RECONSTRUCTION OF PROXIMAL FEMORAL DEFECTS WITH A VASCULAR-PEDICLED GRAFT

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A new method of treating large bony defects of the proximal femur is described. The defect is filled with a large vascular-pediced bone graft from the iliac crest. The graft, being nourished by the deep circumflex iliac vessels, remains viable and therefore induces rapid healing of the bone. This method of bony replacement encourages adequate excision of potentially malignant bone lesions and provides sufficient mechanical support to allow early walking. Six clinical cases are presented to illustrate its application.

Conventional methods of free bone grafting to bridge a large defect in a long bone have generally met with poor results, especially where the gap exceeds 5 to 6 cm. The lengthy process of regaining viability in large grafts often entails unacceptably prolonged periods of immobilisation. This significantly affects the function of the joints involved. Moreover, the grafts often fail to survive.

Östrup and Fredrickson (1975), working with dogs, used direct transfer of grafts of living rib bone to the mandible by microvascular anastomoses. Taylor, Miller and Ham, and later O’Brien successfully used the fibula, ribs and iliac crest as free vascularised bone grafts (Taylor, Miller and Ham 1975; Buncke et al. 1977; Taylor and Watson 1978; O’Brien and Hayhurst 1980). These vascularised grafts filled large bone defects, facilitated rapid bone healing and supplied the mechanical support required, achievements which depended on the viability of the transplanted bone.

The successful use of free vascularised bone grafts requires a meticulous process of isolating the grafts with their feeding arteries and draining veins, transferring them to the recipient sites and there anastomosing the arteries and veins to their counterparts. The microsurgical procedures required demand special training, equipment and expertise.

The bone graft described in this presentation is a pedicled one from the ilium. It does not require special equipment or technique, but it still has the advantages of the vascularised bone graft.

THE VASCULAR-PEDICLED BONE GRAFT FROM THE ILIUM

The iliac crest obtains its main blood supply from small feeding arteries arising from a number of nearby vessels including the ascending branch of the medial circumflex femoral artery, the deep circumflex iliac artery and the gluteal arteries. As the deep circumflex iliac artery leaves the external iliac artery, it approaches the anterior superior iliac spine under the conjoined tendon of the internal oblique and transversus abdominis muscles. Near the anterior superior iliac spine, it gives off branches to anastomose with branches from the ascending branch of the medial circumflex femoral artery. From this point onwards, the deep circumflex iliac artery with its accompanying vein runs very close to the inner edge of the iliac crest in the same plane, while giving branches which run between the internal oblique and transversus abdominis muscles. The main trunks continue along the inner edge of the iliac crest, giving perforating branches to the bone until the highest point of the crest is passed, when they start to leave the inner edge, running directly posteriorly to anastomose with branches from the gluteal vessels, and sending branches into the various muscle planes.

The bone graft to be used includes that portion of the iliac crest reaching from the anterior superior iliac spine to beyond the upper prominence of the iliac crest. The length of this graft varies from 5 to 13 cm; its vertical height varies, but 5 to 6 cm may safely be taken. The vascular pedicle reaches from the external iliac vessels to this region to the anterior superior iliac spine, beyond which a strip of external oblique, internal oblique and transversus muscles is taken with the bone so as to ensure that the perforating branches from the vessels into the bone are preserved (Figs 1 to 5). The vascular pedicle measures 7 to 10 cm and forms the radius on which the bone graft can be rotated down to fill bone defects around the ipsilateral hip.
OPERATIVE TECHNIQUE

The incision extends along the inguinal ligament, from the femoral artery to the anterior superior iliac spine, and thence along the iliac crest to 5 cm beyond its upper convexity. The external iliac vessels are exposed by splitting the inguinal ligament transversely near its inferior border. About 1 cm above the inguinal ligament, vessels and their branches are ligated.

The outer surface of the iliac crest is stripped of periosteum and the required block of bone is outlined on this surface with ink. Along this line the bone is osteotomised by manual cuts from the outer cortex. The periosteum on the inner cortex is left intact and a thin layer of iliacus muscle is allowed to remain on the inner side. Further trimming of the pedicle graft is achieved after swinging the bone graft down on its pedicle, using small bone-cutters. Active bleeding from the cancellous surface is profuse at first but soon diminishes (Fig. 6).

Once these vessels have been identified, they are separated from their adjoining adventitious tissues and traced laterally towards the anterior superior iliac spine. Inferior branches given off from these vessels near the spine are ligated. The vessels described lie in the plane between the extraperitoneal fat and the conjoined tendon of the internal oblique and transversus abdominis muscles. Near the anterior superior iliac spine, branches pierce the fascia, emerging into the plane between the internal oblique and transversus abdominis muscles, while the main trunks remain below the transversus muscle. Half a centimetre of muscle attachment is left intact with the iliac crest to avoid damage to the branches of the deep circumflex iliac vessels. Between the anterior superior iliac spine and the upper prominence of the iliac crest, the vessels are not visualised. Instead, they are allowed to remain buried beneath the muscular insertions of the external and internal oblique and the transversus abdominis. Beyond the upper convexity of the iliac crest the vessels become visible once more as they leave the iliac crest to travel posteriorly in the different muscle planes to join the gluteal vessels. At this point the main vessels are ligated. A second incision is made at the junction of the external and internal oblique muscles and the external oblique muscle is transected. The external oblique muscle and a part of the internal oblique are then separated from the posterior part of its origin, and retracted posteriorly to expose the iliacus muscle and the iliobibial sheet. The iliobibial sheet and a small strip of iliacus muscle are then ligated and excised (Fig. 4—Amount excised to leave 0.1 to 1 cm of free margin). The deep circumflex iliac vessels lie between the iliobibial sheet and the iliacus muscle. They lie lateral to the external iliac artery, which is immediately lateral to the iliobibial sheet (Fig. 5—Bone defect filled with pedicled bone graft to provide rapid osteosynthesis and mechanical support).

The vascular-pedicled iliac-crest graft and its use. Figure 1—Iliac crest supplied by deep circumflex iliac artery (DCI) arising from external iliac artery (El). Figure 2—Bone graft with its vascular pedicle. Figure 3—Benign tumour of proximal femur. Figure 4—Amount excised to leave 0.1 to 1 cm of free margin. Figure 5—Bone defect filled with pedicled bone graft to provide rapid osteosynthesis and mechanical support.

CLINICAL APPLICATION

In the past, benign or locally recurrent lesions occurring in the femoral neck or subtrochanteric region have been removed (by curettage or resection) and the resulting bone defect filled with autogenous cancellous bone (Parrish 1966). Lesions treated in this way include simple
bone cysts, aneurysmal bone cysts, fibrous dysplasia, giant-cell tumours and enchondromata. The results were good when the lesions were small. However, when they were large and occupied more than half the circumference of the bone, problems arose. Since the area involved was weight-bearing, extensive removal of bone resulted in marked weakening. Fracture was likely to follow and a prolonged period of non-weight-bearing was therefore mandatory.

Local recurrence of malignant or potentially malignant tumours is not uncommon in this region because the surgeon, aware of the danger of postoperative fracture, tends to be too conservative when removing the tumour. And when dealing with large benign lesions he may feel that it is safer not to operate at all because the risk of removing a benign lesion might be too great. He is therefore in a dilemma; should he perform a radical excision and risk a fracture or should he be more conservative and risk recurrence. The problem can be solved by filling the defect with a bone graft, providing the graft unites soundly and quickly with the surrounding bone.

The vascular-pedicled graft from the iliac crest satisfies these criteria. We have used it to reconstruct the proximal femur in six patients after extensive resection of tumours arising from the femoral and subtrochanteric regions. Clinical details are summarised in Table I and illustrated in Figures 7 to 11. Figure 7 is a giant-cell tumour, although unusual in not reaching the end of the bone; the diagnosis was however confirmed histologically. All six lesions occupied extensive areas in the proximal femur and in two cases there were soft-tissue extensions which had extensively eroded the bony cortices.

The hips were operated upon through a modified Smith-Petersen approach. The skin incision extended

**Table I. Six cases of proximal femoral defect replaced with vascular-pedicled graft from the iliac crest**

<table>
<thead>
<tr>
<th>Case</th>
<th>Sex</th>
<th>Age (years)</th>
<th>Pathology</th>
<th>Extent of bone tumour</th>
<th>Size of pedicled bone graft (cm)</th>
<th>Length of vascular pedicle (cm)</th>
<th>Method of graft fixation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>20</td>
<td>Giant-cell tumour</td>
<td></td>
<td>8 × 2</td>
<td>8</td>
<td>One wire loop</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>45</td>
<td>Enchondroma</td>
<td></td>
<td>8 × 2.5</td>
<td>10</td>
<td>One wire loop</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>23</td>
<td>Fibrous dysplasia</td>
<td></td>
<td>6 × 2</td>
<td>8.5</td>
<td>No need</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>22</td>
<td>Enchondroma</td>
<td></td>
<td>7 × 2</td>
<td>8</td>
<td>2 Kirschner wires</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>49</td>
<td>Aneurysmal bone cyst (giant-cell tumour)</td>
<td></td>
<td>12 × 2.5</td>
<td>10</td>
<td>External fixator to immobilise hip</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>14</td>
<td>Large bone cyst plus fracture</td>
<td></td>
<td>11 × 2</td>
<td>7.5</td>
<td>3 Kirschner wires</td>
</tr>
</tbody>
</table>
from the iliac crest down the inguinal line to a point just medial to the femoral artery, then curved downwards and laterally towards the anterior border of the tensor fascia lata 5 cm below the greater trochanter. The laterally based skin flap was reflected downwards and the subsequent dissection followed the Smith-Petersen approach.

The benign lesions were curetted out and the cavities were burred. The tumours were excised with a 0.5 to 1 cm margin of healthy bone and the resulting bone cavities were burred with power instruments. Measurements of the bone defects gave the sizes of bone grafts required. These were obtained from the iliac crest and pedicled on the deep circumflex iliac vessels as described. A large tunnel was prepared between the rectus femoris and the capsule of the hip joint. Through this tunnel the graft and its vascular pedicle were passed to the recipient site. The graft was made longer than the defect so that it could be wedged in to fit tightly; more secure fixation was maintained with Kirschner wires or wire loops. Great care was taken to ensure that there was no tension in the vascular pedicle with the hip in the neutral position so that later, when the hip was slightly flexed and medially rotated, the pedicle was still relaxed. The remaining bone defects were filled with cancellous chip grafts. Two suction drains were inserted before closure, a necessary precaution because blood oozing from the bone surfaces was profuse.

After operation the hip was kept 30 degrees flexed and in 15 degrees of medial rotation so as to avoid tension on the vascular pedicle of the graft. Seven to 10 days after operation the patients were allowed to move freely in bed. At three to four weeks they were using wheelchairs and at 7 to 10 weeks they were allowed to walk with the aid of crutches, but still avoiding weight-bearing.

**VIABILITY OF THE GRAFT**

A vascularised bone graft should remain viable and should unite more rapidly to the surrounding bone than a free graft (O'Brien 1977; Pho 1981). In order to investigate the viability of the grafts, angiography and technetium scanning were carried out at six to eight weeks after operation. Angiograms were not done earlier because the contrast medium might have endangered the recently established microcirculation (Mehl et al. 1964; Weiland et al. 1979). Scanning for bone activity also was delayed for six to eight weeks because earlier scans would be considerably influenced by the high vascularity of the operation site (Kim, Thrall and Keyes 1979).

In all except one case, the deep circumflex iliac artery was visible on the angiogram, indicating that the vessel was patent (Figs 12 to 13). Scans showed a high uptake in the grafted area in all six cases and the increased density bone a shape resembling that of the graft itself (Lau and Leung 1982). The arteriogram alone or the scan alone might not have been sufficient evidence of viability, but both together seemed conclusive.

Plain radiographs of all six cases demonstrated early union at 6 to 10 weeks after operation.

**RESULTS**

The follow-up of the six cases ranged from 6 to 38 months, with an average of 25 months. The results are summarised in Table II.
There were no postoperative complications. Wound healing was not a problem and the curved incision gave good scars. Hip movement was allowed early in Cases 1 and 2, where wire loops were used to fix the pedicled graft, and in Case 3, where fixation had not been necessary. When Kirschner-wire fixation was used (Cases 4 and 6), the wires were removed at 10 weeks, after which more active hip movements were possible. An external fixator was used in Case 5 because the graft extended 1 to 4, but delayed until 15 weeks in Case 5 and 18 weeks in Case 6 because in these two bone resection had been so extensive.

The hip movements of Cases 1 to 5 were examined 9 to 18 months after operation. Case 1 had 20 degrees loss of flexion, Cases 2, 3 and 4 had normal movements and Case 5, where an external fixator was used, had 20 degrees loss of abduction and 30 degrees loss of flexion.

At three-and-a-half to five months after operation,

Table II. Results of angiograms, technetium scanning and rehabilitation of the six patients

<table>
<thead>
<tr>
<th>Case</th>
<th>Timing of angiogram (weeks after operation)</th>
<th>Deep circumflex iliac artery</th>
<th>Timing of scanning (weeks after operation)</th>
<th>Technetium uptake</th>
<th>Early radiological signs of bone union (weeks)</th>
<th>Partial weight-bearing (weeks)</th>
<th>Full weight-bearing (weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>Patent</td>
<td>7</td>
<td>Much increased, graft-shaped</td>
<td>10</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>Patent</td>
<td>8</td>
<td>Much increased, graft-shaped</td>
<td>8</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>6.5</td>
<td>Patent</td>
<td>7.5</td>
<td>Much increased, graft-shaped</td>
<td>6</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>Not seen*</td>
<td>8</td>
<td>Much increased, graft-shaped</td>
<td>9</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>Patent</td>
<td>7</td>
<td>Much increased, graft-shaped</td>
<td>12</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
<td>Patent</td>
<td>8</td>
<td>Much increased, graft-shaped</td>
<td>7</td>
<td>8</td>
<td>15</td>
</tr>
</tbody>
</table>

* Not seen because of vascular spasm during angiography

well into the femoral head; it was removed after 12 weeks to allow hip exercises.

Once the angiogram showed a patent vascular pedicle the patient started walking, but was only allowed to take partial weight-bearing on the grafted leg. Full weight-bearing was started after 10 to 14 weeks in Cases

all six patients resumed their previous jobs; none suffered from any limitation of physical activities. Figures 14 and 15 show rapid bone healing four months after operation.

Plain radiography of all cases at 6 to 18 months after operation showed no local recurrence and sound bony union at the resection sites (Figs 16 and 17). In spite of
the close proximity of the resection to the articulating surface in Cases 5 and 6, there was no collapse of the femoral head.

DISCUSSION
In the six cases described the vascular-pedicled graft from the iliac crest succeeded in filling large bone defects; it also ensured mechanical strength because the block of bone filled the whole of the bone defect. The graft was viable from the first day of insertion and this helped achieve early bone union. As soon as angiography and scanning indicated viability (at six to eight weeks) it was felt that walking with crutches and taking partial weight could safely be started. When the defect was exceptionally large, or extended to the femoral head, weight-bearing was delayed for a further four to eight weeks. Nevertheless, the rehabilitation process was much quicker than if chip grafts had been used to fill the defects.

In spite of the sophisticated nature of the operation, no special microvascular technique was required; the vascular pedicle was simply swung down from the external iliac vessels. The rapid blood flow and the pressure in the external iliac artery help to preserve vascular patency.

The advantages of this bone graft are multiple; its potential as a source of healthy vascular bone in the region of the hip could perhaps be further explored and developed.

We are grateful to our colleagues who have given us support in this work. We are indebted to Dr Roy Lau of Queen Elizabeth Hospital, Hong Kong, who has given us tremendous support and encouragement by offering his radiological expertise. Mrs A Kwong, as usual, deserves our special appreciation for her clerical assistance.

REFERENCES