NATIONAL INSTITUTE FOR HEALTH AND CARE EXCELLENCE

INTERVENTIONAL PROCEDURES PROGRAMME

Interventional procedure overview of transaxial interbody lumbosacral fusion for low back pain

As a person gets older, the discs between the vertebrae (back bones) can deteriorate. This can cause severe pain and disability and surgery may be needed.

This procedure is done through a small cut at the base of the spine. Part or all of the damaged disc is removed. An artificial implant and bone graft material are inserted into the remaining disc space. It aims to join 2 back bones together to stop the painful joint moving.

Contents

Introduction

The National Institute for Health and Care Excellence (NICE) prepared this interventional procedure overview to help members of the interventional procedures advisory committee (IPAC) make recommendations about the safety and efficacy of an interventional procedure. It is based on a rapid review of the

medical literature and specialist opinion. It should not be regarded as a definitive assessment of the procedure.

Date prepared

This overview was prepared in December 2017.

Procedure name

- Transaxial interbody lumbosacral fusion for low back pain.

Specialist societies

- British Association of Spinal Surgeons
- Royal College of Surgeons.

Description of the procedure

Indications and current treatment

Chronic low back pain may result from degenerative changes in the intervertebral discs or spinal facet joints. Conservative treatments include pain relief, non-steroidal anti-inflammatory medication and manual therapy (see NICE's guideline on low back pain and sciatica).

For people with severe, life-limiting, chronic low back pain that does not respond to conservative treatments, surgery may be appropriate. This may include bony fusion of vertebrae (to immobilise segments of the vertebral column thought to be responsible for back pain, using either a posterior or anterior approach) or inserting a prosthetic intervertebral disc (which preserves lumbar mobility to reduce the risk of degenerative changes in adjacent intervertebral disc spaces). Other surgical alternatives include non‑rigid stabilisation techniques.

What the procedure involves

Transaxial interbody lumbosacral fusion is done with the patient under general anaesthesia. A small incision is made lateral to the coccyx and a guide-pin introducer is inserted under fluoroscopic guidance. Air insufflation may be used to improve visualisation of the rectum during fluoroscopy. The guide-pin introducer is advanced over the sacrum's midline anterior surface towards the L5–S1 space. A reamer is then passed over the guidewire to the endplate of S1. As with conventional spinal fusion, the disc is removed through the canal created by the reamer. A mixture typically consisting of commercially available bone graft material, patient's own bone extracted from the surgical site and blood is prepared in the operating theatre and injected into the disc space. A special rod

is screwed between the L5 and S1 vertebrae along the canal created by the reamer to maintain segmental height and alignment. Using a posterior approach, pedicle or facet joint screws may be used to provide extra stabilisation.

The potential benefits of the transaxial approach include faster recovery and less postoperative morbidity compared with conventional spinal fusion surgery.

Efficacy summary

Fusion rate

A systematic review of 700 patients who had transaxial interbody lumbosacral fusion reported a fusion rate of 93%. Failed fusion was verified by CT in 12 of the 15 studies and by radiography in the remaining 3 studies.[1] A systematic review of 1,507 patients comparing transaxial interbody fusion with anterior lumbar interbody fusion (ALIF) and transforaminal lumbar interbody fusion (TLIF) reported fusion rates of 91%, 97% and 99% respectively (p=0.002 for axial interbody fusion compared with TLIF and p=0.124 for axial interbody fusion compared with ALIF). [2] In a case series of 164 patients, the rate of solid fusion was 89% at 1-year follow-up; there was clear non-union in 2% of patients and the fusion status was unclear in 9% of patients (no signs of bony bridging but also no signs of loosening). [3] In a non-randomised comparative study of 96 patients (included in the systematic review of 700 patients) solid fusion was reported in 85% (41/48) of patients who had axial interbody fusion and 79% (38/48) of patients who had ALIF (p=not significant). [5] In a case series of 156 patients (included in the systematic review of 700 patients) the fusion rate was 94% (145/155) at 2-year follow-up; the fusion rates were similar between patients treated with or without bone morphogenetic protein (93% and 94%, p=1.00), posterior screw fixation (93% and 97%, p=0.69), and CT assessment of fusion (92% and 94%, p=0.75) respectively. [6]

Back and leg pain

In the case series of 164 patients, the mean back pain score (measured on a visual analogue scale from 0 to 100) improved from 80 (±12.5) at baseline to 34 (±28.7) at the last follow-up (mean 54 months; p<0.001). The mean leg pain score improved from 43 (±30.1) at baseline to 24 (±29.4) at the last follow-up (p<0.001). Clinical success was achieved in 74% of patients for back pain and 54% of patients for leg pain. At the final follow-up, 59% of patients were able to fully stop using analgesic medication and 20% of patients reported daily use of analgesics. [3] In the case series of 156 patients the mean back pain scores improved from 7.7 (±1.6) at baseline to 2.7 (±2.4) at 24-month follow-up (p<0.001); 86% (127/147) of patients had a clinically significant improvement in pain severity. [6]

Functional outcomes

In the case series of 164 patients, the mean Oswestry Disability Index score (range 0 to 100) improved from 46 (±15.8) at baseline to 19 (±19.0) at the last follow-up (mean 54 months; p<0.001). Clinical success was achieved in 77% of patients for the Oswestry Disability Index. The proportion of patients who were fully able to work increased from 32% at baseline to 68% at the last follow-up (p<0.001). [3] In the case series of 156 patients the mean Oswestry Disability Index scores improved from 36.6 (±14.6) at baseline to 19.0 (±19.2) at 24 month follow-up (p<0.001); 74% (57/77) of patients had a clinically significant improvement in function. [6]

Patient satisfaction

In the case series of 164 patients, 65% of patients reported satisfaction and 84% would likely or definitely have the procedure again. [3]

Safety summary

Bowel injury

Bowel injury was reported in 1% (59/9,152) of patients in a case series of 9,152 patients; 29 were high rectal injuries, 14 were low rectal injuries and 16 were of an unreported location. The median time from surgery to detection of bowel injury was 3 days (mean 4 days, range 0 to 48 days) and 77% of these patients needed a colostomy. Surgeon error or deviation was noted in 42% (25/59) of patients with bowel injury. [4] Bowel perforation was reported in 1 patient in a systematic review of 700 patients.[1] Rectal injury, rectocutaneous fistula and pseudarthrosis were reported in a patient described in a case report; the fistula and infections resolved after treatment with antibiotics and total parenteral nutrition, and the patient had revision surgery 9 months after the original procedure. [7]

Ureter injury

Ureter injury was reported in 1 patient in the case series of 9,152 patients. [4]

Vascular injury

Vascular injury was reported in <1% (6/9,152) of patients in the case series of 9,152 patients. [4] There were 2 reports of retroperitoneal haematoma or vascular injury in the systematic review of 700 patients. [1]

Presacral haematoma

Presacral haematoma was reported in <1% (9/9,152) of patients in the case series of 9,152 patients. [4]

Nerve injury

Nerve injury was reported in <1% (3/9,152) of patients in the case series of 9,152 patients. [4]

Transient intraoperative hypotension

Transient intraoperative hypotension was reported in <1% (20/9,152) of patients in the case series of 9,152 patients. There were no adverse sequelae associated with these episodes. [4]

Infection

Systemic infection and superficial wound infection were each reported in <1% (6/9,152 and 3/9,152 respectively) of patients in the case series of 9,152 patients.[4] The systematic review of 700 patients reported an infection rate of 5% (range 3% to 10%). [1] Chronic hardware infection was described in 1 patient in a case report. [8]

Sacral fracture

Sacral fracture was reported in <1% (7/9,152) of patients in the case series of 9,152 patients. [4]

Migration and subsidence

Migration and subsidence were each reported in <1% (5/9,152 and 4/9,152 respectively) of patients in the case series of 9,152 patients. [4]

Broken implant

There were 3 occurrences of a broken implant in the systematic review of 700 patients. [1]

Postoperative radiculopathy

There were 7 occurrences of postoperative radiculopathy in the systematic review of 700 patients. [1]

Reoperation

Additional surgery was needed by 14% of patients (range 11% to 20%) in the systematic review of 700 patients. [1]

Anecdotal and theoretical adverse events

In addition to safety outcomes reported in the literature, specialist advisers are asked about anecdotal adverse events (events which they have heard about) and

about theoretical adverse events (events which they think might possibly occur, even if they have never happened). For this procedure, specialist advisers listed the following anecdotal adverse events: bowel injury needing bowel resection and colostomy, loosening of the screw leading to chronic pain, and loosening of the posterior facet screws that are inserted for additional fixation. They listed the following theoretical adverse events: deep spinal infection and nerve root injury from the facet screws.

The evidence assessed

Rapid review of literature

The medical literature was searched to identify studies and reviews relevant to transaxial interbody lumbosacral fusion for low back pain. The following databases were searched, covering the period from their start to 21 November 2017: MEDLINE, PREMEDLINE, EMBASE, Cochrane Library and other databases. Trial registries and the Internet were also searched. No language restriction was applied to the searches (see literature search strategy for details). Relevant published studies identified during consultation or resolution that are published after this date may also be considered for inclusion.

The following selection criteria (table 1) were applied to the abstracts identified by the literature search. Where selection criteria could not be determined from the abstracts the full paper was retrieved.

Table 1 Inclusion criteria for identification of relevant studies

Characteristic	Criteria
Publication type	Clinical studies were included. Emphasis was placed on identifying good quality studies. Abstracts were excluded where no clinical outcomes were reported, or where the paper was a review, editorial, or a laboratory or animal study. Conference abstracts were also excluded because of the difficulty of appraising study methodology, unless they reported specific adverse events that were not available in the published literature.
Patient	Patients with low back pain.
Intervention/test	Transaxial interbody lumbosacral fusion
Outcome	Articles were retrieved if the abstract contained information relevant to the safety and/or efficacy.
Language	Non-English-language articles were excluded unless they were thought to add substantively to the English-language evidence base.

List of studies included in the IP overview

This IP overview is based on more than 9,000 patients from 2 systematic reviews, 1 non-randomised comparative study, 3 case series and 2 case report. [1–8]

Other studies that were considered to be relevant to the procedure but were not included in the main extraction table (table 2) are listed in the appendix.

Table 2 Summary of key efficacy and safety findings on transaxial interbody lumbosacral fusion for low back pain

Study 1 Schroeder GD (2015)

Details

Study type	**Systematic review**
Country	Not reported for individual studies
Recruitment period	Search date: August 2014
Study population and number	**n=700** (15 articles; 4 prospective and 11 retrospective) Patients with degenerative disc disease, spondylosis, spondylolisthesis, scoliosis, pseudarthrosis or revision surgery
Age and sex	Not reported
Patient selection criteria	Inclusion criteria: age 18 years or above; a pathology of degenerative disc disease, spondylosis, spondylolisthesis, scoliosis, or pseudarthrosis or revision surgery; patients having axial interbody arthrodesis of the lumbosacral junction. Only studies that reported the L5–S1 fusion rate and were published in English in a peer-reviewed, PubMed-indexed journal were included. Exclusion criteria: pathology of tumour, infection or trauma. Studies that reported radiographic outcomes that did not clearly define the fusion rate at L5-S1 were excluded as were case reports. Review articles, abstracts, editorials, letters, repeat publication of the same patient group, and studies reporting the technical feasibility of the surgery were excluded. All studies in which more than 10% of a cohort met the exclusion criteria were excluded.
Technique	Axial interbody arthrodesis of the L5–S1 segment, using the AxiaLIF (Baxano Surgical) implant.
Follow-up	**Not reported**
Conflict of interest/source of funding	The authors of the systematic review reported no conflicts of interest concerning the materials or methods used in this study or the findings specified in the paper. Of the 15 articles included in the analysis, 11 reported conflicts of interest.

Analysis

Follow-up issues: The systematic review does not include any details on completeness of follow-up for the included studies. An additional 4 studies that described the technique but without follow-up were excluded from the review.

Study design issues: Two authors independently searched PubMed and the reference lists of identified eligible studies were also reviewed. A full review of an article was done if it could not be unequivocally dismissed based on the abstract. There were no randomised controlled trials. Only 1 study comparing axial interbody fusion with another interbody fusion technique was identified. Because of the lack of comparative studies, this study was treated as a case series and only patients from the AxiaLIF arm were included in the systematic review. There was variation between the studies in the use of posterior instrumentation and in the use of pedicle or facet screws. The choice of bone graft and biological enhancers varied both between and within the studies. Patient reported outcome measures and radiographic parameters apart from fusion were not addressed in the review.

Study population issues: There was significant heterogeneity in the surgical indications between and within the studies. Of the 15 eligible studies, 11 were categorised as having patients with degenerative disease and 4 were categorised as having patients with deformity-based spinal disease (studies were included in the degenerative group if less than 20% of patients had surgery at 3 or more levels or had a diagnosis of high-grade spondylolisthesis or scoliosis).

Key efficacy and safety findings

<table>
<tr><th>Efficacy</th><th>Safety</th></tr>
<tr><td>Number of patients analysed: 700

Fusion rate=93.2%

Failed fusion was verified by CT in 12 of the 15 studies and by radiography in the remaining 3 studies.

The fusion rate was not significantly affected by any of the factors in the subgroup analyses.</td><td>
Unadjusted number of rare complications
<table>
<tr><th>Complication</th><th>Total reported occurrences</th></tr>
<tr><td>Postoperative radiculopathy</td><td>7</td></tr>
<tr><td>Broken implant</td><td>3</td></tr>
<tr><td>Retroperitoneal haematoma or vascular injury</td><td>2</td></tr>
<tr><td>Myocardial infarction</td><td>2</td></tr>
<tr><td>Stroke</td><td>2</td></tr>
<tr><td>Bowel perforation</td><td>1</td></tr>
</table>
Overall pseudarthrosis rate at L5–S1=6.9% (95% CI 1.0% to 16.2%)
Rate of all complications excluding pseudarthrosis=12.9%
Infection rate=5.4% (range 2.5% to 9.7%)
Additional surgery was needed by 14.4% of patients (range 11.3% to 20.1%)

Subgroup analysis according to type of disease, mean rates (95% CI)
<table>
<tr><th>Parameter</th><th>Deformity-based disease</th><th>Degenerative disease</th><th>p value</th></tr>
<tr><td>Number of articles</td><td>4</td><td>11</td><td></td></tr>
<tr><td>Number of patients</td><td>86</td><td>614</td><td></td></tr>
<tr><td>Pseudarthrosis</td><td>7.1% (2.5% to 18.3%)</td><td>5.9% (0.7% to 34.5%)</td><td>0.87</td></tr>
<tr><td>All complications except pseudarthrosis</td><td>46.3% (16.2% to 79.3%)</td><td>9.2% (6.7% to 12.5%)</td><td>0.004</td></tr>
<tr><td>Revision or subsequent surgery</td><td>28.2% (7.3% to 66.3%)</td><td>15.5% (12.1% to 19.7%)</td><td>0.35</td></tr>
<tr><td>All postoperative infections</td><td>13.8% (5.0% to 33.1%)</td><td>4.4% (2.4% to 8.0%)</td><td>0.06</td></tr>
</table>
Subgroup analysis according to type of data collection
<table>
<tr><th>Parameter</th><th>Prospective</th><th>Retrospective</th><th>p value</th></tr>
<tr><td>Number of articles</td><td>4</td><td>11</td><td></td></tr>
<tr><td>Number of articles</td><td>104</td><td>596</td><td></td></tr>
<tr><td>Pseudarthrosis</td><td>12.1% (2.2% to 45.2%)</td><td>5.4% (1.9% to 14.6%)</td><td>0.40</td></tr>
<tr><td>All complications except pseudarthrosis</td><td>36.8% (14.4% to 66.9%)</td><td>8.7% (6.6% to 11.6%)</td><td>0.003</td></tr>
<tr><td>Revision or subsequent surgery</td><td>22.6% (15.0% to 32.5%)</td><td>12.9% (9.2% to 17.8%)</td><td>0.03</td></tr>
<tr><td>All postoperative infections</td><td>3.4% (0.4% to 22.1%)</td><td>5.9% (3.4% to 9.9%)</td><td>0.61</td></tr>
</table>
Subgroup analysis according to conflict of interest
<table>
<tr><th>Parameter</th><th>Conflicts reported</th><th>No conflicts of interest</th><th>p value</th></tr>
<tr><td>Number of articles</td><td>11</td><td>4</td><td></td></tr>
<tr><td>Number of articles</td><td>586</td><td>114</td><td></td></tr>
<tr><td>Pseudarthrosis</td><td>5.4% (1.9% to 14.6%)</td><td>16.4% (3.0% to 55.8%)</td><td>0.25</td></tr>
<tr><td>All complications except pseudarthrosis</td><td>12.4% (8.2% to 18.4%)</td><td>17.8% (12.0% to 25.6%)</td><td>Reported as <0.0001</td></tr>
<tr><td>Revision or subsequent surgery</td><td>16.4% (11.9% to 22.1%)</td><td>17.1% (11.0% to 25.7%)</td><td>0.87</td></tr>
<tr><td>All postoperative infections</td><td>3.8% (1.7% to 8.4%)</td><td>7.6% (3.4% to 16.2%)</td><td>0.26</td></tr>
</table>
</td></tr>
<tr><td colspan="2">Abbreviations used: CI, confidence interval.</td></tr>
</table>

Study 2 Schroeder GD (2016)

Details

Study type	**Systematic review**
Country	Not reported for individual studies
Recruitment period	Search date: August 2014
Study population and number	**n=1,507** (42 articles; 11 anterior lumbar interbody fusion [ALIF, n=466], 21 transforaminal lumbar interbody fusion [TLIF, n=432], 11 axial interbody fusion [n=609]) Patients with degenerative disc disease, spondylosis, low-grade spondylolisthesis, pseudarthrosis or revision surgery
Age and sex	Not reported
Patient selection criteria	Inclusion criteria: adults; a pathology of degenerative disc disease, spondylosis, low-grade spondylolisthesis, pseudarthrosis, revision surgery; patients having an ALIF, TLIF or axial interbody fusion of the L5/S1 segment; clearly identified L5/S1 fusion rate. Studies included retrospective case series, prospective case series, case-control and comparative studies. Only English-language studies published in a peer-reviewed, PubMed-cited journal were included. Exclusion criteria: age <18 years; a pathology of tumour, infection, trauma, or deformity (defined as high-grade spondylolisthesis or fusions of more than 3 levels); patients having a laparoscopic ALIF; studies that did not report the specific L5/S1 fusion rate. Nonclinical studies and case reports were excluded as were review articles, abstracts, editorials, repeat publication of the same patient group, and studies reporting the technical feasibility of the surgery.
Technique	Not described in detail.
Follow-up	**Not reported**
Conflict of interest/source of funding	4 of the 7 authors of the systematic review declared a conflict of interest, including stock or stock options, consultancies and patents with a number of companies. No outside funds were used for this study. The authors of the review noted that more than 80% of the studies on axial interbody fusion were done by authors with a conflict of interest.

Analysis

Follow-up issues: The review does not discuss completeness of follow-up for the included studies.

Study design issues: Two authors independently did a systematic MEDLINE search using PubMed. The cited papers in the originally identified articles were also systematically reviewed. Any studies in which more than 10% of a cohort met the exclusion criteria were excluded. If there was disagreement between the 2 reviewers about the inclusion of an article, a more senior author reviewed the articles. In addition to the surgical procedure and the overall fusion rate, the following variable were also collected: the use of recombinant human bone morphogenetic protein-2 (rhBMP-2); open versus minimally invasive technique; prospective versus retrospective study; study type; presence of a conflict of interest; total number of patients in study; total number of patients at final follow-up who had a L5/S1 fusion; isolated L5/S1 fusion versus part of a multilevel fusion; the use of bilateral pedicle screw instrumentation. A level of evidence was assigned to each study and the criteria recommended by the Cochrane Back review Group were used to evaluate the bias of each included study. When 6 or more of the individual criterion were determined to have a low risk of bias, the individual study was considered to have a low risk of bias. Of the 42 included studies, 12 were deemed to have a low risk of bias.

The effect of approach and other factors on fusion rates was estimated using a generalised linear mixed model to implement a logistic regression with a study-level random effect. The main outcome was a difference in mean fusion rates.

Key efficacy and safety findings

Efficacy

Number of patients analysed: **1,507** (609 axial interbody fusion, 466 anterior lumbar interbody fusion [ALIF], 432 transforaminal lumbar interbody fusion [TLIF])

Overall fusion rates between ALIF, TLIF, and axial interbody fusions

	ALIF (%)	TLIF (%)	p	ALIF (%)	Axial interbody fusion (%)	p	TLIF	Axial interbody fusion (%)	p
Fusion rate	97.2	99.2	0.179	97.2	90.5	0.124	99.2	90.5	0.002

Range of fusion rates:

- Axial interbody fusion=79.0% to 97.0%
- ALIF=91.0% to 99.2%
- TLIF=96.4% to 99.8%

Comparison of fusion rates with and without recombinant human bone morphogenetic protein-2 (rhBMP-2)

	ALIF (%)	TLIF (%)	p	ALIF (%)	Axial interbody fusion (%)	p	TLIF	Axial interbody fusion (%)	p
Fusion rate with rhBMP-2	93.1	99.3	0.04	93.1	89.8	0.39	99.3	89.8	0.01
Fusion rate without rhBMP-2	100.0	98.4	0.96	100.0	93.4	0.95	98.4	93.4	0.48

The fusion rate of an isolated L5/S1 fusion and the fusion rate of an L5/S1 interbody fusion supplemented by bilateral pedicle screw fixation

	ALIF (%)	TLIF (%)	Axial Interbody (%)	p
Isolated L5/S1 fusion	96.2 (87.1 to 100)	99.2 (95.6 to 99.8)	93.6 (83.3 to 98.0)	0.10
Fusion supported by bilateral pedicle screw fixation	97.4 (74.8 to 99.8)	99.6 (97.3 to 99.9)	95.7 (73.1 to 99.5)	0.15

Safety

No safety outcomes were reported in the review.

Abbreviations used: ALIF, anterior lumbar interbody fusion; rhBMP-2, recombinant human bone morphogenetic protein-2; TLIF, transforaminal lumbar interbody fusion.

Study 3 Zeilstra DJ (2017)

Details

Study type	**Case series**
Country	The Netherlands
Recruitment period	Not reported
Study population and number	**n=164** Patients with a history of back pain for at least 6 months and radiographically confirmed degenerative disc disease
Age and sex	Mean 48 years (range 25 to 67); 65% (106/164) female
Patient selection criteria	Patients with a history of back pain for at least 6 months and radiographically confirmed degenerative disc disease. The diagnosis was confirmed by conventional X-rays and MRI. Whenever feasible, provocative discography followed by anaesthetisation of the disc was done. MR images were studied for abnormalities that could jeopardise the procedure. No patient had previous surgery at the index level other than discectomy, and there were no cases of clear instability. Other contraindications were osteoporosis, trauma, extreme obesity and age >80 years.
Technique	Device: AxiaLIF (TranS1 Inc., US and later Baxano Surgical Inc., US). A variety of bone graft substitutes were used. In the last 95 patients, additional fixation with transfacet screws was used.
Follow-up	**Mean 54 months (range 12 to 120)**
Conflict of interest/source of funding	Not reported

Analysis

Follow-up issues: All patients were followed up for at least 1 year.

Study design issues: Patients were assessed clinically at 6-week and 1-year follow-up and visual analogue scores and Oswestry Disability Index scores were obtained, together with plain X-ray films. In early 2016, patients were interviewed by telephone and then completed a follow-up questionnaire. Clinical success was defined as an improvement in score of 30% or more.

Study population issues: Patients typically had a long history of unsuccessfully treated back pain (mean 31 months). Nonradicular leg pain was also present in 80% of patients. Five patients had previous discectomy at the index level.

Other issues: An earlier report from the same study centre, which included 131 patients, is included in the systematic review by Schroeder et al, 2015.

Key efficacy and safety findings

Efficacy

Number of patients analysed: **164**

Mean back pain visual analogue scale score (VAS, 0 to 100)

- Baseline=80±12.5
- Last follow-up=34±28.7, p<0.001

Mean leg pain VAS (0 to 100)

- Baseline=43±30.1
- Last follow-up=24±29.4, p<0.001

Mean Oswestry Disability Index (ODI) score (0 to 100)

- Baseline=46±15.8
- Last follow-up=19±19.0, p<0.001

Clinical success was achieved in 73.8% of patients for back pain, 53.7% for leg pain and 76.8% for ODI.

Ability to work

	Baseline	Last follow-up	p value
Fully able to work	31.7%	67.7%	<0.001
Limited	25.6%	15.2%	<0.001
Unable to work	42.7%	Not reported	

Analgesic medication use

At final follow-up, 58.5% of patients were able to fully discontinue the use of analgesic medication. 19.5% of patients reported daily use of analgesics.

Patient satisfaction

64.6% of patients reported satisfaction and 84.2% would likely or definitely have the procedure again.

Fusion rate

At 1-year follow-up, the rate of solid fusion was 89.4%. In 8.9% of patients the fusion status was unclear (no signs of clear bony bridging but also no signs of loosening). In 1.6% of patients there was clear non-union.

Univariate baseline predictors of fusion and clinical success

Baseline variable	p value (solid fusion)	p value (clinical success ODI)	p value (clinical success VAS back pain)
Sex	0.025	0.17	0.16
Duration of back pain	0.10	0.08	0.21
Discography	0.59	0.99	0.97
Facet screw fixation	0.19	0.26	0.74
Back pain severity	0.22	0.93	0.49
Working status	0.66	0.45	0.043
Age	0.48	0.19	0.036
BMI	0.49	0.019	0.015
Smoking	0.77	0.30	0.5
Modic changes	0.89	0.081	0.14
Leg pain severity	0.90	0.20	0.26
ODI	0.99	0.88	0.42

Only sex (female), working status (still working), BMI (lower) and Modic type II endplate changes (absent) were correlated with a good result.

Safety

There were no intraoperative complications, including vascular, neural, urological, or bowel injuries. In some patients, light transient paralytic ileus was observed and some bowel distention was not uncommon in the first postoperative X-rays. Symptoms did not qualify as complications in any of the patients.

14.6% (24/164) patients needed further surgery during the follow-up period, 15 (9.5%) being at the treated level.

Reoperations during the follow-up period

Type of reoperation	No. of re-operations	No. of patients	%
Broken facet screw removal	1	1	0.61
Asymptomatic broken facet screw	0	3	1.83
Additional fixation at index level	11	11	6.71
Fusion at another level	5	5	3.05
Total disc replacement at another level	3	3	1.83
Anterior lumbar interbody fusion at L4/5	1	1	0.61
Implantation of a neuro-stimulator and related operations	8	3	1.83
Discectomy at index level	3	2	1.22

Abbreviations used: CI, confidence interval; ODI, Oswestry Disability Index; VAS, visual analogue scale.

Study 4 Gundanna MI (2011)

Details

Study type	**Case series (postmarketing surveillance)**
Country	Not reported
Recruitment period	2005–10
Study population and number	**n=9,152** Patients who had interbody fusion with the AxiaLIF system through an axial presacral approach.
Age and sex	Not reported
Patient selection criteria	Patients who had interbody fusion with the AxiaLIF system through an axial presacral approach.
Technique	Device: AxiaLIF (TranS1 Inc., US). The AxiaLIF 2-level system was used for 2 level fusion. A single-level (L5–S1) fusion was done in 8,034 (88%) patients and a 2-level (L4–S1) fusion was done in 1,118 (12%) patients. Autologous bone and bone graft extenders and/or bone morphogenetic protein were inserted into the disc space. In most of the procedures, pedicle or facet screws were used to provide supplemental fixation.
Follow-up	**3 months to 5 years 3 months**
Conflict of interest/source of funding	The study was supported, in part, by TranS1 (US). TranS1 provided the authors with access to their complaint-reporting database.

Analysis

Study design issues: A database was developed to record complaints definitely or possibly related to the device or procedure through a spontaneous reporting mechanism. Complication data were collected through established complaint reporting as part of ongoing voluntary postmarketing surveillance. Several processes were implemented to encourage complication reporting. A company representative was present during every procedure and discussed each completed case with the treating physician. The complaint-reporting system requires every agent (employee and nonemployee) to report any complaint to the company within 24 hours of first notice. Also, relevant publications were reviewed, and potential complaints were identified. Each complaint was internally investigated to determine the root cause and recorded in the database.

Key efficacy and safety findings

Safety

Number of patients analysed: **9,152**

Complications

Complication	All patients n=9,152	Single level n=8,034	Two level n=1,118	p value (single level versus 2 level)
Number of complications	123	103	20	
Number of patients	120 (1.3%)	102 (1.3%)	18 (1.6%)	0.43
Bowel injury	59 (0.6%)	50 (0.6%)	9 (0.8%)	0.61
Transient intraoperative hypotension	20 (0.2%)	18 (0.2%)	2 (0.2%)	0.96
Presacral haematoma	9 (0.1%)	7 (0.1%)	2 (0.2%)	0.68
Sacral fracture	7 (0.1%)	5 (0.1%)	2 (0.2%)	0.46
Vascular injury	6 (0.1%)	5 (0.1%)	1 (0.1%)	0.77
Systemic infection	6 (0.1%)	6 (0.1%)	0	0.77
Migration	5 (0.1%)	4 (0.1%)	1 (0.1%)	0.60
Subsidence	4 (<0.1%)	3 (<0.1%)	1 (0.1%)	0.99
Nerve injury	3 (<0.1%)	2 (<0.1%)	1 (0.1%)	0.81
Superficial wound infection	3 (<0.1%)	2 (<0.1%)	1 (0.1%)	0.81
Ureter injury	1 (<0.1%)	1 (<0.1%)	0	0.25

The median time from the procedure to the report of the complication was 5 days (mean 33 days, range 0 to 511 days).
Overall, 54% of complications occurred within 5 days of surgery, 63% within 10 days, 75% within 31 days and 90% within 90 days.

Of the 59 reports of bowel injury, 29 were high rectal injuries, 14 were low rectal injuries and 16 were injuries of an unreported location. The median time from surgery to detection of bowel injury was 3 days (mean 4 days, range 0 to 48 days) and 77% of these patients needed a colostomy. Surgeon error or deviation was noted in 42% (25/59) of patients with bowel injury.

There were no adverse sequelae associated with the transient intraoperative hypotensive episodes.

The subsidence occurred at a mean of 62 days (range 17 to 90 days) after the procedure.

All complications were successfully treated and resolved with no further sequelae.

Complication rates with AxiaLIF system, open lumbar fusion and minimally invasive lumbar fusion

Complication	AxiaLIF system (n=9,152)	Open lumbar fusion (n=1,970)	Minimally invasive lumbar fusion (n=122)
Nerve injury	3 (0.03%)	25 (1.3%)	2 (1.6%)
Vascular injury	6 (0.07%)	63 (3.2%)	2 (1.6%)
Infection	9 (0.1%)	2 (0.1%)	0

Complication rates for open lumbar fusion were calculated by pooling outcomes from 6 Food and Drug Administration-regulated trials (n=1,970) using open lumbar fusion for degenerative disc disease as a control. Complication rates for minimally invasive lumbar fusion were calculated by pooling outcomes from 4 selected clinical trials (n=122).

Abbreviations used: CI, confidence interval.

Study 5 Whang PG (2013) – also included in the 2015 systematic review by Schroeder et al.

Details

Study type	**Non-randomised comparative study**
Country	US
Recruitment period	2002–10
Study population and number	**n=96** (48 axial interbody fusion, 48 anterior lumbar interbody fusion [ALIF]) Patients who had had interbody fusions of the L5–S1 segment.
Age and sex	• Axial interbody fusion: mean age=51 years (range 25 to 72); 52% (25/48) female • ALIF: mean age=46 years (range 25 to 73); 60% (29/48) female
Patient selection criteria	Patients aged 18 years or older who had had interbody fusions of the L5-S1 segment through either a standard anterior retroperitoneal approach (ALIF) or using an axially oriented transsacral implant (AxaiLIF) in conjunction with supplementary instrumentation. Each patient needed to have clinical and radiographical follow-up (X-rays and CT) for a minimum of 2 years after the index operation.
Technique	The AxiaLIF implant (TranS1, US) was used for axial interbody fusion. In the ALIF cohort, 21 patients had a femoral ring allograft inserted and 27 had a polyetheretherketone cage. Most of the patients (n=43) in the axial interbody fusion group and all patients in the ALIF group had some type of supplementary posterior fixation at the L5–S1 level. A variety of different graft materials were used.
Follow-up	**24 months**
Conflict of interest/source of funding	Two authors have received benefits from TranS1 for services rendered related to clinical research, one of whom also owns stock in TranS1. One author has received consulting fees for physician training and education and also owns stock in TranS1. Two authors received research grants for data collection.

Analysis

Follow-up issues: All patients were followed up for a minimum of 2 years.

Study design issues: A retrospective review of clinic charts and hospital records at 10 different sites was done to identify eligible patients. Consecutive patients at each site, meeting all of the inclusion criteria and none of the exclusion criteria, were selected until there was an equal number of patients in each group. The primary endpoint of the study was fusion success at 24 months, which was derived from an evaluation of plain radiographs and multiplanar CT imaging by 2 independent observers. Fusion status was based on a 4-point grading scale (1=no fusion [lack of any bone formation], 2=developing bone [ossification present within the disc space which is not continuous with both endplates], 3=bridging bone [involving <50% of the endplates], 4=advanced bridging bone [involving 50% or more of the endplates]). A score of 3 or 4 was considered to represent a solid arthrodesis. Any adverse events documented in the medical records were noted and clinical sites were also told to submit the details of any complications directly associated with the fusion devices.

Study population issues: The most common indication for surgery was lumbar degenerative disc disease followed by spondylolisthesis and stenosis. More patients in the AxiaLIF group were treated with recombinant growth factors than those in the ALIF group (29 versus 11 respectively).

Key efficacy and safety findings

Efficacy	Safety
Number of patients analysed: **96 (48 versus 48)** **Solid fusion** • Axial interbody fusion=85% (41/48) • ALIF=79% (38/48), p=not significant	**Adverse events** *Axial interbody fusion – 10 events in 6 patients* • Incisional drainage or local infection, n=3 (2 were treated with formal irrigation and debridement, 1 of whom also had a vacuum dressing and began to have chronic axial pain within several months) • Worsening leg discomfort, n=1 • Pseudarthrosis, n=2 (1 patient needed a revision arthrodesis) *ALIF – 16 events in 10 patients* • Wound complications, n=4 • Persistent iliac crest graft site pain, n=2 • Intraoperative injury, n=2 (1 involved the left common iliac artery and needed significant fluid resuscitation for 2,400 ml blood loss and the other was a peritoneal laceration, which was repaired primarily. Both these patients complained of increased leg pain immediately after their procedures.) • Lumbar radiculopathy, n=1 (the patient subsequently had a L3–L4 laminectomy 16 months after the index operation. • Chronic back and leg symptoms, n=1 (managed without further surgery)
Abbreviations used: ALIF, anterior lumbar interbody fusion	

Study 6 Tobler WD (2011) – also included in the 2015 systematic review by Schroeder et al.

Details

Study type	**Case series**
Country	US
Recruitment period	Not reported
Study population and number	**n=156** Patients who had had a L5–S1 interbody fusion via an axial presacral approach with the AxiaLIF system
Age and sex	Mean 44 years; 57% (88/156) female
Patient selection criteria	Patients who had had a L5–S1 interbody fusion via an axial presacral approach with the AxiaLIF system and had both presurgical and 2-year radiographical or patient-reported clinical follow-up. In all patients, the procedure was done to treat refractory axial low back pain and failure of nonoperative management of at least 6 months' duration. Previous pelvic surgery was a contraindication for the procedure.
Technique	The AxiaLIF implant (TranS1, US) was used for axial interbody fusion. Autologous bone and bone graft extenders (n=80) or recombinant human bone morphogenetic protein (n=75) were inserted into the disc space. Percutaneous placement of pedicle or facet screws was used in 123 of 156 patients to provide supplemental fixation.
Follow-up	**2 years**
Conflict of interest/source of funding	The study was supported, in part, by TranS1 (US). One or more of the authors received benefits for personal or professional use from a commercial party related directly or indirectly to the subject of this manuscript.

Analysis

Follow-up issues: Patients were only included if they had completed the 2-year follow-up.

Study design issues: Multicentre, retrospective case series. Back pain severity and condition-specific functional impairment were evaluated with an 11-point numeric scale and the Oswestry Disability Index (ODI) respectively, before the procedure and at 2-year follow-up. Clinical success was defined as a 30% or more improvement in pain severity and ODI relative to baseline values. The construct was judged as fused if there was evidence of bridging trabecular bone between the L5 and S1 motion segments and absence of translational and angular motion.

Study population issues: Concomitant radicular symptoms were reported in 63% (97/155) of patients. Approximately 70% of patients had disc degeneration as the primary component of their preoperative diagnosis.

Key efficacy and safety findings

Efficacy	Safety
Number of patients analysed: **156** **Mean back pain scores** • Baseline=7.7±1.6 (n=155) • 24 month follow-up=2.7±2.4 (n=148) • Mean improvement=5.1±2.7 points (approximately 63%, p<0.001) **Oswestry Disability Index scores** • Baseline=36.6±14.6% (n=86) • 24 month follow-up=19.0±19.2% (n=78) • Mean change=18.7±16.1% (approximately 54% improvement, p<0.001) 86.4% (127/147) of patients had a clinically significant improvement in pain severity. 74% (57/77) of patients had a clinically significant improvement in function. Overall radiographic fusion rate at 2 years=94% (145/155) Fusion rates were similar between patients treated with or without bone morphogenetic protein (93% and 94%, p=1.00), posterior screw fixation (93% and 97%, p=0.69), and CT assessment of fusion (92% and 94%, p=0.75) respectively.	There were no vascular, neural, urological or bowel injuries reported in this study group.

Study 7 Siegel G (2013)

Details

Study type	**Case report**
Country	US
Recruitment period	2008
Study population and number	**n=1** Patient with a rectal injury, rectocutaneous fistula and pseudarthrosis after axial lumbar interbody fusion (L5-S1)
Age and sex	35-year-old man
Patient selection criteria	Not applicable. The procedure was done for degenerative disc disease and back pain
Technique	Axial lumbar interbody fusion (AxiaLIF, TranS1) at L5-S1 and bilateral L5-S1 facet screw placement
Follow-up	**4 months**
Conflict of interest/source of funding	None

Safety
Case report – rectocutaneous fistula A 35-year-old man with obesity and no other significant medical history had a transaxial interbody lumbosacral fusion with AxiaLIF, with bilateral L5–S1 facet screw placement, for degenerative disc disease and back pain. The patient's job involved heavy lifting. At the first postoperative visit, the patient reported intermittent bleeding from the parasacral incision. He was given a 4-week course of oral antibiotics and the issue resolved. About 2.5 months after the procedure, the patient noted another episode of significant bleeding with gaseous discharge from his wound. This was treated with oral antibiotics for 2 weeks. The bleeding resolved and the skin healed. At 4 months postoperatively, the patient became febrile and had a syncopal episode, after which he presented to the emergency department. A CT fistulagram and flexible sigmoidoscopy showed a rectal cutaneous fistula and small internal haemorrhoids. Laboratory studies revealed a white blood cell count of 15,500 cells per microlitre, a C-reactive protein level of 152.0 mg/litre and erythrocyte sedimentation rate of 43 mm/hour. Blood cultures were positive for *Enterococcus faecalis*. Treatment was started with vancomycin and piperacillin and tazobactam. After stabilisation, the patient had a peripherally inserted central catheter placed and was discharged on intravenous antibiotics, followed by oral antibiotics for 1 year. He was kept on a clear liquid diet and total parenteral nutrition for 6 weeks. The rectocutaneous fistula and infections resolved within 4 to 6 weeks. The patient could not return to work because of the severity of his back pain. The fusion did not appear to have any interbody growth. There was some lysis noted around the helical screw and the posterior facet screws showed some evidence of loosening. The patient had revision surgery 9 months after his original procedure, which comprised L5–S1 posterolateral fusion with pedicle screw instrumentation and transforaminal lumbar interbody fusion. The patient's back pain subsequently resolved.

Study 8 Hofstetter CP (2011)

Details

Study type	**Case reports**
Country	US
Recruitment period	2008–09
Study population and number	**n=5** Patients needing revision surgery after axial lumbar interbody fusion with AxiaLIF devices.
Age and sex	Mean 58 years (range 38 to 73 years); 3 women, 2 men
Patient selection criteria	Patients who had had revision surgery involving AxiaLIF devices since 2006.
Technique	The AxiaLIF implant was used. The trans-sacral rod was part of multisegment constructs in all 5 patients. Silicate-substituted calcium phosphate was used a bone graft. No bone morphogenetic protein was used during the index procedures.
Follow-up	**Not reported**
Conflict of interest/source of funding	None

Safety

Case 1 – revision surgery after a car accident
Initial surgery involved inserting an L5–S1 AxiaLIF and an L4–5 transforaminal lumbar interbody fusion (TLIF), supplemented with unilateral pedicle screws. The patient was in a car accident 6 months later and had severe lower-extremity pain. Imaging showed loss of L5–S1 intervertebral disc height and S1 superior endplate fracture. The patient had revision surgery with bilateral L5–S1 posterior lumbar interbody fusion (PLIF). The posterolateral pedicle-rod constructs were revised and extended to the iliac crests. The patient has residual back pain 3 years later and the construct has remained stable.

Case 2 – implant removed because of excessive bone resorption around the AxiaLIF screw
The patient had a history of spine fusion for thoracolumbar scoliosis (T5–L4 with Harrington rods). She had lumbar decompression and a 2-level AxiaLIF procedure combined with bilateral posterolateral pedicle screw-rod constructs. After 2 years, the patient had low back pain and imaging showed radiolucency around the AxiaLIF device, which increased over the next 12 months. The implant was removed and an anterior lumbar interbody fusion was done.

Case 3 – implant removed because of chronic hardware infection
The patient had a history of multiple lumbar spine surgeries complicated by chronic infections and hardware failure. She had removal of hardware (L2–S1) and an AxiaLIF implant inserted for instrumentation of L4–5 and L5–S1 combined with an L2–S2 pedicle screw-rod construct. Intraoperative cultures grew *Pseudomonas*, and the patient had intravenous antibiotics followed by permanent oral suppression therapy. After 14 months, the patient's back pain returned and a CT scan showed radiolucency around the left S2 pedicle screw. The posterolateral pedicle screw-rod construct was revised and extended to the iliac bone. Intraoperative cultures were positive for multidrug-resistant *Klebsiella* and the antibiotic suppression therapy was adjusted. Nine months later, there was failure of both pedicle screw rods at L5–S1 and radiolucency around the axial rod. All implants were removed and an anterior lumbar interbody fusion was done.

Case 4 – radiolucency surrounding the AxiaLIF and pedicle screws
The patient had a 2-level AxiaLIF procedure and posterolateral L3–S1 instrumentation. After 1 year, he had low back pain and a CT scan showed radiolucency surrounding the AxiaLIF proximally in the vertebral body of L4 and pedicle screw at L3 and S1. The patient had surgical revision of the posterolateral pedicle screw-rod construct and an L3–4 PLIF.

Case 5 – radiolucency around AxiaLIF device
The patient had a history of L3–5 laminectomy and L3–S1 pedicle screw-rod instrumented fusion and presented with adjacent-segment degeneration at L2–3 and non-union at L5–S1. A transpsoas approach was done at L2–3 supplemented with a lateral plate and an AxiaLIF procedure was done at L5–S1. Continued back pain and worsening leg pain associated with radiolucency around the AxiaLIF device led to revision surgery after 8 months. A posterior approach was used with insertion of bilateral expandable polyetheretherketone cages using Actifuse graft positioned to either side of the retained AxiaLIF device. Posterior pedicle screw-based instrumentation was extended to the iliac crest. Twelve months later, CT imaging showed a stable construct and early signs of a fusion mass.

Validity and generalisability of the studies

- No randomised controlled trials were identified.
- Most of the studies were retrospective.
- There were no UK studies identified.
- The patient populations were heterogeneous with regard to indications for the procedure.
- There was heterogeneity in how a solid fusion was determined; some studies used CT and others used plain radiographs.
- The procedures varied within and between studies, with regard to using bilateral or unilateral pedicle screws, and facet screws. There was also variation in the choice of bone graft and biological enhancers.
- There is a lack of long-term data.
- Fusion rate was the only efficacy outcome reported in the systematic review. The review did not address patient-reported outcome measures or radiographical outcomes other than fusion.

Existing assessments of this procedure

There were no published assessments from other organisations identified at the time of the literature search.

Related NICE guidance

Below is a list of NICE guidance related to this procedure.

Interventional procedures

- Transaxial interbody lumbosacral fusion. NICE interventional procedures guidance 387 (2011). Available from http://www.nice.org.uk/guidance/IPG387 [current guidance]. This guidance is currently under review and is expected to be updated in 2018.
- Lateral interbody fusion in the lumbar spine for low back pain. NICE interventional procedures guidance 574 (2017). Available from http://www.nice.org.uk/guidance/IPG574.

- Minimally invasive sacroiliac joint fusion surgery for chronic sacroiliac pain. NICE interventional procedures guidance 578 (2017). Available from http://www.nice.org.uk/guidance/IPG578.
- Percutaneous intradiscal radiofrequency treatment of the intervertebral disc nucleus for low back pain. NICE interventional procedures guidance 545 (2016). Available from http://www.nice.org.uk/guidance/IPG545.
- Percutaneous electrothermal treatment of the intervertebral disc annulus for low back pain and sciatica. NICE interventional procedures guidance 544 (2016). Available from http://www.nice.org.uk/guidance/IPG544.
- Percutaneous coblation of the intervertebral disc for low back pain and sciatica. NICE interventional procedures guidance 543 (2016). Available from http://www.nice.org.uk/guidance/IPG543.
- Peripheral nerve-field stimulation for chronic low back pain. NICE interventional procedures guidance 451 (2013). Available from http://www.nice.org.uk/guidance/IPG451.
- Non-rigid stabilisation techniques for the treatment of low back pain. NICE interventional procedures guidance 366 (2010). Available from http://www.nice.org.uk/guidance/IPG366.
- Percutaneous intradiscal laser ablation in the lumbar spine. NICE interventional procedures guidance 357 (2010). Available from http://www.nice.org.uk/guidance/IPG357.

NICE guidelines

- Low back pain and sciatica in over 16s: assessment and management. NICE guideline 59 (2016). Available from http://www.nice.org.uk/guidance/NG59.

Additional information considered by IPAC

Specialist advisers' opinions

Specialist advice was sought from consultants who have been nominated or ratified by their specialist society or royal college. The advice received is their

individual opinion and is not intended to represent the view of the society. The advice provided by specialist advisers, in the form of the completed questionnaires, is normally published in full on the NICE website during public consultation, except in circumstances but not limited to, where comments are considered voluminous, or publication would be unlawful or inappropriate. Four specialist adviser questionnaires for transaxial interbody lumbosacral fusion for low back pain were submitted and can be found on the NICE website.

Patient commentators' opinions

NICE's Public Involvement Programme will send questionnaires to NHS trusts for distribution to patients who had the procedure (or their carers). When NICE has received the completed questionnaires, these will be discussed by the committee.

Company engagement

A structured information request was sent to 2 companies who manufacture or supply a potentially relevant device for use in this procedure. NICE received 2 completed submissions. These were considered by the IP team and any relevant points have been taken into consideration when preparing this overview.

Issues for consideration by IPAC

- The list of additional relevant papers at the end of the overview includes some studies on patients with scoliosis. The instructions for use state that 'AxiaLIF or AxiaLIF Plus System is intended to provide anterior stabilization of the L5–S1 or L4–S1 spinal segment(s) as an adjunct to spinal fusion. The AxiaLIF Plus System is indicated for patients requiring fusion to treat pseudoarthrosis (unsuccessful previous fusion), spinal stenosis, spondylolisthesis (Grade 1 or 2 if single-level; Grade 1 if two-level), or degenerative disc disease'. Scoliosis that extends to the treated level(s) is a contraindication for the procedure.

References

1. Schroeder GD, Kepler CK, Vaccaro AR. (2015) Axial interbody arthrodesis of the L5-S1 segment: a systematic review of the literature. Journal of Neurosurgery Spine 23: 314–9
2. Schroeder GD, Kepler CK, Millhouse PW et al. (2016) L5/S1 Fusion Rates in Degenerative Spine Surgery: A Systematic Review Comparing ALIF, TLIF, and Axial Interbody Arthrodesis. Clinical Spine Surgery 29: 150–5
3. Zeilstra DJ, Staartjes VE, Schroder ML. (2017) Minimally invasive transaxial lumbosacral interbody fusion: a ten year single-centre experience. International orthopaedics 41: 113–9
4. Gundanna MI, Miller LE, Block JE (2011) Complications with axial presacral lumbar interbody fusion: A 5-year postmarketing surveillance experience. SAS journal [Electronic Resource] 5: 90–4
5. Whang PG, Sasso RC, Patel VV et al. (2013) Comparison of axial and anterior interbody fusions of the L5-S1 segment: a retrospective cohort analysis. Journal of Spinal Disorders & Techniques 26: 437–43
6. Tobler WD, Gerszten PC, Bradley WD et al. (2011) Minimally invasive axial presacral L5-S1 interbody fusion: two-year clinical and radiographic outcomes. Spine 36: E1296–301
7. Siegel G, Patel N, Ramakrishnan R. (2013) Rectocutaneous fistula and nonunion after TranS1 axial lumbar interbody fusion L5-S1 fixation: case report. Journal of Neurosurgery Spine 19: 197–200
8. Hofstetter CP, James AR, Härtl R. (2011) Revision strategies for AxiaLIF. Neurosurgical Focus 31: E17

Literature search strategy

Databases	Date searched	Version/files
Cochrane Database of Systematic Reviews – CDSR (Cochrane Library)	21/11/2017	Issue 11 of 12, November 2017
HTA database (Cochrane Library)	21/11/2017	Issue 10 of 12, October 2017
Cochrane Central Database of Controlled Trials – CENTRAL (Cochrane Library)	21/11/2017	Issue 4 of 4, October 2016
MEDLINE (Ovid)	21/11/2017	1946 to November Week 2 2017
MEDLINE In-Process (Ovid)	21/11/2017	November 20, 2017
EMBASE (Ovid)	22/11/2017	1974 to 2017 November 21
PubMed	22/11/2017	n/a

The following search strategy was used to identify papers in MEDLINE. A similar strategy was used to identify papers in other databases.

1 Spinal Fusion/
2 Intervertebral Disc/
3 Lumbar Vertebrae/
4 Sacrum/
5 Sacrococcygeal Region/
6 Coccyx/
7 (sacrococcygeal adj4 (fusion* or fuse*)).ti,ab.
8 ((lumbar* or intervertebr* or sacral* or coccyx or sacrum*) adj4 (fusion* or fuse*)).ti,ab.
9 ((spine* or spinal* or lumbosacral or L5-S1 or L4-S1) adj4 (fusion* or fuse*)).ti,ab.
10 ((fusion* or fuse*) adj4 (inter-bod* or interbod*)).ti,ab.
11 or/1-10
12 ((transaxial* or axial* or trans-axial* or trans-1 axial* or transacral or trans-sacral or presacral or L5-S1 or L4-S1 or paracoccygeal or para-coccygeal) adj4 (approach* or fusion* or fuse* or procedure* or fixation* or space* or technique*)).ti,ab.
13 AxiaLIF.ti,ab.
14 12 or 13
15 11 and 14
16 animals/ not humans/
17 15 not 16

Appendix - Additional relevant papers

The following table outlines the studies that are considered potentially relevant to the IP overview but were not included in the main data extraction table (table 2). It is by no means an exhaustive list of potentially relevant studies.

Article	Number of patients/ follow-up	Direction of conclusions	Reasons for non-inclusion in table 2
Anand N, Baron EM, Khandehroo B (2014) Does minimally invasive transsacral fixation provide anterior column support in adult scoliosis? Clinical Orthopaedics & Related Research 472: 1769-75	Case series n=46 FU=mean 48 months	41% (19/46) of patients had fusions extending above the thoracolumbar junction, with 1 patient having fusion into the proximal thoracic spine (T3-S1). 89% (41/46) of patients developed a solid fusion at L5-S1. There were significant improvements in all HRQOL parameters. Eight patients had complications related to the transsacral fusion, including 5 pseudarthroses and 3 superficial wound dehiscences. Three patients underwent revision surgery with iliac fixation. There were no bowel injuries, sacral hematomas, or sacral fractures.	Small case series, which is included in the systematic review by Schroeder GD et al. (study 1).
Anand N, Baron EM, Khandehroo B et al. (2013) Long-term 2- to 5-year clinical and functional outcomes of minimally invasive surgery for adult scoliosis. Spine 38: 1566-75	Case series n=71 FU=mean 39 months	A combination of 3 novel minimally invasive surgical techniques allows comparable correction of adult spinal deformity, with low pseudarthrosis rates, significantly improved functional outcomes, and excellent clinical and radiological improvement, but considerably lowers morbidity and complication rates at early and long-term follow-up.	A combination of 3 techniques was used.
Anand N, Rosemann R, Khalsa B et al. (2010) Mid-term to long-term clinical and functional outcomes of minimally invasive correction and fusion for adults with scoliosis. Neurosurgical Focus 28 (3): E6	Case series n=28	Minimally invasive surgical correction of adult scoliosis results in mid- to long-term outcomes similar to traditional surgical approaches. Whereas operating times are comparable to those achieved with open approaches, blood loss and morbidity appear to be significantly lower in patients undergoing minimally invasive deformity correction. This approach may be particularly useful in the elderly.	Small case series, which is included in the systematic review by Schroeder GD et al. (study 1).
Anand N, Baron EM, Thaiyananthan G et al. (2008) Minimally invasive multilevel percutaneous correction and fusion for	n=12 (5 transaxial interbody	Combination of 3 techniques. There were no surgical complications. None of the patients	Larger or more recent studies are included.

adult lumbar degenerative scoliosis. Journal Spinal Disorders and Techniques 21: 459–67	spinal fusions) Mean follow-up=76 days	required blood transfusion or admission to the ICU.	
Aryan HE, Newman CB, Gold JJ et al. (2008) Percutaneous axial lumbar interbody fusion (AxiaLIF) of the L5-S1 segment: initial clinical and radiographic experience. Minimally Invasive Neurosurgery 51: 225-230	Case series n=35 FU=mean 17.5 months	The percutaneous paracoccygeal approach to the L5-S1 interspace provides a minimally invasive corridor through which discectomy and interbody fusion can safely be performed. It can be used alone or in combination with minimally invasive or traditional open fusion procedures. It may provide an alternative route of access to the L5-S1 interspace in those patients who may have unfavourable anatomy for or contraindications to the traditional open anterior approach to this level.	Small case series, which is included in the systematic review by Schroeder GD et al. (study 1).
Boachie-Adjei O, Cho W, King AB (2013) Axial lumbar interbody fusion (AxiaLIF) approach for adult scoliosis. European Spine Journal 22: S225-31	Review	AxiaLIF is a relatively safe procedure, and it provides good clinical results in both short constructs and long constructs for adult scoliosis surgery. For a safer procedure, surgeons should seek out prior colorectal surgical history and review preoperative imaging studies carefully.	Review focuses on scoliosis. A more recent systematic review is included (study 1).
Bohinski RJ, Jain VV, Tobler WD (2010) Presacral retroperitoneal approach to axial lumbar interbody fusion: a new, minimally invasive technique at L5-S1: Clinical outcomes, complications, and fusion rates in 50 patients at 1-year follow-up. SAS journal [Electronic Resource] 4: 54-62	Case series n=50 FU=1 year	VAS and ODI scores significantly improved by 49% and 50%, respectively, versus preoperative scores. By high-resolution CT scans, fusion was achieved in 44 (88%) patients, developing bone occurred in 5 (10%), and 1 (2%) patient had pseudarthrosis. One patient suffered a major operative complication-a bowel perforation with a pre-sacral abscess that resolved with treatment.	Larger studies, with longer follow-up are included.
Botolin S, Agudelo J, Dwyer A et al. (2010) High Rectal Injury During Trans-1 Axial Lumbar Interbody Fusion L5–S1 Fixation: A Case Report. Spine 35: E144-E148	Case report n=1	After the procedure, the patient presented with an episode of melena and hypogastric pain with nausea and vomiting. A CT scan of the abdomen with intravenous and oral contrast showed presacral soft tissue fluid density with fat stranding and extraluminal rectal contrast and gas with some areas of soft tissue enhancement compatible with probable high rectal perforation. The patient's symptoms gradually subsided during a period of 6 months with aid from a temporary diverting ileostomy and a course of IV antibiotics. No spine implants were removed.	Case report of rectal injury, which is already described in table 2.

Bradley WD, Hisey MS, Verma-Kurvari S et al. (2012) Minimally invasive trans-sacral approach to L5-S1 interbody fusion: Preliminary results from 1 center and review of the literature. International Journal of Spine Surgery 6: 110–4	Case series n=41 FU=mean 22 months	In the group of 28 patients who had single-level AxiaLIF combined with posterior fusion, the visual analogue scale scores assessing back and leg pain and mean Oswestry Disability Index scores improved significantly ($p<0.01$). In the remaining 13 patients, back pain improved significantly with a trend for improvement in leg pain. Reoperation occurred in 19.5% of patients; in half of these, reoperation was not related to the anterior procedure.	Larger studies, with longer follow-up are included.
Cohen A, Miller LE, Block JE (2011) Minimally invasive presacral approach for revision of an Axial Lumbar Interbody Fusion rod due to fall-related lumbosacral instability: a case report. Journal of medical case reports 5: 488	Case report n=1	The Axial Lumbar Interbody Fusion distraction rod may be revised and replaced with a larger diameter rod using the same presacral approach.	Case report.
DeVine JG, Gloystein D, Singh N. (2009) A novel alternative for removal of the AxiaLif (TranS1) in the setting of pseudarthrosis of L5-S1. Spine Journal 9: 910–5	Case report n=1	Removal of the implant for pseudarthrosis was performed through a paramedian retroperitoneal approach with caudal extension.	Case report of device removal.
Durrani A, Mistur R, Shanti N (2011) Presacral approach for L5-S1 fusion. Techniques in Orthopaedics 26: 166-172	Review	Comparison of several large-scale AxiaLIF studies with results from open fusion techniques show comparable fusion rates and clinical outcomes at 2-year follow-up. However, AxiaLIF patients show reduced estimated blood loss, hospital stay, complications, and overall decreased morbidity when compared with patients who undergo open fusion. The studies cited in this review support the safety of this presacral annulus-sparing approach and demonstrate low incidence of vascular and visceral injuries. Our clinical experience with this procedure confirms these findings.	A more recent systematic review is included (study 1).
Fokter SK (2011) Update review and clinical presentation on chronic low back pain treated by AxiaLIF. European Journal of Orthopaedic Surgery and Traumatology 21: 39-42	Review	Additional pedicle or facet screw fixation is recommended to provide stabilization and promote fusion. AxiaLIF represents a solid-based fusion technique for degenerative disc disease at L5-S1 level with minimal collateral damage in carefully selected patients.	A more recent systematic review is included (study 1).
Gerszten PC, Tobler WD, Nasca RJ (2011) Retrospective analysis of	Non-randomised	In this case-matched series, clinical outcomes were similar for patients who underwent an AxiaLIF L5-S1	Study focuses on the use of recombinant human

L5-S1 axial lumbar interbody fusion (AxiaLIF): a comparison with and without the use of recombinant human bone morphogenetic protein-2. Spine Journal: Official Journal of the North American Spine Society 11: 1027-32	comparative study n=99 FU=2 years	interbody fusion with or without rhBMP-2. The data strongly suggest that there is a high confidence for no effect on fusion rate by using rhBMP-2.	bone morphogenetic protein-2. Study is included in the systematic review by Schroeder GD et al. (study 1).
Gerszten PC, Tobler W, Raley TJ et al. (2012) Axial presacral lumbar interbody fusion and percutaneous posterior fixation for stabilization of lumbosacral isthmic spondylolisthesis. Journal of Spinal Disorders & Techniques 25: E36-40	Case series n=26 FU=2 years	The minimally invasive presacral axial interbody fusion and posterior instrumentation technique is a safe and effective treatment for low-grade isthmic spondylolisthesis.	Small case series, which is included in the systematic review by Schroeder GD et al. (study 1).
Hadjipavlou A, Alpantaki K, Katonis P et al. (2013) Safety and effectiveness of retrorectal presacral approach for lumbosacral axial instrumentation. A clinical study. Acta Orthopaedica Belgica 79: 222-9	Case series n=29	The fusion rate in the present series was 92%. The only serious complication in the authors' series was 1 presacral haematoma (1/29, or 35%). Symptomatic subsidence occurred in the stand alone group, resulting in foraminal stenosis and radiculopathy in 2 patients (7%) and back pain in 1 (3.5%). Painful radiolucent halo around the rod was noted in a spondylolytic case (1/29, or 3.5%); it resolved after transpedicular instrumentation.	Small case series, which is included in the systematic review by Schroeder GD et al. (study 1).
Hofstetter CP, Shin B, Tsiouris AJ et al. (2013) Radiographic and clinical outcome after 1- and 2-level transsacral axial interbody fusion. Journal of Neurosurgery: Spine 19: 454-463	Case series n=38 FU=mean 26 months	Overall, surgical intervention led to modest symptomatic improvement; only 26% of patients achieved an MCID of the Oswestry Disability Index and 50% of patients an MCID of the VAS score for back pain. At last follow-up, 72% of L5/S1 levels demonstrated bony fusion (1-level AxiaLIF 81%, 2-level AxiaLIF 33%; $p<0.05$), whereas none of the L4/5 levels in 2-level AxiaLIF fused. Five constructs developed pseudarthrosis and required surgical revision.	Small case series, which is included in the systematic review by Schroeder GD et al. (study 1).
Issack PS, Boachie-Adjei O (2012) Axial lumbosacral interbody fusion appears safe as a method to obtain lumbosacral arthrodesis distal to long fusion constructs. HSS Journal 8: 116-21	Case series n=9	The axial lumbosacral interbody fusion is a minimally invasive and safe method to obtain lumbosacral fixation and arthrodesis distal to a long fusion construct. Longer follow-up of larger numbers of patients are needed prior to recommending this procedure as a routine method to fuse L4-5 or L5-S1.	Small case series, which is included in the systematic review by Schroeder GD et al. (study 1).
Issack PS, Kotwal SY, Boachie-Adjei O (2014) The axial transsacral approach to interbody fusion at L5-S1.	Review	Clinical studies have demonstrated good early results with the use of the axial transsacral approach in obtaining lumbosacral interbody fusion for degenerative disc	A more recent systematic review is included (study 1).

Neurosurgical Focus 36: E8		disease, spondylolisthesis, and below long posterior fusion constructs. The technique is exacting and complications can be major, including rectal perforation and fistula, loss of correction, and pseudarthrosis.	
Lindley EM, McCullough MA, Burger EL et al. (2011) Complications of axial lumbar interbody fusion. Journal of Neurosurgery Spine 15: 273-9	Case series n=68 FU=mean 34 months	The complication rate associated with AxiaLIF in the present study was relatively low (27%). The most common complications were superficial infection and pseudarthrosis. There were 2 cases of rectal perforation associated with AxiaLIF; 1 case was found intraoperatively and the other presented 4 days postoperatively. Both patients underwent emergency repair by a general surgeon and had no long-term sequelae as a result of the rectal injuries. It is important for surgeons to be aware of the potential for these complications. Many of these complications can probably be avoided with proper patient selection and operative planning. Preoperative MR imaging, a detailed patient physical examination and history, full bowel preparation, and the use of live fluoroscopy can all help to prevent complications with AxiaLIF surgery.	Larger or more recent studies are included.
Louwerens JK, Groot D, van Duijvenbode DC et al. (2013) Alternative Surgical Strategy for AxiaLIF Pseudarthrosis: A Series of Three Case Reports. Evidence based Spine care Journal 4: 143-8	Case series n=3 FU=12 months	Anterior fusion with a DEVEX cage in front of a TranS1 screw for AxiaLIF pseudarthrosis is safe and effective.	Small case series of patients needing revision surgery after the procedure.
Luther N, Tomasino A, Parikh K et al. (2009) Neuronavigation in the Minimally Invasive Presacral Approach for Lumbosacral Fusion. Minimally Invasive Neurosurgery 52: 196-200	Case series n=6	The minimally invasive presacral approach to L4-L5-S1 fusion can be performed safely and accurately with intraoperative 3D navigation. This is especially the case in 2-level AxiaLIF procedures, where computer guidance can provide better planning possibilities for optimal screw trajectory.	Larger or more recent studies are included.
Manjila S, Singer J, Knudson K et al. (2012) Minimally invasive presacral retrieval of a failed AxiaLIF rod implant: technical note and illustrative cases. Spine Journal: Official Journal of the North American Spine Society 12: 940-8	Case series n=26	Two cases of failed AxiaLIF that required rod removal were identified for detailed study. Using a minimally invasive presacral approach through the previous surgical corridor, the authors were able to retrieve the AxiaLIF rod implant and then proceed with an alternative fusion technique. Both patients improved clinically and	Study focuses on 2 patients who needed revision surgery after the procedure.

		radiographically after revision. Removal of the presacral rod was not associated with vascular or bowel complications and required minimal operating room time with minimal blood loss.	
Marchi L, Oliveira L, Coutinho E et al. (2012) Results and complications after 2-level axial lumbar interbody fusion with a minimum 2-year follow-up. Journal of Neurosurgery Spine 17: 187-92	Case series n=27 FU=24 months	Patients undergoing presacral 2-level AxiaLIF experienced satisfactory short-term clinical outcomes; however, complications were commonly seen on imaging studies obtained 24 months postoperatively. Additional studies are required to better understand the 2-level indications for this technique.	Small cases series, focusing on 2-level interbody fusion, which is included in the systematic review by Schroeder GD et al. (study 1).
Marotta N, Cosar M, Pimenta L et al. (2006) A novel minimally invasive presacral approach and instrumentation technique for anterior L5-S1 intervertebral discectomy and fusion. Neurosurgical focus 20 (1): E9	Case reports n=2	Uneventful postoperative course. Hospital stay (hours)=32 and 40 In 1 patient, 9-month x-ray showed no subsidence of the segment, with bridging bone seen across the disc space and no hardware migration.	Case reports (no safety issues reported).
Mazur MD, Duhon BS, Schmidt MH et al. (2013) Rectal perforation after AxiaLIF instrumentation: case report and review of the literature. Spine Journal: Official Journal of the North American Spine Society 13: e29-34	Case report n=1	Delayed presentation of rectal perforation with a subsequent anaerobic sepsis is a potential complication of the presacral approach to the L5-S1 disc space. Recognition and treatment with fecal diversion and long-term intravenous antibiotics is an alternative to device removal and sacral reconstruction.	Case report of rectal perforation, which is already described in table 2.
Melgar MA, Tobler WD, Ernst RJ et al. (2014) Segmental and global lordosis changes with two-level axial lumbar interbody fusion and posterior instrumentation. International Journal of Spine Surgery 8 doi: 10.14444/1010	Case series n=58 FU=mean 29 months	Two-level axial interbody fusion supplemented with posterior fixation does not alter segmental or global lordosis in most patients. Patients with postoperative change in lordosis greater than 5° have similarly favourable long-term clinical outcomes and fusion rates compared to patients with less than 5° lordosis change.	Small cases series, focusing on 2-level interbody fusion.
Mistry AM, Godil SS, Parker SL, et al. (2014) Axial presacral lumbar interbody fusion: a systematic literature review. Journal of Managed Care Medicine 17: 47–56	Systematic review	There are no studies directly comparing axial presacral lumbar interbody fusion to the traditional open approach. The outcomes reported for single-level fusion suggest that both approaches are effective at improving pain and disability and achieving fusion. Although the presacral approach was associated with a higher rate of pseudarthrosis compared to open transforaminal interbody fusion, it was also associated with decreased blood loss, operative times, length	A more recent systematic review is included (study 1).

		of hospital stay and reduced surgical morbidity.	
Patil SS, Lindley EM, Patel VV et al. (2010) Clinical and radiological outcomes of axial lumbar interbody fusion. Orthopedics 33: 883	Case series n=50 FU=mean 12 months	At last follow-up, ODI scores were reduced from 46 to 22, and VAS scores were lowered from 8.1 to 3.6. Of the 49 patients with postoperative radiographs, 47 (96%) went on to a solid fusion. There were no significant differences between pre- and postoperative disk space height and lumbar lordosis angle. The most common complications were superficial infection and pseudoarthrosis. Other complications were rectal injury, hematoma, and irritation of a nerve root by a screw. Overall, we found the axial lumbar interbody fusion procedure in combination with pedicle screw placement to have good clinical and radiological outcomes.	Larger or more recent studies are included.
Rapp SM, Miller LE, Block JE (2011) AxiaLIF system: minimally invasive device for presacral lumbar interbody spinal fusion. Medical Devices Evidence and Research 4: 125-31	review	Minimally invasive axial interbody lumbar fusion via a presacral approach is a technically feasible procedure that is associated with high fusion rates, significant improvements in pain and function, and low complication rates.	A more recent systematic review is included (study 1).
Stippler M, Turka M, Gerszten P (2007). Outcomes after Percutaneous TranS1 AxiaLIF® L5-S1 Interbody Fusion for Intractable Lower Back Pain. The Internet Journal of Neurosurgery 5: 1	Case series n=36	These results indicate that the AxiaLIF procedure in combination with supplemental percutaneous pedicle screw placement is a feasible and safe technique for L5-S1 interbody fusion which results in good clinical outcomes.	Larger or more recent studies are included.
Tender GC, Miller LE, Block JE (2011) Percutaneous pedicle screw reduction and axial presacral lumbar interbody fusion for treatment of lumbosacral spondylolisthesis: A case series. Journal of Medical Case Reports [Electronic Resource] 5: 454	Case series n=3	Percutaneous pedicle screw reduction combined with axial presacral lumbar interbody fusion offers a promising and minimally invasive alternative for the management of lumbosacral spondylolisthesis.	Larger or more recent studies are included.
Tobler WD, Ferrara LA (2011) The presacral retroperitoneal approach for axial lumbar interbody fusion: a prospective study of clinical outcomes, complications and fusion rates at a follow-up of two years in 26 patients. Journal of Bone & Joint	Case series n=26 FU=2 years	Significant reductions in pain and disability occurred as early as 3 weeks postoperatively and were maintained. Fusion was achieved in 92% (22/24) of patients at 12 months and in 23 patients (96%) at 24 months. One patient (4%) with a pseudarthrosis underwent successful revision by augmentation of the posterolateral fusion mass	Small case series, which is included in the systematic review by Schroeder GD et al. (study 1).

Surgery - British Volume 93: 955-60		through a standard open midline approach. There were no severe adverse events associated with presacral ALIF, which in this series demonstrated clinical outcomes and fusion rates comparable with those of reports of other methods of interbody fusion.	
Tobler WD, Melgar MA, Raley TJ et al. (2013) Clinical and radiographic outcomes with L4-S1 axial lumbar interbody fusion (AxiaLIF) and posterior instrumentation: a multicenter study. Medical Devices Evidence and Research 6: 155-61	Case series n=52 FU=2 years	The AxiaLIF 2-level device is a safe, effective treatment adjunct for patients with L4-S1 disc pathology resistant to conservative treatments.	Small cases series, focusing on 2-level interbody fusion.
Wilson JR, Timothy J, Rao A et al. (2013) Retrieval of a migrated AxiaLIF lumbosacral screw using fluoroscopic guidance with simultaneous real-time sigmoidoscopy: technical report. Spine 38: E1285-7	Case report n=1	For the retrieval of migrated AxiaLIF lumbosacral screws, intraoperative sigmoidoscopy is technically feasible and serves as a useful adjunct to ensure the integrity of the rectal mucosa is maintained. This technique can be used to avoid the potential morbidity of rectal perforation, and subsequent laparotomy and defunctioning colostomy.	Case report.
Wiltfong RE, Bono CM, Charles Malveaux WMS et al. (2012) Lumbar interbody fusion: Review of history, complications, and outcome comparisons among methods. Current Orthopaedic Practice 23: 193-202	Review	Compared to open techniques, the minimally invasive techniques yield less blood loss, decreased hospital stay, decreased postoperative back pain, and longer operative times. Each method of lumbar interbody fusion results in high rates of fusion and good clinical outcomes, despite complications and learning curves. More level 1 studies are needed to make generalisations regarding the outcomes of one method compared with another.	A more recent systematic review is included (study 1).
Zeilstra DJ, Miller LE, Block JE (2013) Axial lumbar interbody fusion: a 6-year single-center experience. Clinical Interventions In Aging 8: 1063-9	Case series n=131 FU=mean 21 months	Single-level AxiaLIF is a safe and effective means to achieve lumbosacral fusion in patients with symptomatic degenerative disc disease.	A more recent publication from the same centre is included.