Use of a circular external skeletal fixator for stabilization of a comminuted diaphyseal metatarsal fracture in an alpaca

Luis M. Rubio-Martínez, DVM, PhD; Judith B. Koenig, Dr vet med, DVSc, DACVS; Krista B. Halling, DVM, DACVS; Katharine Wilkins, DVM; Kara Schulz, DVM

Case Description—A 3-year-old male alpaca was evaluated because of non–weight-bearing lameness (grade 5/5) in the left hind limb.

Clinical Findings—Clinical and radiographic examination revealed a closed, comminuted, nonarticular, displaced diaphyseal fracture of the left third and fourth metatarsal bones.

Treatment and Outcome—Initial attempts at treatment via reduction of the fracture under traction and subsequent application of a cast were unsuccessful, and more stable fracture fixation was pursued. The alpaca underwent closed reduction of the fracture, which was stabilized by the application of a 3-ring circular external skeletal fixator (CESF). Improved weight bearing on the affected limb was evident soon after surgery and gradually increased; full weight bearing was evident by the seventh day after discharge from the hospital (day 20 after application of the CESF). Lameness was hardly noticeable during walking at that time. After 3 months, complete fracture healing was evident and the CESF was removed; mild outward rotation of the distal fragment and metatarsophalangeal joint was present. A Robert Jones bandage was applied to the limb, and the alpaca was kept in a stall for another 4 weeks. Eleven months after CESF application, the owners and referring veterinarian reported that the alpaca was healthy, not lame, and serving as a stallion without apparent impediment.

Clinical Relevance—Although mostly restricted to small animals, application of a CESF can be a viable alternative for management of long bone fractures in South American camelids. (*J Am Vet Med Assoc* 2007;230:1044–1048)

An 85-kg (187-lb) 3-year-old male alpaca was found lame and unable to bear weight on the left hind limb after being commingled with other male alpacas the previous day. The referring veterinarian diagnosed a left metatarsal fracture, and the alpaca was transported to the Ontario Veterinary College Veterinary Teaching Hospital for further evaluation.

On initial examination, left hind limb lameness (grade 5/5) was evident. Palpation of the metatarsal region of the left hind limb elicited signs of pain, and there was palpable crepitus indicative of an unstable fracture. No external wound was present. With the exception of high respiratory and heart rates, other clinical variables including attitude, rectal temperature, and hydration status were within reference limits. Radiography of the affected area revealed a closed, comminuted, nonarticular, displaced diaphyseal fracture of the left third and fourth metatarsal bones (**Figure 1**). A large butterfly-shaped fragment was evident on the lateral aspect.

A decision was made to anesthetize the alpaca and reduce the fracture under traction with subsequent application of a cast. An IV catheter was placed into the right jugular vein. Atropine[a] (0.02 mg/kg [0.01 mg/lb], IV) and xylazine[b] (0.1 mg/kg [0.05 mg/lb], IV) were administered as premedication. Anesthesia was induced with ketamine[c] (3 mg/kg [1.36 mg/lb], IV) and diazepam[d] (0.23 mg/kg [0.1 mg/lb], IV) and maintained via inhalation of isoflurane and oxygen. The alpaca was positioned in right lateral recumbency; the hair on the left hind limb was clipped, and the limb was cleaned from the midtibia distad. While traction was applied on the distal portion of the limb to reduce the fracture, six 3-inch-wide rolls of synthetic casting material[e] were used to form a full-limb fiberglass cast. Morphine[f] (0.26 mg/kg [0.12 mg/lb], IM) was administered during surgery. After an uneventful assisted recovery from anesthesia, the alpaca was returned to its stall. Postanesthetic pain management included administration of morphine[f] (0.47 mg/kg [0.21 mg/lb], IM) and application of a transdermal fentanyl patch (100 µg/h) in the left axillary region. The following day (day 1), radiography of the left hind limb revealed moderate anatomic alignment of the bone fragments and reduction of the fracture.

For several days, the alpaca remained quiet, spent most of its time lying down, and did not bear weight on the affected limb when standing. The cast remained clean, cool, and dry, and no swelling developed along the proximal portion of the tibia. However, the alpaca's appetite was decreased, and respiratory and heart rates were high. On day 5, radiography was repeated and revealed that the distal end of the proximal fragment had become displaced more laterally. Therefore, concerns of fracture instability (potentially allowing the closed fracture to become open) resulted in the decision to pursue more stable fracture fixation.

Abbreviation

CESF	Circular external skeletal fixator

From the Veterinary Teaching Hospital, Ontario Veterinary College, University of Guelph, Guelph, ON N1G 2W1, Canada (Rubio-Martínez, Koenig, Halling, Schulz); and Campbellford Veterinary Services, 176 Bridge St W Box 908, Campbellford, ON K0L 1LO, Canada (Wilkins).

Address correspondence to Dr. Rubio-Martínez.

Application of a CESF was elected, and the construct was preassembled on the basis of preoperative radiographic findings. Three 84-mm-diameter aluminium rings[g] were used: 1 to secure the distal fragment and 2 to be placed proximal to the fracture. The 3 rings were connected by use of three 6-mm threaded connecting rods.

Before surgery on day 7, penicillin G sodium (22,000 U/kg [10,000 mg/lb], IV), ceftiofur (3 mg/kg, IV), and flunixin meglumine (1.1 mg/kg [0.5 mg/lb], IV) were administered to the alpaca. Anesthesia was induced and maintained by use of the described protocol. The cast was removed, and the surgical site was aseptically prepared. No signs of skin disruption were evident. The alpaca was positioned in dorsal recumbency with the affected limb suspended in a vertical position. The preassembled CESF was positioned around the limb so that the limb was centered in the construct. With fluoroscopic guidance, a 1.6-mm-diameter olive stopper wire[g] was placed in the distal segment in a medial to lateral direction and then secured to the distal ring with fixation bolts and nuts. A second olive fixation wire was placed in the distal segment in a dorsomedial-plantarolateral direction at an angle of 45° to 60° to the first wire and similarly secured to the distal ring. Another 1.6-mm olive wire was placed in a medial to lateral direction in the proximal segment and secured to the most proximal ring. A second wire was similarly placed, again at an angle of 45° to 60° to the first wire. With fluoroscopic guidance, the middle ring was confirmed to be positioned 1 cm proximal to the fracture gap. Two divergent 1.6-mm olive wires were placed through the proximal bone segment and secured to the middle ring. The wires were tensioned to 60 kg (132 lb) by use of a commercial tensioner.[g] Fracture reduction was evaluated radiographically, and by turning the nuts securing the distal ring, the distal segment was distracted 0.5 cm distally to improve the anatomic reduction. The ends of the wires and threaded connecting bars were cut and protected with plastic caps, and a light padded bandage was applied around the fixator and the wire-skin interfaces. Recovery from anesthesia was uneventful, and the alpaca walked toe-touching to the stall. Morphine (0.3 mg/kg [0.14 mg/lb], IM) was administered during surgery and again 6 hours later. A transdermal fentanyl patch (100 µg/h) was placed in the axillary region. Administration of penicillin G sodium (22,000 U/kg, IV, q 6 h) and ceftiofur (3 mg/kg, IV, q 12 h) was continued.

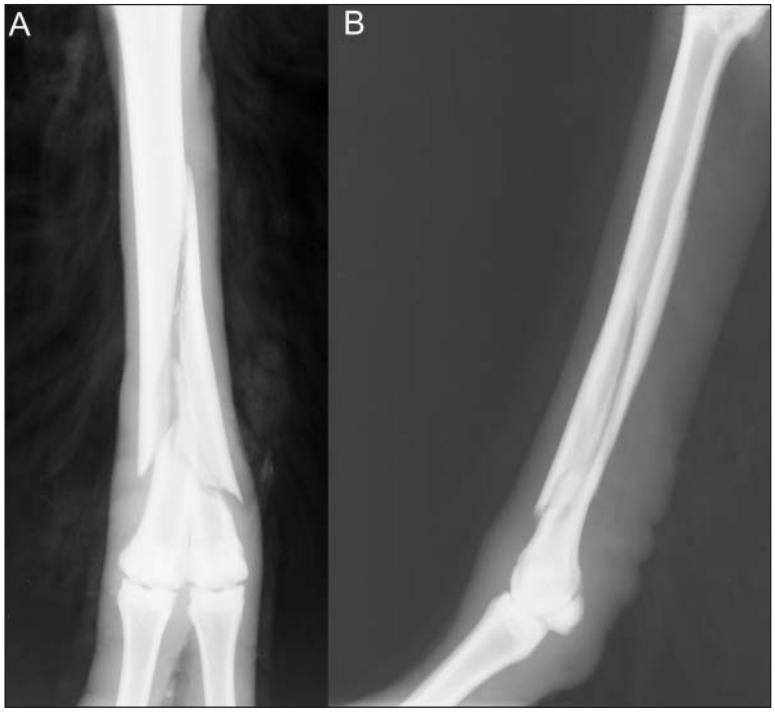

Figure 1—Dorsoplantar (A) and lateromedial (B) radiographic views of the left metatarsal region of an alpaca that was evaluated because of non–weight-bearing lameness of the left hind limb. Notice the comminuted nonarticular, displaced diaphyseal fracture of the left third and fourth metatarsal bones with a large butterfly fragment on the lateral side.

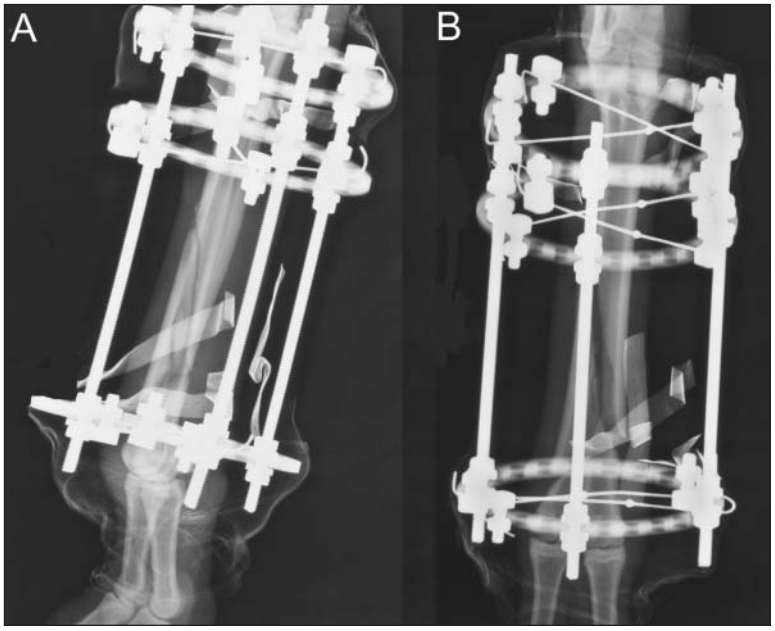

Figure 2—Dorsomedial-plantarolateral oblique (A) and dorsoplantar (B) radiographic views of the left metatarsal region of the alpaca in Figure 1 two days after application of the CESF. Radiopaque strips of the light bandage around the fixator are visible.

During the following 2 days, the alpaca was able to partially bear weight on the affected limb and it could stand and lie down without difficulty. Radiography performed on day 9 revealed that the fracture remained stable and that there was a mild outward rotation of the digits (**Figure 2**). A new fentanyl patch was placed on days 10 and 13. The bandage was changed daily, and there were no signs of swelling of the limb or discharge from the wire-skin interfaces (**Figure 3**). Administration of antimicrobials was discontinued on day 12. On day 13, the alpaca was discharged from the hospital and the owner was instructed to provide rest in a small indoor stall and daily ban-

Figure 3—Photograph of the left hind limb (cranial aspect) of the alpaca in Figure 1 after application of the CESF. Notice the 3 rings of the construct connected by threaded rods. The head of the alpaca is to the left.

Figure 4—Dorsoplantar radiographic view of the left metatarsal region of the alpaca in Figure 1 eighty-nine days after placement of the CESF; the distal aspect of the CESF is visible. Notice the dense bony union of the fracture fragments.

dage changes. The last fentanyl patch was to be removed in 3 days.

Follow-up information was periodically obtained by telephone with the owners and referring veterinarian. The alpaca was maintained in stall rest. A steady increase in weight bearing on the affected limb was detected, and full weight bearing was evident by the seventh day after discharge from the hospital (day 20 after application of the CESF). Lameness was hardly noticeable during walking. The CESF remained stable, and no signs of limb swelling or wire tract discharge were detected. A slight outward deviation of the limb distal to the metatarsophalangeal joint was still present. Forty-nine days after surgery, radiography revealed no displacement of the bone fragments and there was evidence of callus formation and bone bridging across the fracture site. The alpaca continued to improve clinically, and 89 days after surgery, bony union of the fracture segments was evident radiographically (**Figure 4**). Mild outward rotation of the distal fragment and metatarsophalangeal joint was evident. The referring veterinarian reported absence of gait abnormalities and complete use of the affected limb. At the most distal wire-tissue interface, some serous discharge was present during the few days prior to implant removal. The CESF was removed 91 days after surgery while the alpaca was anesthetized with atropine[a] (0.02 mg/kg, IV), ketamine[c] (3 mg/kg, IV), and diazepam[d] (0.23 mg/kg, IV). A Robert Jones bandage was applied to the limb, and the alpaca was kept in a stall for another 4 weeks. Eleven months after CESF application, the owners and referring veterinarian reported that the alpaca was healthy, not lame, and serving as a stallion without apparent impediment.

Discussion

Because of the increase in the population of South American camelids and the industry developed around them in North America, the demand for veterinary care of these animals is increasing. Fractures represent one of the most common orthopedic disorders of South American camelids, in addition to angular limb deformities, septic arthritis, and patella luxations.[1,2] Most frequently, fractures occur in the metacarpal or metatarsal bones (28.7%), followed by the humerus (21.4%), radius and ulna (21.4%), and tibia (7.1%).[2] Therapeutic interventions for fractures developed for other species, especially small ruminants, are commonly applied to South American camelids. These techniques include stall rest, external splints (Thomas-Schroeder), casts (with or without transfixation), external skeletal fixation, internal fixation (intramedullary pins, cerclage wires, and intramedullary interlocking nails), limb amputation, and prosthesis.[1-3] The treatment is selected according to the location of the fracture, the presence of soft tissue and neurovascular damage, whether it is an open or closed fracture, and the experience of the surgeon.

Metacarpal and metatarsal fractures in alpacas have been treated by use of a cast that maintains the carpus in flexion,[4] a cast with the limb extended,[2] a transfixation cast,[5,6] a linear external skeletal fixator,[7] and open reduction and internal fixation.[8,9] Most of these fractures were comminuted and healed satisfactorily. The use of external skeletal fixation has been suggested for failed internally fixated fractures.[7]

The CESF was initially designed by Gavriil Ilizarov in the 1950s. This system has been used in veterinary patients for fracture stabilization, bone lengthening, and treatment of bone defects and angular limb deformities.[10-12] The CESF uses tensioned fixation wires to increase their stiffness while allowing elastic but not plastic deformation (more common in larger-diameter pins). This implies that micromotion is present at the fracture site, which enhances bone healing.[13,14] The superior mechanical properties (torsional and flexural stiffness) of CESFs, compared with Kirschner-Ehmer linear external skeletal fixators, make CESF application an ideal technique for fracture management.[14] The cir-

cular construction and threaded rods of a CESF provide higher versatility, and the use of small-diameter fixation wires is less traumatic for soft tissues than the wide-diameter pins used in a linear external fixator.[10] Circular external skeletal fixators have been well tolerated in veterinary patients and allow weight bearing early after application while preserving the limb and joint function. Among South American camelids, a CESF has been used only for stabilization of a congenital cervical subluxation in a llama,[h] to the authors' knowledge; application of a CESF for fracture stabilization has not been previously reported in these species.

For the alpaca of this report, the CESF provided adequate stability for fracture healing, allowed weight bearing on the affected limb soon after its application, and preserved the range of motion of the tarsal and digital joints. Application of an additional ring or half ring with olive wires would have allowed further fracture reduction and interfragmentary compression of the butterfly fragment.[10,15] The use of 4 fixation elements (wires) in the distal segment would have further enhanced stiffness of the construct.[16] However, additional rings and olive wires were not immediately available at the time of fracture fixation, and on the basis of the weight (85 kg) of the alpaca, it was believed that a 3-ring construct would provide adequate stability. The use of 3-ring constructs in a 2-month-old 85-kg calf[17] and a 5-month-old 52-kg (114-lb) donkey[18] has been described. For those animals, the 3-ring construct provided adequate stability for healing of a comminuted metacarpal fracture[17] and an angular limb deformity after wedge osteotomy of the radius[18]; the 3-ring construct remained in place for 48 and 60 days, respectively, withstanding a body weight of 120 kg (264 lb) in the case of the calf. However, compared with the CESF used in the alpaca of this report, thicker wires (2 mm in diameter) were used in those other instances. Four-ring constructs have been successfully used in an Arabian foal[19] and a calf.[20] For the foal, 1.8-mm wires were used and the construct remained in place for 3 months, by which time the foal weighed 150 kg (330 lb).

Circular external skeletal fixators are widely used in small animals[11,16,21-23]; however, the high body weight of large animals (eg, horse or cow) often precludes CESF application for treatment of fractures. In comparison, South American camelids are considered excellent patients for treatment of fractures for the following reasons: lower body weight (alpaca, 55 to 80 kg [121 to 176 lb]; llama, 100 to 220 kg [220 to 484 lb]), ability to ambulate on 3 limbs, long periods naturally spent in recumbency, stoicism, tolerance for external coaptation devices, and lack of athletic requirement. In the alpaca of this report, the mild lateral digit deviation did not have important considered consequences and limb use was normal; whether this deviation could have affected athletic function (if this had been required) is not known.

Complications secondary to fracture management in South American camelids include delayed union or nonunion of the fracture, osteomyelitis, implant failure, sequestration, and disuse osteopenia.[8,24] In small animals, the most common complications reported with CESFs are wire or pin tract inflammation or infection.[11] The alpaca of this report had a small amount of serous discharge at the most distal wire-tissue interface during the days prior to CESF removal, indicating some degree of wire tract inflammation. No other complications were detected. Biomechanical characteristics of different configurations and different components of CESFs are being widely investigated in small animals[23,25]; however, little is known about the ideal components and characteristics (such as tensioning and diameter of the wires) of the CESF to avoid construct failure in alpacas.

In the treatment of fractures, the use of closed reduction and stabilization via external skeletal fixation better preserves the periosteal vascularization, compared with open reduction and bone plate fixation. Furthermore, the duration of anesthesia, amount of foreign material implanted, and economic cost are also reduced. In the alpaca of this report, closed reduction was successfully achieved and fluoroscopic guidance allowed placement of fixation pins at appropriate distances from the fracture and any adjacent articular surfaces. Other advantages of CESF application included full weight bearing soon after recovery from anesthesia and maintenance of limb use and joint mobility, which lessened the likelihood of the development of joint stiffness, muscle atrophy, or osteopenia.[26] Overall, the use of a CESF provided adequate stability for successful healing of a comminuted metatarsal fracture in an 85-kg alpaca, without major complications. Although further investigation is warranted in the use of CESF in alpacas, this system can be considered a viable method for the stabilization of long bone fractures in South American camelids.

a. Atropine sulphate injection USP, Abbott, Montreal, QC, Canada.
b. Rompun, Bayer, Toronto, ON, Canada.
c. Vetalar, Bioniche, Belleville, ON, Canada.
d. Diazepam injection USP, Sandoz, Boucherville, QC, Canada.
e. Dynacast Extra, BSN Medical Ltd, Brierfield, Lancashire, England.
f. Morphine sulphate injection USP, Sandoz, Boucherville, QC, Canada.
g. IMEX Veterinary Inc, Longview, Tex.
h. Rohde C, Anderson DE, Silveira F, et al. Surgical stabilization of congenital cervical subluxation in a young llama using a ring fixator (abstr), in *Proceedings*. 14th Annu Meet Vet Orthop Soc 1998;2.

References

1. Turner AS. Surgical conditions in the llama. *Vet Clin North Am Food Anim Pract* 1989;5:81–99.
2. Anderson DE. Fracture managements in llamas and alpacas, in *Proceedings*. 2005 Am Coll Vet Surg Symp 2005;139–142.
3. Lillich JD, Roush JK, DeBowes RM, et al. Interlocking intramedullary nail fixation for a comminuted diaphyseal femoral fracture in an alpaca. *Vet Comp Orthop Traumatol* 1999;12:81–84.
4. Manning JP. Fracture of the metacarpal bones in a llama. *J Am Vet Med Assoc* 1956;129:136–137.
5. Kaneps AJ, Schmotzer WB, Huber MJ, et al. Fracture repair with transfixation pins and fiberglass cast in llamas and small ruminants. *J Am Vet Med Assoc* 1989;195:1257–1261.
6. Kaneps AJ. Orthopedic conditions of small ruminants. Llama, sheep, goat, and deer. *Vet Clin North Am Food Anim Pract* 1996;12:211–231.
7. Staudte KL, Gibson NR. Type 1B external fixation of a metacarpal fracture in an alpaca. *Aust Vet J* 2003;81:265–267.
8. Tee SY, Dowling BA, Dart AJ. Treatment of long bone fractures in South American camelids: 5 cases. *Aust Vet J* 2005;83:418–420.

9. Zanolari P, Zulauf M, Nitzl D, et al. Open diagonal fracture of metatarsus III/IV and internal fixation in an alpaca. *Schweiz Arch Tierheilkd* 2003;145:378–385.
10. Lesser AS. Ilizarov technique. In: Bojrab MJ, ed. *Current techniques in small animal surgery*. 4th ed. Baltimore: The Williams & Wilkins Co, 1998;950–963.
11. Lewis DD, Radasch RM, Beale BS, et al. Initial clinical experience with the IMEX™ circular external skeletal fixation system part I: use in fractures and arthrodeses. *Vet Comp Orthop Traumatol* 1999; 12:108–117.
12. Lewis DD, Radasch RM, Beale BS, et al. Initial clinical experience with the IMEX™ circular external skeletal fixation system part II: use in bone lengthening and correction of angular and rotational deformities. *Vet Comp Orthop Traumatol* 1999;12:118–127.
13. Goodship AE, Kenwright J. The influence of induced micromovement upon the healing of experimental tibial fractures. *J Bone Joint Surg Br* 1985;67:650–655.
14. Lewis DD, Bronson DG, Samchukov ML, et al. Biomechanics of circular external skeletal fixation. *Vet Surg* 1998;27:454–464.
15. Collins KE, Lewis DD, Lanz OI, et al. Use of a circular external skeletal fixator for stifle arthrodesis in a dog. *J Small Anim Pract* 2000;41:312–315.
16. Marcellin-Little D. Fracture treatment with circular external fixation. *Vet Clin North Am Small Anim Pract* 1999;29:1153–1170.
17. Olcay B, Bilgili H, Kurum B. Treatment of comminutive metacarpal fracture in a calf using the Ilizarov circular external fixation system. *Israel J Vet Med Assoc* 1999;54:122–127.
18. Eggleston RB, Mueller PO, Chambers JN, et al. Use of an external ring fixator for correction of an acquired angular limb deformity in a donkey. *J Am Vet Med Assoc* 2000;217:1186–1190.
19. Jukema GN, Settner M, Dunkelmann G, et al. High stability of the Ilizarov ring fixator in a metacarpal fracture of an Arabian foal. *Arch Orthop Trauma Surg* 1997;116:287–289.
20. Pistani JR, Miscione H, Redondo, et al. Clinical use of Ilizarov's compression technique in the treatment of a septic pseudoarthrosis in a calf. *Vet Comp Orthop Traumatol* 1997;10:12–15.
21. Anderson GM, Lewis DD, Radasch RM, et al. Circular external skeletal fixation stabilization of antebrachial and crural fractures in 25 dogs. *J Am Anim Hosp Assoc* 2003;39:479–498.
22. Farese JP, Lewis DD, Cross AR, et al. Use of IMEX SK-circular external fixator hybrid constructs for fracture stabilization in dogs and cats. *J Am Anim Hosp Assoc* 2002;38:279–289.
23. Cross AR, Lewis DD, Rigaud S, et al. Effect of various distal ring-block configurations on the biomechanical properties of circular external skeletal fixators for use in dogs and cats. *Am J Vet Res* 2004;65:393–398.
24. Johnson CR, Baird AN, Baird DK, et al. Long-bone fractures in llamas: six cases (1993–1998). *J Am Vet Med Assoc* 2000;216: 1291–1293.
25. Cross AR, Lewis DD, Murphy ST, et al. Effects of ring diameter and wire tension on the axial biomechanics of four-ring circular external skeletal fixator constructs. *Am J Vet Res* 2001;62: 1025–1030.
26. Nunamaker DM, Richardson DW, Butterweck DM, et al. A new external skeletal fixation device that allows immediate full weight bearing application in the horse. *Vet Surg* 1986;15:345–355.