Adjacent Segment Disease following Lumbar Spinal Fusion

Dr Bill Sears

Neurosurgical Society of Australasia Annual Scientific Meeting
Adelaide, September 1st 2017
Disclosures

• Consultant:
  • Paradigm Spine
  • Medtronic

• Royalties:
  • Medtronic: *Interbody fusion implant*
  • Paradigm Spine: *Dynamic stabiliser*
Patient from control arm of Coflex® FDA IDE trial
(Images courtesy of Paradigm Spine)

… fusion disease… or natural history?
Prevalence

- ASDegen 34% (314/926)
- ASDis 14% (173/1216)
Adjacent Segment Disease Following Posterior Lumbar Interbody Fusion: A Retrospective Review of 1000 PLIFs

William Sears
Royal North Shore & Dalcross Adventist Hospitals
Sydney, Australia
NASS 2010 & EuroSpine 2010 & Spine J 2011
Study Population

- 912 patients, 1000 consecutive PLIF procedures
  - October 1993 – November 2009
  - Mean age: 63 yrs (range: 14-92)

- Inclusion criteria:
  - Lumbar degenerative pathology
  - Failed conservative management

- Follow-up:
  - 91 % patients, 92 % procedures
Surgical Technique

• Posterior lumbar interbody fusion (PLIF)
  • Open technique
  • Insert & rotate interbody spacers
  • Pedicle screw instrumentation

• Attempted restoration of coronal & sagittal balance
Levels fused
Results

• Prevalence:
  • 130 / 1000 procedures – 13% (mean f/u: 63 months)
    • 12 laminectomy
    • 118 further fusions

• Annual incidence (all patients) – 2.5% (95% CI: 1.9-3.1)

• Mean time to further surgery – 43 months (range: 2.3 – 162)
ASD relevance?

  Pumberger M et al, *JBJS(Br)* 2012

  → 125,000 – 250,000 further surgeries for ASDs in the U.S. by 2018
... fusion disease... or natural history?
Pre-programmed biological response?
Genetics
The Effect of Spinal Fusion on Intervertebral Disc Composition: An Experimental Study


Raymond Purves Research Laboratories (University of Sydney), The Royal North Shore Hospital of Sydney, St. Leonards, N.S.W. 2065, Australia

Submitted for publication November 19, 1975
Genetics

• Battie et al. *Spine 1995*
  • 115 pairs human male monozygotic twins
  • DDD on MRI
  • Explained by:
    • Genetic factors – primarily
    • Environmental factors – complex contribution (incl. occupation)

• Sambrook et al. *Arthritis Rheum. 1999*
  • 86 monozygotic & 154 dizygotic twins
  • DDD on MRI
  • Genetic inheritance: $\sim 74\%$ contribution
Genetics

  • Cross-sectional study 2256 women
  • 371 monozygotic & 698 dizygotic twins

• Odds ratio for LBP:
  • Monozygotic  6
  • Dizygotic    2.2

• Correlation between LBP and DDD (p<0.001)
Genetics

- Gologorsky & Chi. *Neurosurg.* 2014
  - Lumbar DDD probably polygenic
  - Many genetic variants → small/moderate contributions

  - 71 single-nucleotide polymorphisms of 41 candidate genes correlated to 6 MRI markers of DDD in 809 patients
  - Studies of genetic associations prone to variability
  - Difficult to consider one set of genes responsible
Demographic & Environmental factors

- Age
- Gender
- Occupation
- Smoking
Demographic & Environmental factors

- Age
  - A risk factor in most studies
  - Age > 60 yrs → 2.5x risk of ASD  
    Lee JC et al. *Spine* 2014
  - Retrospective cohort study (n=1000)  
    Sears et al. *Spine J* 2011

![Cox proportional-hazards regression analysis](chart.png)

<table>
<thead>
<tr>
<th>Covariate</th>
<th>Relative Risk (95%CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;45yrs</td>
<td>x 0.25 (0.10 to 0.63)</td>
<td>0.003</td>
</tr>
<tr>
<td>45-60yrs</td>
<td>x 0.55 (0.34 to 0.87)</td>
<td>0.01</td>
</tr>
</tbody>
</table>

![Time from index surgery (months)](chart.png)
Demographic & Environmental factors

• Age

• Gender
  • ASD – no (7 studies)
Demographic & Environmental factors

- Age
- Gender
- Occupation
  - 45 ♂ monozygotic twin study DDD. Battie et al. *Lancet* 2002
  - modest effect
Demographic & Environmental factors

- Age
- Gender
- Occupation
  - 45 ♂ monozygotic twin study DDD. Battie et al. *Lancet* 2002
  - modest effect
  - 115 ♂ monozygotic twin study DDD. Battie et al. *Spine* 1995
  - 7% upper lumbar
  - 2% lower lumbar → 9% with age → 43% with familial aggregation
Demographic & Environmental factors

- **Smoking**
  - Monozygotic twin study → DDD
    

- **ASD**
  - Retrospective (n=89). Mok et al
    → Yes
  - Case control (n=51) & retrospective (n=137). Djurasovic et al & Alentado et al
    → No
Co-mobidities

• Diabetes
  • No clear evidence

• Depression
  • Retrospective ASD study. (n=137) Alentado et al Spine 2016
    → O.R.: 5.35, p=0.03
Co-mobidities

- Cardio-vascular disease
  - Alentado et al → Yes (p=0.02)
  - Lee et al. *J Korean Neurosurg Soc. 2017*  

Hypertension ↔ DDD
Co-mobidities

- **Obesity**
  - Nakashima et al & Alentado et al → No (for ASD)
  - Hangai et al & Lee et al → Yes (for DDD)
  - 1:1 pair analysis (n=100) ASD vs. No ASD → OR: 1.36, p=0.008

- **Diabetes**
  - No clear evidence

- **Depression**
  - Retrospective ASD study. (n=137) Alentado et al Spine 2016
  → OR: 5.35, p=0.03
Pre-existing ASD

- **Yes**
  - Retrospective, n=62  Han et al *J Neurosurg Spine 2016*
    - Pfirrmann grade > 3  →  8.75x risk of ASD (p=0.005)
  - Retrospective 1:1 pair analysis, n=100  Kim JY et al *Spine J 2016*
    - Pre-op **Facet joint degen**  →  ASD (OR: 3.1, p=0.011)
    - Pre-op **DDD**  →  ASD (OR: 2.8, p=0.003)
Pre-existing ASD

• No
  • Case-control retrospective, n=51  Djurasovic et al *Orthopedics* 2008
Biomechanical effects of fusion

- Range-of-motion
- Intradiscal pressures
- Facet joint loads
- Neutral zone

Evidence:
- *Ex vivo*
- *In vivo*
Biomechanical effects of fusion

• *Ex vivo* study methodologies
  • Test protocol
Biomechanical effects of fusion

• *Ex vivo* study methodologies
  • Test protocol
    • Flexibility (load control)
    • Stiffness (displacement control)
    • Hybrid
Biomechanical effects of fusion

- *Ex vivo* study methodologies
  - Test protocol
    - Flexibility (load control)
    - Stiffness (displacement control)
    - Hybrid

- Systematic review of *in vivo* post fusion kinetics
  Malakoutian et al. *Eur Spine J* 2015
  - 5/6 studies reported ↓ ROM post fusion
The Coflex® vs. Fusion IDE Trial – An *in vivo* Biomechanical Study of Adjacent Segment Motion following Fusion

W.R. Sears¹, R.J. Davis², J.D. Auerbach³

¹Wentworth Spine Clinic, Sydney, Australia, ²Greater Baltimore Neurosurgical Associates, Baltimore, MD, USA, ³Albert Einstein College of Medicine, Bronx, NY, USA

NASS 27th Annual Meeting (2012)
Dallas, October 2012
Total lumbar range of motion
(L1-S1 in degrees, fusion patients)

![Bar chart showing total lumbar range of motion for pre-op, 12-months, and 24-months for 1-level and 2-level fusion patients. The chart indicates a decrease in range of motion over time, with a notable decrease from pre-op to 12-months. The graph includes a dashed line at 21°, which represents a reference value. The chart legend indicates that darker bars represent 1-level fusion patients, while lighter bars represent 2-level fusion patients.]
Displacement control – *in vivo*
Fusion variables:
Biomechanical effects and ASD risk

• Length of fusion
• Fusion alignment
  • Sagittal plane
  • Coronal plane
• Fusion rigidity
PROGRESSIVE INCREASE IN MECHANICAL BURDEN ON ADJACENT LEVELS AFTER 1-, 2- & 3-LEVEL LUMBAR FUSIONS: an *in vitro* Study

William Sears*  Ryan Sullivan#  Leonard Voronov#  Robert Havey#  Gerard Carandang#  Muturi Muriuki##  Saeed Khayatzadeh#  Avinash Patwardhan##

*Wentworth Spine Clinic, Sydney, Australia;  #Orthopedic Biomechanics Lab, Edward Hines Jr. VA Hospital, Chicago, USA  
ISASS, SanDiego, Ca.  
April 2015
Test Setup
Mean age: 45 years
(range: 30-51)
Results
Mean pooled Range of Motion @ L4/5
%age of intact, Displacement control

p=0.04
Mean pooled Range of Motion @ L3/4

%age of intact, Displacement control

p<0.001
- L5-S1 v Intact
- L4-S1 v L5-S1
Mean pooled Range of Motion @ L2/3

%age of intact, Displacement control

p<0.01

- L5-S1 v Intact
- L4-S1 v L5-S1
- L3-S1 v L4-S1
Mean Segmental Ranges of Motion

(Displacement Control, Flex/ext, %age of intact)
Mean Segmental Ranges of Motion

*(Load Control, Flex/ext, %age of intact)*

![Bar chart showing mean segmental ranges of motion for different lumbar levels.](chart.png)
Kaplan Meier Survivorship Analysis. n=1000, Sears et al. *Spine J* 2011

Number of Levels Fused: 1, 2, 3 & 4

\[
p < 0.0001
\]
## Annual Incidence & Prevalence vs. Number of Levels Fused

<table>
<thead>
<tr>
<th>No. of Levels Fused</th>
<th>Annual Incidence (95% CI)</th>
<th>Prevalence 5 year</th>
<th>Prevalence 10 year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mixed (all patients)</strong></td>
<td>2.5% (1.9-3.1)</td>
<td>14%</td>
<td>22%</td>
</tr>
<tr>
<td>1</td>
<td>1.7% (1.3-2.2)</td>
<td>9%</td>
<td>16%</td>
</tr>
<tr>
<td>2</td>
<td>3.6% (2.1-5.2)</td>
<td>17%</td>
<td>31%</td>
</tr>
<tr>
<td>3 &amp; 4</td>
<td>5.0% (3.3-6.7)</td>
<td>29%</td>
<td>40%</td>
</tr>
</tbody>
</table>
Range of Motion
in vitro &
in vivo…

ASD
Lumbar Spinal Fusion as a Risk Factor for Adjacent Segment Degeneration – Results of a Randomized Controlled Trial

W. Sears¹, G. Maislin², R. Davis³, T. Errico⁴, H. Bae⁵

¹ Wentworth Spine Clinic, Sydney, Australia; ² Biomedical Statistical Consulting, Wynnewood, PA; ³ Greater Baltimore Neurosurgical Associates, Baltimore, MD, United States; ⁴ NYU Hospital for Joint Diseases, New York, NY; ⁵ Cedars Sinai Spine Center, Los Angeles, CA

Methodology

- Inter-laminar dynamic spacer  US IDE RCT
- Secondary quantitative data analysis
Methodology

- Inter-laminar dynamic spacer vs. posterolateral fusion
Methodology

- Inter-laminar dynamic spacer IDE RCT
  - two-level arm
  - 55 investigational & 27 fusion controls
Methodology

- **Inter-laminar dynamic spacer IDE RCT**
  - two-level arm
  - 55 investigational & 27 fusion controls

- **Secondary radiographic analysis**
  - Pre-op through 5-year post-op.
  - Index, 1st & 2nd adjacent segments
  - Quantitative Motion Analysis (Medical Metrics Inc, TX).
    - angular range-of-motion (ROM)
    - average disc-space heights
Methodology

- Disc-space heights
Results – Segmental angular ROM

P=0.002

Change in angular ROM (degrees)

Interlaminar Stabilizers: Index Level
Interlaminar Stabilizers: 1st Adjacent Level
Fusion controls: 1st Adjacent Level
Results – disc space height (1st adjacent level)

-1.1mm (±1.5mm) or -14%

Inter-laminar Stabilisers
Results – disc space height (1st adjacent level)

-1.1mm (±1.5mm) or -14%

-2.2mm (±2.2mm) or -30%

P=0.007*

* Wilcoxon rank sum
Disc space heights (2nd adjacent level)

Pre-op Month 60

Mean Disc Height (mm)

-0.47mm (±0.8mm)

-1.04mm (±1.5mm)

P=0.031*

* Wilcoxon rank sum
Frequency distribution of Percentage Reductions in relative disc-space height @ 60-months – 1st adjacent level

Fusion vs. ILS

- Fusion
- Interlaminar stabilisers
Fusion variables:
Biomechanical effects and ASD risk

- Length of fusion
- Fusion alignment
  - Sagittal plane
  - Coronal plane
- Fusion rigidity
Sagittal plane fusion alignment and ASD risk

- Retrospective *in vivo* studies – post-op sagittal alignment & ASD
  - Kumar et al. Eur Spine J 2001
  - Djurasovic et al. Orthopedics 2008
  - Bae et al. Neurosurgery 2010
  - Korovessis et al. Spine 2010
  - Nakashima et al. Spine 2015
Iatrogenic/surgical factors and ASD risk

• Surgical approach
  • Muscle damage
  • Ligament damage
  • Rostral laminectomy
  • Facet joint damage
Load tolerance to bending or buckling

- Intact spine: 3000 - 8000N
- Cadaver spine: 20N
Iatrogenic/surgical factors and ASD risk

• Surgical approach
  • Muscle damage – *in vivo* evidence:
    • ↑ *flex/ext ROM at suprajacent segment* ALIF vs. PLF
      • 7.7° vs. 11.6° (p<0.05)
      • Retrospective study (n=28) Kim HJ et al *Clin Invest Med. 2009*
    • ↑ *fatty degen & muscle atrophy in ASD patients*
      • Retrospective logistic regression (n=100) Min et al *Asian Spine J 2009*
Iatrogenic/surgical factors and ASD risk

• Surgical approach
  • M.I.S. – *in vivo* evidence:
    • Varied muscle damage reports
    • Systematic review of ASD. Li et al. *PlosOne 2017*
      • 9 trials, 770 patients but low-moderate quality evidence
      • ↓ *ASD incidence in MIS vs. open*
Iatrogenic/surgical factors and ASD risk

• Surgical approach
  • Muscle damage
  • Ligament damage
  • Rostral laminectomy
  • Facet joint damage

### Cox proportional-hazards regression analysis

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<th>Covariate</th>
<th>Relative Risk $(95%CI)$</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjacent level laminectomy</td>
<td>$\times 2.4$ $(1.09 \text{ to } 5.17)$</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Sears et al. *Spine J* 2011
If ASD a disease... why?
Can we mitigate the effects of fusion?
Adjacent Segment Disease
Mitigation strategies

- Index level... *motion preservation*
  - Disc arthroplasty
    - Nucleus replacement
  - TDR
  - Posterior dynamic stabilizers
    - Interspinous
    - Pedicle screw based
ASD: Disc arthroplasty vs. fusion...

• Systematic review – Wang et al *Spine* 2012
  - Combined 2 RCTs (Berg et al & Guyer et al), n=285 @ 2-5 years
  - Clinical ASD in 1.2% TDR vs. 7.0% fusions (5.9x, p=0.02)

• Cochrane systematic review – Jacobs et al *Spine* 2013
  - “Long term benefits such as ASD not properly assessed”

  - 13 studies, n=1270
    - < 5-years: No difference in clin. ASD (p=0.10)
    - > 5-years: Signif. ↓ASD reoperation rate for TDR (p<0.0001)
Adjacent Segment Disease
Mitigation strategies

• Index level... *motion preservation*
  • Disc arthroplasty
  • Nucleus replacement
  • TDR
  • Posterior dynamic stabilizers
    • Interspinous
    • Pedicle screw based

• Adjacent level... ‘topping off’
  • *Does is it work?*
Topping-off:
Interspinous device
Further surgery for ASD after ‘Topping-off’ with interspinous spacers
The spine: a tower of damped, segmental ‘spring’ elements
Overall spinal & individual segmental load displacement curves – *in vitro*
Measuring segmental stiffness
L3-L4 Regression Slope per Specimen

**L3-L4 / Spec#1**

- **Force (N)**
- **Displacement (mm)**
- Line equation: $y = 25.02x - 0.1429$, $R^2 = 0.8964$
- Line equation: $y = 15.81x - 0.6429$, $R^2 = 0.8167$

**L3-L4 / Spec#2**

- **Force (N)**
- **Displacement (mm)**
- Line equation: $y = 34.71x + 2.8571$, $R^2 = 0.8967$
- Line equation: $y = 15.5x$, $R^2 = 1$

**L3-L4 / Spec#3**

- **Force (N)**
- **Displacement (mm)**
- Line equation: $y = 27.64x + 6.5714$, $R^2 = 0.9096$
- Line equation: $y = 14.35x + 1.5714$, $R^2 = 0.9769$

**L3-L4 / Spec#4**

- **Force (N)**
- **Displacement (mm)**
- Line equation: $y = 32.327x + 5.9286$, $R^2 = 0.8785$
- Line equation: $y = 14.75x + 0.9893$, $R^2 = 0.9999$

**L3-L4 / Spec#5**

- **Force (N)**
- **Displacement (mm)**
- Line equation: $y = 25x + 2.3333$, $R^2 = 0.9745$
- Line equation: $y = 15.5x + 0.8333$, $R^2 = 0.9914$

**L3-L4 / Spec#6**

- **Force (N)**
- **Displacement (mm)**
- Line equation: $y = 35.25x - 0.2381$, $R^2 = 0.9886$
Avg of Individual Regression Slopes

Slope (N/mm)

L2-L3  L3-L4  L4-L5  L5-S1
With degeneration & instability: Segmental stiffness ~10-15N/mm

Dysfunction

Instability

Stabilisation

New total segment stiffness:
10 + 25 + 25 = 60 N/mm
Adjacent Segment Disease
Mitigation strategies

• Index level... *motion preservation*
  • Disc arthroplasty
  • Nucleus replacement
  • TDR
  • Posterior dynamic stabilizers
    • Interspinous
    • Pedicle screw based

• Adjacent level... ‘topping off’
  • *Does this work?*
78 F
Comparative demographics
Historical controls vs. FSD ‘topping off’ (Sep 2011-Present)
Post 2-, 3- & 4-level fusions, 60+ years

<table>
<thead>
<tr>
<th></th>
<th>Historical Controls</th>
<th>FSD Topping-off</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>n</strong></td>
<td>253</td>
<td>76</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td>73yrs (±6.5)</td>
<td>72yrs (±6.4)</td>
</tr>
<tr>
<td><strong>BMI</strong></td>
<td>28 (±6)</td>
<td>28 (±5)</td>
</tr>
<tr>
<td><strong>male : female (%)</strong></td>
<td>39 : 61</td>
<td>32 : 44</td>
</tr>
<tr>
<td><strong>Previous surgeries (mean±SD)</strong></td>
<td>1.0 (±1.1)</td>
<td>1.6 (±0.8)</td>
</tr>
<tr>
<td><strong>No. of levels fused:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>72%</td>
<td>42%</td>
</tr>
<tr>
<td>3</td>
<td>17%</td>
<td>34%</td>
</tr>
<tr>
<td>4</td>
<td>11%</td>
<td>24%</td>
</tr>
</tbody>
</table>
Kaplan Meier Survivorship Analysis

Pedicle screw based couplers vs. Historical controls

2-4 level fusions, aged 60+ yrs, PJK patients excluded

<table>
<thead>
<tr>
<th>Statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log-rank</td>
<td>0.024</td>
</tr>
<tr>
<td>Wilcoxon</td>
<td>0.015</td>
</tr>
<tr>
<td>Tarone-Ware</td>
<td>0.017</td>
</tr>
</tbody>
</table>

Time in Months (31/08/2017)

Historical controls (n=253)  →  Topped off with flexible couplers (n=76)
Conclusions

• ASD: a complex and likely multifactorial pathology
Pure moments

A. Pure moment (pulleys moved)

B. Impure moment (pulleys fixed)

C. Resulting moment and force (pulleys fixed)

From: Panjabi Clin Biomech 2007
Adjacent segment disease

...fusion disease... or natural history?
Kaplan Meier Survivorship Analysis

Lytic (n=103) vs. Degenerative Spondylolistheses (n=221)

<table>
<thead>
<tr>
<th>Spondy Type</th>
<th>Annual Incidence (95%CI)</th>
<th>5 year Prevalence</th>
<th>10 year Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lytic</td>
<td>1.1 % (0.3-1.8)</td>
<td>6 %</td>
<td>8 %</td>
</tr>
<tr>
<td>Degen.</td>
<td>2.4 % (0.7-4.1)</td>
<td>11 %</td>
<td>27 %</td>
</tr>
</tbody>
</table>

p=0.04
Multivariate Risk Factor Analysis
*Cox proportional-hazards regression model*

- **Age** –
  - < 45 (n=130)
  - 45-60 (n=199)
  - > 60-years (n=671)

- **Number of levels fused** –
  - 1-level (n=593)
  - 2-levels (n=216)
  - 3 or 4 levels (n=117) and 5+ levels (n=60)

- **Sex** – male or female

- **Previous surgery** – 0 - 6

- **Laminectomy adjacent** (to the index fused levels)

- **Level of the Distal fused vertebra** – L1, L2, L3, L4, L5 or S1

- **Deformity** – Nil, degen spondy, lytic spondy, scoliosis < 15degs, scoliosis > 15degs, kyphosis/flat-back

<table>
<thead>
<tr>
<th>Covariate</th>
<th>b</th>
<th>SE</th>
<th>P</th>
<th>Exp(b)</th>
<th>95% CI of Exp(b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age = 45-60yrs</td>
<td>-0.587</td>
<td>0.24</td>
<td>0.012</td>
<td>0.55</td>
<td>0.34 to 0.87</td>
</tr>
<tr>
<td>Age = &lt;45yrs</td>
<td>-1.364</td>
<td>0.47</td>
<td>0.003</td>
<td>0.25</td>
<td>0.10 to 0.63</td>
</tr>
<tr>
<td>Levels_fused = 3 or 4</td>
<td>1.121</td>
<td>0.24</td>
<td>&lt;0.0001</td>
<td>3.0</td>
<td>1.89 to 4.86</td>
</tr>
<tr>
<td>Levels_fused = 2</td>
<td>0.775</td>
<td>0.21</td>
<td>0.0003</td>
<td>2.1</td>
<td>1.42 to 3.25</td>
</tr>
<tr>
<td>Lowest_lev = L5</td>
<td>0.498</td>
<td>0.19</td>
<td>0.007</td>
<td>1.7</td>
<td>1.15 to 2.41</td>
</tr>
<tr>
<td>Additional Laminectomy</td>
<td>0.870</td>
<td>0.40</td>
<td>0.03</td>
<td>2.4</td>
<td>1.09 to 5.17</td>
</tr>
</tbody>
</table>
Floating Fusions?
L4/5 vs L4-S1 (Degen spondylolistheses)

\[ p=0.29 \]
Aims

1. Determine
   - Annual incidence
   - Prevalence
   of surgical intervention for ASD following lumbar arthrodesis

2. Examine
   - *Relative risk factors*
Statistical analysis

- Kaplan-Meier survivorship analysis –
  - Prevalence & annual Incidence
- Cox proportional-hazards regression –
  - Multivariate analysis of risk factors

- Xlstat version 2009.6.03 & Medcalc version 11.2.1.0
- Significance set at $p < 0.05$
Discussion

• Methodology:
  • Single surgeon
  • Single technique
  • Personal indications
  • Disadvantages
    • Care required in applying to other surgeons/techniques
  • Advantages
    • Reduction in confounding variables
    • Facilitates multi-variant analysis
      • Yields relative risk factors

• End-point of further surgery may underestimate true incidence

• More work: Roles of pre-existing ASD, Balance, other surgeons/techniques
Conclusions:
Average annual incidence further surgery for ASD

• Cervical –
  • Hilibrand et al, JBJS 1999 – 2.9%

Radiculopathy and Myelopathy at Segments Adjacent to the Site of a Previous Anterior Cervical Arthrodesis*
BY ALAN S. HILIBRAND, M.D.; GREGORY D. CARLSON, M.D.; MARK A. PALUMBO, M.D.;
PATRICK E. JONES, PH.D.; AND HENRY H. BOHLMAN, M.D., CLEVELAND, OHIO
Investigation performed at the Department of Orthopaedic Surgery, University Hospitals Cleveland Institute.
Case Western Reserve University School of Medicine, Cleveland

• Lumbar –
  • Sears et al, Spine J 2011 – 2.5% … but incidence varies…

*Department of Neurosurgery, Royal North Shore Hospital, Sydney, NSW 2065, Australia
Department of Spinal Surgery, Northern Adventist Hospital, Sydney, NSW 2071, Australia
Research Spine, Sydney, NSW 2071, Australia
Accepted 30 September 2000
Adjacent Segment Disease following Lumbar Spinal Fusion

Dr Bill Sears

Neurosurgical Society of Australasia Annual Scientific Meeting
Adelaide, September 1st 2017
Methodology

• Retrospective cohort analysis

• End points:
  • Further surgical intervention - at adjacent level
  • Death / loss to F/U
Indications

- Foraminal stenosis
- Likely post op instability
- Correct painful deformity
- Non-union
- Large or Recurrent disc herniation
- Discogenic back pain
- Instability

![Bar chart showing indications for procedures]
Genetics of ASD

• Omair et al. *Eur Spine J.* 2016
  
  • Studied candidate gene effects on ASDegen.
    • 285 patients from 4 RCTs
    • @ 13 (±4) yrs post fusion or non-op management.
  
  • Consider ASDegen. to be multifactorial with aging discs influenced by:
    • genetics
    • fusion
    • much of the variance still to be accounted for
Change in Intradiscal Pressures (Peak Flexion)

![Graph showing change in intradiscal pressures for different lumbar levels under peak flexion. The graph compares intact and fusion conditions at L5-S1, L4-S1, and L3-S1.]
Results – disc space height (1st adjacent level)

Mean Disc Height (mm)

- Inter-laminar Stabilisers
- Fusion Controls

12.8%, P=0.045
Correlations

Disc height: pre-op vs. change in height

Interlaminar stabiliser group

Fusion group
### Multivariate Risk Factor Analysis

*Cox proportional-hazards regression*

<table>
<thead>
<tr>
<th>Covariate</th>
<th>Relative Risk</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age = &lt;45yrs</td>
<td>x 0.25</td>
<td>(0.10 to 0.63)</td>
<td>0.003</td>
</tr>
<tr>
<td>Age = 45-60yrs</td>
<td>x 0.55</td>
<td>(0.34 to 0.87)</td>
<td>0.01</td>
</tr>
<tr>
<td>2 levels fused</td>
<td>x 2.1</td>
<td>(1.42 to 3.25)</td>
<td>0.0003</td>
</tr>
<tr>
<td>3 or 4 levels fused</td>
<td>x 3.0</td>
<td>(1.89 to 4.86)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Lowest level fused = L5</td>
<td>x 1.7</td>
<td>(1.15 to 2.41)</td>
<td>0.007</td>
</tr>
<tr>
<td>Adjacent level laminectomy</td>
<td>x 2.4</td>
<td>(1.09 to 5.17)</td>
<td>0.03</td>
</tr>
</tbody>
</table>
Results – Frequency distribution of relative disc-space height reductions @ 60-months – **Fusion patients only**
Discussion

Study Strengths:
- Randomised patient cohorts
- Accurately measured post-operative changes in disc-space height

Study Limitations:
- Secondary data analysis
  - Variation in several baseline variables
  - p values: $0.007 < p < 0.02$
- Findings may not be applicable to all forms of spinal fusion
  - What was it exactly about the fusion that contributed to the observed increase in ASDegen?
Conclusions

Based on accurately measured post-operative changes in disc-space height:

- **High-level in vivo evidence:** lumbar spinal fusion is a risk factor for ASDegen.
- Increased ASDegen may be associated with temporary increase in adjacent level angular ROM in fusion patients.
- The finding of less severe ASDegen at
  - 2nd adjacent levels &
  - patients randomized to motion preservation surgery suggests factors other than fusion also play a role in ASDegen.
Acknowledgements

• Paradigm Spine LLC, NY for financial support
• Greg Maislin and Biomedical Statistical Consulting, PA
• Medical Metrics, TX
• My co-authors

Thank you
**Results** – Frequency distribution of relative disc-space height reductions @ 60-months – **Interlaminar stabilisers**

- **1st adj level**
- **2nd adj level**
The spine: a tower of damped, segmental ‘spring’ elements
The spine: a tower of damped, segmental ‘spring’ elements
The spine: a tower of damped, segmental ‘spring’ elements

... stabilized by muscle activity
The spine: a tower of damped, segmental ‘spring’ elements

& if a segment starts to wear...
Between group differences: loss of disc-space height (mm. @ 5-years).

**ANCOVA correction for pre-op variations in:**

- disc space height
- disc space height, patient age & patient height.
Methodology

• *In vitro*
• Human specimens
• T10-S1: **8 levels**
• Pure moments
• 400N Follower load
• Displacement/Hybrid control
  – based on *in vivo* observations - 21°
Kirkaldy-Willis: Stages of Spinal Degeneration