to clinical use: a systematic review of clinical studies utilizing DTI, MT, MWF, MRS, and fMRI. Neuroimage Clin 2016;10:192–238. https://doi.org/10.1016/j.nicl.2015.11.019.

[38] Vedantam A, Jirjis MB, Schmit BD, Wang MC, Ulmer JL, Kurpad SN. Characterization and limitations of diffusion tensor imaging metrics in the cervical spinal cord in neurologically intact subjects. J Magn Reson Imaging 2013;38(4):861–7. https://doi.org/10.1002/jmri.24039.

[39] Szwedowski D, Walecki J. Spinal cord injury without radiographic abnormality (SCIWORA) - clinical and radiological aspects. Pol J Radiol 2014;79:461–4. https://doi.org/10.12659/PJR.890944.

[40] Atesok K, Tanaka N, O'Brien A, Robinson Y, Pang D, Deinlein D, et al. Posttraumatic spinal cord injury without radiographic abnormality. Adv Orthop 2018;2018:7060654. https://doi.org/10.1155/2018/7060654.

[41] Ahuja CS, Schroeder GD, Vaccaro AR, Fehlings MG. Spinal cord injury-what are the controversies? J Orthop Trauma 2017;31(Suppl. 4):S7–S13. https://doi.org/10.1097/bot.0000000000000943.

[42] Connolly SM, Baker DR, Coldiron BM, Fazio MJ, Storrs PA, Vidimos AT, et al. AAD/ACMS/ASDSA/ASMS 2012 appropriate use criteria for Mohs micrographic surgery: a report of the American Academy of Dermatology, American College of Mohs Surgery, American Society for Dermatologic Surgery Association, and the American Society for Mohs Surgery. J Am Acad Dermatol 2012;67(4):531–50. https://doi.org/10.1016/j.jaad.2012.06.009.

[43] Thurnher MM, Bammer R. Diffusion-weighted MR imaging (DWI) in spinal cord ischemia. Neuroradiology 2006;48(11):795–801. https://doi.org/10.1007/s00234-006-0130-z.

[44] Wang M, Dai Y, Han Y, Haacke EM, Dai J, Shi D. Susceptibility weighted imaging in detecting hemorrhage in acute cervical spinal cord injury. Magn Reson Imaging 2011;29(3):365–73. https://doi.org/10.1016/j.mri.2010.10.016.