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Trauma involving the proximal tibial epiphysis

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Summary. Thirty injuries involving the proximal tibial epiphysis were treated during a period of 28 years. The epiphysis was displaced in 16 cases (53%). Three patients presented with peripheral ischemia on admission, and one patient with associated ipsilateral femoral fracture developed delayed thrombosis of the popliteal artery. The treatment results were satisfactory in 21 of the 27 (74%) who were reassessed according to Shelton's evaluation criteria after an average post-traumatic interval of 11.6 years. Three of the six patients with unsatisfactory outcome had a discrepancy in leg length of more than 2.5 cm after concomitant ipsilateral fracture of the femur or the tibia. One patient had a positive 3-cm anterior drawer sign, one patient had a 10° valgus deformity of the tibia, and one had to undergo above-knee-amputation because of delayed diagnosis of the vascular lesion.

Childhood injuries involving the tibial plateau are rare [5, 6]. However, although the incidence of trauma is low, the rate of post-traumatic complications is high. The blood flow in the popliteal artery, which runs directly along the tibial epiphysis on the flexor side, may be impaired or disrupted during the early post-traumatic phase (Fig. 1). Although closed reduction reverses ischemia in most cases, additional bone injuries, shock symptoms, and developing compartment syndrome may mask the severity of the primary trauma to the immature tibial head. A mural thrombus may develop when the intima has been injured, and if diagnosis of the vascular lesion is delayed, in extreme cases amputation may become necessary.

Destruction of the cartilage creates ideal conditions for the ingrowth of connective tissue and capillaries. Mineralization then spreads to the epiphyseal part of the growth plate and bony bridges are formed between epiphysis and metaphysis. The growth potency of the intact part of the growth plate causes angular deformity as a late complication. In cases of complete destruction of the epiphysis, shortening of the leg results.

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Patients and methods

From 1959 to 1987, 30 patients (20 boys and 10 girls) aged 2–18 years (mean age at time of accident 12.7 years) were treated for closed trauma of the proximal tibial epiphysis. The severity of injury to the tibial plateau was classified according to the Salter-Harris system [13, 14] (Table 1). The right leg was affected in 17 cases, the left leg in 13 . Eleven patients had been injured in a traffic accident, 10 fell while skiing, 5 fell due to various other causes, 2 were hurt while tobogganing and 2 when they landed after jumping. Ten of the 11 traffic accident victims were aged 15–18 years. Sixteen of the epiphyseal injuries (53%) were displaced; 8 patients had suffered only a loosening of the epiphysis, which was graded as type 0. This type of injury is characterized by local tenderness at the physis and impaired knee function but normal X-ray findings. A clinical follow-up examination after 1 week shows the same results. Five patients had suffered separation of the epiphysis; 10 had in addition an osseous metaphyseal wedge; an epiphyseal fracture was diagnosed in 5 cases and a combined epi-metaphyseal fracture in one.

One 17-year-old patient presented with genu valgum et recurvatum after a fracture of the proximal tibia, which he had suffered 3 years previously and which had been treated in another depart-

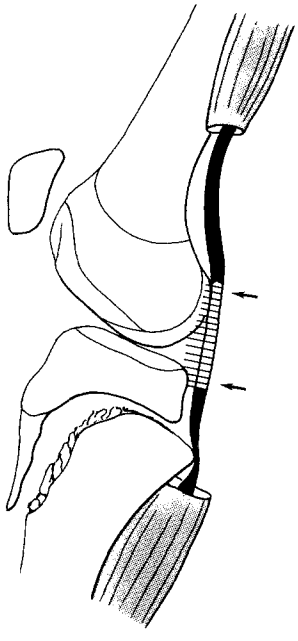


Fig. 1. Course of the popliteal artery in the region of the dorsally displaced tibial metaphysis, showing the fibers at the dorsal capsule which were first described by Boyd

Table 1. Classification of the epiphyseal injuries (Salter-Harris system)

	n	%
Type 0	8	26.7
Type I	5	16.7
Type II	11	36.7
Type III	4	13.3
Type IV	1	3.3
Recurv. + valgus	1	3.3
Total	30	100

Table 2. Significant concomitant ipsilateral injuries (12 patients)

Hip dislocation	1
Femoral fracture	5
Collateral ligament tear: medial	1
lateral	1
Patellar fracture	1
Lower leg fracture	2
Fibular fracture	4
Medial malleolar fracture	1
Ischemia	4
Peroneal paresis	1

Table 3. Treatment of the type-II fractures (11 patients)

Cast	3
Closed reduction + cast	3
Closed reduction + pin fixation + cast	3
Closed reduction + pin fixation + tibial traction	1
Closed reduction + tibial traction + cast	1
Total	11

ment. The deformity was apparently the result of involvement of the tibial epiphysis.

Twelve of the 30 patients (40%) had concomitant ipsilateral injuries. Details are given in Table 2.

Upon admission, all of the 29 patients first treated at our department complained of tenderness of the tibial plateau and impaired function of the knee joint. In addition, signs of effusion were found in 15 cases; mobility was abnormal in 4.

Diagnosis was based on radiological studies in two planes. A comparative roentgenogram of the unaffected contralateral side is a mandatory routine examination in every case of childhood injury of the epiphysis. Treatment depended on the severity of the trauma to the tibial epiphysis and on concomitant injuries. Seven of the 8 type-0 injuries were immobilized for a period of 4 weeks by putting the leg with the knee flexed at 30° in a long leg plaster cast. One polytraumatized child had suffered ipsilateral fractures of the upper and lower leg, which were initially treated by supracondylar and calcaneal pin traction.

All 5 type-I epiphyseolyses were displaced. Closed manual reduction attempted by placing the forearm into the hollow of the knee followed by maximal flexion of the knee joint – as done in hyperextension fractures of the proximal tibia – was always successful [3]. In two cases with persistent instability and a tendency to recurvation, Kirschner pins were inserted percutaneously and guided across the growth plate from the proximal to the distal side. One patient had suffered concomitant ipsilateral fracture of the femur, which was treated by supracondylar traction. One patient was treated by tibial traction immediately after reduction, followed by long leg cast immobilization for 6 weeks. Two other injuries were fixated by plaster cast for 6 weeks immediately following reduction.

Table 3 shows how epiphyseolysis with a metaphyseal wedge (fracture type II) was treated. The typical lateral X-ray view showed the metaphysis to be displaced dorsally by several millimeters (Fig. 2). Peripheral ischemia was present in three of these patients upon admission and developed after a delay in a fourth. Reduction restored blood flow in two patients and one artery was successfully thrombectomized (Fig. 3). In one patient with concomitant fracture of the femur, the vascular lesion was initially not recognized. In this patient delayed revision of the popliteal artery led to ischemic gangrene of the lower leg and finally necessitated amputation above the knee.

Two epiphyseal fractures with lateral plateau involvement (fracture type III), which were not displaced, were only immobilized by plaster cast. In one case (Fig. 3), the posterior part of the growth plate gaped after the first reduction, so that the deformity had to be corrected. In another case, closed reduction of the fracture was followed by percutaneous insertion of Kirschner pins. The mean duration for which long leg plaster casts were left in place was 6 weeks. In one case a loose intra-articular body located in front of the tibial attachment of the anterior cruciate ligament, diagnosed in a type-IV fracture, necessitated arthrotomy for removal of the body. The subsequent plaster cast immobilization lasted 8 weeks (Fig. 4).

High tibial pendulum osteotomy corrected the post-traumatic knee deformity existing in one patient and relieved his pain following strain (Fig. 5).

Results

Twenty-three patients returned for a follow-up examination after a mean post-traumatic interval of 12.7 years (2–29 years). Four patients reported on their condition by telephone. One patient had died. Two of the female patients (one type-III and one type-IV injury) could not be located because they had married and had changed their surname. All patients had completed growth.

By analogy to the criteria used by Shelton and Canale [15], the presence of the following five objective criteria was investigated:

1. Painful ligamentous instability
2. Leg length discrepancy of more than 2 cm
3. Angular deformity of more than 5°
4. Incongruity of the joint with secondary arthritis and pain
5. Neurovascular deficit

If even one of the above criteria was present, the outcome was classified as unsatisfactory.

The four patients questioned by telephone (2 type-0, one type-I, and one type-II injury) were satisfied with their condition; they could fully engage in sports activities.

Seventeen of the 23 patients who came for a follow-up examination (74%) had satisfactory results. The six cases with objective unsatisfactory outcome will be discussed individually below.

One patient had a sport accident 3 years after his type-IV epiphyseal trauma and tore his anterior cruciate ligament. The examination revealed a positive drawer

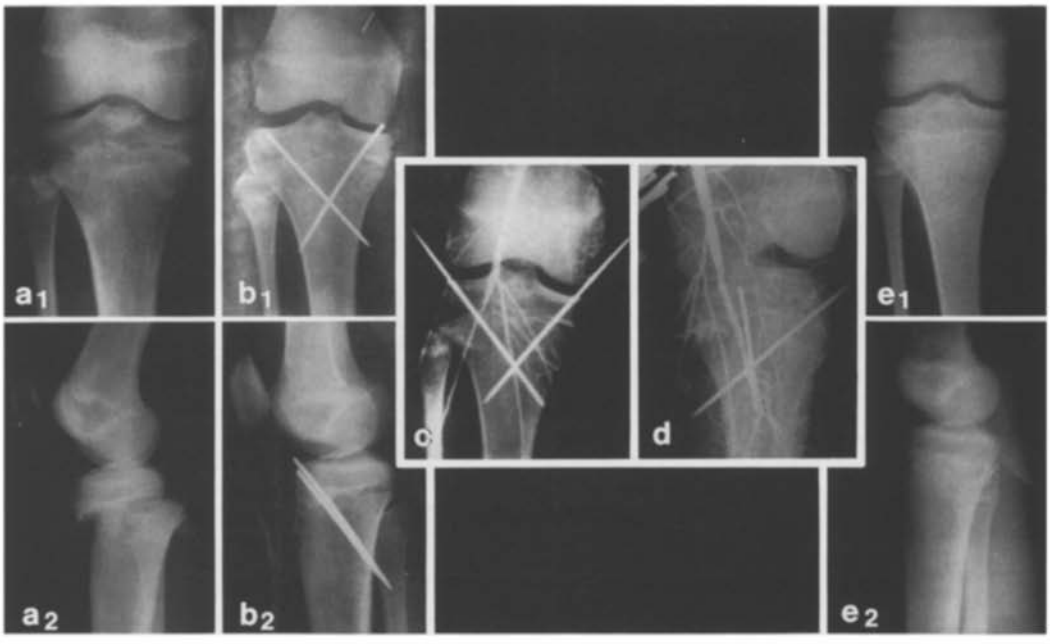
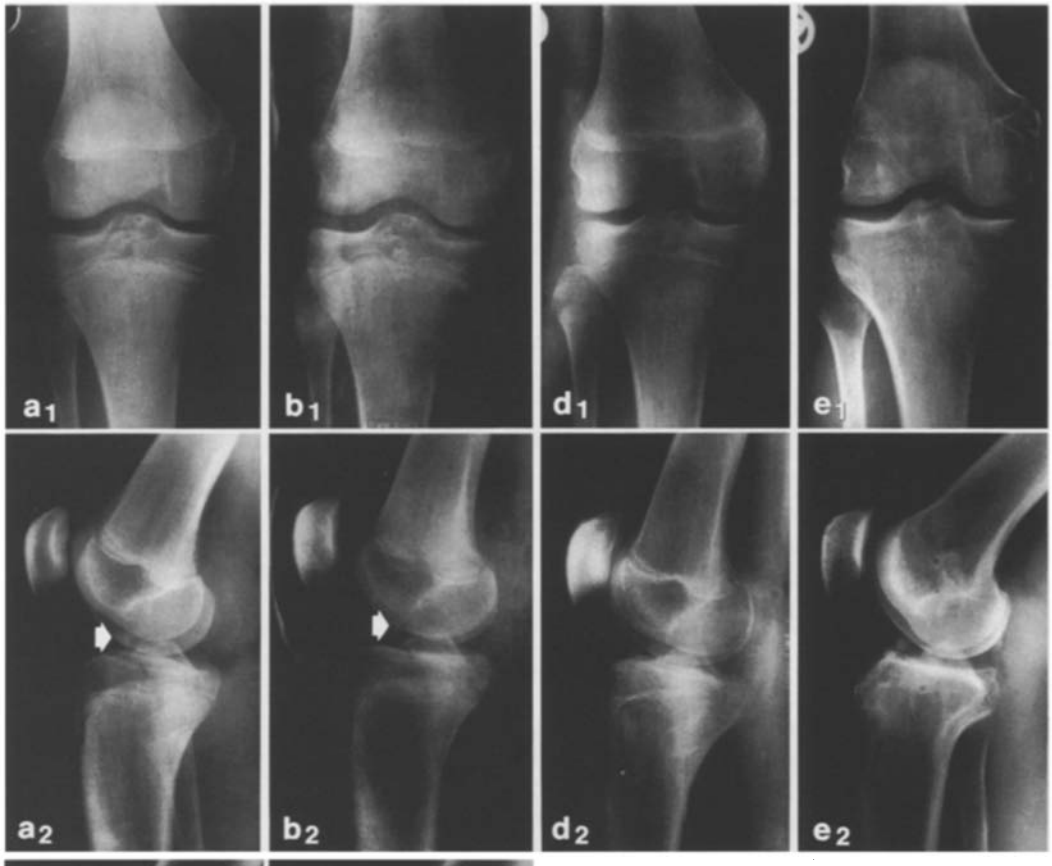


Fig. 2a–e. A 13-year-old girl. **a** 1,2 Initial roentgenograms showing a type-II injury. **b** 1,2 Closed reduction and stabilization with Kirschner wires. **c** Arteriogram showing the occlusion at the physeal fracture. **d** Postoperative arteriogramm after thrombectomy. **e** 1,2 follow-up after 2 years: subjectively and objectively satisfactory result

Fig. 3a–d. A 9-year-old girl. **a** 1,2 Inital roentgenograms show a type-III injury. **b** 1,2 First closed reduction demonstrates gaping of the posterior part of the growth plate. **c** Second closed reduction demonstrates anatomic alignment. **d** 1,2 Follow-up after 3 years: subjectively and objectively satisfactory result

sign of 3 cm and a lax medial collateral ligament with valgus stress. Radiological studies showed signs of incipient arthritis already (see Fig. 4). Nevertheless, the patient did not complain of pain in the knee.

Shortening of the affected leg was seen in three patients, two with ipsilatexal femoral fracture and one with ipsilateral femoral and tibial fracture. In addition, the last mentioned case was complicated by chronic osteomyelitis of the tibia with fistula formation. Additional complex ligamentous instability was seen in two knee joints. All these patients had already developed predominantly medial arthritis.



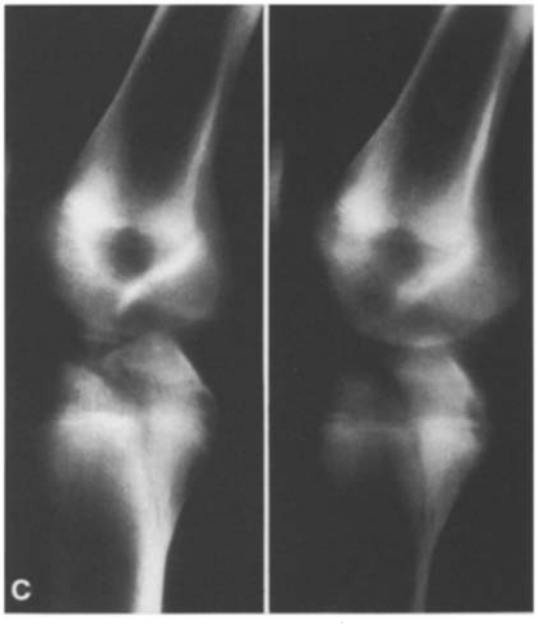


Fig. 4a–e. A 17-year-old boy. **a** 1,2 Initial roentgenograms show a type-IV injury. **b** Cast immobilization. *Arrow*, loose body. **c** Tomograms. **d** 1,2 Postoperative roentgenograms after removal of the loose body. **e** 1,2 Follow-up after 19 years. Three years after epiphyseal trauma, the patient had sustained a rupture of the anterior cruciate ligament; incipient arthritis

Lax medial collateral ligament and occasional pain due to overstrain occurred in a case of type-II injury with ipsilateal fracture of the femur and the tibia and peroneal palsy, but there was no discrepancy in leg length. The paresis had since disappeared spontaneously.

The sixth case is the most unsatisfactory one: delayed diagnosis of a vascular lesion led to amputation above the knee.

Discussion

Despite the existence of the phenomenon of spontaneous correction, epiphyseal injuries must be managed according to the principles of fracture treatment. A typical event is dorsal displacement of the tibial metaphysis, perhaps with simultaneous lateral deviation and torsion (see Fig. 2). In severe cases, clinical examination reveals the signs of knee dislocation. The dorsal shift of the tibial shaft endangers the popliteal artery. Firm connective tissue septa fix the vessel in the terminal part of the adductor canal, in the dorsal area of the articular capsule – these are the fibres described by Boyd – and in the deep portion of the peroneal muscle (see Fig. 1) [1]. They explain the limited capability of the popliteal artery for deviation and adaptation.

Vascular lesions vary in severity from local arterial thrombosis due to intimal lesions to complete rupture. Common to them all is peripheral ischemia. The bone may directly injure the popliteal artery, or a developing compartment syndrome or pressure exerted by the plaster cast may occlude the vascular lumen. It is therefore imperative to check the dorsal pulses before reduction of the fracture and during the subsequent treatment period. These pulses may be absent in a polytraumatized patient in shock. If there is any doubt, the vascular situation must be investigated in detail immediately [4]. Quell and Vecsei [9] reported in their literature survey a 23% incidence of this vascular complication in type-I epiphyseolysis at the head of the tibia. Rivero and Bolden

Fig. 5a–d. A 17-year-old boy. **a** 1,2 Inital roentgenograms show genu valgum et recurvatum after a 3-year-old proximal fracture of the tibia. **b** 1,2 High tibial pendulum osteotomy. **c** 1,2 Follow-up after 1 year. **d** 1,2 Follow-up 8 years: subjectively and objectively satisfactory result

[11] were the first to find impaired blood flow in a type-IV fracture; until then ischemia had been described exclusively in type-I and type-II fractures. Impaired blood flow was present or developed in four patients with type-II injuries, out of the 30 patients included in the present study (incidence 13.3%; see Fig. 2).

The tenet that the physis is the weakest link in the integrity of the growing skeleton is true only to a limited extent. Bertin and Goble [2] found additional ligamentous instability in the long-term results of 7 of 13 patients (54%) who had suffered epiphyseal fractures of the proximal tibia. Five had a positive anterior drawer sign and 4 a lax medial collateral ligament. The authors postulate the following pathomechanism for complex injuries of the growth plate and ligaments: when a valgus force acts upon the knee, a type-V crush trauma of the lateral part of the proximal tibial epiphysis results. During this process the superficial part of the medial collateral ligament inserting at the metaphysis is stressed until it tears. The deep medial collateral ligament, which is attached at the epiphysis, remains intact. This ligament and the cruciate ligaments together fracture the growth plate, as they are stronger than the physis.

Analysis of another patient population showed 4 lesions of the meniscus, 2 ruptures of the cruciate ligaments and 1 rupture of the collateral ligament as concomitant injuries in 5 knee joints out of 9 cases of trauma of the proximal tibia in childhood (55%) [7].

A normal roentgenogram does not rule out ligamentous injury [11]. If, after spontaneous reduction of an epiphyseolysis, instability of the ligaments is suspected, stress roentgenograms should be made, which may show gaping of the joint space, of the physis, or both [14]. Nowadays hemarthrosis requires arthroscopic investigation even in adolescents in order to verify the intra-articular knee lesion, but our patients were injured at a time when artrhoscopy was not yet known or not yet established as a routine procedure. Four of the 23 follow-ups revealed a loosening of the medial or anteromedial knee joint ligament. Three of these 4 patients had sustained a simultaneous ipsilateral fracture of the upper or the lower leg in addition to the injury to the proximal ti-

bial epiphysis. Ligamentous reconstruction was therefore not a dominant issue at primary treatment. The fourth patient suffered his rupture of the anterior cruciate ligament 3 years after the initial trauma, while playing soccer.

Depending on the impact of the acting force, the resulting growth plate lesion will be either partial or complete. Late complications to be expected are growth disturbances manifesting as angular deformities or discrepancies in the length of the lower legs. The majority of our patients with severe epiphyseal lesions were above the age of 15 years and had almost completed bone growth, so that growth disturbances stayed within limits. Shortening of leg length in our own patient population was in two cases due to fracture of the femur and in one case due to osteomyelitis following tibial fracture. Especially in cases of ipsilateral fracture of the upper and/or lower leg, attention must be paid to epiphyseal lesions which either escape radiological detection or are only sketchily shown by the roentgenogram. Tomography and computed tomography should be considered as supplementary diagnostic procedures (Fig. 4c).

Hresko and Kasper [8] reported 5 tibial recurvations in need of treatment due to incomplete proximal epiphyseal closing after metaphyseal fracture of the lower leg. The initial trauma seems to have caused a lesion of the periosteum at the boundary to the proximal epiphysis and asymmetrical epiphyseal closing [10]. Knowledge and early recognition of this combination of injuries should prevent the development of such a deformity. One of our patients with ipsilateral fracture of the upper and lower leg and epiphyseolysis (type-II fracture) developed a 10° valgus deformity of the tibia. Another patient had a 20° recurvation and a 10° valgus deformity combined proximal tibial epiphyseal injury and supracondylar tibial fracture sustained 3 years previously, and treated at that time at another department (Fig. 5). High tibial pendulum osteotomy corrected the angular deformity and secured pain-free functioning of the knee joint.

Conclusions

Undisplaced or closed, anatomically reducible epiphyseal injuries without articular effusion heal after plaster cast immobilization. Unstable epiphyseal injuries must be fixated additionally by Kirschner pins slowly inserted percutaneously. The dorsal pulses must be checked before reduction and during the subsequent treatment period. Articular effusion in a juvenile knee should be investigated by arthroscopy in order to rule out intra-articular lesions. A primarily normal roentgenogram does not exclude epiphyseal lesions, especially in cases of ipsilateral metaphyseal fractures. Radiological follow-ups should be carried out for an observation period of at least 1 year in order to avoid angular deformities.

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