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Beyond ASIA: Rationale for a Multidomain Spinal Cord Injury Classification and Proposal of the MOSAIC-SCI Framework

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Abstract: ***The American Spinal Injury Association Impairment Scale, derived from the International Standards for Neurological Classification of Spinal Cord Injury, remains the global standard for neurological classification after spinal cord injury. It provides a reproducible method for documenting neurological level, sensory and motor impairment, sacral sparing, completeness of injury, and neurological recovery. However, spinal cord injury is not only a sensorimotor disorder. It is also a mechanical, radiological, autonomic, functional, temporal, and patient-centered condition. The ASIA Impairment Scale does not directly classify vertebral-column instability, MRI cord lesion burden, autonomic dysfunction, respiratory compromise, bladder and bowel dysfunction, sexual dysfunction, neuropathic pain, functional independence, examination reliability, pediatric limitations, geriatric frailty, or confounding neurological and musculoskeletal conditions. This review examines the major limitations of using AIS as a stand-alone spinal injury severity descriptor and proposes an adjunctive multidomain framework termed MOSAIC-SCI. MOSAIC-SCI represents Mechanical morphology, Objective cord imaging, Sensorimotor neurology, Autonomic function, Independence/function, and Confounders/context. The proposed classification retains ISNCSCI/AIS as the neurological core but embeds it within a broader clinical profile relevant to acute care, surgical decision-making, rehabilitation planning, outcome prediction, and patient-centered documentation. MOSAIC-SCI is presented as a hypothesis-generating framework requiring prospective multicenter validation before clinical adoption.***

Keywords: Spinal cord injury; ASIA Impairment Scale; ISNCSCI; spinal cord medicine; autonomic dysfunction; spinal trauma; MRI; functional outcome; SCIM; classification

1. Introduction

The ASIA Impairment Scale has become the dominant clinical language for neurological classification after spinal cord injury. Through the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI), clinicians can determine right and left sensory levels, right and left motor levels, the single neurological level of injury, upper- and lower-extremity motor scores, light-touch and pin-prick scores, sacral sparing, zones of partial preservation and final AIS grade. This standardization has been transformative for trauma care, rehabilitation, multicenter studies, clinical trials and medico-legal documentation [1,2].

The value of ASIA/ISNCSCI is not in dispute. Any contemporary spinal cord injury classification should preserve it as the neurological core. The problem arises when AIS is used as a stand-alone descriptor for the total severity of spinal injury. Spinal cord injury is a multidimensional condition. Motor and sensory impairment are central, but vertebral-column stability, cord compression, intramedullary edema, hemorrhage, autonomic instability, respiratory dysfunction, bladder and bowel impairment, sexual dysfunction, pain, spasticity, functional independence and patient priorities also determine clinical severity.

A patient with a high cervical AIS A injury requiring ventilation is not equivalent to a patient with a low thoracic AIS A injury who later becomes wheelchair independent. A patient with AIS D central cord syndrome may retain ambulation but have disabling hand dysfunction, urinary retention and loss of independence. A sedated polytrauma patient may have objective mechanical and radiological evidence of catastrophic injury but cannot be classified neurologically with confidence during the first 24 hours. A patient with diabetic neuropathy, brachial plexus injury, limb fracture, pre-existing myelopathy or severe pain may have an unreliable motor or sensory examination. These situations are routine rather than exceptional.

This review analyzes the limitations of AIS as a stand-alone spinal injury severity descriptor and proposes MOSAIC-SCI, an adjunctive multidomain framework intended to complement ISNCSCI. MOSAIC-SCI does not attempt to replace ASIA. Instead, it organizes clinically relevant domains around ASIA so that the whole injury phenotype can be communicated more completely.

2. Historical and Conceptual Strengths of ASIA/ISNCSCI

The development of standardized neurological classification was a major advance in spinal cord medicine. Earlier descriptions such as complete paraplegia, incomplete tetraplegia or central cord syndrome were clinically recognizable but insufficiently standardized. ISNCSCI provided a structured examination and classification algorithm that could be taught, reproduced and audited across institutions.

The first major strength of the system is standardization. A clinician can communicate C5 AIS A, T12 AIS D or C4 AIS C in a way that is widely understood. The same framework can be used in the emergency department, acute ward, rehabilitation unit and research registry.

The second strength is anatomical precision. ISNCSCI separates sensory and motor levels and captures asymmetry.

It distinguishes light-touch and pin-prick pathways and requires sacral testing. It also provides total motor and sensory scores that can be followed longitudinally.

The third strength is its use in research. AIS conversion, upper-extremity motor score, lower-extremity motor score and sensory scores are commonly used outcomes in clinical trials and natural history studies. Without a standardized neurological language, comparison between studies would be much weaker.

The fourth strength is medico-legal clarity. A properly performed and dated ISNCSCI examination provides defensible neurological documentation. This is especially valuable because spinal cord injury has profound implications for prognosis, disability and long-term support.

Therefore, the critique presented in this article should not be interpreted as an argument against AIS. The central argument is that AIS should not be forced to perform functions for which it was not designed. It is a neurological impairment scale, not a complete spinal injury severity system.

3. Why AIS Alone is Incomplete

A classification system can be judged by whether it describes the injury, guides treatment, predicts outcomes, communicates across disciplines, captures patient priorities and remains practical in real clinical settings. AIS performs well for standardized neurological documentation. It performs less well when expected to represent mechanical instability, imaging severity, autonomic dysfunction, functional dependency, examination uncertainty and chronological evolution.

The limitation is one of scope. The term spinal cord injury implies a neural lesion, but in practice the clinical syndrome sits within a larger injury ecosystem. The vertebral column may be stable or grossly unstable. The cord may show no signal change, focal edema, long-segment swelling, hemorrhage or transection. The patient may have neurogenic shock, ventilatory failure, urinary retention, bowel dysfunction, sexual dysfunction or autonomic dysreflexia. The patient may be independent, partially dependent or completely dependent. The examination may be reliable, partially reliable or impossible.

A single AIS letter cannot carry all of this information. Even when the full ISNCSCI worksheet is available, the final grade often becomes the headline descriptor. This creates a tendency to compress a multidimensional injury into a single categorical label. MOSAIC-SCI is proposed to reduce this compression.

4. Specific Drawbacks of AIS as a Stand-Alone Severity Descriptor

4.1 Sensorimotor dominance

AIS primarily classifies motor and sensory impairment. This emphasis is appropriate for neurological classification but incomplete for whole-patient injury severity. Spinal cord injury affects autonomic, respiratory, urinary, gastrointestinal, sexual, thermoregulatory and pain pathways as well as voluntary motor and conscious sensory pathways. A system that does not directly represent these domains risks underdescribing morbidity.

4.2 Limited autonomic integration

Autonomic dysfunction can be life-threatening and functionally devastating. Neurogenic shock, bradyarrhythmia, orthostatic hypotension, autonomic dysreflexia, impaired sweating, temperature dysregulation, neurogenic bladder, neurogenic bowel, sexual dysfunction and reproductive consequences are central to SCI care. The International Standards to document Autonomic Function following SCI (ISAFSCI) were developed because autonomic consequences require dedicated documentation [4,5]. Yet autonomic function is not integrated into the AIS grade.

4.3 Sacral-sparing dependency

The distinction between complete and incomplete injury depends heavily on sacral sparing. Voluntary anal contraction, deep anal pressure and S4-S5 light-touch or pin-prick sensation are important, but they may be difficult to assess in sedated, intubated, unconscious, pediatric, intoxicated, embarrassed, painful or polytraumatized patients. Pelvic trauma, perineal injury or prior anorectal disease may further confound the examination. A single equivocal sacral finding may change AIS A to AIS B, C or D.

4.4 Heterogeneity within AIS grades

AIS grades are broad. AIS D may include a patient who walks independently and another who remains dependent because of hand dysfunction, trunk impairment, pain or spasticity. AIS A includes high cervical ventilator-dependent injury and low thoracic complete injury with preserved upper-limb independence. AIS C encompasses a wide spectrum of motor-incomplete injuries. These categories are useful but not sufficiently granular for complete severity description.

4.5 Loss of continuous neurological information

The final AIS grade can overshadow the continuous data contained in the ISNCSCI worksheet. UEMS, LEMS, light-touch score, pin-prick score, motor and sensory zones of partial preservation, sacral sensory pattern, voluntary anal contraction and deep anal pressure may carry important prognostic information. A classification that uses AIS alone may obscure these details.

4.6 Timing sensitivity

Neurological findings after acute SCI evolve with spinal shock, cord edema, hemorrhage, ischemia, decompression, perfusion management and early recovery. An AIS grade recorded in the emergency department may differ from one recorded after surgery, after 72 hours, at discharge or at six months. AIS does not inherently encode the timing of assessment. Without a timing modifier, comparisons may be misleading.

4.7 Acute trauma practicality

A complete ISNCSCI examination requires cooperation, adequate exposure, time, examiner training and clinical stability. Acute trauma patients are often intubated, sedated, intoxicated, delirious, in shock, combative or severely painful. Associated fractures, burns, splints, amputations, chest trauma or head injury may prevent accurate testing. In such patients, assigning a definitive AIS grade may create false precision.

4.8 Confounding conditions

ASIA testing assumes that observed motor and sensory findings reflect spinal cord injury. This assumption may fail in peripheral neuropathy, plexopathy, stroke, traumatic brain injury, cauda equina injury, pre-existing cervical myelopathy, radiculopathy, limb fracture, tendon injury, severe arthritis, contracture or amputation. The 2019 revision improved handling of non-SCI conditions, but confounders are still not represented in the final AIS letter [2,3].

4.9 Lack of MRI burden

MRI identifies biological tissue injury that cannot be derived from examination alone. Cord edema, lesion length, hemorrhage, swelling, compression, transection, tissue bridges, disc herniation, epidural hematoma and ligamentous disruption may influence prognosis and treatment planning. MRI-based systems such as the BASIC score demonstrate the value of structural cord grading [6,7]. AIS does not integrate MRI severity.

4.10 Lack of mechanical morphology

Spine surgeons must determine whether the vertebral column is stable, unstable, translated, distracted, dislocated, ankylosed or deformed. AO Spine classification systems incorporate morphology, neurological status and modifiers for clinical decision-making [8,9]. AIS does not classify vertebral-column instability or surgical morphology.

4.11 Functional outcome mismatch

Function depends on level, completeness, hand use, trunk control, respiration, spasticity, pain, age, comorbidity, bladder/bowel management, rehabilitation access and environment. SCIM was developed to measure independence domains such as self-care, respiration and sphincter management, and mobility [10,11]. AIS grade alone cannot predict independence with sufficient precision.

4.12 Pediatric and geriatric limitations

Children may have difficulty cooperating with sensory, motor and sacral testing. Developmental stage affects reliability. Older patients may have frailty, sarcopenia, cognitive impairment, stenosis, myelopathy, neuropathy and medical comorbidities. These factors influence both classification and outcome.

4.13 Non-traumatic SCI limitations

SCI may result from tumor, infection, degenerative compression, vascular insult, inflammatory myelitis, metabolic disease or iatrogenic injury. AIS can document impairment but does not classify etiology, tempo, reversibility, instability, infection burden, oncological instability or vascular mechanism.

4.14 Patient-priority mismatch

Patient priorities often include hand function, walking, bladder control, bowel control, sexual function, pain relief, independence and participation. These outcomes are not captured directly by AIS. A classification that does not map to patient priorities may be clinically standardized yet incomplete for counseling and shared decision-making.

5. Requirements for a Modern Multidomain Classification

A comprehensive spinal cord injury classification should retain ASIA/ISNCSCI while adding domains that are already central to clinical care. It should describe mechanical morphology, objective imaging burden, sensorimotor neurology, autonomic dysfunction, functional independence and the context in which the assessment was performed. It should be usable at admission, after intervention, at discharge and during follow-up. It should allow known domains to be coded even when other domains are not testable.

The ideal system should also avoid unnecessary duplication. Existing instruments should be embedded rather than replaced. For example, AIS should remain the neurological standard, AO Spine descriptors can inform mechanical classification, MRI-based grading can inform objective cord burden, ISAFSCI can inform autonomic documentation, and SCIM/GRASSP/WISCI can inform functional grading.

MOSAIC-SCI was designed around these principles. It is proposed as a structured clinical phenotype rather than a replacement for existing validated systems.

6. Proposed Classification: MOSAIC-SCI

MOSAIC-SCI is an adjunctive multidomain framework. The acronym represents Mechanical morphology, Objective cord imaging, Sensorimotor neurology, Autonomic function, Independence/function and Confounders/context. The code is written as M-O-S-A-I-C, optionally followed by timing modifiers.

For example, M4-O4-S4-A4-I4-C0/T1 describes gross mechanical instability, severe MRI cord tissue injury, complete sensorimotor injury, life-threatening autonomic dysfunction, complete functional dependency, no major confounder and assessment within 24 hours. In contrast, M1-O2-S1-A2-I2-C4/C6/T2 describes a stable or mildly unstable stenotic cervical injury with moderate imaging abnormality, motor-incomplete neurology, bladder/autonomic involvement, moderate dependency, pre-existing spine disease, geriatric/frailty context and assessment within 24-72 hours.

The system is intentionally modular. A clinician may complete M and O from imaging, S from ISNCSCI, A from bedside autonomic and organ-system assessment, I from functional evaluation and C from context. Domains that are unavailable are marked as X rather than guessed.

7. MOSAIC-SCI Domain Descriptions

7.1 M domain: Mechanical morphology and stability

The M domain describes vertebral-column injury and stability. It does not replace AO Spine systems but provides a simplified severity code that can be paired with AO descriptors. M0 indicates no structural instability. M1 and M2 describe stable injuries or compressive patterns. M3 and M4 represent injuries requiring stabilization or gross instability such as fracture-dislocation, translation, distraction, bilateral facet dislocation or ankylosed-spine fracture. MX is used when imaging is incomplete.

7.2 O domain: Objective cord imaging burden

The O domain grades MRI cord injury. O0 denotes normal cord signal. O1 indicates focal T2 hyperintensity. O2 denotes more extensive non-hemorrhagic signal change. O3 denotes circumferential edema, swelling, severe residual compression or long-segment involvement. O4 denotes intramedullary hemorrhage, tissue disruption, cord transection or absent tissue bridge. OX is used when MRI is unavailable, contraindicated or nondiagnostic.

7.3 S domain: Sensorimotor neurology

The S domain preserves formal ISNCSCI/AIS. S0 corresponds to normal neurology or AIS E. S1 describes mild motor-incomplete injury, generally high-function AIS D. S2 describes moderate motor-incomplete injury, generally AIS C or low-function AIS D. S3 describes sensory-incomplete injury without useful motor function, generally AIS B. S4 describes complete sensorimotor injury, generally AIS A. SX is used when neurological classification is unreliable, incomplete or not testable. The full ISNCSCI worksheet remains mandatory when feasible.

7.4 A domain: Autonomic function

The A domain grades cardiovascular, respiratory, thermoregulatory, sudomotor, bladder, bowel, genital and sexual consequences. A0 indicates no clinically evident autonomic dysfunction. A1 describes mild symptoms. A2 describes organ-system dysfunction requiring routine management. A3 describes significant autonomic dysfunction, recurrent autonomic dysreflexia, symptomatic orthostatic hypotension, complex bladder/bowel dysfunction or respiratory compromise. A4 indicates life-threatening autonomic dysfunction such as neurogenic shock, unstable autonomic dysreflexia or ventilator dependence due to SCI.

7.5 I domain: Independence and functional reserve

The I domain grades functional dependency. It may be informed by SCIM, GRASSP, WISCI, respiratory independence and bedside assessment. I0 indicates independence or near-independence. I1 indicates mild dependency. I2 indicates moderate dependency. I3 indicates severe dependency. I4 indicates complete or near-complete dependency, ventilator dependence or total-care requirement. IX is used when functional status cannot be assessed.

7.6 C domain: Confounders, context and chronology

The C domain modifies interpretation. It is not added to the composite severity score. It records non-SCI neurological confounders, unreliable examination, musculoskeletal confounders, pre-existing spine disease, pediatric limitations, geriatric frailty, non-traumatic etiology, timing, post-intervention status and progressive deterioration. This domain is essential because it tells the reader how much confidence to place in the other domains.

8. Composite Severity Tier

A provisional composite score can be calculated by summing M, O, S, A and I grades. The C domain is excluded because it modifies reliability and interpretation rather than directly grading injury severity. The provisional tiers are mild (0-4), moderate (5-8), severe (9-12), critical (13-16) and catastrophic (17-20).

This composite score should not be used for clinical decision-making until validated. Equal weighting is only a starting hypothesis. Future data may show that certain domains, such as intramedullary hemorrhage or ventilator dependence, require greater weight for mortality or functional prediction.

9. Coding Rules

MOSAIC-SCI should be coded using the best available information at the time of assessment. If a domain is unknown, unavailable or unreliable, the X modifier should be used. Clinicians should not infer MRI grade without MRI, autonomic grade without assessment, or neurological grade in an untestable patient.

The recommended minimum code includes M, O, S, A, I and C/T. For example, M3-O2-SX-AX-IX-C2/T1 is appropriate for a sedated polytrauma patient with unstable fracture and MRI cord edema whose neurological, autonomic and functional status cannot yet be tested.

The code should be repeated serially. Important time points include admission, preoperative assessment, postoperative assessment, 72 hours, discharge, six weeks, three months, six months and one year. Serial coding allows recovery or deterioration to be tracked by domain rather than by AIS conversion alone.

10. Worked Clinical Examples

A complete cervical fracture-dislocation may be coded M4-O4-S4-A4-I4-C0/T1 if gross instability, cord hemorrhage, complete sensorimotor injury, neurogenic shock, ventilator dependence and total care needs are present. This code communicates catastrophic multidomain severity more fully than C5 AIS A alone.

Central cord syndrome in cervical stenosis may be coded M1-O2-S1-A2-I2-C4/C6/T2. Although AIS D may appear favorable, MOSAIC-SCI highlights pre-existing stenosis, geriatric/frailty context, bladder dysfunction and functional dependency.

A sedated thoracolumbar burst fracture patient may be coded M3-O2-SX-AX-IX-C2/T1. This prevents premature neurological certainty while still recording known mechanical and imaging severity.

A thoracic complete SCI patient at six months may remain S4 but improve to I1 if wheelchair independence, self-catheterization and independent bowel program are achieved. This demonstrates that complete neurological injury does not necessarily equal complete functional dependency.

11. Clinical Use Cases

In acute trauma, MOSAIC-SCI can improve clarity when the neurological examination is incomplete. Rather than forcing a definitive AIS grade, the clinician can code known imaging and mechanical domains and mark uncertain domains as X. This is more transparent than assigning a premature letter grade.

For spine surgeons, the M domain links neurological classification to stabilization and decompression decisions. For radiologists, the O domain encourages consistent communication of cord edema, hemorrhage, compression and transection. For rehabilitation teams, the I domain brings independence into the headline classification. For intensivists and urologists, the A domain makes autonomic dysfunction visible. For researchers, the complete profile may reduce heterogeneity within AIS categories.

The system may also improve family counseling. AIS grade is often difficult for families to interpret. A multidomain code accompanied by plain-language explanation can separate neurological completeness, respiratory risk, bladder/bowel needs, mechanical instability and expected rehabilitation burden.

12. Research and Trial Stratification

Clinical trials in SCI often stratify by AIS grade and neurological level. This is necessary but may not be sufficient. Within a single AIS category, patients can differ substantially by MRI lesion burden, mechanical morphology, autonomic status, age, comorbidities and functional reserve. These differences may influence spontaneous recovery, response to intervention and risk of complications.

MOSAIC-SCI may support better trial stratification by capturing injury phenotype. For example, AIS C patients with short-segment edema may be analyzed separately from AIS C patients with hemorrhage and severe autonomic dysfunction. Patients with unreliable early examinations may be identified rather than pooled with reliably classified cases. The framework could also support registry design by standardizing variables that are already collected inconsistently across centers.

The research value of MOSAIC-SCI depends on prospective validation. It must demonstrate reliability, feasibility and incremental predictive value beyond AIS, UEMS/LEMS, MRI grade, AO morphology and baseline functional scales.

13. Proposed Validation Strategy

A multicenter prospective observational study should be conducted before clinical adoption. Eligible patients would include traumatic and non-traumatic SCI across cervical, thoracic, thoracolumbar and conus regions. Pediatric, adult and geriatric patients should be analyzed separately. Domains should be coded at standardized time points: within 24 hours, 24-72 hours, 3-14 days, discharge, three months, six months and 12 months.

Primary outcomes should include AIS conversion, change in UEMS and LEMS, SCIM improvement, independent ambulation, hand-function recovery in cervical SCI, bladder/bowel independence and ventilator independence. Secondary outcomes should include autonomic dysreflexia, orthostatic hypotension, neuropathic pain, spasticity, pressure injury, urinary tract infection, length of stay, mortality and quality of life.

Reliability testing should include interobserver and intraobserver agreement for each MOSAIC domain. Imaging agreement should be tested between radiologists and spine surgeons. Classification performance should be assessed in acute, sedated, pediatric, geriatric and non-traumatic subgroups. Predictive modeling should compare AIS alone with AIS plus MOSAIC domains. Incremental predictive utility should be assessed using discrimination, calibration and decision-curve analysis where appropriate.

14. Limitations of MOSAIC-SCI

MOSAIC-SCI is currently a conceptual framework. It is not validated and should not be presented as superior to AIS or as a replacement for ISNCSCI. Its grading thresholds are provisional. The composite score is not evidence-weighted. Some domains may prove redundant, while others may require refinement.

The framework increases documentation complexity. Busy trauma systems may resist additional coding unless it improves communication or outcomes. MRI, formal autonomic standards, SCIM and GRASSP may not be available in all centers. The X categories mitigate this limitation but also reduce completeness.

Another limitation is overlap with existing systems. MOSAIC-SCI draws from AIS, AO Spine, BASIC-style MRI grading, ISAFSCI and functional instruments. This is intentional integration, but it creates a risk of perceived duplication. The value of MOSAIC-SCI will depend on whether a single organized profile improves clarity compared with separate disconnected documentation.

Finally, spinal cord injury is heterogeneous. Traumatic, degenerative, infectious, neoplastic, vascular and inflammatory etiologies may require different weighting. Pediatric and geriatric versions may require modification.

Future validation should determine whether MOSAIC-SCI remains universal or should be adapted for subgroups.

15. Discussion

The ASIA Impairment Scale is one of the most important achievements in spinal cord medicine, but it is often asked to do more than it was designed to do. It describes neurological impairment. It does not fully describe the mechanical spine, the injured cord on MRI, autonomic instability, functional independence or examination reliability. This distinction matters because treatment decisions, prognosis, rehabilitation planning and patient counseling depend on the total injury phenotype.

MOSAIC-SCI reframes classification as a multidomain profile. Instead of reducing a patient to a single letter, it separates mechanical, imaging, neurological, autonomic, functional and contextual elements. This allows two patients with the same AIS grade to be distinguished by clinically relevant differences. It also allows uncertainty to be made explicit when the examination is incomplete.

The framework aligns with multidisciplinary care. SCI management requires trauma surgeons, spine surgeons, neurosurgeons, rehabilitation physicians, intensivists, radiologists, urologists, nurses, physiotherapists, occupational therapists, psychologists and social workers. Each discipline sees a different dimension of severity. MOSAIC-SCI provides a shared structure for those dimensions.

The most immediate benefit may be in acute documentation. A sedated patient with clear cord injury should not be forced into a definitive AIS category. Conversely, a patient with AIS D should not be assumed to have mild injury if severe hand dysfunction, bladder impairment and dependency are present. MOSAIC-SCI can clarify both scenarios.

The second benefit may be prognostic research. AIS categories are necessary but broad. Adding MRI, autonomic and functional domains may improve prediction of ambulation, hand recovery, independence, bladder/bowel outcome, ventilator independence and complications. However, this remains a hypothesis. Validation is mandatory. The third benefit may be patient-centered communication. Many patients prioritize hand function, walking, bladder/bowel control, sexual function, pain reduction and independence. A classification that formally includes autonomic and functional domains is better aligned with these priorities than a purely sensorimotor grade.

MOSAIC-SCI should therefore be considered a proposal for discussion and study. Its purpose is to stimulate a move from single-axis impairment classification toward integrated injury phenotyping.

16. Conclusion

ASIA/ISNCSCI remains the neurological foundation of spinal cord injury classification. However, AIS alone is insufficient as a comprehensive descriptor of spinal injury severity. Its major limitations include sensorimotor dominance, limited autonomic representation, dependence on sacral sparing, broad heterogeneity within grades, timing sensitivity, limited imaging integration, absence of mechanical morphology, limited functional correlation and incomplete documentation of confounders.

MOSAIC-SCI is proposed as an adjunctive multidomain framework integrating Mechanical morphology, Objective cord imaging, Sensorimotor neurology, Autonomic function, Independence/function and Confounders/context. The framework preserves ASIA/ISNCSCI while expanding documentation to reflect surgical, radiological, autonomic, functional and patient-centered realities.

Prospective multicenter validation is required before MOSAIC-SCI can be recommended for routine clinical use.

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Tables

Table 1: Limitations of AIS as a stand-alone descriptor and MOSAIC-SCI response.

Sensorimotor focus	Autonomic, respiratory, bladder/bowel, sexual, pain and functional domains may be underrepresented.	Adds A and I domains while retaining S/ISNCSCI.
Sacral-sparing dependency	Classification may change on uncertain sacral findings, especially in acute trauma or pediatric patients.	Allows SX and C modifiers when the exam is unreliable.
Broad AIS categories	Patients with the same AIS grade may have markedly different function and prognosis.	Adds imaging, autonomic, functional and context domains.
No mechanical morphology	Surgical instability and fracture-dislocation severity are not captured.	Adds M domain informed by CT/radiographs/AO descriptors.
No MRI burden	Cord edema, hemorrhage, transection and lesion length are not represented.	Adds O domain for objective cord imaging.
Limited functional correlation	Independence, hand function, respiration and sphincter management are not directly graded.	Adds I domain using SCIM/GRASSP/WISCI or bedside equivalent.
Timing sensitivity	Early, post-operative and chronic AIS grades may not be comparable.	Adds T and P modifiers.
Confounders	Neuropathy, TBI, limb injuries and pre-existing myelopathy can distort neurological findings.	Adds C modifiers.

Table 2: Summary of MOSAIC-SCI domains.

M	Mechanical morphology and stability	M0-M4, MX	CT/radiographs; AO Spine descriptors where applicable
O	Objective cord imaging burden	O0-O4, OX	MRI; edema, hemorrhage, compression, transection, tissue bridge
S	Sensorimotor neurology	S0-S4, SX	Formal ISNCSCI/AIS worksheet
A	Autonomic function	A0-A4, AX	Clinical autonomic assessment; ISAFSCI when feasible
I	Independence/function	I0-I4, IX	SCIM, GRASSP, WISCI, respiratory/bladder/bowel independence
C	Confounders/context/chronology	C0-C7, T1-T4, P, R, U	Clinical judgment; timing and reliability documentation

Table 3: M domain: Mechanical morphology and stability.

M0	No structural instability; suspected cord injury without unstable osseous or disco-ligamentous lesion.
M1	Stable degenerative or osseous compression without gross instability.
M2	Stable fracture or stenotic compression with canal compromise but no major translational/distraction instability.
M3	Unstable burst fracture, facet injury, posterior ligamentous complex disruption or injury requiring stabilization.
M4	Fracture-dislocation, translation, distraction, bilateral facet dislocation, ankylosed-spine fracture, gross deformity or high-risk instability.
MX	Mechanical status not assessable or imaging incomplete.

Table 4: O domain: Objective MRI cord injury burden.

O0	Normal cord signal.
O1	Focal T2 hyperintensity without hemorrhage or cord expansion.
O2	More extensive T2 hyperintensity without hemorrhage.
O3	Circumferential edema, marked swelling, long-segment lesion or severe residual compression.
O4	Intramedullary hemorrhage, tissue disruption, cord transection, absent tissue bridge or extensive necrosis.
OX	MRI unavailable, contraindicated or nondiagnostic.

Table 5: S domain: Sensorimotor neurological status.

S0	Neurologically normal or AIS E after prior deficit.
S1	Mild motor-incomplete injury; generally high-function AIS D.
S2	Moderate motor-incomplete injury; generally AIS C or low-function AIS D.
S3	Sensory-incomplete injury without useful motor function below the neurological level; generally AIS B.
S4	Complete sensorimotor injury; generally AIS A.
SX	Neurological examination unreliable, incomplete or not testable.

Table 6: A domain: Autonomic function

A0	No clinically evident autonomic dysfunction.
A1	Mild autonomic symptoms not requiring major intervention.
A2	Bladder, bowel, genital/sexual, sudomotor or thermoregulatory dysfunction requiring routine management.
A3	Significant autonomic dysfunction: recurrent autonomic dysreflexia, symptomatic orthostatic hypotension, complex bladder/bowel dysfunction or respiratory compromise.
A4	Life-threatening autonomic dysfunction: neurogenic shock, unstable autonomic dysreflexia, ventilator dependence due to SCI or severe autonomic instability.
AX	Autonomic function not assessed or not assessable.

Table 7: I domain: Independence and functional reserve.

I0	Independent or near-independent; approximate SCIM 80-100.
I1	Mild dependency; approximate SCIM 60-79.
I2	Moderate dependency; approximate SCIM 40-59.
I3	Severe dependency; approximate SCIM 20-39.
I4	Complete or near-complete dependency; SCIM <20, ventilator dependence or total-care requirement.
IX	Functional status not assessed or not assessable.

Table 8: C domain: Confounders, context and chronology modifiers.

C0	No major confounder.
C1	Non-SCI neurological confounder: stroke, neuropathy, plexopathy, peripheral nerve injury or traumatic brain injury.
C2	Unreliable examination: sedation, intubation, delirium, intoxication, severe pain or poor cooperation.
C3	Musculoskeletal confounder: fracture, amputation, burn, contracture, arthritis or tendon injury.
C4	Pre-existing spine disease: stenosis, myelopathy, OPLL, deformity, previous SCI or previous surgery.
C5	Pediatric or developmental limitation.
C6	Geriatric or frailty modifier.
C7	Non-traumatic etiology: tumor, infection, vascular, inflammatory, degenerative or iatrogenic.
T1	Examination within 24 hours.
T2	Examination 24-72 hours.
T3	Examination 3-14 days.
T4	Examination after 14 days or chronic stage.
P	Post-intervention examination.
R	Recurrent or progressive neurological deterioration.
U	Uncertain chronology.

Table 9: Provisional composite severity tiers

0-4	Mild	Low multidomain burden; usually stable, limited imaging abnormality and functional reserve preserved.
5-8	Moderate	Meaningful deficit or imaging/mechanical burden but without critical multisystem impairment.
9-12	Severe	High burden in several domains; likely substantial rehabilitation needs.
13-16	Critical	Major neurological, imaging, autonomic or functional burden; high morbidity.
17-20	Catastrophic	Extreme multidomain injury burden; often gross instability, severe cord tissue injury, complete injury and major autonomic/dependency burden.

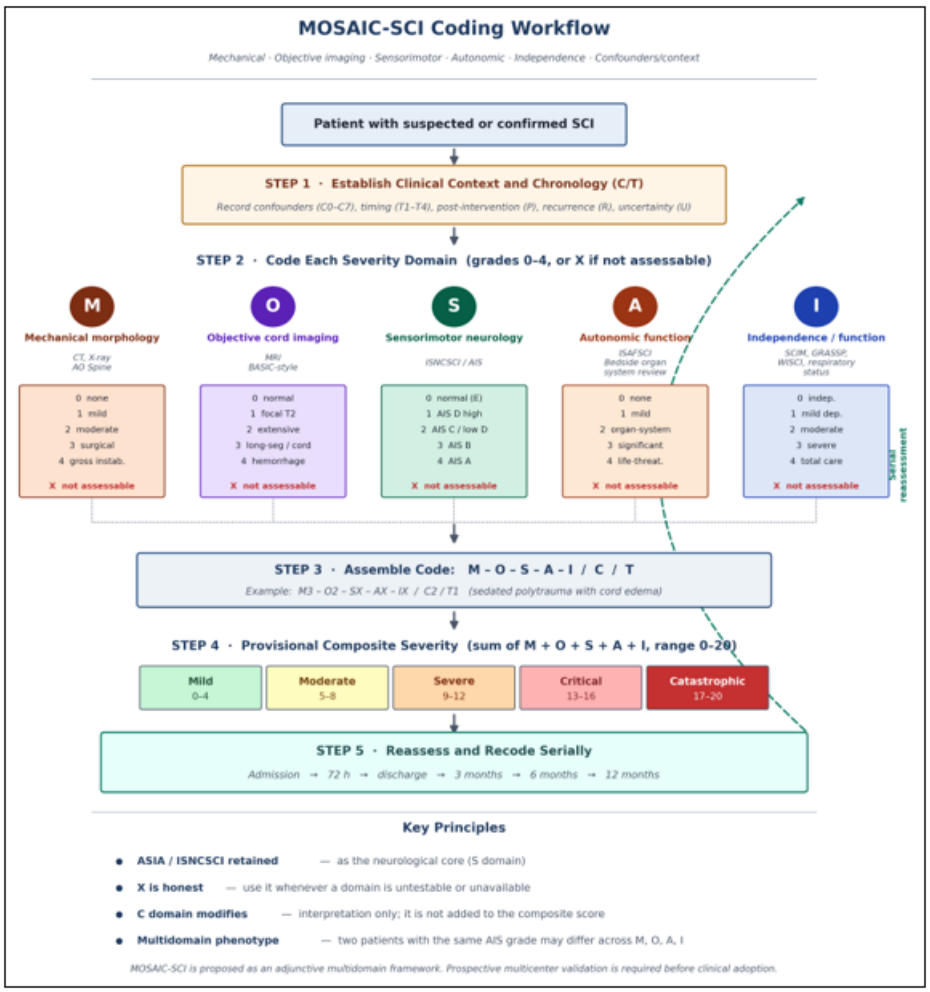
Table 10: Worked examples of MOSAIC-SCI coding.

Complete cervical fracture-dislocation	C5-C6 dislocation, cord hemorrhage, C5 AIS A, neurogenic shock, ventilator dependence	M4-O4-S4-A4-I4-C0/T1	Catastrophic multidomain burden.
Central cord syndrome	Cervical stenosis, focal edema, C4 AIS D, urinary retention, hand dysfunction, older patient	M1-O2-S1-A2-I2-C4/C6/T2	AIS D alone underrepresents hand, bladder and dependency burden.
Sedated polytrauma	Thoracolumbar burst fracture, MRI edema, intubated and sedated	M3-O2-SX-AX-IX-C2/T1	Known mechanical/imaging injury with honest uncertainty in test-dependent domains.
Thoracic complete SCI at follow-up	T10 AIS A but wheelchair independent, self-catheterizing, independent bowel care	M3-O3-S4-A2-I1-C0/T4/P	Complete neurological injury does not equal complete functional dependency.

Table 11: Proposed validation strategy

Design	Prospective multicenter observational cohort.
Population	Traumatic and non-traumatic SCI; cervical, thoracic, thoracolumbar, conus; pediatric/adult/geriatric analyzed separately.
Time points	Within 24 hours, 24-72 hours, 3-14 days, discharge, 3 months, 6 months and 12 months.
Primary outcomes	AIS conversion, UEMS/LEMS change, SCIM, ambulation, hand recovery, bladder/bowel independence, ventilator independence.
Secondary outcomes	Autonomic dysreflexia, orthostatic hypotension, pain, spasticity, pressure injury, UTI, length of stay, mortality, quality of life.
Reliability	Interobserver and intraobserver agreement; junior/senior agreement; radiologist/spine surgeon imaging agreement.
Predictive analysis	Compare AIS alone with AIS plus MOSAIC domains using discrimination, calibration and incremental value metrics.

Figure



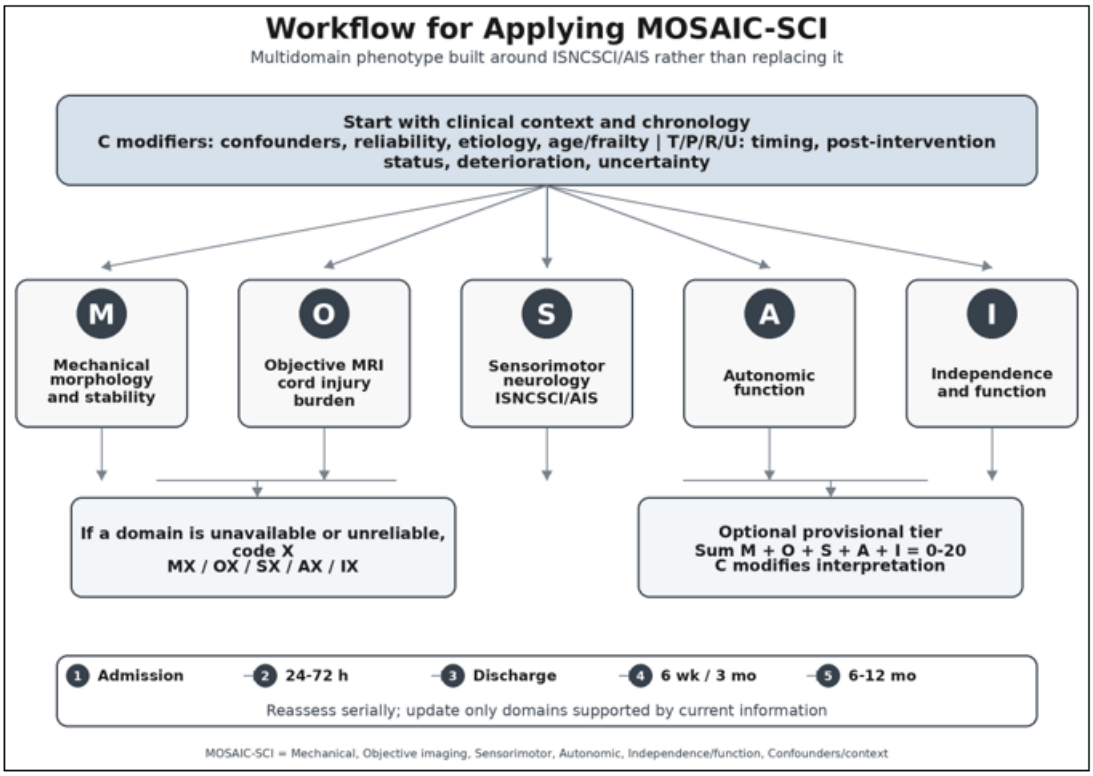


Figure 1: Workflow for applying MOSAIC-SCI. The framework begins with clinical context and chronology, then codes mechanical morphology, MRI cord burden, sensorimotor neurology, autonomic function and independence. Domains that cannot be assessed are marked X and reassessed serially.