Review

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Clavien-Dindo classification in spinal surgery

A narrative review

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Abstract

The standardized reporting of postoperative complications is essential for improving surgical quality and comparing outcomes. However, spinal surgery has historically lacked a universal system and has instead relied on ambiguous terms. This narrative review synthesizes the literature on the adaptation, validation, and application of the therapy-based Clavien-Dindo classification (CDC) and its modified versions in spinal surgery. It focuses on studies across various spinal procedures and patient populations. The evidence shows that adapted CDC systems demonstrate good to excellent inter- and intrarater reliability, particularly for severe complications. These systems also facilitate direct comparison of surgical techniques. Moreover, they reveal strong correlations between complication severity, prolonged hospital stay, and patient factors such as frailty. Nevertheless, key limitations include poor correlation with certain long-term patient-reported outcomes. The CDC cannot capture intraoperative events or the cumulative burden of multiple complications. Subjectivity also exists in grading milder events. Recent spine-specific modifications that improve neurologic deficit assessment have enhanced clinical relevance. Overall, the CDC provides a critical framework for standardizing complication reporting in spinal surgery. Optimal application requires awareness of its limitations. In complex scenarios, the CDC may be applied most effectively as a component within more comprehensive, spine-specific taxonomies that incorporate surgical complexity and structured neurological assessment. The CDC remains a vital tool for improving communication, benchmarking, and ultimately enhancing patient care.

Abbreviations: ASIA = American Spinal Injury Association, AVBT = anterior vertebral body tethering, CCI = comprehensive complication index, CDC = Clavien-Dindo classification, CDSC = Clavien-Dindo-Sink classification, mCDSC = modified Clavien-Dindo-Sink classification, mFI = modified frailty index, PSF = posterior spinal fusion, Roye-mCDSC = Roye's modification of the Clavien Dindo Sink classification, SAVES = spinal adverse events severity system.

Keywords: Clavien-Dindo classification, complication reporting, neurologic complications, spinal surgery

1. Introduction

The objective assessment of surgical outcomes is fundamental to advancing clinical care, guiding patient counseling, and directing quality improvement initiatives. At the core of this assessment lies the accurate and standardized reporting of postoperative complications. Historically, spinal surgery has suffered from a profound lack of uniformity in this domain. Complications were often described using subjective and non-comparable terms such as "major or "minor."[1–3] This inconsistency has impeded reliable comparisons of outcomes across different surgical techniques, institutions, and studies. Consequently, it has limited the field's ability to objectively evaluate the safety profile of evolving technologies and complex procedures.[4,5] In response to this challenge, the spine surgery community has looked to adopt and adapt classification systems from other surgical disciplines.

The Clavien-Dindo classification (CDC) was first published in 1992[6] and refined in 2004.[7] It has become the gold standard for complication reporting in general surgery.[8,9] Its principal strength is its therapeutic-based approach. This approach grades a complication from I to V based solely on the level of intervention required to treat it, moving away from subjective impressions of severity. However, the direct translation of a general surgery system to the unique landscape of spinal surgery

Supplemental Digital Content is available for this article.

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Spine Research (2026) 2:3;154–160

Received: 27 March 2026 / Accepted: 25 June 2026

Published online 28 July 2026

http://dx.doi.org/10.1097/br9.0000000000000040

is not without its challenges. Spinal procedures carry a distinct morbidity profile, notably a high risk of neurologic injury. In these complications, a minor intraoperative event can result in major permanent functional disability. This relationship is not perfectly captured by the original CDC.[10] Furthermore, some complications common in spine surgery do not fit neatly into the original framework. Examples include asymptomatic implant failure and dural tears repaired intraoperatively.[11,12] Consequently, the past decade has seen a concerted effort to modify and validate the CDC specifically for orthopedic and spinal applications.

This narrative review traces the evolution of the CDC in spinal surgery, from its initial adaptations to its current applications across a wide spectrum of spinal pathologies. We evaluate its reliability, utility, and limitations. No review to date has systematically compared the reliability, outcome correlation, and subspecialty modifications of the CDC across the broad range of spinal procedures. To address this gap, we synthesize the evidence on these aspects in diverse spinal surgical contexts, thereby providing the comprehensive assessment that is currently lacking. We also discuss emerging spine-specific systems that build upon its foundation. Ultimately, this review offers a comprehensive overview of the CDC's role in standardizing complication reporting and improving patient care.

2. Methods

A literature search was conducted on PubMed and Embase for publications from inception until January 31, 2026, using the following keywords: "Clavien-Dindo" OR "Clavien-Dindo-Sink" OR "Clavien" OR "Dindo" AND "spine surgery" OR "spinal surgery" OR "orthopedic surgery" OR "orthopaedic surgery." The search was limited to English-language publications.

Inclusion criteria were: clinical studies of spinal surgery (including degeneration, trauma, deformity, tumors, inflammation, infection, etc.); validation or reliability studies of the CDC or its modified versions in spinal or orthopedic surgery; comparative effectiveness research using the CDC to assess complication profiles; and cohort studies (prospective or retrospective). Exclusion criteria were: case reports, technical notes, editorials, conference abstracts, and studies not involving spinal surgery.

The initial search yielded 825 records (PubMed: 390; Embase: 435). After removing 303 duplicates, 522 articles underwent title and abstract screening, excluding 414 articles that did not meet the inclusion criteria. The remaining 108 full-text articles were assessed for eligibility, of which 17 were included in this narrative review. The screening process was conducted independently by two authors (ZL and KC), with disagreements resolved by consensus or consultation with a third author (HW).

3. Results

3.1. Origin and initial adaptation in orthopedics

The original CDC is a five-grade system where Grade I represents any deviation from the normal postoperative course not requiring pharmacological, surgical, endoscopic, or radiological interventions; Grade II complications require pharmacological treatment; Grade III complications require surgical, endoscopic, or radiological intervention (subdivided into IIIa, not under general anesthesia, and IIIb, under general anesthesia); Grade IV refers to life-threatening complications requiring intensive care unit management (IVa, single organ dysfunction; IVb, multiorgan dysfunction); and Grade V is the death of the patient.[7] In a pivotal 2012 publication, Sink et al.[13] recognized the need for a standardized system in orthopedics but identified several aspects of the original CDC that were misaligned with orthopedic practice. Their critical modifications, developed for hip preservation surgery, established the template for its use in spine surgery (Table 1). The subcategories for Grades III (IIIa/b) and IV (IVa/b) were eliminated. This was justified by the rarity of complications in orthopedics that are resolved under local anesthesia (making IIIa/b unnecessary) and the extreme rarity of life-threatening single or multiorgan failure following

Table 1

The evolution and spinal adaptation of the CDC.

Core reference(s)	Methodology	Key contribution	Problem solved	Year	Phase
Clavien et al.[6] Dindo et al.[7]	Methodological study with a retrospective cohort analysis	Established the therapy-based five-grade classification as the gold standard for complication reporting in general surgery.	Lack of a uniform, objective standard for reporting surgical complications.	1992, 2004	Foundation
Sink et al.[13]	Methodological study with a reliability analysis	Pivotal initial adaptation: simplified tiers and explicitly defined "chronic disability" as Grade IV, creating the CDSC.	The original CDC was misaligned with the morbidity profile of orthopedic and spinal procedures.	2012	Orthopaedic adaptation
Dodwell et al.[14]	Methodological study with a reliability analysis	The most spine-relevant advancement: created the mCDSC, introducing critical stratification for permanent nerve injuries (IVa vs. IVb).	The original system lacked granularity for the most dreaded complications in spine surgery.	2018	Neurologic refinement
Ridolfi et al.[15]	Methodological study with a reliability analysis	Operationalized the framework for spine surgeons: provided extensive spine-specific clinical examples, confirming high reliability.	Bridged the gap between theoretical framework and clinical practice, reducing interpretive variability.	2024	Spinal contextualization

elective joint or spinal procedures (making IVa/b superfluous). Furthermore, the suffix "d", which denoted complications managed in an outpatient setting, was removed. Instead, the concept of permanent disability or functional impairment was integrated directly into the definition of Grade IV. The resulting adapted five-grade system (Clavien-Dindo-Sink classification, CDSC) thus emphasized the level of intervention and long-term morbidity, with Grade IV explicitly defined as a complication resulting in chronic disability or functional impairment. When tested by ten international surgeons on 44 clinical scenarios, this modified scheme demonstrated high interobserver and intraobserver reliability, showcasing its strong potential to standardize reporting in orthopedics, including spinal surgery.

3.2. Early application and outcome correlation in spinal surgery

The adapted CDC was quickly adopted to grade complications in spinal surgical cohorts. Early studies confirmed its validity and clinical utility. For instance, Camino-Willhuber et al.[16] used it in a multicenter study of 172 adult spinal deformity patients, finding a 30-day complication rate of 45%, with the presence and increasing CDC grade of complications being strongly correlated with a prolonged hospital stay (from 7.8 days with no complications to 17 days with complications) and higher readmission rates. However, whether the CDC grade correlates with long-term patient-reported outcomes remains a critical question. Grainger et al.[17] investigated this directly. Their analysis initially suggested that patients with lower-grade (I/II) complications had significantly greater improvements in pain and disability at two years compared with those with higher-grade (III/IV) complications. This relationship, however, was entirely confounded by baseline factors. Patients with higher-grade complications had undergone surgery on more levels and presented with worse baseline disability and quality of life. After multivariate adjustment, the CDC grade itself showed no significant independent association with 1- or 2-year outcomes. This landmark finding indicated that preexisting patient factors and surgical complexity are stronger determinants of long-term functional outcome than the severity of the perioperative complication itself, challenging a straightforward assumption about the system's predictive value for recovery.

3.3. Refinement for neurologic complications

A significant limitation of the initial adaptation was its insufficient granularity for neurologic complications, which are a primary concern in spine surgery. In 2018, Sink group refined the system for universal orthopedic use, developing the modified Clavien-Dindo-Sink classification (mCDSC).[14] The key advancement was a nuanced stratification of nerve injuries. Under this refinement, a transient neuropraxia resolving with observation only is classified as Grade II, while deficits requiring surgical intervention, such as nerve exploration or hematoma evacuation, are categorized as Grade III. Most importantly, the system now differentiates permanent neurologic injuries: those with potential for functional recovery after treatment (e.g., with tendon transfers or nerve grafting) are designated Grade IVa, whereas irreversible deficits resulting in lasting, significant disability are classified as Grade IVb. This refinement provided a more accurate and clinically relevant framework for assessing the true impact of the most dreaded complications in spine surgery. This validated system demonstrated good interrater and excellent intrarater reliability, making it a practical tool for the spine community.

3.4. Reliability and spine-specific elaboration

The reliability of the mCDSC was formally tested in adult spinal surgery by Ridolf et al.[15] Their study confirmed excellent overall interrater and intrarater reliability. A critical insight was that consensus was strongest for severe complications (Grades III–V), while grading of milder events (Grades I and II) exhibited only moderate to good agreement. This gradient reflects the inherent subjectivity in judging minor deviations from the normal postoperative course. The principal contribution of this work was not altering the framework but meticulously elaborating it with spine-specific clinical examples. The authors populated each grade with highly relevant scenarios, particularly for neurological injury, such as differentiating a transient C5 palsy (Grade II) from a permanent but reconstructable deficit (Grade IVa) and a devastating permanent paralysis (Grade IVb). This work effectively translated the validated mCDS framework into a practical, context-rich tool for spine surgeons, mitigating interpretive variability.

3.5. Utility in comparing surgical techniques

The standardized nature of the CDC/mCDSC allows for direct, objective comparison of complication profiles between different surgical techniques. Chen et al.[18] leveraged this in a network meta-analysis of 18 randomized controlled trials comparing discectomy techniques for lumbar disc herniation. Using the CDC, they found that while direct comparisons were often underpowered, statistical ranking indicated that percutaneous endoscopic lumbar discectomy ranked best for overall and Grade I complications, while microdiscectomy had the lowest intraoperative complication rates. This provides a procedure-specific safety ranking based on complication severity, invaluable for surgical decision-making. More recently, Vorhies et al.[19] used the Roye modification of the Clavien-Dindo-Sink classification (Roye-mCDSC) to provide a stark comparison between anterior vertebral body tethering (AVBT) and posterior spinal fusion (PSF) for idiopathic scoliosis. They classified 49% of complications after AVBT as severe (Grade III or higher), with 42% being Grade IIIb requiring unplanned surgery. This Roye-mCDSC-based analysis objectively quantified a more severe complication spectrum for the newer AVBT technique compared with the established PSF standard, where severe complications are documented in only about 7% of cases.

3.6. Applications in pediatric spinal deformity

The mCDSC has been extensively applied and further adapted in pediatric spinal deformity surgery. Keil et al.[20] retrospectively reviewed 424 adolescent idiopathic scoliosis patients undergoing PSF. Using the mCDSC, they found nearly half experienced at least one complication, with 15% having clinically significant events (mCDSC ≥ II)—a rate substantially higher than typically found in surgeon-reported registries. This highlights the system's value in capturing the true scope of postoperative morbidity, essential for realistic patient counseling. To improve granularity, Guissé et al.[21] added "prolonged initial hospital stay" as a Grade II criterion for adolescent idiopathic scoliosis, better capturing common postoperative courses requiring extended care without reoperation. This adapted system showed very good reliability. For Early-Onset Scoliosis, the Roye-mCDSC was adapted by subdividing Grade III into IIIa (unplanned readmission) and IIIb (unplanned reintervention), better distinguishing the clinical significance and resource utilization between these events.[22] This adaptation achieved substantial to near-perfect reliability among pediatric spine surgeons.

3.7. Use in high-risk populations

The CDC is particularly useful in stratifying risk in complex patient populations. Multiple studies have demonstrated its effectiveness in capturing escalating risk related to frailty and obesity. Owodunni et al.[23] showed a clear correlation between CDC grade, frailty (measured by the risk analysis index), and obesity. Rates of CD III complications rose from 2.1% in robust patients to 12.1% in the very frail, and CD IV complications from 1.1% to 13.8%, with frailty and obesity having a synergistic deleterious effect. Similarly, in spinal oncology, Bangash et al.[24] used the CDC (Grade III–V representing major morbidity/mortality) in surgery for spinal metastases. They found that unplanned surgery did not predict major complications. Instead, independent predictors were patient frailty, preoperative hematological derangements, and surgical complexity. Matsuo et al.[25] prospectively found that a modified frailty index (mFI) ≥ 0.27 was not only a predictor of complications but was strongly correlated with higher CDC grades, indicating that frailty is associated with more severe adverse events, not just a higher incidence. These studies underscore the CDC's utility in focusing preoperative risk stratification on modifiable biologic variables.

3.8. Limitations and evolving spine-specific frameworks

Despite its widespread adoption, the Clavien-Dindo system is not without criticism when applied to spine surgery, highlighting areas for improvement and the potential need for adjunctive systems. Bortz et al.[26] presented a pointed critique regarding its application in cervical deformity surgery. They identified several critical limitations. First, in their study, higher CDC grades did not associate with increased estimated blood loss, prolonged length of stay, or inferior 1-year health-related quality of life outcomes, suggesting a poor correlation with certain meaningful outcomes. Second, the classification does not account for intraoperative complications (e.g., dural tear, vascular injury managed during the index surgery) or delayed radiographic complications (e.g., junctional kyphosis, implant failure without immediate symptoms), which are frequent in cervical deformity surgery and significantly impact long-term recovery. Moreover, the system assigns a single grade based on the most severe complication, completely overlooking the cumulative effect of multiple complications—a common scenario in complex spinal procedures that undoubtedly affects patient recovery. These shortcomings underscore that the CDC, while valuable, can lack the specificity and sensitivity needed to capture the unique morbidity profile of complex spinal patients, necessitating a more specialized taxonomy. A summary of key studies and limitations is provided in Table S1, Supplemental Digital Content, https://links.lww.com/SPRES/A6.

3.9. Beyond a single grade: the development of spine-specific classifications

The limitations of the CDC have spurred the development of novel, comprehensive spine-specific complication classification systems. One of the most advanced proposals to date comes from Farshad et al.[27] Their framework moves beyond a single grade to incorporate four axes: surgical complexity (Grades I–III), complication type (surgical or medical), therapeutic consequence (grades A–E, adapted from CDC), and neurological deficit (assessed with structured scales like American Spinal Injury Association [ASIA] or muscle grading). Analyzing 934 patients, they found a significant association between increasing therapeutic consequence grade and prolonged hospital stay, confirming discriminative validity. Crucially, the length of stay also varied significantly with increasing neurological deficit severity, independent of the therapeutic intervention. This resolves a critical gap in the CDC by specifically capturing the disproportionate functional impact of neural injuries. This system advances standardized reporting by simultaneously quantifying treatment burden and neurological morbidity, offering a more holistic view of the complication's impact.

4. Discussion

As this narrative review illustrates, the adaptation of the CDC into the mCDSC marks considerable progress in systematizing postoperative outcomes assessment. The core strength of this system lies in its therapy-based foundation. This foundation enhances objectivity. It also demonstrates consistently good to excellent interrater reliability, especially for severe complications. Moreover, it allows for meaningful comparisons across diverse surgical techniques and institutions. The system has further proven valuable in elucidating relationships between

complication severity, extended hospital stays, and patient-specific variables such as frailty.

Nonetheless, this review also underscores several important limitations that necessitate further refinement. The CDC is inherently retrospective and treatment-centered. It does not capture intraoperative adverse events, radiographic abnormalities, or the aggregated burden of multiple complications. All of these are common in complex spinal procedures.[28,29] Critically, higher CDC grades do not invariably predict worse long-term functional outcomes, as demonstrated by Grainger et al.[17] and Bortz et al.[26] Preoperative patient status and surgical complexity often serve as dominant confounding factors.[30–33] To enhance its clinical applicability, the system must evolve in several key aspects.

The CDC does not capture intraoperative adverse events. To address this specific limitation, the spinal adverse events severity system (SAVES) may offer a complementary solution. Originally developed for spine surgery research, SAVES provides a standardized framework to grade both intraoperative and postoperative events. Grading is based on clinical impact and required intervention, using a severity scale that ranges from minor (no or minimal intervention) to catastrophic (permanent neurologic deficit or death).[34] Unlike the CDC, which is inherently treatment-based and retrospective, SAVES explicitly includes intraoperative events and allows for separate grading of surgical versus medical complications.[35] For researchers and clinicians seeking to capture the full intraoperative morbidity profile, using SAVES either alongside the CDC or as an adjunct in prospective registries can fill a critical gap. However, SAVES has not been as widely adopted or validated across diverse spinal pathologies as the CDC. Its grading categories still require some subjective judgment.

Another limitation is that the CDC assigns a single grade based on the most severe complication. This overlooks the cumulative effect of multiple events, which is a common scenario in complex spinal surgery. The comprehensive complication index (CCI) is mathematically derived from the CDC grades of all individual complications. It provides a continuous additive score (0–100) that better captures the overall morbidity burden.[36] But several caveats warrant emphasis. First, because the CCI is built directly upon CDC grading, any misclassification or inconsistency in the underlying CDC assignment propagates into the CCI. This renders it equally vulnerable to the same limitations.[37] Second, the CCI is more complex to calculate in routine clinical practice. It requires access to a validated online calculator, which limits its bedside utility. Third, it does not resolve how to weigh functionally disparate events (e.g., a dural tear versus a urinary tract infection) when they co-occur. Therefore, the CCI represents a methodological advance for research settings, particularly in large retrospective analyses. Its routine clinical adoption remains constrained. It is more appropriately viewed as a supplementary metric rather than a replacement for the CDC.

The mCDSC's differentiation between Grade IVa and IVb deficits represents a substantial advance in evaluating neurologic injury, but the determination of "permanence" remains challenging. Future iterations would benefit from incorporating a temporally defined criterion. For instance, permanence could be defined as a deficit persisting beyond one year.[38] More importantly, they should integrate structured neurological assessment tools. For example, nerve root injuries could be graded using the Medical Research Council motor scale,[39] while spinal cord injuries could be classified via the ASIA Impairment Scale or Frankel grade.[40] To make this concrete, we propose the following practical classification. A deficit corresponding to ASIA grade A to C or Medical Research Council ≤ 2 at 12 months typically qualifies as Grade IVb (irreversible significant disability). In contrast, a deficit that has stabilized but allows functional recovery with reconstructive measures (e.g., tendon transfer) may be designated as Grade IVa. Table S2, Supplemental Digital Content, https://links.lww.com/SPRES/A7 provides two clinical scenarios illustrating how these criteria would be applied in practice. This bridges the gap between the theoretical framework and clinical decision-making.

Furthermore, the current CDC framework does not separately classify and grade surgical complications versus medical complications. This distinction is essential for driving specialized quality improvement initiatives.[41] A more robust approach would involve establishing two parallel tracks for categorization, rather than appending a simple modifier. One track would be for procedure-related events (e.g., dural tear, implant malposition, or surgical site infection).[27] The other would be for internal medical events (e.g., hospital-acquired pneumonia, urinary tract infection, or cardiac events).[42] Each track could retain the core therapy-based grading scheme. They would be analyzed independently to better reflect their different origins, management strategies, and implications for system improvement. This separation would allow for more precise benchmarking, better targeted preventive measures, and clearer comparisons across surgical populations.

Looking ahead, the ultimate goal is to transition from a standalone grading tool to an integrated, multiaxial complication reporting system. This system would combine classification, severity grading, and cumulative scoring. A comprehensive system could capture: the type and causality of the complication; the therapeutic intensity (represented by the CDC grade); the anatomical and neurological severity (assessed through structured scales); and the cumulative burden of multiple complications. Building on the pioneering work of Farshad et al.,[27] such a framework would provide a holistic appraisal of postoperative morbidity. It would simultaneously capture intervention requirements, functional impact, and overall morbidity load.

Despite the conceptual advance of such multi-axial frameworks, the mCDSC and the multi-axial system are not mutually exclusive but rather serve complementary roles. The mCDSC offers the advantage of simplicity. It requires only a single therapy-based grade that can be assigned rapidly with good reliability. This makes it well-suited for routine spinal procedures (e.g., discectomy, decompression, and

short-segment fusion). It is also ideal for large-scale registry or quality benchmarking efforts where efficiency and comparability across institutions are paramount. In contrast, the multiaxial system provides greater discriminative capacity by decoupling treatment intensity from neurological consequence and by distinguishing surgical from medical events. This granularity is particularly valuable in complex spinal deformity, revision surgery, or oncologic resections. In these settings, intraoperative events, cumulative morbidity, and nuanced neurological deficits often render a single CDC grade insufficient. However, the multiaxial system demands more extensive data collection, training in neurological grading scales, and has not yet undergone wide external validation. Therefore, the mCDSC remains the pragmatic standard for general use. The multiaxial system is more appropriately reserved for high-risk or research contexts. In these contexts, the full morbidity profile must be disaggregated to inform targeted prevention and preoperative counseling. In this landscape, the CDC/mCDSC would remain essential as the core measure of therapeutic burden, serving as a critical component within a broader, more nuanced spine-specific outcome assessment tool.

5. Conclusions

The adaptation and validation of the CDC for spinal surgery have provided the field with an invaluable and long-overdue tool for standardizing complication reporting. The mCDSC, through its refined neurologic stratification, offers a reliable and practical framework. It improves communication, facilitates outcome comparison, and enhances risk stratification. This is particularly true in complex populations such as the frail or those with spinal tumors. Although not a panacea, its limitations have proven instructive, prompting the development of next-generation, spine-specific classification systems. Hitherto, the mCDSC remains the most robust universal standard available. Its consistent application across research and clinical registries is essential for generating comparable data, benchmarking quality, and ultimately improving the safety and outcomes of spinal surgical care. Surgeons are encouraged to adopt this system while remaining mindful of its constraints and supporting the evolution towards a more robust, multiaxial scoring system that fully captures the spectrum of surgical morbidity.

Acknowledgements

Not applicable.

Ethical statement

Not applicable.

Conflicts of interest

Hongli Wang serves as a member of the Editorial Board of this journal. He was not involved in the editorial review or decision-making process for this manuscript. All editorial decisions were made independently by other members of the Editorial Board who have no conflicts of interest.

Funding source

Not applicable.

Data availability statement

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

Author contributions

ZL—writing—original draft, data curation, formal analysis, investigation, methodology, visualization, writing—review and editing.
KC—writing—original draft, data curation, investigation.
CS—data curation, investigation, methodology.
SY—data curation, investigation, validation.
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XM—resources, supervision.
HW—conceptualization, supervision, project administration, writing—review and editing.
JJ—conceptualization, supervision, project administration, resources.

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How to cite this article: Lin Z, Chen K, Sun C, Yang S, Zou F, Ma X, Wang H, Jiang J. Clavien-Dindo classification in spinal surgery: A narrative review. *Spine Res*. 2026;2(3):154–160. doi: 10.1097/br9.0000000000000040