Autogenous iliac crest bone graft versus banked allograft bone in scoliosis surgery in patients with Duchenne muscular dystrophy

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Abstract A total of 36 consecutive nonambulatory DMD patients underwent scoliosis surgery. Patients were divided into two groups: the autogenous iliac crest bone graft group (the ICBG group; 20 patients) and the allogeneous bone graft group (the ALBG group; 16 patients). The mean preoperative curves measured 87° and 31° at the last follow-up in the ICBG group and 83° and 28° in the ALBG group. In the ICBG group, three (15%) patients had intraoperative sacroiliac joint penetration, five (25%) had iliac crest inner cortex penetration and three (15%) had postoperative prolonged wound drainage at the donor site. At three months after surgery, donor site pain caused by bone harvest was found in 50% with severe pain limiting their physical function and causing difficulties in sitting in a wheelchair in 40% of the patients, whereas patients in the ALBG group returned to their preoperative level of function soon after surgery.

Introduction

Posterior spinal fusion in nonambulatory Duchenne muscular dystrophy (DMD) patients has been accepted as the optimal procedure to prevent progression of scoliosis and maintain upright and comfortable sitting [1, 4, 17, 20, 22].

Harvesting autogenous or allogeneous bone graft to increase the fusion rate using segmental instrumentation for scoliosis has been a standard procedure. Advantages of autogenous bone graft over allogeneous bone graft have been well established. The posterior iliac crest is the most common donor site for autogenous bone graft for spinal fusion. However, donor site morbidity caused by bone harvest remains a concern. Furthermore, this procedure is accompanied by many complications because of longer operative time and greater blood loss [18, 24]. Several studies have reported minor and major complications, with a wide range of incidences varying between 1% and 39% [2, 8, 18, 20, 25].

The aim of this study was to compare the outcome and complication rates of scoliosis surgery in nonambulatory patients with DMD using either autogenous posterior iliac crest bone graft (ICBG) or allogeneous bone graft (ALBG).

Materials and methods

From March 2003 to October 2006, a total of 36 consecutive DMD patients underwent posterior spinal fusion and instrumentation (thoracic hooks and lumbar screws) for scoliosis. The patients were prospectively collected and followed. The minimum follow-up period was two years. Patients were divided into two groups: the

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iliac crest bone graft group (the ICBG group; 20 patients in whom posterior iliac crest bone graft was used) and the allogeneous bone graft group (the ALBG group; 16 patients in whom banked allograft bone was used).

Surgical technique

All the patients had standard posterior spinal fusion performed by the same surgeon (M.T.). The posterior elements of the spine were exposed from the upper thoracic spine to the sacrum by stripping the muscles subperiosteally. Spinal cord function was monitored throughout the procedure. Autotransfusion via preoperative storage and intraoperative collection was used. Distal fixation comprised 6-mm pedicle screws in the lumbar spine. Apical and proximal fixation comprised hooks in the thoracic spine. The rods were contoured to recreate the sagittal profile and coronal balance was achieved by sequential reduction of the segments toward the rods. In the ALBG group, allograft bone obtained from Kitasato University Bone Bank (KUBB) was used. The bone was again cleaned of all the attached soft tissue, and the bone mill morselised the grafts and further separated the soft tissue from the bone (Fig. 1). Alternatively, in the ICBG group, a conventional approach to the iliac crest was used to obtain autogenous bone grafts. Grafts were harvested from both iliac crests. The posterior elements were decorticated and bone grafts were placed on the decorti-

cated bed along the length of the instrumentation from T3 or T4 to L5.

Clinical and radiological assessments

Assessment was performed clinically and with radiological measurements. All of the patients were reviewed clinically and questioned about whether they felt back pain at one week and at a three-month interval for 24 months after surgery. Intraoperative complications, along with postoperative complications, were recorded.

The patients in the ICBG group were specifically questioned about whether they had local pain at the donor site at one week and at a three-month interval for 24 months after surgery.

The questions consisted of the following:

1. Do you have pain in the back hip area where the iliac crest bone graft was harvested? If yes, rate your pain on a scale of 1 to 10.
2. Do you have any problems with daily activities (difficulties in sitting in a wheelchair) due to the pain?

Sitting anteroposterior and lateral radiographs were taken and evaluated the day before surgery, at one week, three and 24 months after surgery and at the last follow-up. The deformity in the coronal plane was measured by the Cobb angle method. Clinical evaluation was made by the senior author.

Fig. 1 **a** Banked allograft bone obtained from Kitasato University Bone Bank. **b** Banked allograft bone placed into the bone mill. The bone mill morselises the bone graft. **c** A large quantity of milled bone graft is obtained. **d** Adequate quantity of bone grafts for the fusion were placed on the decorticated posterior elements of the spine

Fusion was defined as: first, stable coronal and sagittal alignment over the follow-up period; second, no clinical complaints; third, no evidence of nonunion radiographically; fourth, stable hardware. All four criteria must be present for definition of fusion in this study. CT scans were not available in every patient in this study, and therefore not used for assessment of fusion.

Results

A total of 36 patients (20 in the ICBG group and 16 in the ALBG group) were enrolled in the study. No patients were lost to follow-up. The mean follow-up period was 4.3 years (range, 2.5–6.1 years). Demographic details and surgical parameters are shown in Tables 1 and 2.

There were no significant differences in age, the preoperative and postoperative Cobb angles, or the number of levels fused between the two groups. The operative time and intraoperative blood loss were higher in the ICBG group than in the ALBG group (253 min. versus 233 min.; 850 ml vs. 775 ml).

The ICBG group

There were three (15%) instances of sacroiliac joint penetration and five (25%) instances of iliac crest inner cortex penetration possibly due to a poor pelvis. Prolonged wound drainage at the donor site was observed in three (15%) patients, and treated only with observation resolving in two weeks. There were no neurological complications or infections. There was no instrumentation failure during the follow-up period. Paralytic ileus occurred in four (20%)

Table 1 Details of the patients and operative parameters in the ICBG group

Patient number	Age (y)	Scoliotic curvature (°)					Operative time (min)	Intraoperative blood (ml)	Donor site pain (>3months) and other donor site complications or morbidity
		The day before surgery	Immediately after operation	Three months after surgery	Two years after surgery	Last follow-up			
1	11	100	38	40	40	42	249	889	-
2	13	60	20	20	22	23	230	860	Pain for 9 months; sacroiliac joint penetration
3	13	52	18	19	19	20	205	920	Pain for 3 months; prolonged wound drainage
4	13	55	13	12	13	15	250	866	-
5	12	93	35	36	37	36	267	867	-
6	12	91	32	33	33	33	271	921	-
7	14	81	27	27	28	30	264	964	-
8	13	93	20	20	22	22	268	868	-
9	14	130	38	40	44	43	327	933	-
10	11	100	38	37	37	37	268	968	Pain for 3 months
11	17	101	40	40	42	44	256	856	Pain for 9 months; sacroiliac joint penetration
12	11	81	32	30	32	32	267	767	-
13	13	98	35	35	35	37	266	866	-
14	13	128	28	28	32	32	277	820	Pain for 3 months; prolonged wound drainage
15	13	100	35	36	36	38	301	944	Pain for 6 months; sacroiliac joint penetration
16	12	85	30	32	32	33	266	806	-
17	11	95	35	35	37	37	270	960	Pain for 6 months; sacroiliac joint penetration
18	12	90	18	20	20	22	276	860	Pain for 6 months; sacroiliac joint penetration
19	13	50	23	22	22	24	260	860	Pain for 3 months
20	13	60	20	22	22	23	255	978	Pain for 6 months; sacroiliac joint penetration
Mean	13	87	29	29	30	31	253	850	

ICBG iliac crest bone graft

Table 2 Details of the patients and operative parameters in the ALBG group

Patient number	Age (y)	Scoliotic curvature (°)					Operative time (min)	Intraoperative blood loss (ml)
		The day before surgery	Immediately after operation	Three months after surgery	Two months after surgery	Last follow-up		
1	12	60	26	26	27	28	192	580
2	14	62	23	22	22	24	205	460
3	16	62	15	15	16	16	240	800
4	19	64	27	25	25	27	280	970
5	13	66	25	27	27	27	210	450
6	12	78	20	20	20	22	295	660
7	15	85	30	30	34	34	235	1150
8	13	96	20	20	22	24	280	670
9	13	130	38	40	41	42	225	733
10	13	82	19	19	20	20	228	777
11	13	65	9	12	12	12	165	1010
12	13	101	40	40	42	44	235	656
13	20	60	15	15	19	19	215	900
14	13	82	25	25	27	27	255	850
15	12	110	38	38	40	41	230	865
16	14	120	30	30	34	34	236	875
Mean	13	83	25	25	27	28	233	775

ALBG allogeneous bone graft

patients, and cleared after 48 hours following observation without oral intake. There were no secondary operations for any reason, nor any second hospital admissions related to surgery.

At one week after surgery, all of the patients reported back pain in the region of the instrumentation surgery. At three months after surgery, 30% (6/20) reported back pain. At six months, 5% (1/20) reported back pain and at nine months 5% (1/20) reported back pain. At 12 months after surgery, none of the patients reported back pain. Therefore, no clinical complaints in the region of the instrumentation surgery were noted at one year after surgery.

Ninety percent (18/20) of the patients reported donor site pain at one week after surgery. The self-reported pain values ranged from 4 to 7 with a mean of 6. All of the patients with documented pain reported that they had problems with daily activities (difficulties in sitting in a wheelchair) due to pain. At three months after surgery, 50% (10/20) of the patients reported continued pain at the donor site and 40% (8/20) reported problems with daily activities. The self-reported pain values ranged from 1 to 7 with a mean of 5. At six months after surgery, 40% (8/20) of the patients reported continued pain at the donor site and 30% (6/20) reported problems with daily activities. The self-reported pain values ranged from 1 to 7 with a mean of 5.

At nine months after surgery, 15% (3/20) of the patients reported continued pain at the donor site and 5% (1/20) reported problems with daily activities. The self-reported pain values were from 1 to 3 with a mean of 2. At 12 months after surgery, none of the patients reported continued pain and problems with daily activities.

The mean preoperative deformity in the coronal plane was 87°. The mean postoperative deformity was 29° at three months after surgery, 30° at 24 months and 31° at the last follow-up. There was a significant difference in the preoperative and postoperative Cobb angles. We noticed less than 4° in the loss of correction at the last follow-up.

The ALBG group

There were no neurological complications or infections. There was no instrumentation failure during the follow-up period. Paralytic ileus occurred in 19% (3/16) of the patients, which was treated by observation without oral intake and cleared in 48 hours. Transient tachycardia, possibly due to the underlying cardiomyopathy, occurred in 19% (3/16) of the patients, and resolved with adequate medication. There have been no further operations for any reason, nor any second hospital admissions related to surgery.

At one week after surgery, all the patients reported back pain in the region of the surgery. At three months after

surgery, 31% (5/16) reported back pain. At six months, 13% (2/16) reported back pain, and at nine months none of the patients reported back pain. Therefore, no clinical complaints in the region of the instrumentation surgery were noted at nine months after surgery. None reported pain in the pelvis over the follow-up period. All the patients sat in their wheelchairs by the third postoperative day and returned to their preoperative level of function by the seventh postoperative day.

The mean preoperative deformity in the coronal plane was 83° . The mean postoperative deformity was 25° at three months after surgery, 27° at 24 months and 28° at the last follow-up. There was a significant difference in the preoperative and postoperative Cobb angles. No significant loss of correction was noted between postoperative time and the last follow-up.

Figure 2 shows a radiographic example in the ALBG group.

Discussion

Scoliosis is almost universal in DMD patients. Natural history studies on DMD demonstrated an almost invariable progression in the scoliosis with progression of the underlying disease [1, 4, 14, 20, 22]. Posterior spinal fusion for scoliosis in DMD has been widely accepted as the optimal procedure to prevent progression of scoliosis and maintain sitting balance and comfort [1, 4, 14, 20, 22].

The posterior iliac crest is the most common donor site for autogenous bone graft for posterior spinal fusion. However, donor site morbidity caused by bone harvest, which can interfere with daily activity of wheelchair-dependent patients, has remained a concern.

The advantages of autogenous bone graft over allograft have been well recognised. Large quantities and good quality of corticocancellous bone graft may be obtained from the iliac crest. However, harvesting ICBG involves an additional surgical procedure, blood loss, postoperative morbidity and complications. The complications of harvesting ICBG have been also well recognised [12]. The complication rate reported in the literature varies widely, ranging from 1% to 25 % for major complications and 9.4% to 39% for minor complications [2, 8, 18, 21]. Major complications included large haematoma, wound infection, reoperation, unsightly scar, severe pain interfering with daily activity, and chronic pain limiting physical function [2, 18, 25]. Minor complications included dysaesthesia, prolonged wound drainage, and superficial infection [2, 18, 25]. Robertson et al. [16] reported on donor site morbidity, significant pain, tenderness, and local sensory loss, which were worst at six months after surgery and improved by one year. Although the major complication rate in most of

Fig. 2 **a** and **b** Radiograph of a 13-year-old boy. Sitting anteroposterior preoperative radiograph demonstrates a significant thoracolumbar curve of 80° from T9 to L5. **c** and **d** At the time of surgery, banked allograft bone was used. Postoperative radiograph at 1 week after surgery is demonstrated. The postoperative deformity measures 19° . **e** and **f** Radiograph at a long-term follow-up of 3.2 years after surgery demonstrates the absence of loss of correction and instrumentation failure, which indicates the probability of the absence of pseudarthrosis

the reports is relatively small, the minor complication rate is significant.

Donor site pain after harvesting from iliac crest is common. Lehmann et al. [13] reported this complication

in 55% of the adult patients. Skaggs et al. [19] found this complication to be 24% in children. They reported pain severe enough to interfere with daily activity was noted in 15% in children at a more than four-year follow-up. In our series, at three months after surgery, 50% (10/20) of the patients reported continued pain at the donor site, and 40% (8/20) reported problems with daily activities and difficulties in sitting in a wheelchair due to the pain in the back hip area even though the pain improved gradually by one year.

Indeed, in adolescent idiopathic scoliosis surgery, a large quantity and good quality of corticocancellous bone may be obtained from the iliac crest. However, in our experience, the pelvis in this group of patients with DMD who cannot walk is often small. We felt the amount of bone obtained from the iliac crest, even if bone grafts were harvested from both iliac crests, were inadequate for long posterior spinal fusion in DMD scoliosis. Also, a high rate of intraoperative sacroiliac joint and iliac crest inner cortex penetration was observed. These complications may have led to continued postoperative donor site pain and prolonged wound drainage.

To resolve the problems, we began to use banked allograft bone for posterior spinal fusion in DMD scoliosis. We have routinely used banked allograft bone obtained from the Kitasato University Bone Bank (KUBB). Banked allograft bone has both osteoinductive and osteoconductive activities, although less active than those of autografts [10, 11, 24]. In a study of 87 consecutive patients who underwent idiopathic scoliosis surgery, Grogan et al. [9] showed the ability of allograft bone to produce reliable results compared with autograft bone. Fabry [7] concluded that there was no significant difference in the clinical and radiographic results (loss of correction, fusion rate, complication) between the two groups of scoliosis patients operated using either autograft (iliac crest) or allograft (femoral heads) and recommended the use of allograft bone to prevent problems of discomfort at the donor site scar. Dadd et al. [6] concluded that even in the presence of adequate iliac crest, the use of bank bone is superior for grafting in adolescent idiopathic scoliosis surgery. Thus, allograft bone seems to give good results [3]; however, banked allograft bone is not always available in many countries for spine surgery. Potential risks of bacterial contamination and viral transmission have also been suggested, although such a risk is very small [5, 15, 23].

In Japan, there are two kinds of bone banks—regional bone banks and institutional bone banks. A regional bone bank retrieves, processes and preserves bone and supplies bones to other institutions. Our bone bank (KUBB) is one of the regional bone banks, of which there are two such institutions in Japan. Therefore, banked allograft bone is always available for spine surgery at any time in Japan.

To the best of our knowledge, there have been no previous articles in the literature comparing autogenous ICBG and banked allograft bone in instrumented posterior spinal fusion in DMD scoliosis. This study shows a comparable overall radiological fusion rate and clinical outcome using either autogenous ICBG or banked allograft bone but with reduced morbidity, complications, operative time and blood loss in the ALBG group. Curve correction and maintenance of correction were excellent in the both groups, with minimal loss of correction. There was no pseudarthrosis, infection or instrumentation failure in either group. However, intra/postoperative morbidity or complications that could be attributed to the donor site were observed in the ICBG group. Scoliosis surgery in non-ambulatory DMD patients should be aimed at maximising function and improving QOL. However, donor site pain in the ICBG group was severe enough to interfere with daily activity and caused difficulties in sitting for nonambulatory DMD patients, although the incidence of pain decreased with time. With the results of this study, we do not recommend the use of autogenous ICBG for posterior spinal fusion in nonambulatory DMD patients.

Study limitation

There are some limitations to this study. The number of cases in both groups was relatively small. Radiological assessment of fusion was never perfect. Determination of fusion has been a difficult issue, with no methods having been shown as reliable. In this study, a definition that combined radiological minimal loss of correction and no clinical complaints was selected. However, the lack of progression of spinal deformity and the absence of instrumentation failure during a minimum two-year follow-up period indicate the probability of the absence of pseudarthrosis.

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