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INPLASY

Clinical Predictors of Degenerative Lumbar Adjacent Segment Disease in Patients Undergoing Spinal Fusion Surgery: An Umbrella Review

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ADMINISTRATIVE INFORMATION

Support - None.

Review Stage at time of this submission - Completed but not published.

Conflicts of interest - M.H.P. reports consultant fees from Medtronic, Globus, and Carlsmed outside the submitted work. H.A.G. and T.Y.K. declare no conflicts of interest.

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 1 August 2026 and was last updated on 1 August 2026.

INTRODUCTION

Review question / Objective The primary objective is to synthesize and critically evaluate the deduplicated meta-analytic evidence on clinical, radiographic, and surgical predictors of adjacent segment disease (ASD) in adults undergoing lumbar spinal fusion, in order to identify which predictors demonstrate robust, credible associations with ASD risk. Specific review questions are:
1. Among patients undergoing lumbar spinal fusion, which patient-level factors are associated with the development of ASD compared with patients without these factors?
2. Among patients undergoing lumbar spinal fusion, which sagittal alignment parameters are associated with the development of ASD compared with patients with normal/unaffected alignment?
3. Among patients undergoing lumbar spinal fusion, which surgical and radiographic factors are associated with the development of ASD compared with patients without these factors?
4. Of the predictors showing statistically significant pooled associations with ASD, which demonstrate consistent, robust effects across future populations and other study samples?

Rationale ASD is a recognized long-term complication of lumbar spinal fusion, characterized by symptomatic degeneration of the mobile spinal segments immediately cephalad or caudad to a prior arthrodesis. Clinically, ASD may present as recurrent back pain, radiculopathy, or neurogenic claudication, and can necessitate revision surgery. Proposed mechanisms include altered biomechanical load transfer across the fused construct, increased motion and force at adjacent mobile segments, and iatrogenic disruption of posterior stabilizing structures.

A substantial secondary literature of systematic reviews and meta-analyses (MA) has examined

demographic, clinical, radiographic, and surgical predictors of ASD following lumbar fusion. However, individual MA typically evaluate only a subset of candidate predictors, frequently draw on overlapping primary studies, and report inconsistent effect metrics and comparison groups. This overlap and heterogeneity make it difficult to distinguish predictors with genuinely robust associations from those whose apparent significance is an artifact of study duplication or methodological variation. Consequently, despite an extensive body of primary and secondary evidence, no validated, evidence-based risk calculator exists to identify patients at elevated ASD risk prior to fusion.

An umbrella review addresses this gap. By systematically identifying overlap across existing MA, deduplicating shared primary studies, and re-pooling effect estimates, an umbrella review generates corrected, non-redundant summary associations. This framework additionally supports formal appraisal of evidence credibility for each predictor through prediction intervals, small-study effect testing, and excess significance bias testing rather than relying on nominal statistical significance alone, which individual MA cannot provide in isolation. To the authors' knowledge, no umbrella review has synthesized ASD risk factors following lumbar spinal fusion.

Condition being studied ASD.

METHODS

Search strategy PubMed: ((“Spinal Fusion”[Mesh] OR “spinal fusion”[tiab] OR “lumbar fusion”[tiab]) AND “lumbar”[tiab]) AND (“Spinal Fusion/adverse effects”[Mesh] OR “adjacent segment disease” [tiab] OR “adjacent segment pathology”[tiab] OR “adjacent segment degeneration”[tiab] OR “ASD” [tiab]) AND (“risk factors”[Mesh] OR “predictors” [tiab] OR “associated with”[tiab]) AND (“age”[tiab] OR “osteoporosis”[tiab] OR “sarcopenia”[tiab] OR “bone mineral density”[tiab] OR “PI-LL mismatch” [tiab] OR “alignment”[tiab] OR “fusion level”[tiab] OR “construct length”[tiab] OR “surgical technique”[tiab] OR “rod material”[tiab]) NOT (“cervical”[tiab] OR “thoracic”[tiab])

Embase: ('spinal fusion'/exp OR 'spinal fusion':ti,ab OR 'lumbar fusion':ti,ab) AND 'lumbar':ti,ab AND ('adjacent segment disease':ti,ab OR 'adjacent segment degeneration':ti,ab OR 'adjacent segment pathology':ti,ab OR 'asd':ti,ab) AND ('risk factor'/exp OR 'predictor':ti,ab OR 'associated with':ti,ab) AND ('age':ti,ab OR 'osteoporosis':ti,ab OR 'sarcopenia':ti,ab OR 'bone mineral density':ti,ab OR 'pi-ll mismatch':ti,ab OR 'alignment':ti,ab OR 'fusion level':ti,ab OR 'construct length':ti,ab OR 'surgical technique':ti,ab OR 'rod material':ti,ab) NOT ('cervical':ti,ab OR 'thoracic':ti,ab) AND [humans]/lim AND [english]/lim AND [20152025]/py

Web of Science: TS=("spinal fusion" OR "lumbar fusion") AND TS=("lumbar") AND TS=("adjacent segment disease" OR "adjacent segment pathology" OR "adjacent segment degeneration" OR "ASD") AND TS=("risk factors" OR "predictors" OR "associated with") AND TS=("age" OR "osteoporosis" OR "sarcopenia" OR "bone mineral density" OR "PI-LL mismatch" OR "alignment" OR "fusion level" OR "construct length" OR "surgical technique" OR "rod material") NOT TS=("cervical" OR "thoracic").

Participant or population Adult human patients undergoing lumbar spinal fusion surgery for degenerative lumbar spine conditions.

Intervention Any candidate clinical, radiographic, or surgical predictor of ASD, including but not limited to: age, sex, diabetes, bone mineral density, body mass index (BMI), smoking, preoperative adjacent disc degeneration (Pfirrmann grade ≥3 vs <3), preoperative Japanese Orthopaedic Association (JOA) score, sacral inclusion, fusion length, superior facet joint violation, and sagittal alignment parameters (preoperative lumbar lordosis, postoperative pelvic tilt, postoperative pelvic incidence, sacral slope, pelvic incidence–lumbar lordosis mismatch, lumbosacral sagittal plumb-line distance).

Comparator Patients with absence of the given exposure (e.g., non-smokers; lower BMI; younger age; normal alignment). Inconsistent directionality of reference groups across reviews will be harmonized prior to pooling.

Study designs to be included Peer-reviewed systematic reviews that performed quantitative meta-analysis for each predictor of a patient-level, surgical, or radiographic risk factor for ASD following lumbar spinal fusion.

Eligibility criteria Exclusion criteria is as follows:
- Population: animal models and cadaveric/biomechanical studies; patients undergoing cervical or thoracic spinal fusion; patients undergoing fusion for non-degenerative indications (trauma, tumor, infection, deformity).
- Intervention: predictors evaluated only in cervical/thoracic fusion; predictors reported in only a single primary study without meta-analytic pooling;

predictors assessed exclusively in non-degenerative fusion surgery.
- Other: articles published in language other than English, articles published before the year 2015.

Information sources PubMed, Embase, and Web of Science (Science Citation Index Expanded).

Main outcome(s) Development of radiographically confirmed adjacent segment disease in the lumbar spine adjacent to the fusion construct. Variation in the operational definition of ASD across source reviews will be recorded and considered qualitatively.

Data management Records retrieved from all databases are imported into Covidence, where duplicate records are removed prior to screening.

Quality assessment / Risk of bias analysis Methodological quality will be assessed using AMSTAR-2 and risk of bias will be assessed using ROBIS, Egger's test for small-study effects, Ioannidis' criteria for excess significance bias. Certainty of evidence will be assessed using the GRADE approach.

Strategy of data synthesis Data will be combined using random-effects meta-analysis performed in R (version 4.5.0) using the metaumbrellapackage (version 1.1.0), with Hartung-Knapp-Sidik-Jonkman (HKSJ) variance correction. For each candidate predictorreported in ≥2 eligible meta-analyses, overlapping primary studies will first be identified using a corrected coverage area (CCA) matrix and deduplicated (retaining the primary study from the higher AMSTAR-2-rated review) to prevent double-counting. De-duplicated primary study data will then be re-pooled to generate a single corrected summary estimate per predictor. Categorical predictors will be reported as pooled odds ratios (OR); continuous predictors reported on differing scales (mean difference, standardized mean difference, weighted mean difference) will be standardized to Hedges' g standardized mean difference (SMD) prior to pooling. Predictors operationalized differently across reviews (e.g., age as a binary versus continuous variable) will be pooled separately rather than combined into a single estimate. Between-study heterogeneity will be quantified using I^2. For each pooled estimate, 95% confidence intervals, 95% prediction intervals, Egger's test for small-study effects, and Ioannidis' test for excess significance bias will be calculated to assess the credibility and consistency of each association. A p-value < 0.05 will be considered statistically significant.

Subgroup analysis None.

Sensitivity analysis Restriction of primary studies or source MA to the highest quality article based on AMSTAR-2 criteria. Running each pooled estimate without deduplication.

Language restriction English language only.

Country(ies) involved United States.

Other relevant information Nonr

Keywords adjacent segment disease; risk factors; lumbar fusion; spine surgery; risk calculator; umbrella review.

Contributions of each author

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