Local Bone Grafting Is Sufficient for Instrumented Adolescent Idiopathic Scoliosis Surgery: A Preliminary Study

Alper Yataganbaba, MD, Abhay Gahukamble, MD,* Georgia Antoniou, BSc,* Brian J.C. Freeman, MB, BCh, BAO, DM, FRCS, FRACS, FAOrthA,*† and Peter J. Cundy, MBBS, FRACS*†*

Background: Several options for grafting exist; iliac crest bone grafting, allografts, and bone substitutes. Local bone graft (LBG) offers high-quality bone graft and no commercial cost. The aim of this study was to assess the clinical and radiologic results of adolescent idiopathic scoliosis (AIS) surgery with posterior instrumentation and fusion (PIF) in patients using only LBG and to measure the quantities harvested.

Methods: A total of 218 AIS patients who underwent pedicle screw PIF surgery using only LBG with a minimum 1-year follow-up were reviewed. Bone was harvested during surgery from the excised facet joints, spinous processes (not from the end instrumented vertebrae) and decortication of laminae and transverse processes in the operative field. The harvested bone graft weight of 127 patients was recorded prospectively and then computed to graft weight per kilogram body weight (GWPK) and graft weight per motion segment (GWPMS).

Results: The median follow-up time was 24.7 months (12.1 to 133 mo) with 128 of the 218 patients having over 2 years follow-up. A total of 280 curves were fused. One hundred fifty-six of the patients had single curve instrumentation and 62 had double curve surgery. The median preoperative primary Cobb angle was 57.0 (31 to 100) degrees and postoperatively was 20.0 (0 to 66) degrees, indicating a median correction of 65.3% (17.5% to 100%). The median graft weight was 30 g (14 to 62 g), GWPK was 0.54 g/kg (0.24 to 1.29 g/kg) and GWPMS was 3.3 g/motion segments (2.3 to 10.0 g/kg). Twelve of 218 patients (5.5%) required subsequent surgery. Only 2 patients developed pseudarthrosis (0.91%), noting that modern segmental instrumentation warrants longer follow-up for increased confidence of complete fusion.

Conclusions: LBG achieved successful fusion in over 99% of patients undergoing PIF for AIS. The described terms GWPK and GWPMS can be insightful for future studies. LBG offers a safe and low-cost solution for bone grafting in AIS surgery.

Level of Evidence: Level IV.

Key Words: adolescent idiopathic scoliosis, bone graft, local, posterior fusion, allograft, pseudarthrosis

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From the *Department of Orthopaedic Surgery, Women's and Children's Hospital; and †Centre for Orthopaedic and Trauma Research, University of Adelaide, Adelaide, SA, Australia.

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Reprints: Peter J. Cundy, MBBS, FRACS, Women's and Children's Hospital 72 King William Road North, Adelaide, SA 5006, Australia. E-mail: peter.cundy1@gmail.com.

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Surgical treatment for adolescent idiopathic scoliosis (AIS) aims to correct spinal curvature and maintain trunk balance. Posterior spinal fusion (PSF) with segmental spinal instrumentation (SSI) is the most commonly used method for surgical treatment.[1]

Occasionally pseudarthrosis of the spine becomes evident and is defined as a failure of arthrodesis that is diagnosed ≥1-year after the index surgery.[2] This may reduce quality of life and require revision surgery to achieve solid fusion. Patients with nonunion may present with clinical issues such as back pain, increasing deformity, or radiologic evidence of implant failure.[2,3]

To ensure arthrodesis, it is recommended that the intervertebral spaces in the fusion site be filled with graft material.[4] Several options for grafting exist, namely autografts, allografts or bone substitutes, with iliac crest bone grafting (ICBG) widely accepted.[5] However, the harvesting process of ICBG has associated morbidities, including chronic pain, scar formation, donor site infection, blood loss, hematoma, increased surgery time, and sacroiliac joint instability.[6,7] Allografts and bone substitutes have become popular in recent years.[4] The use of allograft offers similar results to ICBG and is reported to have fewer comorbidities.[5,8,9] Bone substitutes such as porous ceramics, calcium phosphate, and osteogenic protein-1 have variable results,[10–13] but remain popular due to their ease of use for the surgeon, with ready availability through industry sources and active promotion by manufacturers.

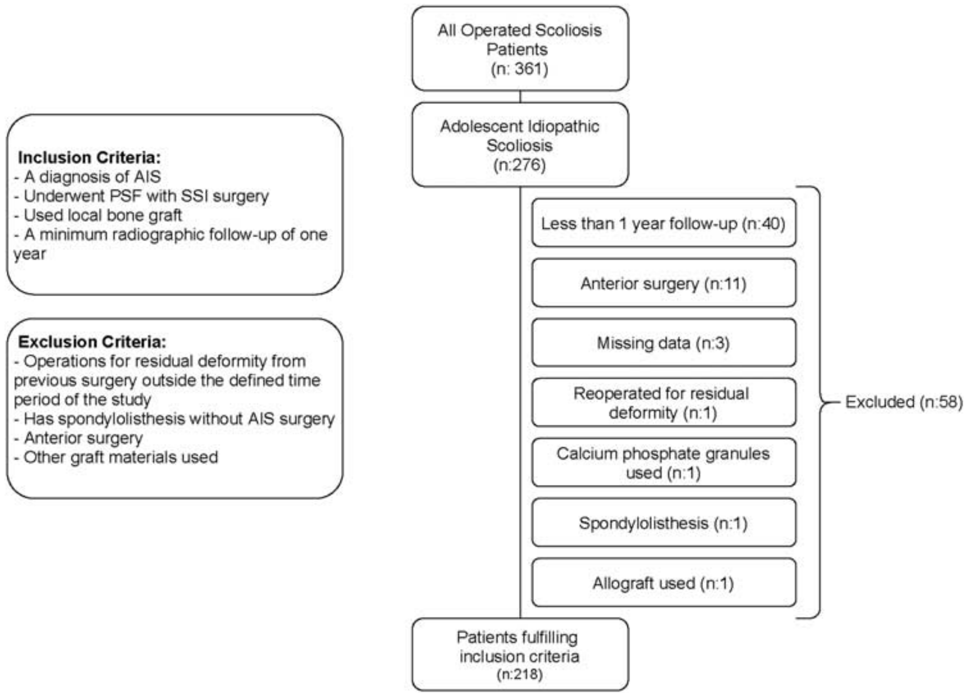

FIGURE 1. Flow diagram for patient selection. AIS indicates adolescent idiopathic scoliosis; PSF, posterior spinal fusion; SSI, segmental spinal instrumentation.

However, the high relative cost of allografts is a major disadvantage of this method[14,15] with additional risks of immune reaction, bacterial contamination, and viral transmission.[16] Allograft availability depends on supply from donors, often cadaveric or femoral heads from total hip arthroplasty patients. Commercially available allografts are expensive with current costs in the vicinity of US$ 5000 per patient.[15] Some surgeons employ expanders or enhancers such as bioactive glass, calcium sulfate, tricalcium phosphate (TCP), and bone marrow aspirate (BMA) with an expectation that they aid union.[11,17–21]

In contrast, local bone graft (LBG) offers the advantage of providing bone of similar quality to the widely accepted standard (ie, ICBG) at no additional cost.

An analysis in 2004 of a small group of patients having scoliosis surgery using LBG in isolation, with no enhancer or extender, demonstrated good outcomes for patients with AIS.[22] However, there is a paucity of other publications on the use of only LBG in patients with scoliosis and one using rib bone from thoracoplasty.[23]

This study aimed to assess the clinical and radiologic results of AIS surgery with posterior instrumentation and fusion in patients using only LBG and to measure the quantities harvested.

METHODS

This study was a retrospective analysis of patients who underwent posterior instrumentation and fusion surgery with the diagnosis of AIS at a significant tertiary pediatric hospital with a prospective component measuring the weights of LBG harvested. Institutional ethics approval was granted (HREC Audit 61A).

Pediatric spine patients who underwent surgery between 1999 and 2017 were identified through a prospective database with the following inclusion criteria; (1) a diagnosis of AIS and (2) underwent PSF with SSI surgery (3) used LBG and (4) a minimum radiographic follow-up of 1 year. Pedicle screw density ranged from 1.4 to 2. Exclusion criteria listed; (1) operations for residual deformity from previous surgery outside the defined time period of study, (2) spondylolisthesis without AIS surgery, (3) anterior surgery, and (4) other graft materials used (Fig. 1).

Routinely patients were followed for a minimum of 2 years postoperatively, with radiographic assessment at 1 and 2 years. Computed tomography (CT) imaging was not routinely performed due to concerns regarding unnecessary irradiation.

Surgical Technique

Patients were routinely placed in the prone position under general anesthesia after cefazolin prophylaxis and administration of intravenous tranexamic acid. Paraspinal muscles and paravertebral soft tissues were dissected subperiosteally using electrocautery. Dissection was completed to the lateral portion of transverse processes and facet joints excised. Pedicle screws were inserted in the concave and convex vertebral bodies. The concave rod was prepared and placed into concave pedicle screws achieving a significant correction. The convex rod was inserted into the convex screws and tightened. Once the instrumentation was secure, the spinous processes were excised to be flush with the laminae. The transverse processes were decorticated using bone rongeurs. The 2 most proximal and the 2 most distal spinous processes and interspinous ligaments between were preserved. The obtained bone graft had soft tissue attachments removed and was weighed before placement on the spine. Routine closure was performed without the use of surgical drains.

Two hundred eighteen patients met the criteria to be included in the study. Demographic data, instrumentation levels, and the number of instrumented vertebrae were retrieved from the scoliosis database.

At the latest follow-up, patients were assessed clinically and radiologically. Clinical indicators of complications included persistent, localized pain, neurological symptoms, increased deformity, physical function, balance, and self-image evaluation.

Standing posteroanterior and lateral radiographs taken at preoperative, early postoperative, and final assessment were evaluated. Curvatures within the instrumentation level were measured by Cobb technique at the same level on each radiograph. We observed changes in the exact segment undergoing PSF with SSI surgery in an attempt to quantify changes as one of several ways to suspect pseudarthrosis. The major curves were separately measured for clinical monitoring of the patients, both preoperative and in postoperative monitoring and were recorded in each patient's charts and data sets for clinical management. However, for the purposes of this study we focused on the instrumented curve for signs of loss of correction in this specific region. The curve reduction relative to the preoperative radiograph (over the same levels), any loss of reduction as well as the position and continuity of the implants were noted. One author performed all measurements and, for complex cases, the senior author of the study was consulted. Evidence of consolidated fusion was observed on the latest radiograph, noting that this can be difficult to assess using plain radiographs.[24,25] All radiographs were checked for signs of pseudarthrosis, including evidence of screw breakage, rod fracture, implant migration, and curve progression, as well as clinical progress for symptoms of pseudarthrosis[26,27] Separately CT imaging was performed in 5 patients with radiologic or clinical suspicion of pseudarthrosis. In patients who subsequently underwent revision surgery, the fusion site was evaluated intraoperatively.

Pseudarthrosis diagnosis was determined if one or more of the following 3 elements were present after the 1-year postoperative timepoint; (1) persistent, localized pain with radiologic evidence of pseudarthrosis, (2) implant failure with radiologic evidence of pseudarthrosis, or (3) intraoperative observation of a pseudarthrosis.[4,25]

The LBG weights of 127 of the 218 patients were measured intraoperatively using precision scales. Graft weight measurement commenced routinely in 2011; therefore, graft weights of patients operated between 1999 and 2011 could not be obtained. Calculations were performed to establish graft weight per motion segment (GWPMS) and graft weight per kilogram body weight (GWPK). Total estimated blood loss was recorded, including accurate cell-saver collection (used in all cases) and weighing of surgical packs and swabs.

TABLE 1. Weights of Local Bone Graft Harvested (GRAMS)

# Patients	Graft Weight Median	Graft Weight Per Kilogram Body Weight	Graft Weight Per Motion Segment	Pseudarthrosis
127 (g)	30 (14-62)	0.54	3.3	1
91	Not measured	Not measured	Not measured	1

RESULTS

A total of 218 patients with AIS were included in this study, noting that 186 (85%) were female, and 32 (15%) were male. Mean age at surgery was 14.7 years (SD = 1.6, range: 10.8 to 19.4). The median number of motion segments fused was 9 (range: 3 to 13).

While the minimum follow-up period of the patients included in the study was 1 year, the follow-up period of 128 of the 218 patients was 2 years and above. The median follow-up time for all patients was 24.7 months (12.1 to 133 mo).

Of the 218 patients, a total of 280 curves were fused. In all, 156 of the patients had single structural curves, and 62 had double structural curves. The median preoperative major curve as measured by Cobb technique was 57.0 (31 to 100) degrees. Postoperatively the median curve was 20.0 (0 to 66) degrees, indicating a median curve correction of 65.3%.

The median graft weight of 127 patients was 30 g (14 to 62 g). The median GWPK was 0.54 g/kg (0.24 to 1.29 g/kg) and the median GWPMS was 3.3 g/motion segment (2.3 to 10 g/motion segment) (Table 1).

Postoperative Issues

The cohort of 218 patients included the following postoperative issues; transient paresthesia 8 (3.7%), postoperative anemia 11 (5%), postoperative anemia requiring blood transfusion 5 (2.3%), constipation 6 (2.7%), nausea and vomiting 4 (1.8%), drug induced colitis 1 (0.4%), paralytic ileus 1 (0.4%), urinary retention 2 (0.9%), pulmonary embolism 1 (0.4%), cerebrospinal fluid leak 3 (1.4%), and lung atelectasis 1 (0.4%). All were managed without need for additional surgical intervention.

Hematoma occurred in 3 (1.4%) patients with 1 patient requiring reoperation at 1 week after surgery. Five patients (2.2%) had a superficial infection that healed with oral antibiotic treatment. A further 6 (2.7%) patients underwent surgical drainage and debridement, along with prolonged intravenous antibiotic treatment. A further 1 patient developed an abscess in the third postoperative year (after an uncomplicated recovery), and ultimately underwent implant removal with evidence of growth of cutibacterium acnes. A solid fusion was observed intraoperatively. This was classified as a late-onset deep surgical site infection (SSI) in accordance with the Centers for Disease Control and Prevention.[28]

One patient had 2 distal screws migrate posteriorly immediately after surgery. Two new screws were reimplanted

TABLE 2. Complications That Required Surgery

Complications That Required Surgery (n:12)	Surgery
Deep infection (n:6)	Washed-out
Infection 3 years after surgery (n:1)	Removal of all metalwork, solid fusion seen intraoperatively
Irritating pedicle screw (n:1)	Screw removed, no pseudarthrosis seen on CT imaging
Migrated out distal pedicle screws, immediately after surgery (n:1)	Screws replaced 1 wk after initial surgery
Hematoma (n:1)	Washed-out
Infection 6 y after surgery (n:1)*	Removal of all metalwork, pseudarthrosis seen on CT imaging after surgery
Screw fracture 1 y after surgery, pseudarthrosis seen on CT (n:1)*	Extension of instrumentation level

*Pseudarthrosis (n:2) (0.91%).
CT indicates computed tomography.

1 week later with good result. One patient had evidence of breakage in 1 screw 2 years after surgery, without symptoms. CT imaging did not show evidence of pseudarthrosis; therefore, an intervention was not required.

In 1 patient, the lowermost right L1 screw was removed due to prominence and local pain. There was no pseudarthrosis on CT imaging. In another patient, who underwent T4-T12 posterior instrumentation, a breakage occurred in the left T12 screw, and displacement occurred in the right T12 screw at 1-year postoperative. CT imaging showed bilateral nonunion between T11 and T12. In light of pain symptoms, the instrumentation level was extended to L1 with evidence of successful union on radiographs 1-year later.

One patient was involved in a motor vehicle accident 6 years postoperative. The patient had a lump in the lumbar region, and a needle biopsy performed by a family physician led to the introduction of a staphylococcus infection and subsequent development of an abscess adjacent to the instrumentation. The instrumentation was removed. Curvature had not increased during follow-up. Pseudarthrosis was seen on CT in the fourth year after implant removal.

Overall, 12 of 218 patients (5.5%) required additional surgery (Table 2). Two of these patients were diagnosed with pseudarthrosis (0.9%). One was operated for pseudarthrosis with extension distally by 1 level. The other patient, described in previous paragraph, underwent implant removal due to the iatrogenic deep infection and had pseudarthrosis seen on a postoperative CT but required no further intervention.

DISCUSSION

We have demonstrated that LBG, without enhancer or extender, is safe and efficient in posterior fusion surgery for AIS. This method has shown comparable results with other studies using allografts, ICBG, and bone substitutes in terms of pseudarthrosis and maintenance of correction.[4,22,29] The use of LBG avoids the complications associated with ICBG.[6,7] In comparison to bone substitutes, LBG has no additional costs, and as such, is vastly more cost-effective. The extra time taken to collect the bone is negligible, and the authors often include the harvesting during routine surgical exposure.

A similar paper assessing the efficacy of LBG in surgery for AIS retrospectively analyzed 25 patients who received LBG (in isolation) using Cotrel-Dubousset Instrumentation.[22] Our study evaluated the same graft methods but used pedicle screw instrumentation instead of the hooks of Cotrel-Dubousset. They reported no pseudarthrosis with a mean follow-up of 5 years and no loss of correction. However, the patient number was small.

In another study, 39 AIS patients underwent posterior instrumentation along with LBG and rib graft. They compared this cohort with 37 patients using allograft only and reported only 1 pseudarthrosis among patients followed for at least 5 years.[23]

Several other studies have used LBG with an additive that is intended to increase the quantity of graft material. These have included bioactive glass, calcium sulfate, TCP, and BMA.[11,17–21] One study reported that BMA and ICBG had similar fusion rates (85.7% vs. 90.5%), but calcium sulfate had a significantly lower fusion rate (45.5%).[19] These studies demonstrate low pseudarthrosis rates and low complications comparable to ICBG figures; however, the necessity of these additional measures and costs involved have not been adequately assessed.

Studies on cost analysis of grafting methods provide evidence that ICBG has higher costs and lower utility than bone morphogenetic protein (BMP) and included the expenses incurred to manage complications associated with ICBG.[13,30] A comparison of LBG, BMP, ICBG, deproteinized bone graft+LBG, and corticocancellous allograft chips (CCA)+LBG in a study on adult 60-year-old plus patient group found that BMP was the most cost-effective method and CCA was the least cost-effective.[14] However, it should be taken into consideration that older adult patients were used in all of these studies.[13,14,30]

Since 1999, LBG has been used in almost all our scoliosis patients. Allograft is mostly reserved for neuromuscular curves and revision cases where sufficient LBG may not be available. Not infrequently, LBG appears sufficient in even these specific disease states such that allograft/bone substitutes, while available, are not used.

A reason supporting the transition to LBG is the high cost of allografts. Cost is increasingly relevant in times of spiraling health expenditure. A fully synthetic cancellous bone graft substitute, consisting of pure β-TCP, may cost US $ 500 to 1000 for 5 to 10 mL of granules. Other substitutes such as injectable, moldable, and biocompatible calcium phosphate can be easy to use and readily visible on postoperative radiographs but may cost US$ 1300 to 2000 for 5 to 10 mL quantities. LBG incurs no extra direct cost to the health care system and only takes a few minutes to collect.

Our analysis of the weight of LBG provides guidance to determine the regularly available amount (median 30 g) as well as the GWPK of 0.54 g/kg and the GWPMS of 3.3 g/motion segment. These quantities fill the spaces adequately and, for this defined pediatric scoliosis population, appear sufficient to ensure adequate fusion. The terms GWPK and GWPMS described in this study can be insightful for future studies and clinical intraoperative guidance.

The number of short fusions did not allow sufficient power for us to accurately analyze a statistical difference to longer fusions. However, of the 2 patients with pseudarthrosis, 1 had surgery over 9 motion segments, and the other had 10 motion segments.

The detection of pseudarthosis can be difficult. It can be asymptomatic and modern forms of instrumentation (with dual rod constructs, strong and durable rods as well as high pedicle screw densities) have the potential to firmly hold the spine despite the lack of bone fusion across vertebra. Longer term follow-up of this cohort, up to 5 years, would be appropriate to detect late pseudarthosis. Indeed, the strong fixation afforded by robust pedicle screw anchors and strong rods should prompt discussion on an amended definition of the minimum time interval for detection of pseudarthosis.

Since the patients included in the study are from a young adolescent population (who generally heal quickly with bones amenable to fusion), the results cannot be generalized to all spinal fusion surgeries, especially to the adult population likely to have more significant risk factors for healing.

In conclusion, LBG facilitates a zero-cost, low-complication, and easy-to-obtain bone graft material that can be used safely in AIS patients to achieve solid arthrodesis.

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