Research

Peer-Reviewed Publications on SDI Biomarkers from Our Research Team and the Scientific Community

SURGEON
DECISION
INTELLIGENCE

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1 Paraspinal muscles

1.1 Prognostic / outcome-associated studies

1.1.1 Relationship between posterior paraspinal muscle fat infiltration and early conversion to lumbar spinal fusion following decompression surgery

Erika Chiapparelli[1], Thomas Caffard[1,2], Samuel J Medina[1], Krizia Amoroso[1], Jiaqi Zhu[1,3], Ali E Guven[1], Gisberto Evangelisti[1,4], Jan Hambrecht[1], Paul Kohli[1,5], Koki Tsuchiya[1,6], Vidushi Tripathi[1], Bruno Verna[1], Jennifer Shue[1], Andrew Sama[1], Federico P Girardi[1], Frank P Cammisa[1], Alexander P Hughes[7]

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Published: June 13th, 2025. European Spine Journal.

Link to full article:

Objective:

- To investigate if changes in the posterior paraspinal muscles (PPM) are associated with early conversion to lumbar fusion procedure after first-time laminectomy

Study design:

- Retrospective review of a prospectively collected database of patients undergoing lumbar fusion procedure between 2014 and 2013

Key findings:

- Higher PPM fatty infiltration (FI) was associated with early conversion to fusion. Early converters had significantly higher total PPM FI (median 53.2% [IQR 52.4–54.8]) than late converters (median 51.1% [IQR 44.9–57]); p = 0.03
- Sagittal alignment did not differ between timing groups. No significant differences were found in alignment parameters (e.g., SVA, PI–LL, PT, SS) across early/intermediate/late conversion groups
- Common indications for fusion after decompression in this cohort included spondylolisthesis (54%), spinal stenosis (54%), and degenerative disc disease (46%)

TAKE HOME MESSAGE

Higher pre-decompression PPM FI was associated with earlier "failure" of decompression (conversion to fusion within 2 years).

1.1.2 Multifidus Degeneration: The Key Imaging Predictor of Adjacent Segment Disease

Marco D. Burkhard, MD[1,] Erika Chiapparelli, MD[1], Jan Hambrecht, MD[1], Paul Köhli, MD[1], Ali E. Guven, MD[1], Koki Tsuchiya, MD[1], Lukas Schönnagel, MD[1], Thomas Caffard, MD[1], Krizia Amoroso, MD[1], Franziska C. S. Altorfer, MD[1], Gisberto Evangelisti, MD[1], Jiaqi Zhu, MS[2], Jennifer Shue, MS[1], Michael J. Kelly, MD[1], Federico P. Girardi, MD[1], Frank P. Cammisa, MD[1], Andrew A. Sama, MD[1], and Alexander P. Hughes, MD[1]

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Published: November 6th, 2024. Global Spine Journal.

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/39503528/

Objective:

- To identify pre- and perioperative imaging predictors (disc degeneration, paraspinal muscle status, spinopelvic alignment) associated with future revision surgery for adjacent segment disease (ASD) after open posterior lumbar fusion

Study design:

- Retrospective cohort study of prospectively enrolled cohort with >2-year follow-up

Key findings:

- Multifidus (MF) fatty infiltration (FI) was the only independent imaging predictor of ASD revision in multivariable analysis ($P = 0.004$), with OR 1.05 per 1% FI increase (95% CI 1.02–1.09)
- MF FI ≥ 58.3% predicted ASD revision with OR 2.7 (95% CI 1.1–6.5; $P = 0.032$)
- No significant differences in Modic changes or Pfirrmann grades between the ASD group and controls were found

TAKE HOME MESSAGE

Preoperative MF FI was the strongest MRI-based predictor of clinically relevant ASD requiring revision after lumbar fusion.

1.1.3 The Impact of Paraspinal Muscle Degeneration on Oswestry Disability Index Subsections Two Years After Spinal Surgery for Degenerative Lumbar Spondylolisthesis

Jan Hambrecht, MD[1], Paul Köhli, MD[1,2], Roland Duculan, MD[1], Ranqing Lan, MS[3], Erika Chiapparelli, MD[1], Ali E. Guven, MD[1], Gisberto Evangelisti, MD[1], Marco D. Burkhard, MD[1], Koki Tsuchiya, MD[1], Jennifer Shue, MS[1], Andrew A. Sama, MD[1], Frank P. Cammisa, MD[1], Federico P. Girardi, MD[1], Carol A. Mancuso, MD[4,5], and Alexander P. Hughes, MD[1]

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Published: October 16th, 2024. Spine (Phila Pa 1976).

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/39411894/

Objective:

- To investigate how preoperative paraspinal muscle fatty infiltration (FI) affects postoperative Oswestry Disability Index (ODI) subsection scores 2 years after elective lumbar surgery for degenerative lumbar spondylolisthesis (DLS)

Study design:

- Secondary analysis of a prospective study, with outcomes assessed preoperatively and at 2 years postoperatively

Key findings:

- Erector spinae (ES) fatty infiltration (FI) was associated with worse disability postoperatively: Higher ES FI predicted higher (worse) postoperative ODI scores across all subsections and the overall ODI (Est = 0.45, 95% CI 0.20–0.71, P = 0.004)
- Multifidus (MF) FI showed a more specific functional signal. Higher MF FI was significantly associated with worse ODI subsections standing (Est = 0.02, 95% CI 0.01–0.03, P = 0.033) and walking (Est = 0.02, 95% CI 0.01–0.03, P = 0.017) 2 years postoperatively
- Psoas (PS) FI was not a key driver of postoperative ODI in this cohort

TAKE HOME MESSAGE

Higher preoperative ES FI predicts worse overall disability 2 years post DLS surgery, whereas MF FI is linked to greater disability in standing and walking.

1.1.4 Importance of the lumbar paraspinal muscles on the maintenance of global sagittal alignment after lumbar pedicle subtraction osteotomy

Thomas Caffard, MD,[1,2] Artine Arzani, BS,[1] Krizia Amoroso, MD,[1] Erika Chiapparelli, MD,[1]Samuel J. Medina, BS,[1] Lukas Schönnagel, MD,[1,3] Jiaqi Zhu, MA,[4] Bruno Verna, MD,[1] Kyle Finos, BS,[1] Isaac Nathoo, BS,[1] Soji Tani, MD, PhD,[1,5] Gaston Camino-Willhuber, MD,[1] Ali E. Guven, MD,[1] Arman Zadeh, BS,[1] Ek Tsoon Tan, PhD,[6] John A. Carrino, MD,[6] Jennifer Shue, MS,[1] Oliver Dobrindt, MD,[2] Timo Zippelius, MD,[2] David Dalton, MD,[1,7] Andrew A. Sama, MD,[1]Federico P. Girardi, MD,[1] Frank P. Cammisa, MD,[1] and Alexander P. Hughes, MD[1]

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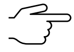
Published: June 7th, 2024. Journal of Neurosurgery.

Link to full article:

 https://pubmed.ncbi.nlm.nih.gov/38848601/

Objective:

- To investigate the influence of preoperative lumbar paraspinal muscle quality on postoperative maintenance of global sagittal alignment after lumbar pedicle subtraction osteotomy (PSO)

Study design:

- Single-center retrospective cohort of 77 primary lumbar PSO patients (2016 – 2021) with pre-op T2w MRI and serial standing whole-spine radiographs

Key findings:

- After adjustment for the aforementioned parameters, the model showed that the multifidus (MF) fatty infiltration (FI) was significantly associated with the postoperative progression of positive sagittal vertical alignment (SVA) over time
- A 1% increase from the preoperatively assessed total MF FI was correlated with an increase of 0.92 mm in SVA postoperatively (95% CI 0.42–1.41, $p < 0.0001$)
- Other sagittal alignment parameters and/or other muscles (e.g., psoas and erector spinae FI) were not significantly correlated with postoperative sagittal alignment maintenance in this analysis

TAKE HOME MESSAGE

Patients undergoing lumbar PSO with severe MF FI may be at higher risk for sagittal decompensation.

1.1.5 Georg Schmorl Prize of the German Spine Society (DWG) 2023: the influence of sarcopenia and paraspinal muscle composition on patient-reported outcomes: a prospective investigation of lumbar spinal fusion patients with 12-month follow-up[1]

Henryk Haffer[1,2], Maximilian Muellner[1,2], Erika Chiapparelli[1], Yusuke Dodo[1], Gaston Camino-Willhuber[1], Jiaqi Zhu[3], Ek T. Tan[4], Matthias Pumberger[2], Jennifer Shue[1], Andrew A. Sama[1], Frank P. Cammisa[1], Federico P. Girardi[1], Alexander P. Hughes[1]

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Published: May 27th, 2024. European Spine Journal.

Link to full article:

Objective:

- To investigate the impact of sarcopenia and lumbar paraspinal muscle composition on patient-reported outcomes (PROMs) after lumbar fusion surgery with 12-month follow-up

Study design:

- Prospective observational investigation of elective lumbar fusion patients with 12-month follow-up

Key findings:

- Higher preoperative fatty infiltration (FI) of the posterior paraspinal muscles predicted worse 12-month disability (Oswestry disability index (ODI)) in multivariable analysis ($\beta = 0.442$, $p = 0.012$) after adjustments of covariates
- Lower psoas FI was associated with worse ODI at 12 months ($\beta = -0.439$, $p = 0.029$) after adjustment of covariates
- Sex-specific differences: univariate analyses suggested that sarcopenia (psoas muscle index at L3) and posterior paraspinal muscle FI related more strongly to worse PROMs in females, whereas in males the association highlighted posterior paraspinal muscle FI with worse ODI

Take Home Message

Preoperative paraspinal muscle quality, especially posterior paraspinal muscle F) helps identify lumbar fusion patients at risk for worse disability (ODI) at 12 months, with notable sex-specific associations.

1.1.6 Importance of the cervical paraspinal muscles in postoperative patient-reported outcomes and maintenance of sagittal alignment after anterior cervical discectomy and fusion

Thomas Caffard, MD,[1,2] Artine Arzani, BS,[1] Bruno Verna, MD,[1] Vidushi Tripathi, BS,[1] Erika Chiapparelli, MD,[1] Lukas Schönnagel, MD,[1,3] Jiaqi Zhu, MA,[4] Samuel J. Medina, BS,[1] Soji Tani, BS,[1,5] Gaston Camino-Willhuber, MD,[1] Ali E. Guven, MD,[1,3] Krizia Amoroso, MD,[1] Ek Tsoon Tan, PhD,[6] John A. Carrino, MD,[6] Jennifer Shue, MS,[1] Oliver Dobrindt, MD,[2] Timo Zippelius, MD,[2] David Dalton, MD,[1] Andrew A. Sama, MD,[1] Federico P. Girardi, MD,[1] Frank P. Cammisa, MD,[1] and Alexander P. Hughes, MD[1]

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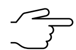
Published: May 3rd, 2024. Journal of Neurosurgery.

Link to full article:

 https://pubmed.ncbi.nlm.nih.gov/38701526/

Objective:

- To investigate how preoperatively assessed cervical paraspinal muscle parameters influence postoperative patient-reported outcomes (PROMs) and maintenance of cervical sagittal alignment after anterior cervical discectomy (ACDF)

Study design:

- Prognostic cohort analysis with prospective enrollment of elective ACDF patients (2015–2018), using preoperative cervical MRI plus pre/post standing lateral radiographs and postoperative Neck Disability Index (NDI) follow-up

Key findings:

- Greater functional cross-sectional area (fCSA) of the posterolateral muscle group at each subaxial level was significantly associated with less progression of C2–7 sagittal vertical axis (SVA) over time

- Less fat infiltration (FI) in the posterolateral group at C4–6 was significantly associated with less progression of C2–7 SVA

- Greater FI of the posteromedial group (multifidus (MF) /rotatores) at C7 correlated with less improvement in NDI at 4–6 months after ACDF

TAKE HOME MESSAGE

Preoperative cervical paraspinal muscle morphology/quality, particularly posterolateral fCSA and FI (notably C7 posteromedial FI), acts as a predictor of both maintenance of sagittal alignment (C2–7 SVA) and postoperative patient-reported recovery (NDI) after ACDF.

1.2 Association studies

1.2.1 Machine learning-based identification and ranking of risk factors for lumbar paraspinal muscle atrophy

Lukas Schönnagel[1,2], Tom Folkerts[3,4], Ali Guven[1,2], Erika Chiapparelli[2], Jiaqi Zhu[5], Gaston Camino-Willhuber[2], Thomas Caffard[2,6], Artine Arzani[2], Paul Köhli[1,2], Marco D. Burkhard[2], Jennifer Shue[2], Andrew A. Sama[2], Federico P. Girardi[2], Frank P. Cammisa[2], Alexander P. Hughes[2]

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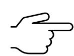
Published: March 28th, 2026. Archives of Orthopaedic and Trauma Surgery.

Link to full article:

 https://pubmed.ncbi.nlm.nih.gov/41915077/

Objective:

- To analyze factors linked to paraspinal (PM) atrophy in patients undergoing lumbar fusion using machine learning, aiming to clarify the multifactorial mechanisms underlying this condition

Study design:

- Retrospective observational study using machine learning models

Key findings:

- Both logistic regression extreme gradient boosting (XGBoost) machine learning models effectively predicted severe multifidus (MF) atrophy, with an area under the curve (AUC) of 0.83 (95% CI 0.74–0.83) for the logistic regression and 0.88 (95% CI 0.81–0.88) for the XGBoost

- In the logistic regression model, only sex, age, and facet joint degeneration were significant predictors

- The XGBoost model identified the same top three variables, while the lumbar endplate score and bone mineral density ranked higher than in logistic regression

TAKE HOME MESSAGE

This study introduced a novel framework for analyzing factors influencing PM atrophy, highlighting the intricate interplay between demographic variables like age and sex and facet joint degeneration. By applying modern machine learning techniques, the predictive accuracy was improved and identified endplate and bone changes as strongly associated factors, offering valuable insights into the mechanisms shaping muscle health in lumbar conditions.

1.2.2 The Association of Vascular Health With Cervical Paraspinal Muscle Atrophy and Disc Degeneration

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Published: March 13th, 2026. Global Spine Journal, online ahead of print.

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/41823596/

Objective:

- To evaluate the relationship between carotid artery stenosis (CAS) and cervical paraspinal muscle atrophy as well as its association with intervertebral disc integrity

Study design:

- Retrospective cross-sectional study

Key findings:

- Higher mean stenosis was significantly associated with increased fatty infiltration (FI) in multiple muscle groups at C3, as well as the posteromedial (PM) at C4 and sternocleidomastoid (SCM) at C5 ($P < 0.05$)
- Higher mean stenosis was significantly associated with reduced functional cross-sectional area (fCSA) in the PM and SCM at C4 ($P < 0.05$)
- Higher maximum stenosis was associated with increased FI in the SCM and trapezius (TP) at C3 and the posterolateral (PL) at C4, along with reduced fCSA in the SCM at C4 ($P < 0.05$).
- No significant associations were observed with disc degeneration.

TAKE HOME MESSAGE

CAS was associated with cervical muscle atrophy, suggesting a potential link with vascular health. In contrast, disc degeneration showed no association with CAS, suggesting that muscle atrophy and disc degeneration may follow distinct pathways.

1.2.3 Associated factors for increased fat infiltration in the erector spinae in patients undergoing lumbar surgery for degenerative conditions

Jan Hambrecht[1], MD, Paul Köhli[1,2], MD, Roland Duculan[1], MD, Ranqing Lan[3], MS, Erika Chiapparelli[1], MD, Ali E. Guven[1], MD, Gisberto Evangelisti[1], MD, Marco D. Burkhard[1], MD, Koki Tsuchiya[1], MD, Lukas Schönnagel[2], MD, Jennifer Shue[1], MS, Andrew A. Sama[1], MD, Frank P. Cammisa[1], MD, Federico P. Girardi[1], MD, Carol A. Mancuso[4,5], MD, Alexander P. Hughes[1], MD

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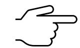
Published: August 4th, 2025. Spine (Phila Pa 1976).

Link to full article:

 https://pubmed.ncbi.nlm.nih.gov/40755221/

Objective:

- To identify demographic, clinical, and radiographic factors associated with increased erector spinae (ES) fat infiltration (FI) in patients undergoing elective lumbar surgery

Study design:

- Single-center secondary analysis of prospectively collected data of elective lumbar surgery patients from 2014–2023

Key findings:

- More severe disc degeneration was independently associated with ES FI > 40%. Higher combined Pfirrmann score: OR 1.2 (95% CI 1.04–1.26), P = 0.004
- More severe vacuum phenomenon was independently associated with ES FI > 40%. Higher combined vacuum severity score: OR 1.3 (95% CI 1.07–1.28), P < 0.001

- Degenerative lumbar scoliosis was independently associated with ES FI > 40%. OR 1.9, P = 0.038.

TAKE HOME MESSAGE

In lumbar surgery candidates, ES FI > 40% was independently linked to more advanced disc degeneration (Pfirrmann), vacuum phenomenon severity, and degenerative scoliosis.

1.2.4 Introducing the Paraspinal Muscle Quality (PMQ) Score: A Novel T2 MRI-Based Intensity Parameter for Lean Muscle Assessment in Spine Patients

Ali E. Guven, MD[1], Kyle Finos, BSc[1], Isaac Nathoo, BSc[1], Paul Köhli, MD[1,2], Marco D. Burkhard, MD[1], Erika Chiapparelli, MD[1], Artine Arzani, MD[1], Jan Hambrecht, MD[1], Gisberto Evangelisti, MD[1], Koki Tsuchiya, MD[1,3], Bruno Verna, MD[1], Jennifer Shue, MS[1], Andrew A. Sama, MD[1], Federico P. Girardi, MD[1], Frank P. Cammisa, MD[1], Alexander P. Hughes, MD[1]

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Published: May 7th, 2025. Spine (Phila Pa 1976).

Link to full article:

Objective:

- To analyze relationships between the novel paraspinal muscle quality (PMQ) score and muscle atrophy parameters, patient demographics, comorbidities, and functional disability

Study design:

- Retrospective cross-sectional study of patients undergoing primary posterior lumbar surgery for degenerative disease (Dec 2014–July 2023)

Key findings:

- PMQ (lean muscle-to-CSF intensity ratio) was reproducible (high interrater reliability). Interclass correlation coefficients (ICC) were 0.867 (95% CI 0.720–0.932) for erector spinae (ES) and 0.874 (95% CI 0.767–0.931) for multifidus (MF)

- PMQ correlated positively with age, female sex, BMI, ASA score, hypertension, and FI, and negatively with vertebral bone mineral density (BMD) and functional cross-sectional area (fCSA)
- Pain intensity was predicted by ES (OR: 6.07, 95% CI: 1.16–31.74, P= 0.033) and MF PMQ scores (OR: 4.88, 95% CI:1.31–18.20, P= 0.019).

TAKE HOME MESSAGE

The PMQ score is a reliable T2-MRI–based marker of lean paraspinal muscle quality (beyond FI and fCSA) and is independently associated with back pain intensity, suggesting value for detecting earlier muscle changes not captured by standard atrophy metrics.

1.2.5 Association between subaxial paraspinal muscle parameters and cervical vertebral bone quality in preoperative patients

Artine Arzani, MD[1], Bruno Verna, MD[1], Thomas Caffard, MD[1,2], Vidushi Tripathi, BS[1], Erika Chiapparelli, MD[1], Gaston Camino-Willhuber, MD[1], Lukas Schönnagel, MD[1,3], Maximilian Muellner, MD[3], Lisa Oezel, MD[4], Ichiro Okano, MD[5], Stephan Salzmann, MD[6], Jiaqi Zhu, MA[7], Ek Tsoon Tan, PhD[8], John A. Carrino, MD[8], Jennifer Shue, MS[1], Timo Zippelius, MD[2], Andrew A. Sama, MD[1], Frank P. Cammisa, MD[1], Federico P. Girardi, MD[1], and Alexander P. Hughes, MD[1]

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Published: April 4th, 2025. Journal of Neurosurgery.

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/40184677/

Objective:

- To explore the relationship between cervical vertebral bone quality (VBQ) scores and subaxial cervical paraspinal muscle parameters

Study design:

- Retrospective review of prospectively collected data in 75 preoperative ACDF patients (2015–2018)

Key findings:

- Anterior muscle functional cross-sectional area (fCSA) at C3 inversely associated with VBQ across levels C2–T1, implying that patients with larger fCSA of this muscle group had lower VBQ scores

- Anterior muscle FI at C3 positively associated with VBQ across levels C2–T1

- C3 is the most “informative” muscle measurement level (highest number of significant associations), suggesting C3 muscle metrics may be representative of bone quality throughout the subaxial spine

TAKE HOME MESSAGE

Preoperative MRI-derived paraspinal muscle morphology, particularly C3 anterior muscle fCSA and FI, showed robust associations with cervical vertebral bone quality (VBQ) across C2–T1, suggesting a potentially practical imaging proxy for assessing subaxial bone quality.

1.2.6 Relationship Between Lumbar Foraminal Stenosis and Multifidus Muscle Atrophy A Retrospective Cross-Sectional Study

Ali E. Guven, MD[1], Lukas Schönnagel, MD[1,2], Erika Chiapparelli, MD[1], Gaston Camino-Willhuber, MD[1], Jiaqi Zhu, MA[3], Thomas Caffard, MD[1,4], Artine Arzani, MD[1], Kyle Finos, BSc[1], Isaac Nathoo, BSc[1], Krizia Amoroso, MD[1], Jennifer Shue, MSc[1], Andrew A. Sama, MD[1], Frank P. Cammisa, MD[1], Federico P. Girardi, MD[1], and Alexander P. Hughes, MD[1]

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Published: August 1st, 2024. Spine (Phila Pa 1976).

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/39087423/

Objective:

- To evaluate the relationship between lumbar foraminal stenosis (LFS) and multifidus muscle atrophy

Study design:

- Retrospective cross-sectional study of patients undergoing posterior lumbar fusion for degenerative lumbar disease (Dec 2014–Feb 2024).

Key findings:

- Upper level foraminal stenosis predicted multifidus (MF) atrophy at L4. In adjusted linear mixed models, greater L2–L3 lumbar foraminal stenosis (LFS) severity significantly predicted higher MF fatty infiltration (FI) (estimate +1.7%, 95% CI 0.1–3.3, P = 0.043) and lower functional cross sectional area (fCSA) (estimate −18.6 mm^2, 95% CI −34.3 to −2.6, P = 0.022) measured at the L4 upper endplate

- The relationship was level-specific (not uniform across the lumbar spine). No significant association was found for L1–L2, L3–L4, or L4–L5 LFS severity with MF atrophy measured at L4, suggesting a more specific "segmental/innervation-related" link rather than a generalized degeneration effect

- An opposite association was reported at L5–S1. Higher L5–S1 LFS severity was associated with a decrease in MF FI (estimate −1.3%, 95% CI −2.4 to −0.3, P = 0.013) at the L4 measurement level

TAKE HOME MESSAGE

In degenerative lumbar fusion patients, the severity of L2–L3 foraminal stenosis was associated with worse MF muscle quality (more FI, less fCSA).

1.2.7 Relationship between facet joint osteoarthritis and lumbar paraspinal muscle atrophy: a cross-sectional study

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Published: June 24th, 2024. Journal of Neurosurgery.

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/38875728/

Objective:

- To quantify atrophy of the psoas (PS), erector spinae (ES), and multifidus (MF) and assess their associations with overall facet joint osteoarthritis (FJOA) burden in the lumbar spine

Study design:

- Retrospective cross-sectional study of surgical patients with available preoperative CT and MRI.

Key findings:

- Only the MF showed an independent association with FJOA burden. After adjustment, higher total FJOA predicted lower MF fCSA (estimate −4.69, 95% CI −6.91 to −2.46; $p < 0.001$) and higher MF FI (estimate 0.64, 95% CI 0.33–0.94; $p < 0.001$)
- No independent association for ES or PS. In adjusted models, ES and PS parameters were not significantly predicted by total FJOA (examples reported: ES fCSA $p = 0.836$; ES FI $p = 0.912$; psoas fCSA $p = 0.335$)
- FJOA was common and most severe at L4–5. Significant FJOA (grade ≥2) was present in 82% of patients, with the highest burden at L4–5 (median right + left Weishaupt grade 5, IQR 2–6).

TAKE HOME MESSAGE

Lumbar facet joint osteoarthritis burden is specifically associated with MF atrophy (more fat, less functional area), but not with ES or PS degeneration.

1.2.8 Association between severity of cervical central spinal stenosis and paraspinal muscle parameters in patients undergoing anterior cervical discectomy and fusion

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Published: April 12th, 2024. Spine (Phila Pa 1976).

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/38605673/

Objective:

- To evaluate the association between the severity and level of cervical central stenosis (CCS) and fat infiltration (FI) of the cervical multifidus/rotatores (MR) across subaxial levels

Study design:

- Retrospective study

Key findings:

- Spinal cord compression at a given level was associated with higher MR FI below that level
- After adjustment for confounders, spinal cord compression at C3/4 and C4/5 was significantly associated with greater FI of the MR from C3 to C6 and C5 to C7, respectively
- Spinal cord compression at C5/6 or C6/7 was significantly associated with greater FI of the MR at C7

TAKE HOME MESSAGE

In ACDF patients, cervical spinal cord compression was associated with increased fatty degeneration of the multifidus /rotatores, especially at levels below the stenosis.

1.3 Comparative studies

1.3.1 Cervical Muscle Composition in Degenerative Dropped Head Syndrome A Propensity Score Matching Study

Thomas Caffard, MD[1,2], Bruno Verna, MD[1], Lukas Schönnagel, MD[1,3], Ali E. Guven, MD[1], Artine Arzani, MD[1], Erika Chiapparelli, MD[1], Marco D. Burkhard, MD[1], Ranqing Lan, MA[4], Jennifer Shue, MS[1], Angela Rosenbohm, MD[5], Jan Kassubek, MD[5], Oliver Dobrindt, MD[2], Andrew A. Sama, MD[1], Federico P. Girardi, MD[1], Frank P. Cammisa, MD[1], Timo Zippelius, MD[2], and Alexander P. Hughes, MD[1]

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Published: June 13th, 2025. Spine (Phila Pa 1976).

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/40509854/ Source

Objectives:

- To compare cervical muscle composition in patients with non-neuromuscular dropped head syndrome (DHS) caused by degenerative disease of the cervical spine to patients without DHS who underwent anterior cervical discectomy and fusion (ACDF) pre-operatively

Study Design:

- Retrospective cross-sectional study of patients between 2012 and 2023

Key findings:

- DHS patients had significantly higher fatty infiltration (FI) in multiple cervical muscle groups compared with patients with degenerative conditions of the cervical spine who underwent ACDF surgery

- DHS patients had significantly higher FI in the anterior muscle group at all levels except C3 ($P < 0.005$ except C3 $P = 0.243$), and also higher FI in the scalenus ($P < 0.01$), suggesting degeneration beyond the classic “posterior extensor weakness only” explanation

- DHS showed consistently higher FI in the posterolateral ($P < 0.001$) and posteromedial ($P < 0.01$) groups across levels, with about ~25% higher FI (posterolateral) and ~30% higher FI (posteromedial) in DHS, plus higher FI in trapezius ($P < 0.005$)

TAKE HOME MESSAGE

Degenerative DHS is associated with widespread cervical muscle degeneration on MRI compared with matched degenerative ACDF patients.

1.3.2 The Association between prior arthroplasty and Paraspinal Muscle Degeneration in patients undergoing elective lumbar surgery

Jan Hambrecht[1], Paul Köhli[1,2], Erika Chiapparelli[1], Jiaqi Zhu[3], Ali E. Guven[1], Gisberto Evangelisti[1], Marco D. Burkhard[1], Koki Tsuchiya[1], Roland Duculan[1], Jennifer Shue[1], Andrew A. Sama[1], Frank P. Cammisa[1], Federico P. Girardi[1], Carol A. Mancuso[4], Alexander P. Hughes[1]

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Published: August 21st, 2024. European Spine Journal.

Link to full article:

Objective:

- To evaluate the association between prior total hip arthroplasty (THA) and/or total knee arthroplasty (TKA) and paraspinal muscle degeneration in patients undergoing elective lumbar surgery for degenerative conditions

Study design:

- Single-center retrospective analysis of elective lumbar surgery patients

Key findings:

- Prior TKA was independently associated with worse multifidus (MF) degeneration: Higher MF fatty infiltration (FI) (Est = +4.3%, $p = 0.013$) and lower MF functional cross-sectional area (fCSA) (Est = −0.9 cm^2, $p = 0.012$) versus the non-arthroplasty group (adjusted)

- Overall arthroplasty history was linked to higher FI in posterior paraspinal muscles: FI was higher in the arthroplasty group for both MF (61% vs 54%, $p < 0.001$) and erector spinae (ES) (43% vs 39%, $p < 0.001$) compared with no arthroplasty
- THA alone was not a significant independent driver after adjustment: isolated THA did not show a significant adjusted association with paraspinal FI or fCSA

TAKE HOME MESSAGE

Among elective lumbar surgery patients, prior total knee arthroplasty, more than hip arthroplasty, was associated with worse MF muscle quality (higher FI, lower fCSA), supporting a clinically relevant knee–spine relationship.

2 Disc / Endplate

2.1 Prognostic / outcome-associated studies

2.1.1 Ten-Year Clinical Outcomes After Decompression Surgery for Lumbar Spinal Stenosis: The Impact of Preoperative Modic Changes

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Published: July 15th, 2025. Global Spine Journal.

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/40662494/

Objective:

- To evaluate the 10-year progression of Modic changes (MCs) and determine whether preoperative MC status (and MC type) is associated with long-term clinical outcomes after decompression surgery for lumbar spinal stenosis

Study design:

- Retrospective cohort study of patients undergoing posterior decompression for lumbar spinal stenosis with 10-year follow-up

Key findings:

- Preoperative MCs were present in 23/62 (37.1%) but increased to 74.2% at 10 years on MRI
- At 10 years, Modic-positive patients trended toward worse total Japanese Orthopaedic Association (JOA) score vs Modic-negative (20.6 ± 5.3 vs 23.1 ± 4.2; P = 0.051)
- Modic Type 2 was associated with significantly worse long-term outcomes: lower 10-year JOA score (18.2 ± 4.9) vs Type 1 (23.3 ± 5.0; P = 0.02) and worse recovery rate (Modic-negative 56.6% vs MC2 24.3%; P < 0.01 after adjustment for disc space narrowing)
- Type 1 changes appeared more "dynamic" over time, frequently progressing toward Type 2/3, while Type 2 changes were linked to more advanced, less-reversible degeneration

TAKE HOME MESSAGE

Preoperative Modic Type 2 changes were associated with inferior 10-year clinical recovery after decompression surgery for lumbar spinal stenosis, suggesting MC2 may be a useful long-term prognostic marker.

2.1.2 The Modic change grade is associated with patient-reported outcomes in lumbar spinal stenosis surgery

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Published: July 8th, 2025. Clin Neurol Neurosurg.

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/40651162/

Objective:

- To evaluate the impact of the Modic Change Grade (MCG) on patient-reported outcomes (PROs) in patients undergoing lumbar spinal stenosis (LSS) surgery

Study design:

- Registry-based retrospective comparative cohort study

Key findings:

- 208 patients were included; no significant difference in preoperative PROs between minor vs major Modic change grade groups
- At 2-year follow-up, major MC (MCG-B+) had worse outcomes than minor MC (MCG-A): VAS back pain 44 vs 32 ($p = 0.045$), VAS leg pain 45 vs 27 ($p = 0.003$), ODI 30 vs 22 ($p = 0.036$)
- Modic change grading used vertical extent categories: MCG-A <25%, MCG-B 25–50%, MCG-C >50%; patients were grouped as Minor (MCG-A) vs Major (MCG-B+)

TAKE HOME MESSAGE

In lumbar spinal stenosis surgery, major Modic change grade (≥25% vertebral height involvement) is associated with significantly worse pain and disability at 2 years, even when preoperative PROs are similar.

2.1.3 Modic Changes in Patients Who Have Undergone Anterior Cervical Discectomy and Fusion: The Correlation With Fusion Success and Subsidence

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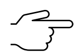
Published: February 24th, 2025. Orthop Surg.

Link to full article:

 https://pubmed.ncbi.nlm.nih.gov/39993912/

Objective:

- To assess Modic change (MC) in patients undergoing ACDF by investigating its incidence, risk factors, and correlation with fusion success and cage subsidence

Study design:

- Retrospective cohort study of 154 patients undergoing single-level ACDF (January 2010–December 2020), minimum follow-up 12 months

Key findings:

- MC prevalence at baseline was 44.2% (68/154)
- Fusion rate was 88.2% (60/68) in MC vs 97.7% (84/86) in non-MC (p = 0.02)
- The MC group presented a subsidence rate of 27.9%, which was substantially higher than in the non-MC group (9.3%, $p < 0.01$).

TAKE HOME MESSAGE

Preoperative Modic changes are associated with lower fusion rates and higher cage subsidence after single-level ACDF, and should prompt careful perioperative risk management (e.g., bone health/osteoporosis and immobilization strategy).

2.1.4 Clinical and Radiological Outcomes of Cervical Disc Arthroplasty in Patients with Modic Change

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Published: May 22nd, 2024. Orthop Surg.

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/38778356/

Objective:

- To evaluate clinical and radiological outcomes after cervical disc arthroplasty/ replacement (CDA/CDR) in patients with cervical Modic change (MC), with a focus on heterotopic ossification (HO) and whether MC is associated with HO

Study design:

- Retrospective observational cohort study (patients undergoing single- or two-level CDA with Prestige-LP disc, January 2008–December 2019; minimum follow-up 2 years)

Key findings:

- 139 patients were evaluated (mean follow-up 46.53 ± 26.60 months); MC prevalence was 35.3% (Type 2 most common)
- Radiographically, MC patients had higher HO rates (83.7% vs 53.3%) and high-grade HO (30.6% vs 2.2%), with MC identified as a significant risk factor for HO (multivariable adjusted OR reported 4.62, 95% CI 1.87–11.39); Range of motion at the index level (shell angle, functional spine unit angle, range of motion) and functional spine unit height were worse in the MC group
- Clinical outcomes (Japanese Orthopaedic Association (JOA), Neck Disability Index (NDI), Visual Analogue Score (VAS)) showed no significant differences between MC vs non-MC groups

TAKE HOME MESSAGE

In cervical disc arthroplasty patients, preoperative Modic change strongly predicted heterotopic ossification (including high-grade HO) and less favorable segmental motion metrics, while patient-reported clinical scores were similar to those without Modic change.

2.1.5 Do Modic changes affect the fusion rate in spinal interbody fusion surgery? A systematic review and network meta-analysis

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Published: May 20th, 2024. J Clin Neurosci.

Link to full article:

Objective:

- To compare the fusion rates of spinal interbody fusion in patients with Modic changes (MCs)

Study design:

- Systematic review and network meta-analysis (PRISMA 2020; PROSPERO CRD42024538023), searching PubMed, Embase, Web of Science Core Collection, ClinicalTrials.gov, and Cochrane Library through March 28, 2024

Key findings:

- Seven studies (total 1162 patients/segments) showed higher fusion rates in non-Modic changes (NMCs) than MCs at 3 months ($p = 0.0001$) and 6 months ($p = 0.002$).
- There was no significant difference in fusion rates at 12 months ($p = 0.34$) or at final follow-up ($p = 0.41$).
- Subgroups: no significant difference in cervical fusion ($p = 0.88$) or TLIF ($p = 0.51$); in PLIF, NMCs had a significantly higher fusion rate than MCs ($p < 0.00001$), and NMCs were higher than MC2 and MC3 in PLIF.

TAKE HOME MESSAGE

Modic changes are associated with worse early fusion (3–6 months), particularly in PLIF (not clearly in cervical fusion or TLIF), while differences largely disappear by 12 months and final follow-up.

2.1.6 Modic Changes Increase the Cage Subsidence Rate in Spinal Interbody Fusion Surgery: A Systematic Review and Network Meta-Analysis

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Published: October 20th, 2023. World Neurosurg.

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/37865194/

Objective:

- To compare the effect of different Modic change (MC) grades on cage subsidence rates after spinal interbody fusion surgery.

Study design:

- Systematic review and network meta-analysis of randomized trials and prospective/retrospective cohort studies (database search through August 13, 2023)

Key findings:

- Six studies including 716 segments were analyzed; overall, non-Modic changes (NMC) had a significantly lower subsidence rate than MC
- Subgroup results: NMC had significantly lower subsidence than MC in TLIF, and also in the subgroup with extra instrumentation; in oblique lumbar interbody fusion (OLIF), no significant difference was identified between groups
- By MC grade: NMC had significantly lower subsidence than MC1 and MC2; no significant differences were found between NMC vs MC3, or among MC1/MC2/MC3 comparisons

TAKE HOME MESSAGE

Modic changes were associated with a higher cage subsidence risk after interbody fusion (especially versus MC1/MC2), and OLIF may be a preferable option for lumbar degenerative disease with Modic changes.

2.1.7 Does Preoperative Modic Changes Influence the Short-term Fusion Rate of Single Level Transforaminal Lumbar Interbody Fusion? A Matched-pair Case Control Study

Yang Xiao, MM[1], Peng Xiu, MD[1], Xi Yang, MD[1], Liang Wang, MD[1], Tao Li, MD[1], Quan Gong, MD[1], Limin Liu, MD[1], Yueming Song, MD[1]

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Published: July 13th, 2023. Orthop Surg.

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/37439298/

Objective:

- To compare the short-term fusion rate of lumbar degenerative disease patients with and without Modic changes (MCs) after single-level transforaminal lumbar interbody fusion (TLIF)

Study design:

- Retrospective matched-pair case-control study (100 TLIF patients; 50 with MCs matched 1:1 to 50 without MCs; follow-up imaging from 3 months to 2 years)

Key findings:

- Lower fusion rates with MCs vs. non-MC at every time point assessed: 3 months 23.8% vs 62.5%, 6 months 52.6% vs 78.9%, 1 year 61.1% vs 83.3%, 2 years 74.0% vs 90.0%
- Lower cage–endplate union ("cage union ratio") with MCs on CT: coronal upper endplate 54.3% ± 17.5% vs 75.0% ± 17.2%, coronal lower endplate 73.3% ± 12.0% vs 84.9% ± 8.0% (and similarly lower sagittal-plane ratios)
- Within the MCs group, cage material did not materially change fusion performance (n-HA/PA66 vs PEEK comparable), while higher BMI (OR 1.735) and smoking (OR 5.659) were identified as independent risk factors for poorer fusion among MC patients

TAKE HOME MESSAGE

Preoperative Modic changes were associated with substantially worse early fusion and lower CT cage–endplate union after single-level TLIF, and smoking/high BMI further increase the risk of nonunion in MC patients.

2.1.8 Evaluating the Impact of Modic Changes on Operative Treatment in the Cervical and Lumbar Spine: A Systematic Review and Meta-Analysis

Mark J. Lambrechts[1], Parker Brush[1], Tariq Z. Issa[1], Gregory R. Toci[1], Jeremy C. Heard[1], Amit Syal[1], Meghan M. Schilken[1], Jose A. Canseco[1], Christopher K. Kepler[1], Alexander R. Vaccaro[1]

[1]Rothman Orthopedic Institute, Thomas Jefferson University, Philadelphia, PA 19107, USA

Published: August 16th, 2022. Int J Environ Res Public Health.

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/36011795/

Objective:

- To evaluate whether preoperative Modic changes (MCs) affect postsurgical outcomes after cervical or lumbar spine surgery

Study design:

- Systematic review and meta-analysis conducted according to PRISMA guidelines, including studies of cervical or lumbar spine surgical outcomes in patients with documented preoperative MCs

Key findings:

- 29 studies were included with 6013 total patients, of whom 2688 had preoperative Modic changes; included procedures spanned studies that evaluated cervical spine surgery (n=8), lumbar discectomies (n=11), lumbar fusion surgery (n=9), and lumbar disc replacements (n=3)
- The presence of cervical Modic changes did not impact clinical outcomes across cervical procedures
- In the lumbar spine, most included studies found Modic changes did not significantly impact outcomes after lumbar fusion, lumbar discectomy, or lumbar disc replacement.
  - Meta-analyses showed no significant association between Modic changes and VAS back pain or ODI after lumbar discectomy JOA or neck pain after ACDF

TAKE HOME MESSAGE

Across the cervical and lumbar spine literature, patients with Modic changes generally improved after surgery, and outcomes were broadly similar to those without Modic changes, with meta-analysis showing no clear disadvantage in key pain/disability measures.

2.1.9 Improving effect of microendoscopic decompression surgery on low back pain in patients with lumbar spinal stenosis and predictive factors of postoperative residual low back pain: a single-center retrospective study

Ryo Taiji[1]*, Hiroshi Iwasaki[1], Hiroshi Hashizume[1], Yasutsugu Yukawa[1], Akihito Minamide[1,2], Yukihiro Nakagawa[3], Shunji Tsutsui[1], Masanari Takami[1], Keiji Nagata[1], Shizumasa Murata[1], Takuhei Kozaki[1], Munehito Yoshida[4] and Hiroshi Yamada[1]

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Published: November 15th, 2021. BMC Musculoskeletal Disorders.

Link to full article:

Objective:

- To evaluate whether microendoscopic laminotomy (MEL) for lumbar spinal stenosis (LSS) improves low back pain (LBP), and to identify preoperative predictors of postoperative residual LBP at 1 year

Study design:

- Single-center retrospective study of 202 consecutive patients undergoing MEL for LSS (inclusion: preop LBP-VAS ≥ 40 mm)

Key findings:

- Decompression meaningfully improved pain and function at 1 year: JOA score 14.1 → 20.2, LBP-VAS 66.7 → 29.7 mm, leg pain VAS 63.8 → 31.2 mm, leg numbness VAS 63.3 → 34.2 mm (all $p < 0.001$).
- Residual low back pain was still common: 48.5% (98/202) met the study definition of postoperative residual LBP (1-year LBP-VAS ≥ 25 mm or required additional surgery for residual LBP within 1 year).
- Modic type 1 was the strongest predictor of residual LBP (multivariable model): Modic type 1 OR 5.61 (95% CI 1.68–18.68, $p = 0.005$), preop LBP-VAS ≥ 70 mm OR 2.19 (95% CI 1.17–4.08, $p = 0.014$), and female sex OR 1.98 (95% CI 1.09–3.89, $p = 0.047$)

TAKE HOME MESSAGE

Microendoscopic decompression (MEL) for lumbar spinal stenosis generally improves low back pain, but patients with Modic type 1 changes, very high baseline LBP (≥ 70 mm VAS), and females have a higher risk of residual postoperative low back pain at 1 year.

2.1.1 Lumbar Disc Herniation and Preoperative Modic Changes: A Prospective Analysis of the Clinical Outcomes After Microdiscectomy

Dinesh Kumarasamy, DNB[1], Shanmuganathan Rajasekaran, MS, DNB, MCh, PhD[1], Sri Vijay Anand K. S., MS, FISS[1], Dilip Chand Raja Soundararajan, MS, DNB, FNB[1], Ajoy Prasad Shetty T., MS, DNB[1], Rishi Mugesh Kanna P., MS, MRCS, FNB[1], Pushpa B. T., DNB, FRCR[2]

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Published: January 19th, 2021. Global Spine J.

Link to full article:

Objective:

- To elucidate the relationship between preoperative Modic endplate changes and clinical outcomes after a lumbar microdiscectomy

Study design:

- Prospective comparative cohort study of consecutive patients undergoing microdiscectomy for lumbar disc herniation (LDH), comparing outcomes between patients with vs without preoperative Modic changes

Key findings:

- Patients with Modic changes had poorer back-pain and ODI scores at 3 months, 6 months, and 1 year (reported p = 0.001)
- Despite statistically worse scores, the between-group minimal clinically important difference (MCID) was not significant (MCID p = 0.18 for back pain; p = 0.58 for ODI)
- No difference was noted among Modic types in the pre-operative and postoperative pain and functional outcomes

TAKE HOME MESSAGE

Preoperative Modic changes were associated with less favorable postoperative back pain/function and satisfaction after lumbar microdiscectomy, though the between-group differences may not be clinically meaningful by MCID.

2.1.2 The Impact of Modic Changes on Preoperative Symptoms and Clinical Outcomes in Anterior Cervical Discectomy and Fusion Patients

James D. Baker[1,2], Garrett K. Harada[1,2], Youping Tao[3], Philip K. Louie[1,2], Bryce A. Basques[1,2], Fabio Galbusera[4], Frank Niemeyer[3], Hans-Joachim Wilke[3], Howard S. An[1,2], Dino Samartzis[1,2]

[1]Department of Orthopaedic Surgery, Rush University Medical Center, Chicago, IL, USA, [2]International Spine Research and Innovation Initiative (ISRII), Rush University Medical Center, Chicago, IL, USA, [3]Institute of Orthopaedic Research and Biomechanics, Centre for Trauma

Research Ulm, Ulm University Medical Centre, Ulm, Germany, [4]IRCCS Istituto Ortopedico Galeazzi, Milan, Italy

Published: March 31st, 2020. Neurospine.

Link to full article:

Objective:

- To assess the impact of Modic changes (MC) on preoperative symptoms and postoperative outcomes in anterior cervical discectomy and fusion (ACDF) patients

Study design:

- Retrospective study of prospectively collected, consecutive ACDF patient data at a single institution (with MC stratified by type and location and compared to patients without MC)

Key findings:

- MC were present in 356/861 (41.3%) patients; MC most frequently occurred at C5–6 (15.1%), and type II was most common (61.2% of MC)
- Presence of MC was associated with older age (p<0.001), more levels fused (p<0.001), and longer duration of symptoms, but not with specific preoperative symptom profiles
- MC at C7–T1 was associated with higher postoperative disability (p<0.001), while MC did not increase risk of adjacent segment degeneration or reoperation

TAKE HOME MESSAGE

In ACDF patients, Modic changes appear to mark a more chronic/debilitating preoperative state but generally do not worsen key surgical outcomes (e.g., reoperation/ASD), with a notable exception of higher postoperative disability when MC were present at C7–T1.

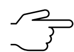
2.1.3 The influence of endplate (Modic) changes on clinical outcomes in lumbar spinal stenosis surgery: a Swiss prospective multicenter cohort study

Nils H. Ulrich[1,5], Jakob M. Burgstaller[1], Isaac Gravestock[1], Sebastian Winklhofer[2], François Porchet[3], Giuseppe Pichierri[1], Maria M. Wertli[1,4], Johann Steurer[1], Mazda Farshad[5] on behalf of the LSOS Study Group

[1]Horten Centre for Patient Oriented Research and Knowledge Transfer, University of Zurich, Zurich, Switzerland, [2]University Spine Centre Zurich, Balgrist University Hospital, University of Zurich, Zurich, Switzerlan, [3]Horten Centre for Patient Oriented Research and Knowledge Transfer, University of Zurich, Zurich, Switzerland, [4]Institute of Diagnostic and Interventional Radiology, University Hospital Zurich, University of Zurich, Zurich, Switzerlan, [5]Department of Orthopedics and Neurosurgery, Spine Center, Schulthess Clinic, Zurich, Switzerland, [6]Division of General Internal Medicine, Bern University Hospital, Bern University, Bern, Switzerland, [7]University Spine Centre Zurich, Balgrist University Hospital, University of Zurich, Zurich, Switzerland

Published: March 10th, 2020. European Spine Journal.

Link to full article:

 https://pubmed.ncbi.nlm.nih.gov/32157388/

Objective:

- To determine whether the presence (vs absence) of preoperative endplate Modic changes (MC) predicts clinical outcomes after surgery for degenerative lumbar spinal stenosis (DLSS), and whether this differs by surgical strategy (decompression alone vs decompression + fusion)

Study design:

- Retrospective analysis of data from a Swiss prospective multicenter cohort: the Lumbar Stenosis Outcome Study (LSOS)

Key findings:

- Improvement after surgery occurred in all groups and was generally maintained up to 36 months
- No evidence that Modic changes affected outcome trajectories, regardless of whether patients had decompression alone or fusion. Reported Kruskal–Wallis p-values for between-group differences in outcome score changes ranged from 0.390 to 0.964 (i.e., non-significant)
- 70–90% of patients maintained a clinically important improvement up to 36 months across groups
- A predictive modeling approach (LASSO) likewise found MCs had no prognostic value, while baseline health status (e.g., comorbidity burden and baseline pain) and age were more relevant predictors

TAKE HOME MESSAGE

In this Swiss multicenter DLSS cohort, preoperative Modic changes did not predict better or worse patient-reported outcomes after surgery, and this held independent of surgical strategy (decompression alone vs fusion).

2.1.4 Do Modic changes have an impact on clinical outcome in lumbar spine surgery? A systematic literature review

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Published: May 13th, 2016. Eur Spine J.

Link to full article:

Objective:

- To provide a systematic literature review of the impact of preoperative Modic changes (MCs) on the clinical outcome following lumbar spine surgery for degenerative lumbar spine disease

Study design:

- Systematic literature review (PubMed search until 31 October 2015)

Key findings:

- Fourteen included studies (7 prospective, 7 retrospective) covered 1652 surgical patients; at least 804 (>49%) had preoperative Modic changes
- In discectomy for lumbar disc herniation (6 studies; n = 607), there was a trend toward less improvement in low back pain and/or ODI when Modic changes were present preoperatively
- In total disc replacement (4 studies; n = 500), there was a trend toward greater improvement when Modic changes were present preoperatively, while fusion studies (3 studies; n = 454) were low-evidence and conflicting, preventing firm conclusions

TAKE HOME MESSAGE

Preoperative Modic changes may be associated with worse improvement after discectomy and better improvement after total disc replacement, while evidence in fusion surgery remains insufficient and clinical meaningfulness (MCID) is uncertain.

2.2 Association studies

2.2.1 Endplate Degeneration and Intervertebral Vacuum Phenomenon Are Positively Correlated: A Retrospective Study in Patients Undergoing Lumbar Fusion Surgery

Gaston Camino-Willhuber, MD[1], Lukas Schönnagel, MD[1,2], Erika Chiapparelli, MD[1], Paul Köhli, MD[1,2], Krizia Amoroso, MD[1], Ali E. Guven, MD[1], Thomas Caffard, MD[1,3], Gisberto Evangelisti, MD[1], Bruno Verna, MD[1], Jiaqi Zhu, MS[4], Jennifer Shue, MS[1], Gbolabo Sokunbi, MD[1], William D. Zelenty, MD[1], Mariana Bendersky, MD, PhD[5,6], Federico P. Girardi, MD[1], Andrew A. Sama, MD[1], Frank P. Cammisa, MD[1], and Alexander P. Hughes, MD[1]

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Published: April 1st, 2025. Journal of Clinical Spine Surgery.

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/40167183/

Objective:

- To analyze the correlation between intervertebral vacuum phenomenon (IVP) severity and total endplate damage score (TEPS) in lumbar fusion patients

Study design:

- Retrospective cohort study of 317 lumbar fusion patients (2013–2021) evaluating the association between TEPS and IVP severity

Key findings:

- TEPS strongly associated with more severe IVP (unadjusted): OR 1.78 (95% CI 1.62–1.95), P < 0.001.
- TEPS remained independently associated after adjustment: OR 1.32 (95% CI 1.17–1.49), P < 0.001.
- Other independent contributors: Pfirrmann grade OR 7.44 (95% CI 4.40–12.58), P < 0.001; age OR 1.07 (95% CI 1.04–1.10), P < 0.001.

TAKE HOME MESSAGE

Endplate damage score is independently and strongly associated with IVP severity, supporting the concept that endplate degeneration plays a key role in advanced disc degeneration in lumbar fusion populations.

2.2.2 Risk factors for progression of nucleus pulposus degeneration in the lumbar intervertebral disc: a retrospective analysis using the disc signal intensity index

Koki Tsuchiya, MD, PhD[1,2], Ichiro Okano, MD, PhD[2], Ali E. Guven, MD[1], Paul Köhli, MD1, Jan Hambrecht, MD[1], Gisberto Evangelisti, MD[1], Erika Chiapparelli, MD[1], Marco D. Burkhard, MD[1], Jennifer Shue, MS[1], Federico P. Girardi, MD[1], Frank P. Cammisa, MD[1], Andrew A. Sama, MD[1], Alexander P. Hughes, MD[1]

[1]Spine Care Institute, Hospital for Special Surgery, New York, NY, USA, [2]Department of Orthopaedic Surgery, Showa University School of Medicine, Tokyo, Japan

Published: February 1st, 2025. Spine Journal.

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/39900250/

Objective:

- To identify risk factors for progression of lumbar nucleus pulposus degeneration using the quantitative disc signal intensity index (DSI2) on longitudinal MRI

Study design:

- Retrospective longitudinal study of 325 patients (1,439 discs) with two lumbar MRIs ≥3 years apart and no lumbar surgery between scans, using multivariable linear mixed regression to identify factors associated with DSI2 change

Key findings:

- Congestive heart failure (CHF) was an independent risk factor for disc nucleus degenerative progression (regression coefficient −0.302; $p < 0.001$)

- Older age was independently associated with progression (regression coefficient −0.0011; $p < 0.001$)

- Diabetes mellitus showed a statistically significant positive effect in the model (regression coefficient 0.0310; $p = 0.033$)

TAKE HOME MESSAGE

In longitudinal lumbar MRI follow-up using DSI2, CHF and age emerged as key risk factors for progression of nucleus pulposus degeneration and the DSI2 method offers a promising alternative evaluation method for future disc research.

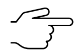
2.2.3 Quantitative assessment of cervical disc degeneration using disc signal intensity index

Koki Tsuchiya, MD, PhD[1,2], Ichiro Okano, MD[2], Ali E. Guven, MD[1], Bruno Verna, MD[1], Paul Köhli, MD[1], Jan Hambrecht, MD[1], Gisberto Evangelisti, MD[1], Erika Chiapparelli, MD[1], Marco D. Burkhard, MD[1], Vidushi Tripathi, MD[1,3], Jennifer Shue, MS[1], Federico P. Girardi, MD[1], Frank P. Cammisa, MD[1], Andrew A. Sama, MD[1], Alexander P. Hughes, MD[1],*

[1] Spine Care Institute, Hospital for Special Surgery, New York, NY, USA, [2] Department of Orthopaedic Surgery, Showa University School of Medicine, Tokyo, Japan, [3] Weill Cornell Medicine, New York, NY, USA

Published: December 5th, 2024. Spine Journal.

Link to full article:

 https://pubmed.ncbi.nlm.nih.gov/39645168/

Objective:

- To apply the Disc Signal Intensity Index (DSI2) to the cervical intervertebral discs and identify factors associated with cervical disc degeneration

Study design:

- Single-center cross-sectional study using retrospectively collected ACDF-database cervical MRIs (2015–2018)

Key findings:

- Age (β = −0.130, p<.05), BMI (β = −2.06, p<.05), and Modic type 1 change (β = −2.70, p<.01) assessed with DSI2 were independent contributors to disc degeneration
- C4/5 (β = 1.37, p<.001) and C7/T1 (β = 2.63, p<.001) levels were less prone to disc degeneration
- Diabetes history associated with higher DSI2 (β = 5.31, p<.01)

TAKE HOME MESSAGE

DSI2 provides an objective, quantitative way to assess cervical disc degeneration and detects clinically relevant associations (age, BMI, Modic changes; plus segment-level effects restoring

nuance beyond Pfirrmann grading), supporting DSI2 as a practical research tool for cervical degenerative conditions.

2.3 Background

2.3.1 Measuring and reporting of vertebral endplate bone marrow lesions as seen on MRI (Modic changes): recommendations from the ISSLS Degenerative Spinal Phenotypes Group

Aaron J. Fields[1], Michele C. Battié[2], Richard J. Herzog[3], Jeffrey G. Jarvik[4], Roland Krug[5], Thomas M. Link[5], Jeffrey C. Lotz[1], Conor W. O'Neill[1], Aseem Sharma[7]; for the ISSLS Degenerative Spinal Phenotypes Group

[1] Department of Orthopaedic Surgery, University of California, San Francisco, CA, USA, [2] Faculty of Health Sciences and Western's Bone and Joint Institute, University of Western Ontario, London, ON, Canada, [3] Department of Radiology, Hospital for Special Surgery, New York, NY, USA, [4] Departments of Radiology, Neurosurgery and Health Services, and the Comparative Effectiveness, Cost and Outcomes Research Center, University of Washington, Seattle, WA, USA, [5] Department of Radiology and Biomedical Imaging, University of California, San Francisco, CA, USA [7] Mallinckrodt Institute of Radiology, Washington University School of Medicine in St. Louis, St. Louis, MO, USA

Published: August 24th, 2019. European Spine Journal.

Link to full article:

Objective:

- To provide recommendations to standardize how Modic changes are measured and reported on MRI, because variation in imaging equipment and scan parameters affects MC conspicuity and undermines comparisons across studies.

Study design:

- Non-systematic literature review with reporting recommendations from the ISSLS Degenerative Spinal Phenotypes Group

Key findings:

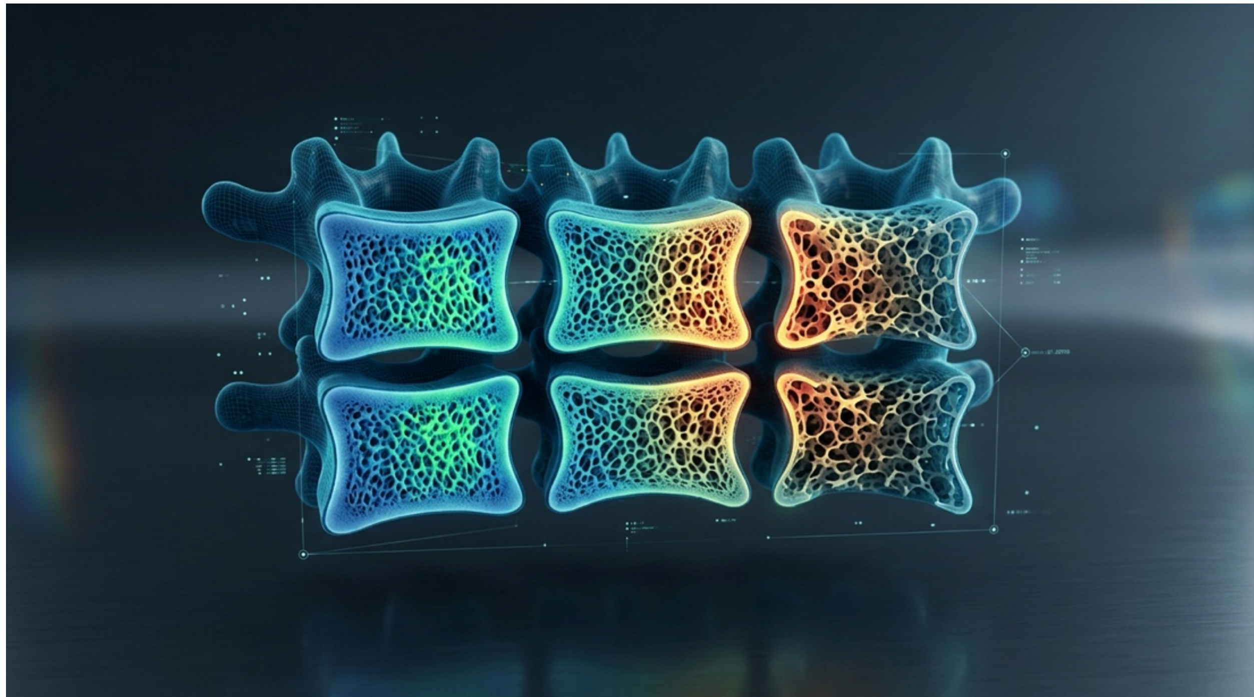
- Interrater and intrarater variability in Modic classification is a major reason different studies report different strengths of association between Modic changes and low back pain
- Imperfect reliability leads to misclassification, which directly reduces diagnostic sensitivity and contributes to both between-study and within-study variability in findings
- Interrater and intrarater variability in Modic classification is a major reason different studies report different strengths of association between Modic changes and low back pain

- The paper emphasizes that imperfect reliability leads to misclassification, which directly reduces diagnostic sensitivity and contributes to both between-study and within-study variability in findings
- Modic changes tend to show high diagnostic specificity for a painful spinal level, which supports the positive association seen when Modic changes are identified confidently
- However, sensitivity is low and variable, so absence of Modic changes on MRI (or failure to classify them consistently) does not rule out pain and can dilute measured associations
- The paper links poor sensitivity to multiple factors, including other pain generators, limited MRI resolution, and imperfect classification reliability
- Technical MRI factors can worsen or improve both conspicuity and rater agreement, including magnetic field strength and pulse sequence parameters
- Use of fat suppression can change how Modic Type 2 appears; if fat-suppressed T2 images are used, authors should clearly define how Type 2 is classified under that protocol to avoid systematic misclassification
- To make results comparable and interpretable, studies should explicitly report what was rated (levels covered, which sagittal slices/planes, and the rating approach)
- The paper recommends mandatory reporting of reliability metrics: inter- and intra-rater kappa for categorical Modic type classification, and ICC if quantitative measurements are used.
- Improving reliability and reducing misclassification is presented as essential for clarifying the true clinical relationship between Modic changes and pain and for integrating Modic changes into a meaningful “pain phenotype” research framework.

TAKE HOME MESSAGE

Lack of standardized Modic change (MC) MRI acquisition, classification, and reporting is responsible for substantial misclassification and variable sensitivity across studies, which in turn drives inconsistent and hard-to-compare findings on the strength of the association between MC and low back pain.

3 Vertebrae



3.1 Prognostic / outcome-associated studies

3.1.1 The MRI-based vertebral bone quality score is a predictor of pedicle screw loosening following instrumented posterior lumbar fusion

Yung-Hsueh Hu[1,2,3,5], Jian-Hong Chou[2,3,5], Yu-Cheng Yeh[1,2,3], Ming-Kai Hsieh[1,2,3], Tsung-Ting Tsai[1,2,3], Wen-Jer Chen[4], Lih-Hui Chen[1,2,3], Po-Liang Lai[1,2,3], Chi-Chien Niu[1,2,3]

[1] Department of Orthopedic Surgery, Chang Gung Memorial Hospital, Taoyuan, Taiwan, [2] Bone and Joint Research Center, Chang Gung Memorial Hospital, Taoyuan, Taiwan, [3] College of Medicine, Chang Gung University, Taoyuan, Taiwan, [4] Department of Orthopedic Surgery, Chung Shan Hospital, Taipei, Taiwan, [5] Contributed equally to this work

Published: January 11th, 2025. Scientific Reports.

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/39799229/

Objective:

- To investigate the predictive ability of the MRI-based vertebral bone quality (VBQ) score for pedicle screw loosening following instrumented transforaminal lumbar interbody fusion (TLIF)

Study design:

- Retrospective cohort study

Key findings:

- Pedicle screw loosening occurred in 75 of 211 patients (35.6 %) at 24-month follow-up
- On multivariable analysis, higher VBQ score, male sex, and longer fusion length were significant independent factors associated with screw loosening
- VBQ predicted screw loosening with an accuracy of 78.9%

TAKE HOME MESSAGE

A higher preoperative MRI-based VBQ score independently predicts pedicle screw loosening after instrumented TLIF and may be a useful preoperative bone-quality screening tool.

3.1.2 Bone turnover markers in the preoperative assessment of bone quality – A prospective investigation of bone microstructure and advanced glycation end products in lumbar fusion patients

Henryk Haffer, MD[1,2], Maximilian Muellner, MD[1,2], Erika Chiapparelli, MD[1], Jiaqi Zhu, MS[3], Yi Xin Han[4], Eve Donnelly[4,5], Jennifer Shue, MS[1], Alexander P. Hughes, MD[1]

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Published: August 6th, 2024. Journal of Archives of Orthopaedic and Trauma Surgery.

Link to full article:

Objective:

- To investigate associations of the bone formation marker serum bone alkaline phosphatase (BAP) and bone resorption marker urine collagen cross-linked N-telopeptide (uNTX) with lumbar volumetric bone mineral density (vBMD), fluorescent advanced glycation endproducts (fAGEs), and bone microstructure in lumbar fusion patients

Study design:

- Cross-sectional analysis using prospective data of patients undergoing lumbar spinal fusion

Key findings:

- Bone turnover markers inversely correlated with fAGEs: uNTX decreased with cortical fAGEs ($\rho = -0.331$, $p < 0.005$) and trabecular fAGEs ($\rho = -0.380$, $p < 0.001$); BAP decreased with cortical fAGEs ($\rho = -0.245$, $p < 0.025$)
- Adjusted association persisted for uNTX and trabecular fAGEs: In multivariable analysis, uNTX decreased with increasing trabecular fAGEs after adjustment ($\beta = 0.923$, $p = 0.031$)
- Both uNTX and BAP could not predict osteopenia / osteoporosis: ROC analysis for BAP and uNTX discriminated osteopenia/osteoporosis with AUC of 0.477 and 0.561, respectively

TAKE HOME MESSAGE

Preoperative BAP and uNTX were not good surrogates for spinal bone density, but they showed consistent relationships with bone collagen quality (fAGE accumulation), especially uNTX, suggesting a complementary role alongside vBMD in lumbar fusion preoperative assessment.

3.1.3 Vertebral Bone Quality Score Independently Predicts Proximal Junctional Kyphosis and/or Failure After Adult Spinal Deformity Surgery

Cathleen C. Kuo, BS[1], Mohamed A. R. Soliman, MD, MSc, PhD[2,3,4], Alexander O. Aguirre, BS[1], Nicco Ruggiero, BS[1], Marissa Kruk, BS[1], Asham Khan, MD[2,3], Moleca M. Ghannam, MD[2,3], Neil D. Almeida, MD[2,3], Patrick K. Jowdy, MD[2,3], David E. Smolar, MD[2,3], John Pollina, MD[2,3], Jeffrey P. Mullin, MD, MBA[2,3]

[1] Jacobs School of Medicine and Biomedical Sciences at University at Buffalo, Buffalo, New York, USA, [2] Department of Neurosurgery, Jacobs School of Medicine and Biomedical Sciences at University at Buffalo, Buffalo, New York, USA, [3] Department of Neurosurgery, Buffalo General Medical Center, Kaleida Health, Buffalo, New York, USA, [4] Department of Neurosurgery, Faculty of Medicine, Cairo University, Cairo, Egypt

Published: May 1st, 2023. Neurosurgery.

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/36700747/

Objective:

- To investigate the utility of the VBQ score in predicting proximal junctional kyphosis (PJK) and/or proximal junctional failure (PJF) after adult spinal deformity correction

Study design:

- Retrospective chart review of patients age ≥50 years undergoing adult spinal deformity (ASD) surgery spanning 5+ thoracolumbar levels

Key findings:

- 34/116 patients (29.3%) developed PJK/PJF after surgery
- Mean VBQ was higher in those with PJK/PJF vs without (3.13 ± 0.46 vs 2.46 ± 0.49)
- On multivariable analysis, VBQ score was the only significant predictor of PJK/PJF (OR 1.745, 95% CI 1.558–1.953), with predictive accuracy reported as 94.3%

TAKE HOME MESSAGE

Higher preoperative VBQ on MRI was independently associated with PJK/PJF after adult spinal deformity surgery and may help with preoperative risk stratification and surgical planning.

3.1.4 A Novel Cervical Vertebral Bone Quality Score Independently Predicts Cage Subsidence After Anterior Cervical Diskectomy and Fusion

Mohamed A. R. Soliman, MD, MSc, PhD[1,2,3], Alexander O. Aguirre, BS[4], Cathleen C. Kuo, BS[4], Nicco Ruggiero, BS[4], Asham Khan, MD[1,2], Moleca M. Ghannam, MD[1,2], Kyungduk Rho, MD[1,2], Patrick K. Jowdy, MD[1,2], Jeffrey P. Mullin, MD, MBA[1,2], John Pollina, MD[1,2]

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Published: April 1st, 2023. Neurosurgery.

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/36729684/

Objective:

- To create an MRI-based scoring system for the cervical spine (C-VBQ), correlate C-VBQ scores with computed tomography Hounsfield units, and evaluate whether this score

independently predicts cage subsidence after single-level anterior cervical diskectomy and fusion

Study design:

- Retrospective cohort study

Key findings:

- Cage subsidence occurred in 17 of 59 patients (28.8%) after single-level anterior cervical diskectomy and fusion
- Mean C-VBQ scores were higher in subsidence levels (2.83 ± 0.38) than in non-subsidence levels (2.22 ± 0.36)
- On multivariate analysis, higher C-VBQ was significantly associated with subsidence (odds ratio 1.85, 95% CI 1.39–2.46) and was the only significant independent predictor; C-VBQ showed a significant negative correlation with Hounsfield units ($r^2 = -0.49$)

TAKE HOME MESSAGE

A higher preoperative cervical VBQ score on MRI independently predicts cage subsidence after single-level ACDF and may serve as a practical tool for assessing cervical bone quality preoperatively.

3.1.5 Vertebral bone quality score to predict cage subsidence following oblique lumbar interbody fusion

Yong Huang[1]†; Qian Chen[1,2]†; Limin Liu[1]*; Ganjun Feng[1]*

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Published: March 30th, 2023. Journal of Orthopaedic Surgery and Research.

Link to full article:

Objective:

- To assess whether the MRI-based vertebral bone quality (VBQ) score can predict postoperative cage subsidence after oblique lumbar interbody fusion (OLIF)

Study design:

- Retrospective cohort study of patients undergoing single-level OLIF with ≥1 year follow-up, using univariable and multivariable logistic regression plus ROC/AUC analysis to evaluate predictive performance

Key findings:

- Cage subsidence occurred in 39/102 patients (38.24%).
- In multivariable analysis, a higher VBQ score was the only independent predictor of subsidence (OR 23.158, 95% CI 4.381–122.399, $p < 0.001$)
- VBQ predicted subsidence better than average lumbar DEXA T-score (AUC 0.839 vs 0.695), with an optimal VBQ cutoff of 3.435 (sensitivity 69.23%, specificity 88.89%)

TAKE HOME MESSAGE

Preoperative MRI-based VBQ is a strong, radiation-free predictor of cage subsidence after OLIF and may help identify high-risk patients for preventive strategies.

3.2 Association studies

3.2.1 Preoperative MRI-based vertebral bone quality (VBQ) score assessment in patients undergoing lumbar spinal fusion

Stephan N Salzmann[1], Ichiro Okano[1], Conor Jones[1], Jiaqi Zhu[1], Shuting Lu[1], Ikenna Onyekwere[1], Venkatesh Balaji[1], Marie-Jacqueline Reisener[1], Erika Chiapparelli[1], Jennifer Shue[1], John A Carrino[1], Federico P Girardi[1], Frank P Cammisa[1], Andrew A Sama[1], Alexander P Hughes[2]

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Published: March 24th, 2022. The Spine Journal.

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/35342015/

Objective:

- To evaluate whether the MRI-based VBQ score correlates with quantitative computed tomography (QCT)-derived spine bone mineral density (BMD) and whether VBQ can identify patients with osteopenia/osteoporosis (per QCT definition)

Study design:

- Retrospective cross-sectional study using retrospectively collected data (single-center lumbar fusion cohort, 2014–2019)

Key findings:

- VBQ vs QCT BMD correlation: Significant negative correlation $r = -0.358$ (95% CI −0.473 to −0.23; $p < .001$)
- The osteopenic/osteoporotic group had higher VBQ than normal BMD (~2.6 vs 2.2, $p < 0.0001$)
- Diagnostic discrimination: VBQ cutoff 2.388 yielded sensitivity 74.3%, specificity 57.0%, with AUC 0.7079 for identifying low BMD by QCT. Source

TAKE HOME MESSAGE

VBQ score showed moderate diagnostic ability to differentiate patients with normal BMD versus osteopenic/osteoporotic BMD based on QCT. VBQ may be an interesting adjunct to clinically performed bone density measurements in the future

3.3 Validation study

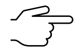
3.3.1 Adding Vertebral Bone Quality to the Fusion Risk Score: Does It Improve Predictions of Postoperative Complications?

Omar Ramos, MD[1], Jacob Razzouk, BS[2], Eduardo Beauchamp, MD[1], Benjamin Mueller, MD, PhD[1], Eiman Shafa, MD[1], Amir A. Mehbod, MD[1], Wayne Cheng, MD[2], Olumide Danisa, MD[2], Bayard C. Carlson, MD[1]

[1] Twin Cities Spine Center, Minneapolis, MN, [2] Loma Linda University Medical Center, Loma Linda, CA

Published: February 29th, 2024. Spine.

Link to full article:

 https://pubmed.ncbi.nlm.nih.gov/38419578/

Objective:

- To evaluate whether adding the MRI-based Vertebral Bone Quality (VBQ) score to the Fusion Risk Score (FRS) improves prediction of perioperative outcomes

Study design:

- Retrospective review of prospectively collected data

Key findings:

- 353 patients met inclusion and exclusion criteria
- Adding VBQ to FRS improved predictive ability for 90-day reoperation compared with FRS alone
- Both scores showed fair predictive ability for any adverse event, major adverse events, minor adverse events, and 2-year reoperation, but poor predictive ability for other outcomes

TAKE HOME MESSAGE

Adding VBQ to the Fusion Risk Score improves prediction of reoperation risk and provides a more complete preoperative risk profile for thoracic and lumbar fusion patients.

3.3.2 MRI-based vertebral bone quality score compared to quantitative computed tomography bone mineral density in patients undergoing cervical spinal surgery

Lisa Oezel[1,3], Ichiro Okano[1], Conor Jones[1], Stephan N. Salzmann[1,6], Jennifer Shue[1], Dominik Adl Amini[1,4], Manuel Moser[1,5], Erika Chiapparelli[1], Andrew A. Sama[1], John A. Carrino[2], Frank P. Cammisa[1], Federico P. Girardi[1], Alexander P. Hughes[1]

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Published: March 7th, 2023. European Spine Journal.

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/36882579/

Objective:

- To evaluate the correlation between MRI-based vertebral bone quality (VBQ) scores and bone mineral density measured by quantitative computed tomography in the cervical spine

Study design:

- Retrospective cohort study

Key findings:

- Cervical VBQ values (C2–T1) correlated strongly with each other, with higher VBQ at C2 and lower VBQ at T1
- VBQ scores showed statistically significant but only weak-to-moderate negative correlations with QCT bone mineral density across C2–T1
- The VBQ value corresponding to a given bone mineral density was level-specific, suggesting limited interchangeability across cervical levels

TAKE HOME MESSAGE

Cervical VBQ scores correlate only weakly to moderately with QCT-derived bone mineral density, which may limit their accuracy as a standalone surrogate for cervical BMD estimation in surgical patients.

3.3.3 MRI-Based Score for Assessment of Bone Mineral Density in Operative Spine Patients

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Department of Spine Surgery, Hospital for Special Surgery, New York, NY

Published: January 15th, 2023. Spine (Phila Pa 1976).

Link to full article:

Objective:

- To determine whether a previously developed MRI-derived bone mineral density scoring system can differentiate between healthy and osteoporotic vertebrae and to validate this scoring system against quantitative computed tomography measurements

Study design:

- Retrospective comparison

Key findings:

- VBQ differentiated between healthy and osteoporotic groups
- A greater VBQ score was associated with presence of osteoporosis, with a VBQ cutoff of 2.6 giving sensitivity 58% and specificity 90%
- VBQ scores weakly correlated with QCT-derived BMD and T scores

TAKE HOME MESSAGE

The MRI-based VBQ score can help identify osteoporosis in operative spine patients and serves as a practical screening approach without additional radiation.

3.3.4 Novel MRI-based score for assessment of bone density in operative spine patients

Jonathan Ehresman[1], Gregory C. Murphy[2], Daniel M. Sciubba[1]

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Published: November 1st, 2019. The Spine Journal.

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/31683066/

Objective:

- To create a simple MRI-based score to evaluate bone quality and evaluate the degree to which it correlates with conventional DEXA scores

Study design:

- Retrospective cohort

Key findings:

- Among 68 operative spine patients, 37 had osteopenia/osteoporosis based on DEXA (T-score < −1.0)
- A greater VBQ score was significantly associated with osteopenia/osteoporosis with a predictive accuracy of 81%
- VBQ scores correlated moderately with femoral neck T-scores and the lowest overall T-score, and correlated fairly with total hip T-scores

TAKE HOME MESSAGE

The VBQ score derived from routine lumbar T1-weighted MRI can opportunistically screen for low bone density in operative spine patients and shows meaningful correlation with DEXA.

4 Vasculature

4.1 Prognostic / outcome-associated studies

4.1.1 Abdominal aortic calcification is associated with impaired fusion after elective spinal fusion

Marco D. Burkhard, MD[1],*, Thomas Caffard, MD[1], Lukas Schönnagel, MD[1], Samuel Medina, BS[1], Ali E. Guven, MD[1], Anna-Maria Mielke, MD[1], Bruno Verna, MD[1], Erika Chiapparelli, MD[1], Giuseppe Loggia, MD[1], Alexander C. Gregg, MD[2], Ranqing Lan, MSc[3], Jennifer Shue, MS[1], Federico P. Girardi, MD[1], Frank P. Cammisa, MD[1], Andrew A. Sama, MD[1], Alexander P. Hughes, MD[1]

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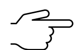
Published: April 9th, 2025. Spine Journal.

Link to full article:

 https://pubmed.ncbi.nlm.nih.gov/40216361/

Objective:

- To investigate the association between abdominal aortic calcification (AAC) severity and fusion success following posterior lumbar spinal fusion surgery

Study design:

- Retrospective cohort study of patients undergoing open posterior lumbar fusion (2010–2021) with postoperative CT at ≥12 months, assessing AAC on preop lateral radiographs and fusion outcomes on CT

Key findings:

- AAC independently predicted impaired posterolateral fusion (PLF): OR 1.10 (95% CI 1.02–1.20), $p = 0.015$
- AAC independently predicted combined PLF / interbody fusion (IBF): OR 1.16 (95% CI 1.06–1.29), $p = 0.002$
- Multivariable analysis revealed that each one-point increase in the AAC-24 score increased the odds of combined fusion impairment by 16%, and an increase of one standard deviation was associated with approximately a 2-fold increase in risk

TAKE HOME MESSAGE

Preoperative AAC (AAC-24 on standard lateral radiographs) is an independent risk factor for posterolateral and overall fusion impairment after elective posterior lumbar fusion.

4.1.1 Abdominal aortic calcification is an independent predictor of perioperative blood loss in posterior spinal fusion surgery

Ali E Guven[1], Gisberto Evangelisti[1,2], Lukas Schönnagel[1,3], Jiaqi Zhu[4], Krizia Amoroso[5], Erika Chiapparelli[1], Gaston Camino-Willhuber[1], Soji Tani[1,6], Thomas Caffard[1,7], Artine Arzani[1], Jennifer Shue[1], Andrew A Sama[1], Frank P Cammisa[1], Federico P Girardi[1], Ellen M Soffin[5], Alexander P Hughes[8]

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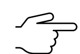
Published: March 13th, 2024. European Spine Journal.

Link to full article:

 https://pubmed.ncbi.nlm.nih.gov/38480623/

Objective:

- To evaluate whether abdominal aortic calcification (AAC) on lateral lumbar radiographs is associated with (and independently predicts) perioperative blood loss in posterior spinal fusion (PSF) surgery

Study design:

- Retrospective observational cohort study of PSF cases (March 2016–July 2023) using multivariable regression to identify predictors of blood loss

Key findings:

- AAC was common in posterior spinal fusion patients: AAC was present in 106/199 patients (53.3%)
- AAC independently predicted higher perioperative blood loss (even after adjustment): In multivariable regression, AAC was associated with +4.46 percentage points higher %EBL / TBV (95% CI 1.17-7.74, $p = 0.008$)
- AAC presence aligned with clinically higher bleeding/transfusion in unadjusted outcomes: Patients with AAC had higher median EBL (1589 ml vs 1227 ml, $p < 0.001$) and higher PRBC transfusion rate (17.9% vs 5.4%, $p = 0.013$)

TAKE HOME MESSAGE

AAC seen on routine lateral lumbar radiographs is an actionable preoperative risk marker that independently signals higher perioperative blood loss and transfusion risk in posterior spinal fusion surgery.

4.1.1 Does Atherosclerosis Have Negative Impacts on Early Adjacent Segment Degeneration After Posterior Lumbar Interbody Fusion?

Hironobu Sakaura[1], Daisuke Ikegami [1], Takahito Fujimori[1], Tsuyoshi Sugiura[1], Yoshihiro Mukai[2], Noboru Hosono[3]

[1]Japan Community Healthcare Organization Osaka Hospital, Osaka, Japan, [2]Nishinokyo Hospital, Nara, Japan, [3]Japan Community Healthcare Organization Hoshigaoka Medical Center, Osaka, Japan

Published: April 23rd, 2021. Global Spine Journal.

Link to full article:

☞ https://pubmed.ncbi.nlm.nih.gov/32875899/

Objective:

- To examine whether atherosclerosis (measured by abdominal aortic calcification, AAC) has negative impacts on early adjacent segment degeneration (ASD) after single-level traditional-trajectory PLIF (TT-PLIF)

Study design:

- Retrospective study of a surgical cohort with 3-year follow-up after TT-PLIF

Key findings:

- Early radiological ASD (R-ASD) was common, especially cranial: 41.6% at the suprajacent level vs 8.3% at the subjacent level by 3 years
- Higher AAC (more atherosclerosis) was significantly associated with early R-ASD: AAC 4.9 ± 4.2 in the R-ASD group vs 3.1 ± 3.7 in the no R-ASD group (p = .0192)
- Symptomatic ASD (S-ASD) was rare (total ~5.2%), and while AAC was numerically higher in S-ASD (5.8 ± 2.1 vs 3.8 ± 4.1), it was not statistically significant (p = 0.134)

TAKE HOME MESSAGE

Advanced AAC (atherosclerosis) was associated with a higher risk of early radiological adjacent segment degeneration after single-level TT-PLIF.

4.1.2 Abdominal Aortic Calcification Is a Significant Poor Prognostic Factor for Clinical Outcomes After Decompressive Laminotomy for Lumbar Spinal Canal Stenosis

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[1]Japan Community Healthcare Organization Osaka Hospital, Osaka, Japan.

Published: February 13th, 2019. Global Spine Journal.

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/31552153/

Objective:

- To examine whether chronic kidney disease (CKD) or advanced abdominal aortic calcification (AAC) negatively affects clinical outcomes after decompressive laminotomy for lumbar spinal canal stenosis (LSCS)

Study design:

- Retrospective study of 143 patients with ≥2-year follow-up after decompressive laminotomy

Key findings:

- AAC strongly associated with worse 2-year outcomes: AAC score had a relatively strong negative correlation with Japanese Orthopaedic Association (JOA) score at 2 years ($r = -0.587$) and with JOA recovery rate ($r = -0.520$), both statistically significant
- CKD was not a significant predictor in this cohort: Recovery rate was numerically lower in CKD patients (67.3% vs 70.5%) but not statistically significant ($p = 0.43$)
- Age correlated with baseline and 2-year JOA scores (not recovery): Age showed weak but significant negative correlations with preop JOA and 2-year JOA, but did not significantly correlate with recovery rate ($p = 0.32$)

TAKE HOME MESSAGE

Higher AAC burden is a meaningful "red flag" for worse clinical recovery after decompressive surgery for lumbar stenosis, whereas CKD alone was not clearly predictive in this dataset.

4.2 Association studies

4.2.1 Abdominal aortic calcification is associated with degeneration of the paraspinal muscles – a retrospective cross-sectional study

Friederike Schömig, MD[1,2], Lukas Schönnagel, MD[1,2], Jiaqi Zhu, MS[5], Phillip Suwalski, MD[1,6], Paul Köhli, MD[1,2], Thomas Caffard, MD[1,3], Ali E. Guven, MD[1], Erika Chiapparelli, MD[1], Artine Arzani, MD[1], Krizia Amoroso, MD[1], Jennifer Shue, MS[1], Andrew A. Sama, MD[1], Frank P. Cammisa, MD[1], Federico P. Girardi, MD[1], Alexander P. Hughes, MD[1]

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Published: May 8th, 2024. Spine (Phila Pa 1976).

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/38717315/

Objective:

- To analyze the relationship between abdominal aortic calcification (AAC) and paraspinal muscle degeneration (reduced cross-sectional area (CSA) and increased fatty infiltration (FI) in patients undergoing lumbar fusion surgery

Study design:

- Retrospective cross-sectional cohort study of 301 lumbar fusion patients for degenerative spinal pathology.

Key findings:

- AAC was independently associated with greater erector spinae (ES) FI in multivariable regression ($b = 0.270$, 95% CI 0.08–0.45, $p = 0.006$)
- AAC was independently associated with smaller psoas (PS) CSA ($b = -0.260$, 95% CI −0.43 to −0.09, $p = 0.003$)
- After adjustment, AAC was not independently associated with multifidus (MF) FI ($b = 0.166$, 95% CI −0.16 to 0.50, $p = 0.302$), despite a significant univariable association.

TAKE HOME MESSAGE

AAC is independently associated with ES and PS degeneration.

4.2.2 Abdominal aortic calcification assessed on standard lateral lumbar radiographs as a screening tool for impaired bone status in spine surgery

Maximilian Muellner [1,2], Henryk Haffer [1,2], Erika Chiapparelli [1], Yusuke Dodo [1], Jennifer Shue [1], Andrew A Sama [1], Frank P Cammisa [1], Federico P Girardi [1], Alexander P Hughes [1]

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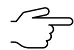
Published: July 14th, 2023. European Spine Journal.

Link to full article:

 https://pubmed.ncbi.nlm.nih.gov/37450043/

Objective:

- To determine whether abdominal aortic calcification (AAC) visible on routine lateral lumbar radiographs is associated with (and can discriminate) impaired bone status, using volumetric BMD (vBMD) from quantitative computed tomography (QCT) as the reference

Study design:

- Retrospective, cross-sectional diagnostic/association study in a spine surgery population (lumbar fusion candidates)

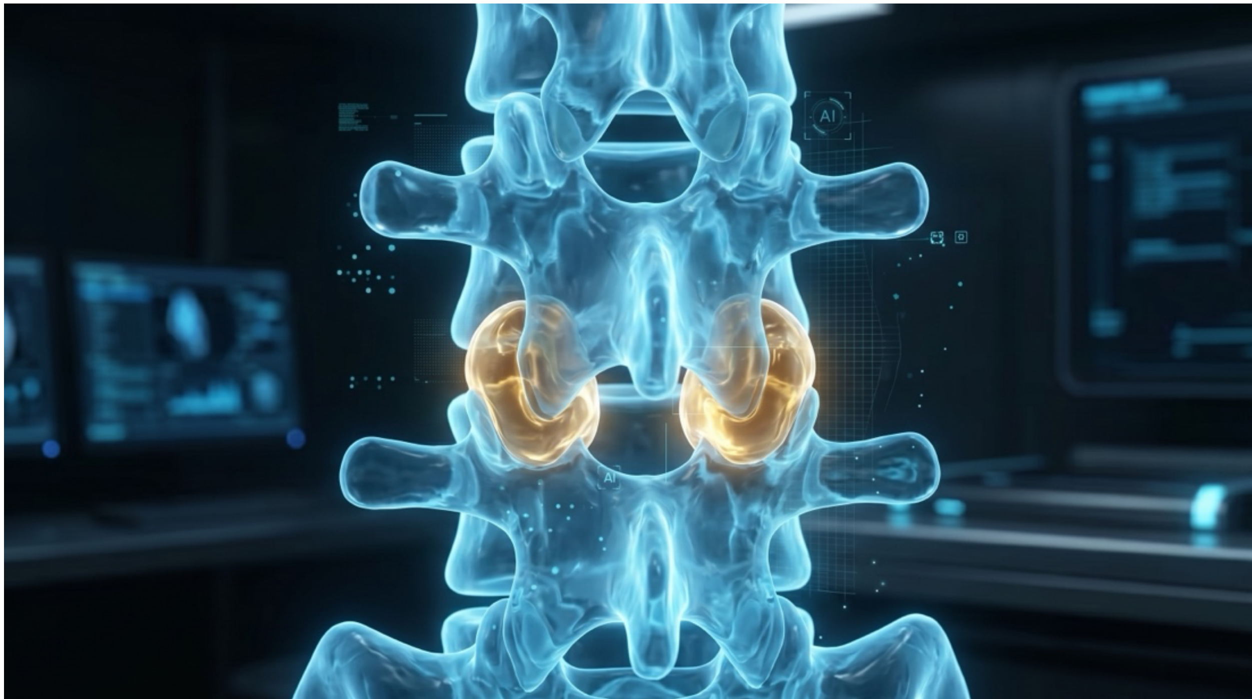
Key findings:

- AAC on lateral lumbar X-ray is linked to substantially lower bone density (QCT vBMD). Patients with AAC had significantly lower vBMD than those without AAC (97.8 mg/cm³ vs 121.5 mg/cm³, $p < 0.001$)
- More AAC = lower vBMD (moderate inverse relationship). AAC severity scores correlated moderately and inversely with vBMD (approx AAC24 −0.382; AAC8 −0.390; AAC4 −0.384, all $p < 0.01$)
- AAC has only "moderate" screening performance for impaired bone status (not definitive). Using vBMD ≤ 120 mg/cm³ as impaired bone status, AAC discrimination performance was AUC ~0.672–0.674, with sensitivity 70.1% and specificity 60.2%

TAKE HOME MESSAGE

Abdominal aortic calcification (AAC) seen on a routine lateral lumbar X-ray is a practical red flag for low bone density (impaired QCT vBMD) in spine surgery patients and should prompt formal bone health evaluation, even though AAC is only a moderate screening test.

5 Facet Joints



5.1 Prognostic / outcome-associated studies

5.1.1 A Simple Preoperative Score Predicting Failure Following Decompression Surgery for Degenerative Lumbar Spinal Stenosis

Dimitris Dimitriou[1], Elin Winkler[1], Sabrina Weber[1], Samuel Haupt[1], Michael Betz[1], Mazda Farshad[1]

[1]Department of Orthopedics, Balgrist University Hospital, University of Zürich, Zürich, Switzerland

Published: January 19th, 2023. Spine (Phila Pa 1976).

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/36728033/

Objective:

- To investigate the treatment failure rate following decompression surgery for degenerative lumbar spinal stenosis and to introduce a simple preoperative score to aid surgical decision-making

Study design:

- Retrospective observational study

Key findings:

- Baseline low back pain ≥ 7, facet joint effusion >2 mm on MRI, and disk degeneration (Pfirrmann > 4) were independently associated with higher risk of treatment failure
- A composite score (VAS back, facet joint effusion, and disk degeneration) of > 6 predicted treatment failure with 90% sensitivity and 64% specificity
- Patients with a score > 6 had substantially increased odds of treatment failure (odds ratio 15.5, 95% CI 4.6–52.2)

TAKE HOME MESSAGE

A simple preoperative score using low back pain severity, facet effusion, and disk degeneration can identify degenerative lumbar stenosis patients at high risk of failing decompression-alone and needing revision fusion.

5.1.2 Relationship between facet joint opening on CT and facet joint effusion on MRI in patients with lumbar spinal stenosis: analysis of a less invasive decompression procedure

Kentaro Yamada[1], Hidetomi Terai[2], Hitoshi Tonomura[2], Akinobu Suzuki[2], Shinji Takahashi[2], Koji Tamai[2], Katsumi Yabuki[2], Hiroaki Toyoda[2], Shoichiro Ohyama[2], Akito Yabu[2], Hiroaki Nakamura[2]

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Published: October 22nd, 2021. Journal of Neurosurgery.

Link to full article:

https://pubmed.ncbi.nlm.nih.gov/34678767/

Objective:

- To investigate the relationship between facet joint opening (FJO) on CT and facet joint effusion (FJE) on MRI in patients undergoing less invasive decompression for lumbar spinal stenosis
- To evaluate the impact of these findings on clinical outcomes, particularly the need for further surgery

Study design:

- Retrospective cohort study of 293 patients (1465 lumbar levels, L1–2 to L5–S1) who underwent less invasive decompression for lumbar spinal stenosis with at least 5 years of follow-up, assessing preoperative CT for facet joint opening (≥2 mm) and MRI for facet joint effusion, and analyzing level-specific risk of further surgery

Key findings:

- FJO was present in 27% of levels (402/1465) and FJE in 21% of levels (306/1465), with only modest correspondence between the two findings (70% agreement, low kappa)
- Levels with both FJO and FJE (9% of levels) more commonly demonstrated other deformity/instability-associated findings such as lateral olisthesis, lateral wedging, and axial intervertebral rotation
- Having both FJO and FJE at the same level was associated with higher likelihood of requiring further surgery (OR 2.42)

TAKE HOME MESSAGE

In lumbar spinal stenosis treated with less invasive decompression, the combination of FJO on CT and facet joint effusion on MRI identifies levels at higher risk for needing further surgery and warrants careful long-term follow-up.

5.1.3 Can facet joint fluid on MRI and dynamic instability be a predictor of improvement in back pain following lumbar fusion for degenerative spondylolisthesis?

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Published: April 22nd, 2016. European Spine Journal.

Link to full article:

Objective:

- To investigate the relationship between lumbar facet joint fluid and dynamic instability in degenerative spondylolisthesis
- To compare patient-reported outcomes following single-level posterior lumbar fusion for static versus dynamic spondylolisthesis

Study design:

- Retrospective analysis of consecutive patients with degenerative spondylolisthesis undergoing single-level posterior lumbar fusion (December 2010 to January 2013) at a single academic institution, assessing facet fluid on MRI, dynamic instability, and patient-reported outcomes

Key findings:

- Increasing facet joint fluid was associated with higher likelihood of dynamic instability, with a 41.6% increase in odds of dynamic instability per 1 mm of facet fluid
- Facet fluid <0.5 mm corresponded to a 90% probability that dynamic instability was absent
- Presence of facet fluid and presence of dynamic instability were each associated with achieving a minimal clinically important difference in low back pain improvement after fusion

TAKE HOME MESSAGE

In degenerative spondylolisthesis, facet joint fluid on MRI is linked to dynamic instability and may help predict meaningful back pain improvement after posterior lumbar fusion.

5.2 Association studies

5.2.1 Lumbar facet joint effusion in MRI: a sign of instability in degenerative spondylolisthesis?

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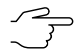
Published: September 20th, 2011. European Spine Journal.

Link to full article:

 https://pubmed.ncbi.nlm.nih.gov/21932065/

Objective:

- To investigate whether facet joint effusion on conventional supine MRI indicated increased abnormal motion in degenerative spondylolisthesis and rotational translation

Study design:

- Retrospective study of 160 patients identified from a spine surgery database who had preoperative upright X-rays (AP and lateral) and supine MRI, assessing slippage and MRI/X-ray parameters including facet joint effusion and rotational translation

Key findings:

- Patients with larger facet joint effusion more often showed a > 3% difference in percent slip between upright X-ray and supine MRI
- Facet effusion size correlated with the relative slippage difference between standing and supine positions ($r = 0.64$, $p < 0.001$)
- Greater left–right asymmetry in facet effusion was associated with the presence of rotational translation

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On routine supine lumbar MRI, facet joint effusion and especially asymmetry are associated with radiographic markers of instability in degenerative spondylolisthesis.

5.3 Comparative studies

5.3.1 Lumbar Total Disc Replacement Leads to Increased Subsequent Facet Injections Compared to Anterolateral Lumbar Interbody Fusions

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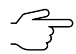
Published: June 11th, 2024. Global Spine Journal.

Link to full article:

 https://pubmed.ncbi.nlm.nih.gov/38860341/

Objective:

- To compare the usage of therapeutic lumbar facet injections as a measure of symptomatic facet arthrosis following single-level, stand-alone lumbar total disc replacement versus anterolateral lumbar interbody fusion (ALIF/LLIF)

Study design:

- Retrospective matched cohort study using the PearlDiver database (2010–2021), with 1:1 matching on age, sex, insurance, year of operation, and medical comorbidities, evaluating facet injection use at 1, 2, and 5 years and secondary outcomes including subsequent lumbar surgeries and complications

Key findings:

- Facet injections occurred more frequently after total disc replacement than after ALIF/LLIF at 1 year (6.07% vs 1.66%), 2 years (8.40% vs 3.74%), and 5 years (11.47% vs 6.40%)
- Five-year injection-free probability was lower after total disc replacement (87.1%) than after ALIF/LLIF (92.9%)
- Rates of subsequent lumbar surgeries and surgical complications were not meaningfully different between the two groups over follow-up

TAKE HOME MESSAGE

Compared with ALIF/LLIF, lumbar total disc replacement is associated with more subsequent facet injections and does not appear to reduce reoperation risk.

5.4 Background

5.4.1 Biomechanics of the Lumbar Facet Joint

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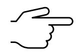
Published: April 26th, 2019. Spine Surgery and Related Research.

Link to full article:

 https://pubmed.ncbi.nlm.nih.gov/32039290/

Objective:

- To summarize the lumbar facet joint anatomy relevant to biomechanical function and describe facet joint biomechanical behavior under different loading conditions

Study design:

- Narrative literature review

Key findings:

- Facet joints are true synovial joints with complex, non-flat articular surfaces; the term “facet” (flat surface) is essentially a misnomer, and the joint is better understood as a 3D saddle-shaped (parabolic hyperboloid) articulation
- Facet joints and the intervertebral disc function together as a “three-joint complex” (motion segment/articular triad), balancing motion guidance with protection against injurious movements
- Facet load-sharing depends strongly on posture. In slight lumbar extension (about 2°, erect standing), facet joints can transmit a meaningful portion of axial load (reported around 16%), whereas in slight flexion (erect sitting) they may transmit little to no axial load
- Disc degeneration (especially loss of disc height) increases facet loading and contact pressure, shifting more compressive force to the posterior elements and altering the mechanical environment of the facet joint
- Three main mechanisms by which axial compressive load can be transmitted through/around the facet region: (a) through articular surfaces, (b) through capsular ligaments, and (c) via bony contact/impingement involving articular process tips and the neural arch (lamina/pars), particularly with extension and reduced disc height

- In lumbar extension, the inferior articular processes translate/rotate such that contact areas move inferiorly, and with degeneration there may be "tip impingement" that is repeatedly proposed as a pain-generating mechanism (capsular/bony impingement)
- In forward flexion, facet surfaces tend to separate inferiorly while the inferior articular process glides upward and forward; this supports the concept of facets acting like hooks/bony restraints that help resist anterior translation (relevant to degenerative spondylolisthesis concepts)
- Facet joints are emphasized as key limiters of axial rotation: during rotation one side tends to approximate/impact, while the opposite side gaps/opening increases, which helps limit excessive torsion and protect the disc
- Lateral bending is coupled with axial rotation in the lumbar spine (e.g., left lateral bending often coupled with right axial rotation), and this coupling is important for understanding facet loading patterns during "pure" bending tasks
- The facet capsule is not a simple sleeve: the outer layer includes organized fiber bands (described as superior "dome-like," middle horizontal, and inferior "hammock-like" patterns) and the capsule's wrap-around attachment can create compressive effects and stabilizing constraints that matter biomechanically.

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Lumbar facet joints are complex 3D load-bearing structures whose biomechanics change substantially with degeneration, helping explain their role in spinal pain and degenerative disorders.

5.4.2 Facet Joints of the Spine: Structure–Function Relationships, Problems and Treatments, and the Potential for Regeneration

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Published: June 4th, 2018. Annual Review of Biomedical Engineering.

Link to full article:

Objective:

- To review facet joint anatomy and functional properties, describe major problems/pathologies and current treatments, and introduce the potential for facet joint regeneration with engineering-based strategies

Study design:

- Narrative review

Key findings:

- The zygapophysial (facet) joint is a diarthrodial joint that, together with the intervertebral disc, supports spinal motion while contributing to spinal stability
- Facet joints are a major contributor to spine-related pain and disability burden
- Facet joints are susceptible to early osteoarthritic degeneration, which can drive pain across lumbar, thoracic, and cervical regions
- Degeneration of the facet joint and intervertebral disc are mechanically linked; changes in one can alter loading and function of the other
- Facet-related pain can be difficult to diagnose definitively and is often approached with targeted diagnostic blocks in clinical practice
- Noninvasive treatments can reduce symptoms but generally do not provide durable, long-term relief for many patients
- Invasive treatments may reduce pain but commonly do not restore or preserve native joint function
- Existing procedural options (e.g., injections/denervation approaches) are typically symptom-modifying rather than structure-restoring
- Current surgical approaches can address pathology but may alter biomechanics and create downstream issues (e.g., adjacent segment effects)
- Regenerative strategies (including tissue engineering concepts) are presented as a longer-term, motion-preserving approach to restoring facet joint structure and function

TAKE HOME MESSAGE

Facet joints play a central role in spinal mechanics and back/neck pain, and because current therapies often relieve symptoms without restoring function, regenerative approaches are an important future direction.