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PRONATION INJURIES OF THE ANKLE IN CHILDREN

Retrospective Study of Radiographical Classification and Treatment

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In a retrospective study in children aged 0–18 years, 457 ankle fractures in children were classified traumatologically according to Gerner-Smidt or Lauge-Hansen. Anatomically, ankle fractures with open growth plates were classified according to the Salter-Harris classification.

Pronation injuries constituted 18% of the ankle injuries and showed different fracture patterns.

In total 83 pronation injuries were found. Of these, 52 showed open growth plates: 25 pronation-abduction, 23 pronation-eversion, and 4 pronation-dorsal flexion injuries.

The pronation-abduction injuries were classified into two groups. In 15, a detachment of the deltoid ligament at the medial malleolus, visible on radiographs as a minimal fragment or transverse fracture of the medial malleolus, was found; seven showed in addition a fracture through the growth plate (Salter-Harris type I or II) or a metaphyseal fracture of the distal fibula. In 10, a physeal fracture through the distal tibia (Salter-Harris type I) was found. Of these, seven had in addition a metaphyseal fibular fracture.

Pronation-eversion injuries showed in 21 cases a physeal-metaphyseal fracture (Salter-Harris type II) with an antero-lateral metaphyseal fragment (Stage I–II); 17 had in addition a metaphyseal fibular fracture (Stage III). A minimal postero-lateral metaphyseal fragment of the distal tibia represents the fourth stage but could not adequately be separated from the third, so Stages III and IV were combined.

Pronation-dorsal flexion showed a physeal-metaphyseal fracture in four cases with an anteriorly situated metaphyseal fragment (Stages I–II); one case also had a metaphyseal fracture of the distal fibula (Stage III).

Pronation-eversion injuries showed frequently displacement and were more commonly treated by reduction than pronation-abduction and supination injuries including supination-eversion injuries of intra-articular type. However, complete reduction of pronation-eversion injuries with closed methods often proved difficult.

Key words: adolescence; ankle fracture; children; epiphysis; growth plate; radiographical classification

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Pott (1775) described ankle fractures in the adult due to abduction. The names of Dupuytren (1836) and Maisonneuve (1840, 1863) were later associated with these injuries.

Abduction fractures in children were anatomically described by Bruns (1882) and Poland (1898). They showed a fracture of the distal tibial growth plate with an antero-lateral metaphyseal fragment. Helferich (1906) demonstrated the radiographical appearance, and associated this fracture with the adult injury earlier described by Pott and Dupuytren.

Demoulin & Douay (1910) described another type of fracture through the growth plate of the

distal tibia, but without metaphyseal or epiphyseal fragment accompanied with a fracture of the fibular metaphysis; but no injury of the tibio-fibular ligaments as in the adult (Lauge-Hansen 1942). Both Demoulin & Douay (1910) and Broca & Phelip (1910) considered these injuries comparable to the abduction injury in the adult.

Abduction injuries in children were later described by Bishop (1935) and Carothers & Crenshaw (1955). Lauge-Hansen (1942, 1953) separated a pronation-eversion injury (pronation-external rotation) with a metaphyseal fragment localized antero-laterally, and a pronation-dorsal flexion injury with a metaphyseal fragment localized anteriorly.

Gerner-Smidt (1963) experimentally produced two types of pronation injuries: Pronation-abduction and pronation-eversion. The pronation-abduction injuries were classified into two subgroups, each type with two stages. Four stages were identified in the pronation-eversion injuries. Diaz & Tachdjian (1978) described a pronation-eversion-external rotation injury with only one stage.

Compared to the supination injuries, the pronation injuries are rare but show certain characteristics. This report presents the radiographical appearance and the clinical treatment of pronation injuries in a retrospective material.

MATERIAL AND METHODS

Using the diagnosis code register (Ekenstam et al. 1976) 919 fractures of the ankle and/or the lower leg in 903 children aged 0–18 years were traced. The patients were treated at the Department of Orthopaedics, University Hospital in Lund during 1971–79. A total of 457 ankle fractures in 453 patients were found; 361 children with 363 fractures had open growth plates. Traumatologically, ankle fractures with open growth plates were classified according to Gerner-Smidt (1963) concerning the pronation-abduction and pronation-eversion injuries. Pronation dorsal flexion injuries and injuries with closed growth plates were classified according to Lauge-Hansen (1942, 1953). Anatomically, the fractures were classified according to Salter & Harris (1963).

RESULTS

In total, there were 83 pronation injuries. Of these 52 showed open growth plates; 25 pronation-abduction, 23 pronation-eversion, and 4 pronation-dorsal flexion injuries (Tables 1–4, Figure 1).

Table 1. Distribution of pronation-abduction injuries in boys and girls with open growth plates. Average ages ± S.D.

PA stage	Salter – Harris		Sex	No. of cases	Mean age ± s.d.
	Tibia	Fibula			
I a		–	♂	2	13.5±3.5
			♀	6	10.0±2.4
IIa(IIIa)*	–(III)	I,II(–)	♂	6	12.0±3.0
			♀	1	13.0±0.0
			♂	8	12.4±2.9
			♀	7	10.4±2.4
Ib	I	–	♂	1	13.0±0.0
			♀	2	12.0±0.0
IIb	I	–	♂	3	13.3±1.5
			♀	4	10.3±3.2
			♂	4	13.3±1.3
			♀	6	10.8±2.6
			♂	12	12.7±2.5
			♀	13	10.6±2.4

* Transitional fracture pattern to adult type.

Table 2. Distribution of pronation-eversion injuries in boys and girls with open growth plates. Average ages ± s.d.

PE stage	Salter – Harris		Sex	No. of cases	Mean age ± s.d.
	Tibia	Fibula			
I–II	II	–	♂	3	8.3±6.1
			♀	1	14.0±0.0
III–IV	II(III,I+IV)	–	♂	17	13.9±2.3
			♀	2	12.5±0.7
			♂	20	13.1±3.6
			♀	3	13.0±1.0

Table 3. Distribution of pronation-abduction and pronation-eversion injuries in cases with closed growth plates. Average ages ± S.D.

Type of trauma	Stage	Sex	No.	Mean age of cases ± S.D.
PA or PE	I	♂	7	15.9±0.0
		♀	10	15.6±2.1
PA or PE	II	♂	3	15.7±1.2
		♀	2	15.0±1.4
PA	III	♂	3	15.3±0.6
		♀	2	16.5±0.7
PE	III–IV	♂	3	16.7±0.6
		♀	1	16.0±0.0
		♂	16	15.9±0.9
		♀	15	15.7±1.8

Table 4. Distribution of pronation-dorsal flexion injuries in boys and girls with open growth plates. Average ages ± S.D.

PD stage	Salter – Harris		Sex	No. of cases	Mean age ± s.d.
	Tibia	Fibula			
I–II	II	–	♂	2	13.5±3.5
			♀	1	3.0±0.0
III	II	–	♂	1	14.0±0.0
			♀	0	– –
			♂	3	13.7±2.5
			♀	1	3.0±0.0

RADIOGRAPHY AND TREATMENT

Open growth plates

Pronation-abduction (PA): Stage I a (epiphyseal/physeal fracture of the medial malleolus (Figures 2 and 3). According to Gerner-Smidt stage I a.

Distal tibia: Epiphyseal fracture, rarely physeal of Salter-Harris (S-H) type III or detachment of deltoid ligament.

Distal fibula: no injury.

Two boys, aged 11 and 16 years; six girls, aged 6–13 years.

Six children showed a fracture at the tip of the medial malleolus; in two, the fragment was about 5 mm; in the others, about 2–3 mm. In one case,

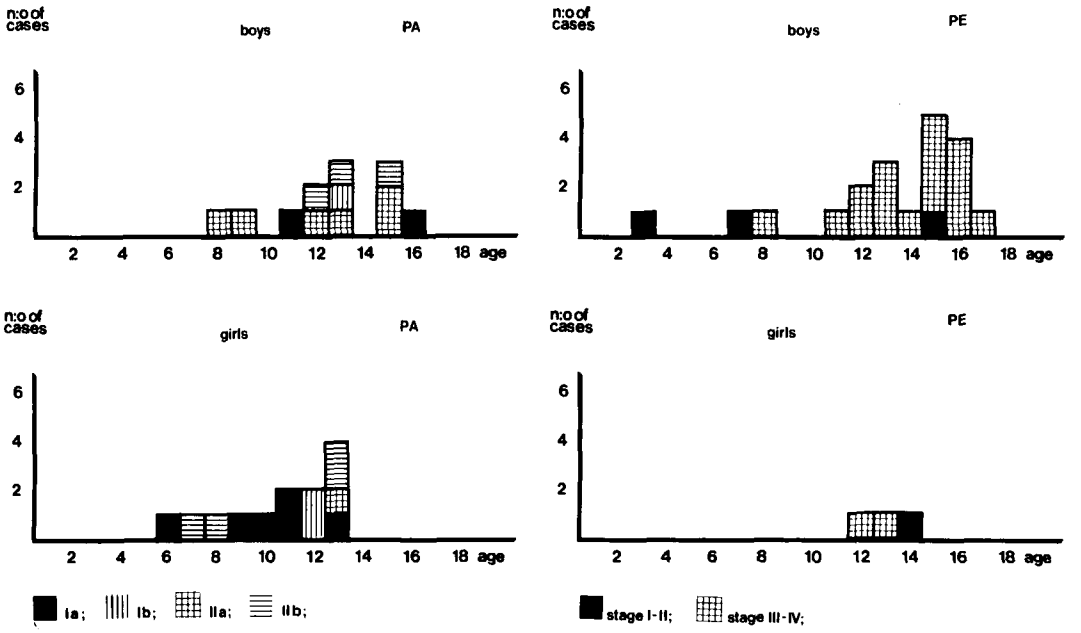


Figure 1. Distribution of pronation-abduction (PA) and pronation-eversion (PE) injuries in boys and girls with open growth plates.

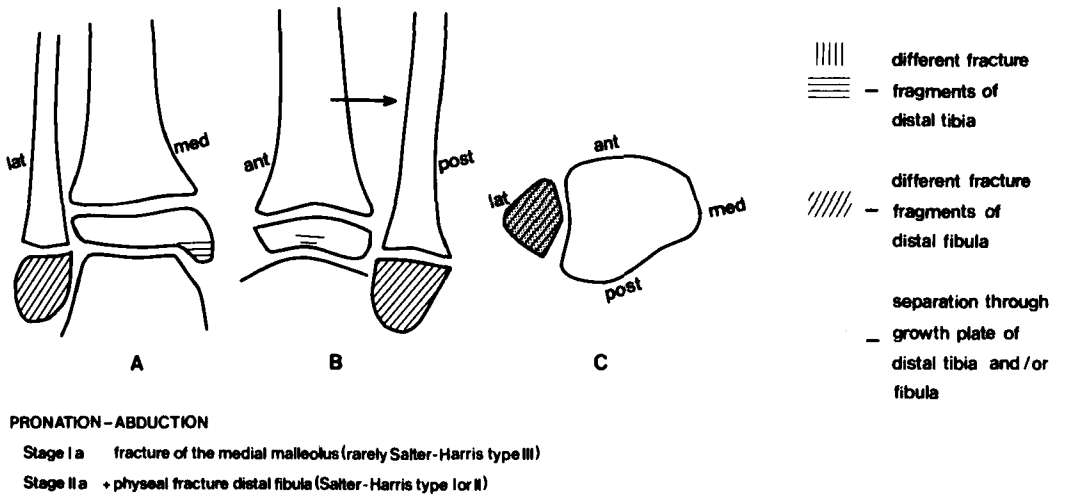
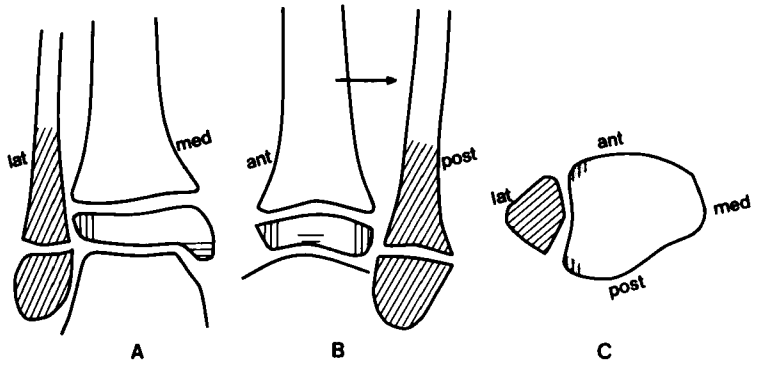


Figure 2. Schematic drawing of pronation-abduction stage I–II a injuries.

a transverse fracture of medial malleolus somewhat more proximally was found. One 13-year-old girl showed an oblique fracture engaging the medial part of the growth plate.

Figure 3. Pronation-abduction stage I a. a) AP. b) Lateral.



PRONATION – ABDUCTION, TRANSITIONAL FRACTURE PATTERN

Stage I	fracture of medial malleolus
Stage II	+ rupture of anterior and posterior tibio–fibular ligaments or epiphyseal tibial fractures (Salter–Harris type III)
Stage III	+ metaphyseal (or physeal) fibular fracture (Salter–Harris type I–II)

Figure 4. Schematic drawing of pronation-abduction injury stage I–III a (transitional type to adult pattern). For symbols see Figure 2.

Figure 5. Pronation-abduction stage III a (transitional type). Fracture during 1980 (not included in the material). a) AP: Lateral displacement of the talus. Fracture of the medial malleolus and the lateral tibial epiphysis verified at operation (third fragment of Tillaux). Fibular fracture. b) Lateral.

Plaster fixation was performed in all cases.

Stage II a (and III a) (in addition to the stage I injury; physeal fracture through the distal fibula) (Figures 2 and 4). According to Gerner-Smidt stage II a.

Distal tibia: Epiphyseal fracture, rarely Salter-Harris type III or detachment of the deltoid ligament.

Distal fibula: Salter-Harris type I or II.

Six boys, aged 8–15 years; one girl, 13 years.

According to Gerner-Smidt the second stage could be represented also as an epiphyseal fracture not engaging the growth plate or a rupture of the ligaments at the tip of the lateral malleolus. In the older child, the second stage, as in the adult, is represented as a rupture of the anterior and posterior tibio-fibular ligaments, sometimes visible on radiographs as small fragments at the antero-lateral and/or postero-lateral corner of the distal tibial epiphysis – third fragment of Tillaux (1892) (Figure 5a and b).

Two cases had a minimal fragment at the tip of the medial malleolus in combination with a fracture through the growth plate of the lateral malleolus; in one case, represented as a S-H type II injury with a lateral metaphyseal fragment. Two children had a transverse fracture at the medial malleolus; and two a more oblique fracture starting close to the growth plate in combination with a S-H type I injury through the distal fibula. Two of these children, a 15-year-old boy and a 13-year-old girl, had also a rupture of the anterior tibio-fibular ligament verified at operation.

One boy aged 15 years had a fracture at the tip of the medial malleolus and a metaphyseal fibular fracture; probably also a rupture of the tibio-fibular ligaments (no operation performed).

Open reduction was performed in two cases besides plaster fixation.

Stage I b (physeal separation through the distal tibia without meta- or epiphyseal fragment) (Figure 6). According to Gerner-Smidt stage I b.

Distal tibia: Salter-Harris type I.

Distal fibula: No injury.

One boy, 13 years old; two girls, both 12 years old.

These three injuries showed no, or almost no, displacement. The fractures were revealed radiographically 3–4 weeks after injury as a subperiostal metaphyseal callus formation laterally at the distal tibial metaphysis.

Plaster fixation was performed in all cases.

Stage II b (in addition to stage I metaphyseal fracture through the distal fibula) (Figure 6).

According to Gerner-Smidt stage II b.

Distal tibia: Salter-Harris type I.

Distal fibula: Metaphyseal fracture.

Three boys, 2–15 years old; four girls 7–13 years old.

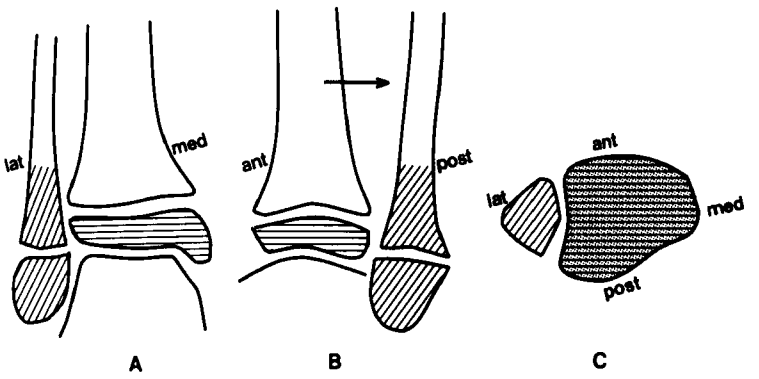


Figure 6. Schematic drawing of pronation-abduction stage I–II b. For symbols see Figure 2.

Figure 7. Pronation-abduction stage II b. a) AP: Lateral displacement. Widening of the physis medially. b) Lateral.

Transverse or oblique fracture through the metaphysis of the distal fibula in addition to the first stage. All patients had a transverse or sometimes oblique or/and comminuted fracture at the distal fibular metaphysis, in association with a S-H type I injury through the distal tibia (Figure 7 a and b).

Three cases were treated with closed reduction besides plaster fixation.

Pronation-eversion (PE): Stage I–II (physeal-metaphyseal fracture through distal tibia) (Figures 8, 9a and b). According to Gerner-Smidt stage I–II.
Distal tibia: Salter-Harris type II.
Distal fibula: No injury.
Three boys, 3–15 years old; one girl 7 years old.

Fracture through the growth plate of the distal tibia (stage I), with an antero-lateral metaphyseal fragment (stage II). According to Gerner-Smidt the first stage could be represented as a fracture through the medial malleolus, thus cannot be separated from pronation-abduction injuries stage I a.

All cases in this study showed an antero-lateral or lateral metaphyseal fragment with a height from 0.5–7 cm. The height of the metaphyseal fragment was about the same in all stages of pronation-eversion injuries.

Closed reduction was performed in one case with a stage I–II injury.

Stage III–IV (metaphyseal fibular fracture, small posterolateral metaphyseal fragment of distal tibia in addition to the I and II stage) (Figures 8, 10a and b). According to Gerner-Smidt stage III–IV.
Distal tibia: Salter-Harris type II.
Distal fibula: Metaphyseal fracture.
Fifteen boys, 8–16 years old; two girls, 12 and 13 years old.

This injury is characterised by a spiral, oblique,

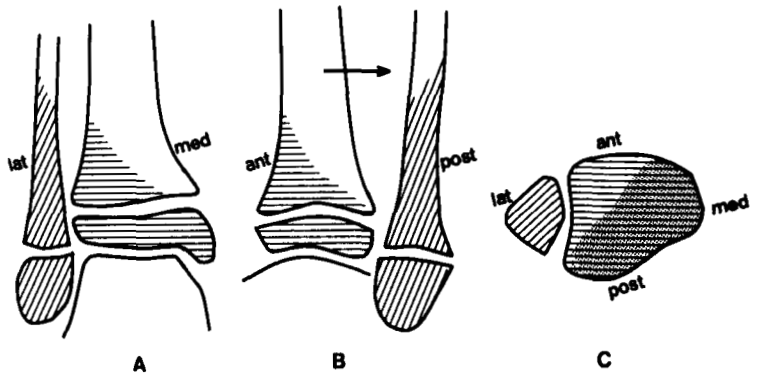


Figure 8. Schematic drawing of pronation-eversion stage I–IV. For symbols see Figure 2.

PRONATION – EVERSION

Stage I – II physeal – metaphyseal fracture distal tibia (Salter – Harris type II)

Stage III – IV + metaphyseal fibular fracture, postero – lateral metaphyseal fragment

or sometimes comminuted fracture of the distal fibula at the level of or above the tip of the metaphyseal fragment in the distal tibia (stage III) and detachment of the insertion of the posterior tibio-fibular ligament above the growth plate visible on radiographs as a postero-lateral fragment (stage IV).

In some cases the metaphyseal fragment ex-

Figure 9. Pronation-eversion stage II. a) AP: Lateral displacement. Widening of the physis medially. b) Lateral: Widening of the physis posteriorly.

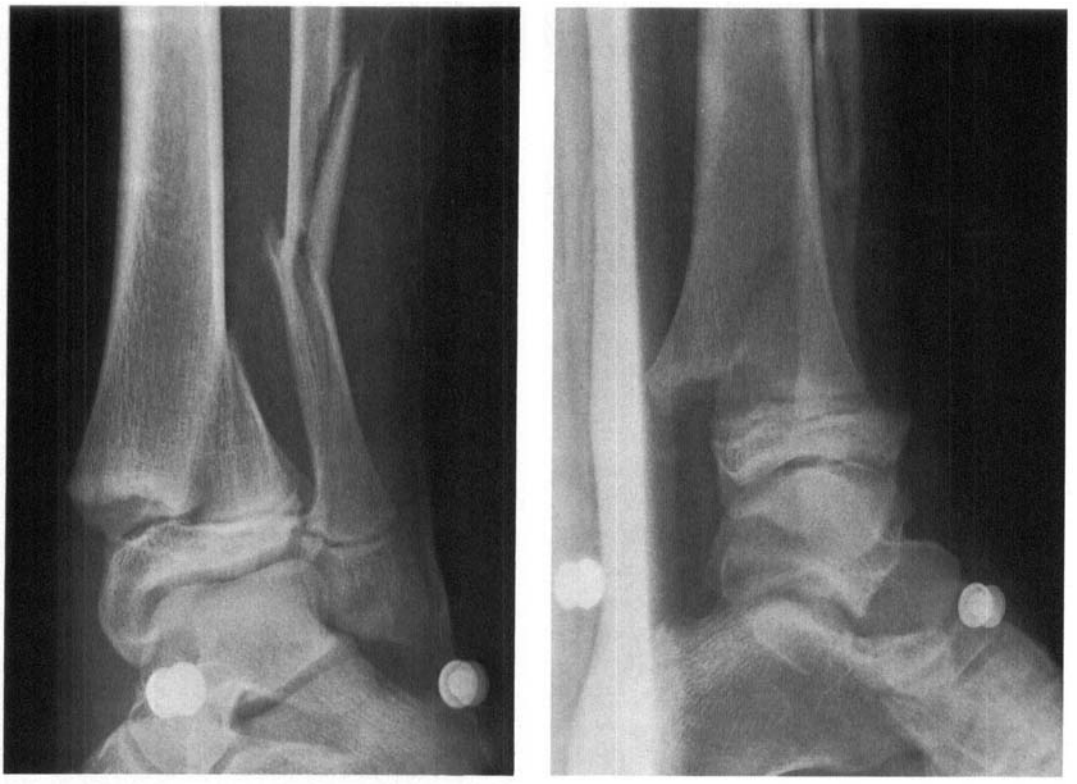


Figure 10. Pronation-eversion stage III–IV. a) AP: Lateral displacement. Fibular fracture. b) Lateral: Anterior displacement.

tended to the postero-lateral part of the distal tibia as a sign of a stage IV injury, but the distinction between the third and fourth stage could otherwise not be performed adequately; these two stages were considered as an entity. When displacement was found, the distal tibial epiphysis with the antero-lateral fragment was displaced antero-laterally.

Thirteen patients were treated with closed reduction.

Atypical fracture pattern:
Distal tibia: Salter-Harris type III or I + IV.
Distal fibula: metaphyseal fracture.
Two boys, 16 and 17 years old.

One boy showed a transverse fracture of the medial malleolus, a fracture through the antero-lateral corner of the distal tibial epiphysis (S-H type III), and a short spiral fracture 7 cm proximal to the distal end of the fibula. The fracture was treated with open reduction and fixation due to displacement.

The other boy showed a fracture through the growth plate of the distal tibia, a longitudinal fracture through the metaphysis, the growth plate, and the epiphysis separating the antero-lateral corner of the distal tibia; in addition, an oblique fracture through the metaphysis of the distal fibula. The antero-lateral tibial fragment constituting a part of the epiphysis, the physis, and the metaphysis was displaced antero-laterally. Treatment was performed with closed reduction (Figures 11, 12a and b).

Pronation-dorsal flexion (PD): Stage I–II (physeal-metaphyseal fracture of distal tibia) (Figure 13). According to Lauge-Hansen (1953) stage I–II.
Distal tibia: Salter-Harris type II.
Distal fibula: No injury.

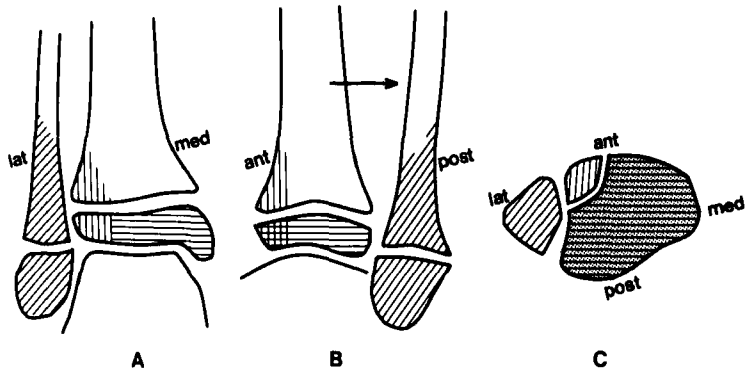


Figure 11. Schematic drawing of an atypical pronation-eversion injury. For symbols see Figure 2.

Two boys, 11 and 16 years old; one girl, 3 years old.

Fracture through the growth plate of the distal tibia with an anterior metaphyseal fragment.

Two children had a small anterior metaphyseal fragment (0.5 cm), the other had one somewhat larger (2.5 cm). Almost no displacement. Treatment was performed with plaster fixation in all cases.

Stage III (metaphyseal fibular fracture in addition to the I and II stage) (Figures 14a and b). According to Lauge-Hansen (1953) stage III.

Figure 12. Atypical fracture of pronation-eversion type. a) AP oblique view: Lateral epi-metaphyseal fragment and lateral displacement of tibial epiphysis. b) Lateral: Anterior epi-metaphyseal fragment and the remaining part of the epiphysis displaced anteriorly.

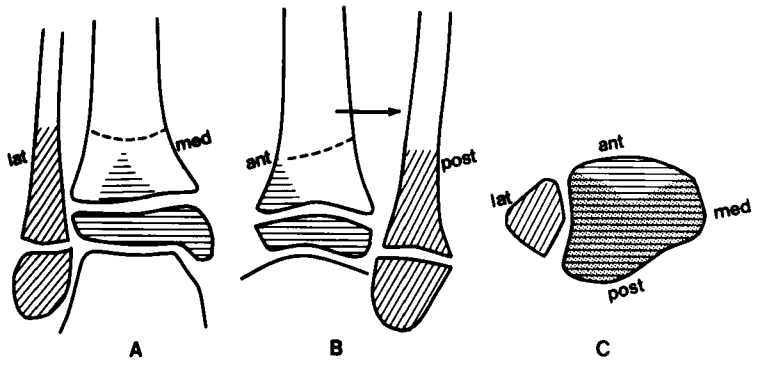


Figure 13. Schematic drawing of pronation-dorsal flexion injury. For symbols see Figure 2.

PRONATION-DORSAL FLEXION

Stage I–II physeal–metaphyseal fracture distal tibia

Stage III + metaphyseal fracture distal fibula

(Stage IV + transverse metaphyseal tibial fracture indicated by a dashed line)

Distal tibia: Salter-Harris type II.
Distal fibula: Metaphyseal fracture.
One boy, 14 years old.

Figure 14. Pronation-dorsal flexion stage III. a) AP: Transverse fracture of the fibular metaphysis (arrow). No obvious fracture of the distal tibia. b) Lateral: Anterior metaphyseal fragment attached to the epiphysis (arrow). Minimal anterior displacement.

Oblique or transverse fracture through the metaphysis of the distal fibula. This patient showed a Salter-Harris type II injury of the distal tibia with an anterior metaphyseal fragment with a height of 2 cm and an oblique fracture through the metaphysis of the distal fibula. No displacement. Plaster fixation was performed.

Closed growth plates

Patients with closed growth plates were classified according to Lauge-Hansen (1942). However, it is impossible to separate stage I pronation-abduction and pronation-eversion injuries from each other. This applies also to the stage II injuries as a rupture of the posterior tibio-fibular ligament is routinely not visualized during the operation. Thus, in this study, the stage I and stage II pronation-abduction and pronation-eversion injuries were not separated from each other.

Pronation-abduction and pronation-eversion

Stage I: seven boys aged 15–17 years; 10 girls aged 13–18 years.

Stage II: three boys aged 15–17 years; two girls aged 14–16 years.

Pronation-abduction stage III: three boys aged 15–16 years; two girls aged 16 and 17 years.

Pronation-eversion stage III–IV: three boys aged 15–17 years; one girl aged 16 years.

All except five stage I injuries were treated with open reduction and fixation. All had plaster fixation for 5–7 weeks.

Sex and age distribution (Tables 3 and 4)

The average age for boys and girls with different types of injury and different stages was evaluated with Student's t-test. The distribution of boys and girls between different stages and types was evaluated with Fisher's exact test. The distribution of boys and girls with pronation-abduction and pronation-eversion injuries was evaluated with χ^2-test.

The average age for girls with pronation-abduction injury was less than for boys ($P < 0.05$). The stage I a injury was proved more common in girls than in boys, whereas the stage II a injury was more common in boys ($P < 0.05$).

The average age for girls with PE-injuries showed no statistical differencies compared with boys. However, pronation-eversion injuries were more common in boys than in girls compared with pronation-abduction injuries ($P < 0.05$). The present material was not selected from a defined population, which is important when interpreting the significant differences.

DISCUSSION

Ankle fractures in children show certain characteristics enabling a traumatological classification. Besides the earlier mentioned classifications (Lauge-Hansen 1942, 1953, Carothers & Crenshaw 1955, Gerner-Smidt 1963, Diaz & Tachdjian 1978) Bartl (1954) described an injury of the distal tibia (S-H type II) but with a postero-lateral metaphyseal fragment interpreted as a pronation-rotational injury. Ehalt (1961) and Titze (1967) described four types of pronation injuries all with a transverse fracture of the medial malleolus, one of these of transitional type between child and adult pattern. Transitional fractures of pronation-abduction and pronation-eversion type were also found in this study; was earlier found of supination-eversion type by Gerner-Smidt (1963) and Kärrholm et al. (1982a).

The frequency of each type of pronation injury is small and the pronation-dorsal flexion injury is rare. The frequency of pronation injuries in this material was 18%; in children with open growth plates 15%. Gerner-Smidt (1963) reported a lower frequency (if ligamentous injuries were included), and a higher frequency if only fractures are considered in children 0–16 years of age. The number of boys with PE injuries was higher than the number of girls, compared with the distribution of SE injuries, as was earlier found by Gerner-Smidt. He also found a dominance of boys among the PA injuries (28/15), whereas the total number PA injuries in this material was fairly equally distributed. The dominance of boys suffering a stage II a injury could indicate that

boys more often suffer a high energy trauma and a higher stage, as found among supination-eversion injuries (Kärrholm et al. 1982a).

The PA stage I a injury usually does not engage the growth plate. No or minimal problems (Gerner-Smidt 1963) are reported in the literature. Ehalt (1961) reported one case of delayed union after a fracture of the medial malleolus, but according to Blount (1955) pseudarthrosis is not encountered in children with malleolar fractures. Fracture of the medial malleolus can be due to pronation-eversion and also pronation-abduction, which can partly explain the high frequency of fractures of the medial malleolus, especially of adult type as found in this material.

The PA injuries stage II a showed a S-H type I or type II injury of the distal fibula. According to Gerner-Smidt (1963), the second stage could be present as a transverse fracture of the distal fibular epiphysis or ligamentous injuries at the tip of the lateral malleolus but was not found in this material. However, the separation between pronation-abduction stage II a injuries and supination-adduction stage II can be difficult when no or minimal displacement is present.

The PA stage I b injury with a S-H type I injury through the distal tibia shows difficulties in radiographical diagnosis when non-displaced as the fibular injury in the PA stage II a injury. In this study, the radiographical diagnosis of PA stage I–II b injuries was set in some cases first at control examination some weeks after injury. Undisplaced physeal fractures of Salter-Harris type I in the distal tibia can also be revealed by scintimetry 1–2 weeks after fracture (Neugebauer et al. 1981).

According to this study, isolated Salter-Harris type I injuries of the distal tibia are rare (3 out of 363 cases). Gerner-Smidt (1963) found only two cases and believed that the first and second stages were produced almost simultaneously, as was later suggested by Diaz & Tachdjian (1978) concerning injuries due to pronation-eversion. However, as earlier stressed radiographical diagnosis of the PA stage I b injury is difficult initially, and this injury might be more common than found in this material. Bartl (1957) found 37% (87/232) Salter-Harris type I through distal tibia, but does not mention the number of type I injuries without fibular fracture. The large total frequency of type I injuries through distal tibia could possibly be because injuries with minimal posterior or antero-lateral fragment were included; injuries that in this material have been classified as due to supination-eversion (Kärrholm et al. 1982a) or pronation-eversion.

Usually, the trauma producing a S-H type I injury of distal tibia is an abduction force to the foot in the position of pronation (Gerner-Smidt 1963). However, solitary cases of a rotatory injury with the fibula fixed behind the tibia in association with a physeal fracture through the distal tibia have been described by some authors (Lovell 1968, Duran et al. 1977, Nevelös & Colton 1977, Henke & Kiple 1979) and was experimentally produced by Brock & Greer (1970) after transverse incision through the growth plate of the distal tibia. It is not known whether there exists a rotatory fracture of Salter-Harris type I in the distal tibia without fibular injury or displacement.

PE injuries in this material always showed an anterior or antero-lateral displacement, contrary to the statement by Diaz & Tachdjian (1978) who reported a lateral or posterolateral displacement. Gerner-Smidt (1963) regarded the PE and the PD injuries as closely related concerning the genesis of production. According to Lauge-Hansen (1953) the anterior metaphyseal fragment in the pronation-dorsal flexion injury should be large, but this study found mainly small fragments. The PD injury according to Lauge-Hansen (1953) is extra-articular. However, high energy trauma of PD type can produce an intra-articular injury, as described by Duran et al. (1977); a similar injury classified as PE stage IV was found in this material, but without total displacement of the talus.

Open reduction of medial malleolar fractures of pronation type was recommended by Ehalt (1961) because of risk for pseudarthrosis and by Titze (1967) in cases with periosteal interposition. In large materials (Bartl 1957, Gerner-Smidt 1963, Spiegel et al. 1978) all comparable injuries were treated without surgical intervention. The fracture of the medial malleolus is intra-

a b

Figure 15. Pronation-eversion stage III–IV. After closed reduction: a) AP: Small displacement. b) Lateral: Anterior displacement. Five weeks after fracture: c) AP: Callus. Valgus position. d) Lateral: Anterior displacement. Five years after fracture: e) AP: Synostosis between tibia and fibula. Lengthening of the tibia of about 1 cm compared with the intact side. No differences in length between right and left fibula. Thus relative shortening of the fibula seemingly displaced upwards. No obvious valgus deformity. f) Lateral: No obvious recurvation.

articular and a displacement exceeding 2 mm should be reduced to avoid secondary arthrosis.

The PE injuries showed a high frequency of displacement in this material. These children had often suffered a high energy trauma. Moreover, the PE stage III–IV injuries showed the highest frequency of closed reduction of all ankle injuries. Thus, these injuries were more frequently treated with some kind of reduction than the supination-eversion (including the intra-articular type) and supination-adduction injuries (Kärrholm et al. 1982a, b). Gerner-Smidt (1963) reported a large frequency of displaced PE injuries: 16 treated with closed reduction, one with open reduction out of 21 PE stage III–IV injuries and in 12 patients, the displacement was less than 2 mm after reduction. This study had 14 patients treated with closed and one with open reduction out of 19 PE III–IV injuries. After reduction seven patients showed a displacement less than 2 mm, seven showed a displacement between 2 and 5 mm, mainly about 3 mm, but in one case it amounted to about 5 mm. The patient treated with open reduction showed almost no remaining displacement.

Süssenbach & Weber (1970) treated these injuries with open reduction because of periosteal interposition and noted a metaphyseal deformity (Weber & Süssenbach 1978) visible on radiographs medially and interpreted as a residue after periosteal interposition. One boy in this study with a PE stage III–IV injury developed another type of deformity, not previously reported; a synostosis between the tibia and fibula at the level of the fibular fracture and a post-traumatic growth stimulation resulting in a lengthening of tibia distal to the tibio-fibular synostosis at follow-up 5½ years after fracture (Figure 15a–f).

d

Figure 15c

The most common S-H type II injury of the distal tibia is produced by supination-eversion (Kärrholm et al. 1982a). The second most common is due to pronation-eversion. These injuries can be separated by different localization of metaphyseal fragment and different displacement. The PE injuries are more often displaced, indicating that they are probably produced by a high energy trauma. The type of reduction differs from the SE injuries, and the risk of periosteal interposition (Olerud & Reuterskiöld 1971), making reduction more difficult, is probably higher. Moreover, the PE injuries show a different post-traumatic growth pattern with a tendency to varus deformity of the ankle joint (Kärrholm et al. 1982c). The PA injuries with no or minimal displacement often show diagnostic problems, as found in this study; those PA stage II b injuries that were followed up have shown a remaining valgus position of the ankle probably due to asymmetrical growth.

In conclusion, this study and earlier (Gerner-Smidt 1963, Kärrholm et al. 1982a, b) have shown that the traumatological classification facilitates the diagnosis and treatment and indicates possible complications such as growth dis-

Figure 15e *f*

turbance, redislocation (Bartl 1957, Gerner-Smidt 1963, Kärrholm et al. 1982c), and/or joint incongruity.

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