FREE VASCULARISED FIBULAR STRUT GRAFT FOR ANTERIOR SPINAL FUSION

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A vascularised fibular strut graft was used for anterior spinal fusion in 16 patients with spinal kyphosis. The procedure was abandoned in three because of difficulty in establishing a vascular anastomosis and in one because the grafted fibula dislodged two days after operation. One patient died after five days. Of the 11 remaining patients, there were seven males and four females. Their ages at the time of operation averaged 30.9 years (12 to 71). The number of vertebrae fused averaged 6.7 (5 to 9) and the length of fibula grafted averaged 10.9 cm (6.5 to 18).

Average follow-up was 54 months (27 to 84). Bone union occurred at both ends of the grafted fibula in all 11 patients, with an average time to union of 5.5 months (3 to 8). We did not see a fracture of the grafted fibula. Two patients had postoperative complications; the graft dislodged in one and laryngeal oedema occurred two days after operation in the other.

A vascularised fibular strut graft provides a biomechanically stable and long-standing support in spinal fusion because the weak phase of creeping substitution does not take place in the graft.

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An anterior strut graft has been widely employed in the treatment of spinal kyphosis. When a conventional rib or fibular bone graft is used for the strut, few osteocytes survive and the grafted bone is replaced by creeping substitution,¹⁻⁸ which may take up to two years. During the phase of resorption, the grafted bone is mechanically weak and there is a risk of fatigue fracture.^{3,4,9}

Bradford et al³ encountered fatigue fractures in four of 23 patients in whom they used an anterior strut graft of non-vascularised fibula for spinal kyphosis. They therefore resorted to pedicled vascularised rib grafts with intact intercostal vessels to achieve rapid bone union and prevent fatigue fracture,⁵ but the rib is curved and mechanically weak.

Grafting with vascularised bone from the ilium or fibula is useful in the treatment of complicated pseudarthrosis and osteomyelitis.¹⁰⁻¹³ A free vascularised fibular graft may be used to manage kyphosis of any length or angle throughout the spine and is stronger than a rib.^{3,5,7,8}

We have attempted to use this graft in 16 patients with spinal kyphosis to obtain an anterior spinal fusion. We were successful in achieving this in 11 who are the subject of this study.

PATIENTS AND METHODS

Eleven patients with symptoms from severe spinal kyphosis were treated by a free vascularised fibular graft (Figs 1 and 2). Full details in tabular form are available from the authors. There were seven males and four females, whose ages ranged from 12 to 71 years (average 30.9).

The sites of the fusion were cervical in two patients (C2-C7 and C3-C7), cervicothoracic in two (both C4-T2), thoracic in five (T3-T9, T3-T11, T4-T10, T4-T11 and T7-T12), and thoracolumbar in two (T9-L2 and T9-L3). The method of harvest of the vascularised fibula has been described.¹⁰⁻¹³ The peroneal vessels from the graft were anastomosed to recipient vessels using an operating microscope. In four of the 11 patients vein grafts were required because the recipient vessels were too short to anastomose with those from the donor.

The number of vertebrae fused averaged 6.7 (5 to 9), but this did not always correspond to the number of vertebrae comprising the main curve. The length of the fibula graft

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Fig. 1a

Fig. 1b

Fig. 1c

Fig. 1d

Fig. 1e

Case 1, a male aged 14 years, with atlantoaxial subluxation and cervical kyphosis due to the Larsen syndrome, with spinal cord compression. Anteroposterior (a) and lateral (b) views in neutral position show atlantoaxial subluxation and kyphotic deformity at C3/C4 and C4/C5. A tomogram shows an os odontoideum, C2/C3 body fusion, dystrophic vertebral bodies in C4/C7 and bone wedge between C7 and T1 (c). A free vascularised fibular strut graft from C3 to C7 was performed (d). Four years after operation the grafted fibula was completely incorporated with correction of kyphosis. Atlantoaxial subluxation was reduced with a solid Gallie type fusion (e).

averaged 10.9 cm (6.5 to 18). In two patients, fibulae of 17 and 18 cm in length (cases 6 and 8) were used as barrel grafts.

In the cervical and cervicothoracic regions the superior thyroid artery was used as the recipient artery with a branch of the external jugular vein as the receiving vein in two patients, the external carotid vein in one and the inferior thyroid vein in one. In the thoracic, thoracolumbar and lumbar regions, the recipient vessels were segmental (intercostal) arteries and their venae comitantes.

It was difficult to confirm the vascularity of the graft after operation because of the depth at which the fibula was

located. Bone scintigraphy was carried out 1, 2 and 4 weeks after operation to assess this (see Fig. 2).

From eight weeks after operation plain radiographs were taken every two and tomograms every four weeks to determine when bone union had occurred as determined by the continuity of bone trabeculae between both ends of the grafted fibula and the vertebral bodies.

RESULTS

The average length of follow-up was 54 months (27 to 84). The operations took between 6 and 17 hours (average

Fig. 2a

Fig. 2b

Fig. 2c

Fig. 2d

Fig. 2e

Fig. 2f

Case 10, a female aged 43 years, with thoracolumbar kyphosis due to congenital kyphoscoliosis with severe paresis of the spinal cord and cauda equina. Anteroposterior (a) and lateral (b) views show a posterior fusion with Cotrel-Dubousset instrumentation between L3 and S1. A vascularised fibular anterior strut graft was placed between T9 and L3. A scintigram taken one week after operation shows positive uptake in the vascularised grafted fibula (c). One month later posterior fusion with Cotrel-Dobousset type instrumentation was carried out between T8 to L3 (d). Anteroposterior (e) and lateral (f) views show that the grafted fibula has fused solidly to the bodies and that the kyphosis is slightly improved four years after operation.

10.4). Four of five patients in whom the operating time was more than 12 hours had segmental vessels selected as the recipient vessels and these are difficult to anastomose in the deep space. The total blood loss averaged 2171 ml (509 to 3820).

Following operation, there was marked radioisotope uptake on bone scintigraphy in nine and moderate uptake in two patients. The vascularity of all the grafted fibulae was

successfully maintained.

Bone union. Union of the grafted fibula was obtained in all patients in between 3 to 8 months (average 5.5).

Correction of kyphosis and scoliosis. The average angle of kyphosis before operation was 72.5° (25° to 112°) which was corrected to 47.6° (3° to 83°) immediately after the operation, and maintained at 51.5° (0° to 93°) at the final review. The average correction attained was 24.9° , and the

loss at final review averaged 3.9°. We also measured the angle of scoliosis in six patients; before operation it averaged 42.0° (15° to 73°), improved to 27.3° (12° to 40°) after operation, and was 30.7° (12° to 44°) at the final review. The correction achieved averaged 14.7°, and the loss after operation averaged 3.4°.

Operative and postoperative complications. No complications were encountered at the donor site. The procedure was attempted in sixteen patients. Inability to obtain a vascular anastomosis resulted in abandoning the operation in three. Dislodgement of the graft occurred two days after surgery in one patient and an attempted replacement failed. Another patient with ossification of the posterior longitudinal ligament in the cervical spine developed retrolaryngeal leakage of cerebrospinal fluid after seven days, and death resulted from suffocation caused by the iatrogenic meningocele.

Dislodgement of the graft immediately after operation was revised successfully in one patient. Laryngeal oedema occurred in another, but both these patients went on to a successful outcome. There were no fractures of the graft.

DISCUSSION

The use of a fibula or rib for anterior support in the management of kyphosis is well documented. Streitz et al⁴ reported that osteocytes died immediately when non-vascularised bone graft was used, and that remodelling took place only after the stage of creeping substitution during healing. Resorption of the graft during this process leaves the bone so weak that the graft may fracture. Goldberg et al⁹ studied the characteristics of vascularised and non-vascularised grafts. Superior mechanical properties were present in the vascularised fibular model three months after operation, suggesting that preservation of viable osteocytes in the vascularised graft provided biological acceleration of biomechanical strength and stiffness because the stage of creeping substitution was avoided. The vascularised grafts showed earlier bone union and incorporation with greater strength and stiffness compared to non-vascularised grafts.

An anterior strut graft of non-vascularised bone is mechanically weak and has a risk of fatigue fracture. In an attempt to resolve this Bradford et al³ and Bradford⁵ recommended the use of a pedicle rib graft, but Hubbard et al⁷ and Kaneda et al⁸ suggested that a rib was too weak; it is oval in cross-section, curved and has a thin cortex. The fibula is more suitable for a long graft because it is straight and strong.

A free vascularised fibular graft is particularly suitable for patients whose kyphotic deformities are long and rigid, with severe dystrophic changes such as in von Recklinghausen's disease. It is indicated when vertebrectomies are needed to decompress the spinal cord, and where there is difficulty in obtaining contact between the graft and the vertebrae at the apex of the kyphosis. A vascular pedicled

rib is unsuitable in these circumstances because of the location of the kyphosis and the length and structural strength of the strut graft required.

Our results in 11 of our patients with free vascularised fibular strut grafts were satisfactory because early solid bony incorporation occurred, and the risk of fractures and other complications were reduced. However, various problems were encountered in the whole series. It is difficult to determine the viability of the graft because it is deeply situated, precluding a monitoring flap positioned on the skin. We used ^{99m}Tc methylene diphosphonate bone scans to assess viability of the grafted bone.¹⁴ Serial scans at one, two and four weeks after operation all showed positive uptake in the graft, which confirmed its vascularity. However, it is difficult to assess blood flow continuously by this method; this prevents an emergency rescue operation if there is occlusion of the vessels. An operative modification allowing continuous monitoring should be devised in the future.

Vascularisation of the graft also presents technical difficulties which may lead to complications. Three operations were abandoned. Two of the three cases were in the lumbar spine where the operative field was too deep to perform the anastomosis. The other was in a tuberculous spine in which the recipient vein was too fragile. We now routinely use a vein graft to elongate the vascular pedicle after harvesting the fibula.

Careful haemostasis of the muscle sleeve of the grafted fibula is important since haematoma formation may induce infection or pressure on the surrounding organs. This is particularly important in the cervical spine because of the proximity of the trachea to the grafted bone. Lateral radiographs must be taken routinely after operation to evaluate tracheal displacement.

A rib pedicle graft is less invasive and does not necessitate vascular anastomosis^{2,5} but the area suitable for this method is restricted to the thoracic and thoracolumbar regions, because of the limited arc of motion allowed by the intact intercostal vessels. The free vascularised fibula can be used in any part of the spinal column and its use should be determined by the location, size and grade of kyphosis. If a kyphotic curve is flexible, an inlay graft of a non-vascularised fibula may be accepted in a gutter made in the vertebral bodies.

A free vascularised fibular strut graft is most valuable in patients with high-grade kyphosis in which the strut graft has to be placed far anterior to the apex of kyphosis.

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