Extra-articular subtalar arthrodesis
A LONG-TERM FOLLOW-UP IN PATIENTS WITH CEREBRAL PALSY

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Of 23 children (35 feet) with cerebral palsy who had undergone a Grice extra-articular subtalar arthrodesis for a valgus hindfoot between 1976 and 1981, we reviewed 17 (26 feet), at a mean of 20 years (17 years 3 months to 22 years 4 months) after operation. Seven were quadriplegic, eight spastic diplegic, and two hemiplegic. They were all able to walk at the time of operation.

Thirteen patients (20 feet) were pleased with the Grice procedure, 13 had no pain and 15 (23 feet) were still able to walk. The clinical results were satisfactory for most feet. Radiography showed that the results had been maintained over time but 14 feet developed a mean ankle valgus of 11˚ (6 to 18) with a compensatory hindfoot varus in 12 feet. No deformity of the talus or arthritis of adjacent joints was noted.

The Grice procedure gives good long-term results in children with cerebral palsy.

Equinovalgus is the most common deformity of the foot seen in children with cerebral palsy (CP). This is the result of muscle imbalance which displaces the hindfoot into valgus. Spasticity and tightness of the calf and peroneal muscles are the main causes.1,2 A tight triceps surae causes a bowstring effect across the ankle and subtalar joints.3-6 Bracing is usually insufficient to stop the progression of the deformity during active growth. Surgery should be performed before fixed contractures and structural bone changes occur. It is difficult to operate on a child’s foot without affecting growth. In 1952, Grice7 described a subtalar extra-articular arthrodesis for stabilising the hindfoot without interfering with the subsequent growth of the foot. This stabilisation of the subtalar joint can restore stability of the stance phase during gait.8 The method was recommended as a definitive procedure in young children, rather than deferring surgery until the child was old enough to have a triple arthrodesis.9-14 Initially, the indication for the Grice procedure was a paralytic valgus deformity caused by poliomyelitis.7,13,15-24 The first reports were favourable,7,10 and during the following years, Grice and others expanded the indications to include the valgus foot in spina bifida, paralytic calcaneovalgus, congenital vertical talus, talocalcaneal coalition, valgus deformity associated with cerebral palsy, overcorrected congenital equinovarus, myelodysplasia and even idiopathic planovalgus.1,11-13,16,19,23

Many large studies have reported the results of treatment of patients with a valgus hindfoot secondary to poliomyelitis and other causes with a short follow-up (less than five years),7,10,14,20,23,24 a medium follow-up (between five and ten years)13,16,23-27 and with a long-term follow-up (more than ten years).18,21 Most studies in children with cerebral palsy have a short,1,28-33 or medium-term follow-up.2,5,9,34-36 There are few reports of the long-term results or of patients who had reached skeletal maturity at the time of follow-up and these are small series. Scott, Janes and Stevens37 reviewed ten skeletally mature feet and Ross and Lyne38 17 feet in patients in whom the mean follow-up was 11 years and six months. Taussig and Pilliard39 reviewed 18 patients older than 13 years but only five had a mean follow-up of more than ten years.

Our study concerns children with cerebral palsy reviewed with a minimum follow-up of 17 years. We wished to evaluate the long-term results and consequences of subtalar arthrodesis on the surrounding joints.

Patients and Methods
Between 1976 and 1981, 23 children with cerebral palsy underwent an extra-articular subtalar arthrodesis for severe valgus hindfoot. From this group, 17 (26 feet) were reviewed retrospectively. There were eight girls and nine boys, seven of whom were spastic quadriplegics (11 feet), eight spastic diplegics (13 feet)
and two hemiplegics (two feet). All the patients had a valgus hindfoot deformity secondary to spasticity which was correctable passively. Two had cavus feet instead of flat feet. All the children were able to walk at the time of operation.

The mean age at the time of surgery was five years and five months (3 years 10 months to 8 years 7 months). Four children (five feet) had had a previous operation; the procedure of Scholder, Scholder-Durnur and Saudan in one, bilateral ‘Cavalier’ procedures in one, and the ‘Cavalier’ procedures combined with lengthening of tendo Achillis in two. The mean follow-up was 20 years, 3 months (17 years 3 months to 22 years 4 months).

Pre-operative radiological review. All the weight-bearing radiographs were evaluated by the same author (SB). The lateral talocalcaneal angle (TCA) and the talar declination angle (TDA) were measured on the standing lateral radiographs. The TCA was used because of its reliability in assessing subtalar valgus or varus. The normal range for the TCA in children is between 25˚ and 55˚ and for the TDA between 15˚ and 55˚. The mean pre-operative TCA was 54˚ (42 to 75) and the mean pre-operative TDA 46˚ (24 to 64).

The Kite anteroposterior angle (KA) was measured on the anteroposterior view of the standing hindfoot. Normal KA values have not been clearly defined in the literature and differ considerably among authors ranging from 15˚ to 55˚ depending on age. The mean pre-operative KA was 31˚ (16 to 48).

Pre-operative ankle valgus was assessed indirectly from the standing lateral view of the foot by using the technique described by Malhotra, Puri and Owen and previously used by Scott et al. The method consists of evaluating the relationship between distal tibial and fibular growth plates. There is a correlation between the extent of shortening of the fibula and the severity of wedging of the distal tibial epiphysis leading to ankle valgus. Since pre-operative weight-bearing anteroposterior films of the ankle were available for a few children, we were able to correlate the extent of the fibular shortening with the exact ankle valgus (Fig. 1). Using this method, 14 feet were in grade 0, 11 in grade I, and one in grade II. No foot was in grade III.

Operative technique. For all the patients, the operative technique was a modification of the original Grice technique as described by Chigot and Sananes in 1965. The incision was the same but the graft was a full segment of the fibula instead of a double layer of corticocancellous tibial graft. In 20 feet, the graft was taken from the distal fibula and in six, from the mid-third of the fibula, respecting the periosteum in each case. In ten feet the graft was stabilised with a Kirschner wire for six weeks. Additional surgery performed at the time of subtalar arthrodesis included lengthening of tendo Achillis in 12 patients (17 ankles) who had equinovalgus feet (conventional Z incision in two feet and conventional Z incision associated with the procedure of Scholder et al. in 15), release of the talonavicular capsule in two patients (3 feet) and one Steindler Procedure in one of the two cavus feet.

The patients were immobilised in a non-weight-bearing long-leg cast for four to eight weeks followed by a short-leg cast with weight-bearing for two to eight weeks.

Post-operative radiological review. The same angles were measured on the post-operative radiographs. We also determined the position of the graft relative to the weight-bearing axis of the foot. If the proximal end of the graft was angled anterior to the weight-bearing axis it was termed anterior placement and if the proximal end lay posterior to the axis, perpendicular to the subtalar movement as recommended by Grice, it was termed posterior. Alignment of the graft was termed neutral if it was perpendicular to the floor.

Clinical and radiological review at the final follow-up. Clinical follow-up included assessment of walking, the type of
EXTRA-ARTICULAR SUBTALAR ARTHRODESIS

Table I. Details of the radiological findings (mean, range) in degrees

<table>
<thead>
<tr>
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<th>TCA</th>
<th>TDA</th>
<th>KA</th>
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<tbody>
<tr>
<td>Pre-operative</td>
<td>54 (42 to 74)</td>
<td>46 (24 to 64)</td>
<td>31 (16 to 48)</td>
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<tr>
<td>Immediate post-operative</td>
<td>40 (22 to 60)</td>
<td>28 (15 to 40)</td>
<td>17 (0 to 28)</td>
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<tr>
<td>Final follow-up</td>
<td>39 (26 to 56)</td>
<td>22 (12 to 34)</td>
<td>14 (0 to 32)</td>
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Results

Immediate post-operative results

Clinical findings. One superficial skin necrosis under a cast was the only immediate complication. The records of all patients were reviewed to record the clinical outcome. Cosmetic appearance and walking were markedly improved.

Radiological findings. The radiological results are summarised in Table I. The mean improvement was 14˚ (4 to 36). Two of the 26 feet had a TCA more than 55˚ and one less than 25˚. Thus, two feet were under-corrected and one over-corrected. All the feet had a normal TDA. The mean improvement in the KA was 13˚ (-6 to 28). Five of the 26 feet had a KA less than 15˚ and thus were over-corrected. No foot was under-corrected.

Six feet had neutral alignment of the graft, ten had anterior and ten posterior alignment.

Long-term results at a mean follow-up of 20 years, 3 months

Clinical findings. In the overall series, 13 of the 17 patients (20 feet) were pleased with the Grice procedure. Four patients (six feet) expressed no opinion.

Fifteen patients (23 feet) were still walking, of whom nine required no help. Of those unable to walk, one patient was still able to stand. Two patients required orthopaedic shoes. Thirteen patients had no foot pain. The four who had pain were pleased with their feet because the pain was not severe or disabling. Of the eight patients who had undergone a unilateral Grice procedure, the opposite foot served as a control. There was no difference in shoe size. Nineteen feet had a normal footprint, type-I flat foot or first-degree cavus. Six had a type-II flat foot and one third-degree cavus. Eighteen feet had a normal hindfoot position during the stance phase. Three had hindfoot varus deviation between 5˚ and 10˚ and five had varus hindfoot below 10˚. No recurrence of the deformity was observed.

None of the patients had callosities on the sole. Three patients (six feet) had hallux valgus (Fig. 2), none had claw toes.

Radiological findings. All the feet had normal TCA and two feet had TDA below 15˚; 12 of 26 feet had KA below 15˚ (Table I).

On the weight-bearing anteroposterior views of the ankle, 14 feet had a mean ankle valgus of 11˚ (6 to 18). Of

Fig. 2a

Fig. 2b

Photographs (a and b) showing a good clinical result except that hallux valgus had developed on one side (b). The patient is still able to walk with crutches but needs a wheelchair outdoors.
these, 12 had ‘compensatory-heel’ varus but in one foot, the heel varus was greater than the ankle valgus (Fig. 3), in this foot, therefore the hindfoot was clinically in a varus position. Only two feet had a clinically obvious valgus hindfoot.

Seven grafts had resorbed. Eleven feet had an extra-articular subtalar union and three feet complete fusion of the talocalcaneal joint (Fig. 4). Incorporation of the graft was not influenced by its position (Table II). Of the 26 Grice procedures, 19 showed complete fibular regeneration, and

| Table II. Influence of the position of the graft on its incorporation (feet) |
|-----------------------------|-------------|-------------|
|                             | Anterior    | Neutral     | Posterior   |
| Extra-articular subtalar fusion | 5           | 4           | 2           |
| Complete union of the talocalcaneal joint | 0           | 1           | 2           |
| Uncertain fusion            | 2           | 0           | 3           |
| Graft resorption            | 3           | 2           | 2           |
| Total                       | 10          | 7           | 9           |

Figure 3a – Photograph of the feet of a patient who had had a bilateral Grice procedure 22 years previously, the right hindfoot is normal. The left hindfoot varus is less than 10°. The patient is asymptomatic. Figure 3b – Radiograph of the right foot of the same patient. There is ankle valgus of 12° with a compensatory hindfoot varus. The foot is clinically normal.

Radiograph showing complete fusion of the talocalcaneal joint 19 years after a Grice procedure.
six had a fibular bony scar at the donor site. Only one fibular pseudarthrosis with a distal tibiofibular synostosis was observed (Fig. 5).

None of the patients showed evidence of degenerative changes such as narrowing of the joint space or formation of a spur in the tibiotalar or midtarsal joints. Also, no ball-and-socket ankle was observed.

Discussion

When evaluated on the basis of function, subjective impression and cosmetic appearance the findings of the 26 feet of our series are good 20 years after operation. However, walking ability must be excluded from functional assessment because it tends to worsen over time in cerebral palsy.47 In their long-term review, Ross and Lyne38 noticed, as we did, that most of their patients had no significant symptoms and, consequently, the clinical examination gave a satisfactory outcome.

On the basis of radiography, the mean results have been maintained over time for the TCA, TDA and KA even if some of the feet had an abnormal TDA or KA at the longest follow-up.

In many previous studies, one of the reasons for unsatisfactory results has been resorption of the graft. In children with cerebral palsy resorption of the graft, independent of its source, has been noted to occur in between 6% and 33% of patients undergoing the Grice procedure.3,10,27,31,37,38 Some authors, however, have not reported resorption.4,12 We found obvious fibular resorption of the graft in seven feet, which did not, however, affect the clinical outcome. Contrary to Scott et al,37 in our series incorporation of the graft did not necessarily lead to recurrence of the deformity because there was sufficient fibrosis to maintain the alignment of the subtalar joint.3,35,37,38,49 This could be the explanation for the absence of recurrence of the deformity in the seven cases of resorption of the fibular graft in our series.

Ankle valgus is another cause of clinical failure.5,13,17,18,27,28,37,38,48,49 Late ankle valgus has been observed in between 23%38 and 50%37 of patients but some authors have not recorded this complication.4,12 Underdevelopment of the fibula is often observed in paralysed limbs leading to ankle valgus.50 In most cases, ankle valgus is present before stabilisation but tends to deteriorate after the arthrodesis.13,17,37,38,49,50 Unrecognised ankle valgus can cause over-correction of the hindfoot into varus and associated supination and adduction of the forefoot.13,37 When the ankle valgus has not been recorded before the operation, its cause is disputed. Some authors,7,10,11,27,50,51 have noted that taking the bone graft from the tibia may cause overgrowth of the tibia and valgus tilting of the tibial plafond but others have not reported this phenomenon.13,25,35,37 Paluska and Blount27 and Hsu et al32 reported the adverse valgus influence of resection of a portion of the fibula. They observed valgus of the ankle after harvesting of a fibular graft especially from the lower third of the fibula when it failed to regenerate fully resulting in pseudarthrosis. Wiltse31 found that in most cases of non-union of the fibula in a child, a valgus deformity developed. By contrast, other authors have not noted ankle valgus or pseudarthrosis of the fibula after harvesting a fibular graft.5,9,12,35,53,54 Wiltse51 and De Leon-Falewski17 reported that osteotomy only at the distal end of the fibula or taking the graft from the fibula could stimulate its growth and prevent ankle valgus. In contrast to Scott et al,37 we did not find any correlation between the degree of pre-operative fibular shortening and late ankle valgus, but their series included patients with many different diagnoses.

No author has mentioned the development of ‘compensatory’ varus in the subtalar joint with ankle valgus at the same time leading to an acceptable position of the hindfoot. Obliquity of the ankle mortise in radiographs is not necessarily associated with a functional valgus or varus deformity of the heel.27

We cannot clearly explain the late valgus hindfoot with the compensatory varus hindfoot. In 1972 Hsu et al52 reported that pseudarthrosis occurred in 71% of patients after harvesting a fibular graft from the lower third but, in 1986, noted none after harvesting the fibular graft from the middle third. Fibular pseudarthrosis could be the explanation of the late ankle valgus because nonunion of the fibula causes elevation of the lateral malleolus.27,51,52 In our series, fibular pseudarthrosis cannot be accepted as an explanation for late ankle valgus because we noticed only one case of fibular pseudarthrosis and 13 examples of ankle valgus. In the child’s ankle, there is such a very delicate balance that any disturbance of growth may affect the normal horizontal status of the joint.51 Great care must be taken in harvesting a fibular graft in children with cerebral palsy.

Nevertheless, hindfoot varus has been noted to occur as a consequence of an over-correction of the deformity.4,7,10,11,25,31,37,38,48 In our series, only one foot was over-corrected (TCA < 25°) and the ankle valgus at the final follow-up was not significant (4°).

For Grice,7 the main interest in his procedure was the preservation of growth of the foot. Bratberg and Scheer25 found retardation of growth in some cases as a result of the Grice procedure. In our series, of the eight patients who had a unilateral procedure, none had a difference in shoe size.

Grice and many other authors2,4,5,9,11,16,30,33,43,44,48 pointed out that muscle balance should be restored before or at the time of operation. In cerebral palsy, this is especially true for the correction of equinus. In the major reviews, lengthening of tendo Achillis or the aponeurosis of the gastrocnemius was performed in between 30% and 100%1,3,4,9,30,31,33,39,41 of the feet. In our series, lengthening of tendo Achillis was performed in the 17 equinus feet.

Degenerative changes in adjacent joints have been noted to occur in between 6% and 84% of cases.13,18,21,38 Saper et al21 noticed in their review of 19 feet with a mean follow-up of 12.1 years, that there was only one ball-and-
socket ankle. We did not observe any in our series with a mean follow-up of 20 years.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References
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