2 Differential Diagnosis of Single Skeletal Defects

Introduction

This section focuses on the radiographic differential diagnosis of single defects of the fetal skeleton. Complying with the character of this book as a radiographic tool, the number of conditions in the differential lists has been limited in two ways:

1. The disorder should have at least one radiographic sign in addition to the key feature, thus allowing one to make a diagnosis or suspect a diagnosis by radiographic analysis alone. For instance, the combination of an amputated limb with anencephaly – both recognizable on a fetogram – leads to a diagnosis of the ADAM complex. On the other hand, isolated vertebral segmentation defects in the upper thoracic spine without additional radiographic findings are relatively unspecific and can be seen in a great number of disorders. As radiology does not help in the differential diagnostic process, these isolated defects have not been included.
2. The disorder should be relatively common, i.e., have an entry in the OMIM database. Isolated case reports without an OMIM number have not been included in the differential diagnostic lists. Comprehensive lists of all possible disorders associated with a given defect are available in databases such as POSSUM or the London dysmorphology databases.

The radiodiagnostic process requires the complete and thorough analysis of the available radiographs. Form, size, position, proportions, structure, and maturational status of all skeletal elements must be scrutinized. Soft tissue changes must be recorded. A pattern of findings may emerge from which a key skeletal feature is selected. Consulting the subsection devoted to this key feature, a diagnosis may emerge from a match between the given and a listed pattern. The presence of widespread, often symmetric, skeletal abnormalities raises the possibility of a generalized skeletal dysplasia (see Chap. 3). Tables in the appendix simplify this approach.

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Limbs

Amelia – Amputation – Phocomelia

Definition

- Amelia: no formation of extremity
- Amputation: transverse terminal defects of limb (**Fig. 2.1**)
- Phocomelia: band-like transverse or segmental defects within a limb (**Fig. 2.2**)

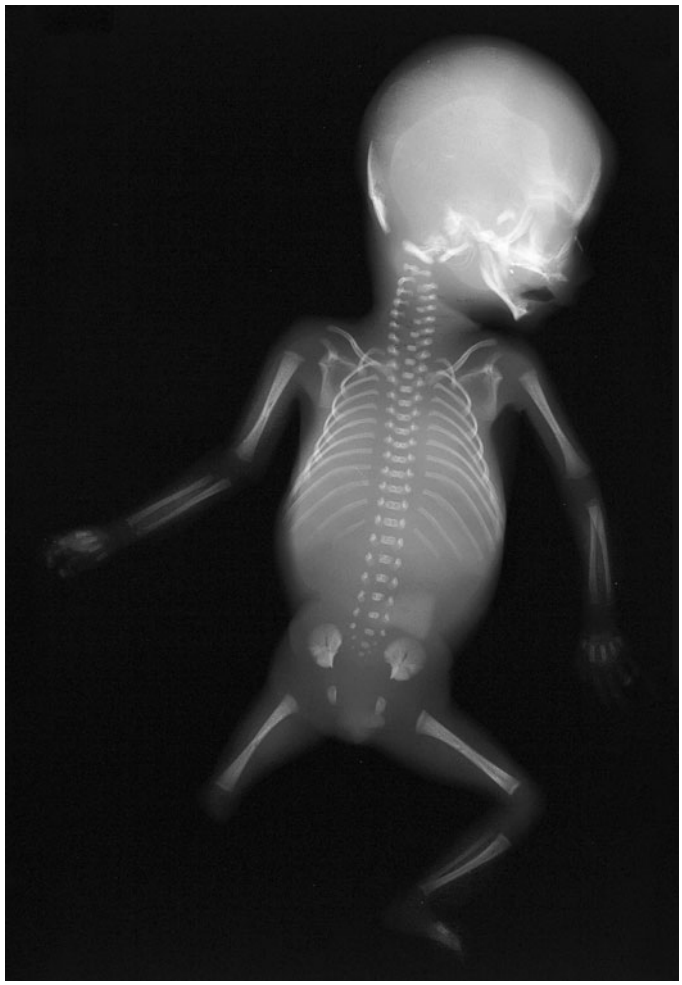

Fig. 2.1. ***18th gestational week.*** Amputation of the right shank in amniotic disruption sequence, otherwise normal skeleton

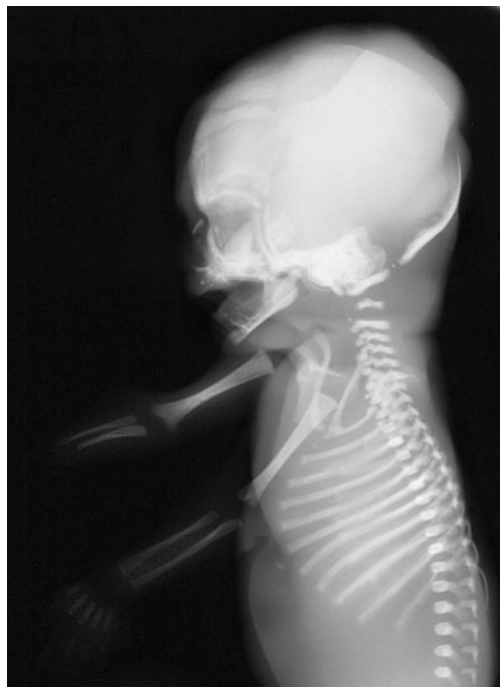

Fig. 2.2. ***23rd gestational week.*** Phocomelia of the left forearm with tiny fingers and a few dot-like phalangeal ossification centers

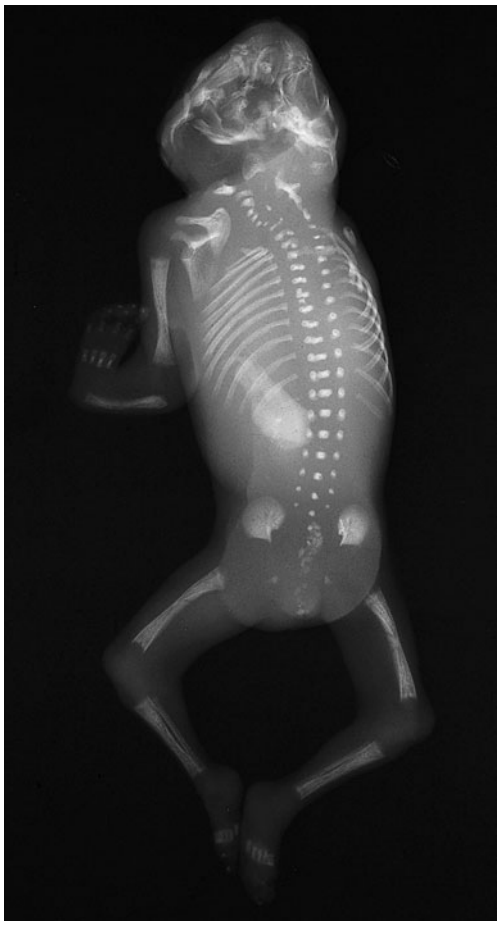

Fig. 2.3. ***15th gestational week.*** Amputation of the left arm in ADAM complex. Aplasia of the right radius and thumb; anencephaly, duplication of right scapula, hypoplastic clavicle

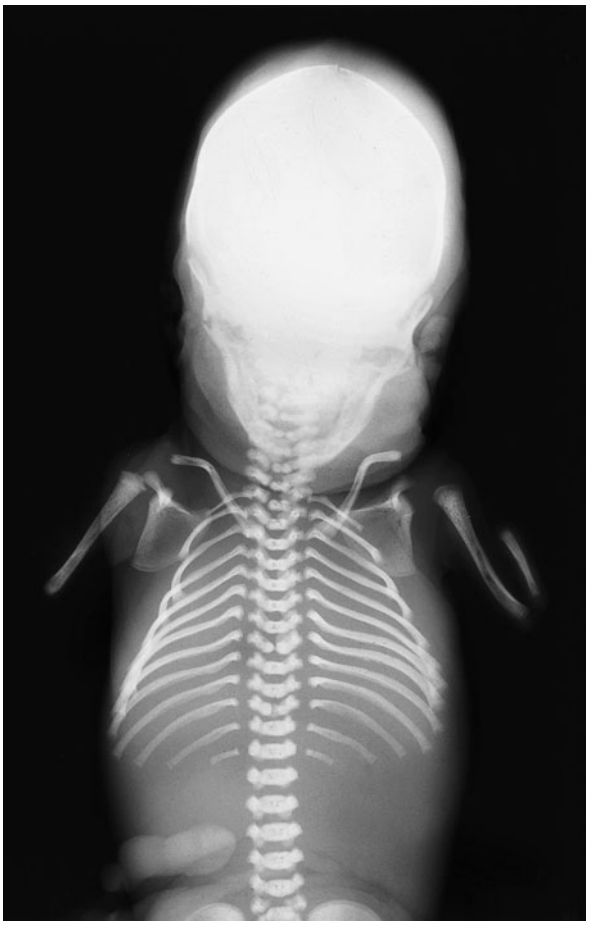

Fig. 2.4. ***27th gestational week.*** Asymmetric reduction defects of the forearms in oromandibular-limb hypogenesis syndrome. Hypoplasia of humeri. Sagittal clefts of the vertebral bodies of D8 and D11. Thirteen pairs of ribs

Diagnosis	Accessory radiological findings in the fetus
Acrofacial dysostosis, type Rodriguez [1] MIM 201170	Phocomelia of arms, defective ulnar ray, short humerus and fibula, hypoplastic scapula
Amelia, autosomal recessive [2] MIM 601360	Amelia of upper limbs and terminal transverse defect through femora, micrognathia
Amnioic band/disruption sequence ADAM complex *(Amniotic* Deformity, Adhesions, Mutilations); **Fig. 2.3** Limb-bodywall complex [3] MIM 217100	Terminal limb defects, constriction bands, distal lymphedema, different degree of mutilations, craniofacial clefts, ectopia cordis, cephalocele/anencephaly, body wall defects
Diabetic embryopathy [4]	Caudal regression, segmentation defects of the spine, defects of ulna and tibia, femoral aplasia
DK phocomelia [5] von Voss-Cherstvoy syndrome MIM 223340	Microcephaly; upper limb anomalies: absent or hypoplastic humerus, radius, ulna, metacarpals, thumb; oligodactyly; syndactyly of fingers
Disorganisation-like syndrome [6] MIM 223200	Anencephaly, asymmetry, pre-/postaxial polydactyly, lower limb aplasia/duplication

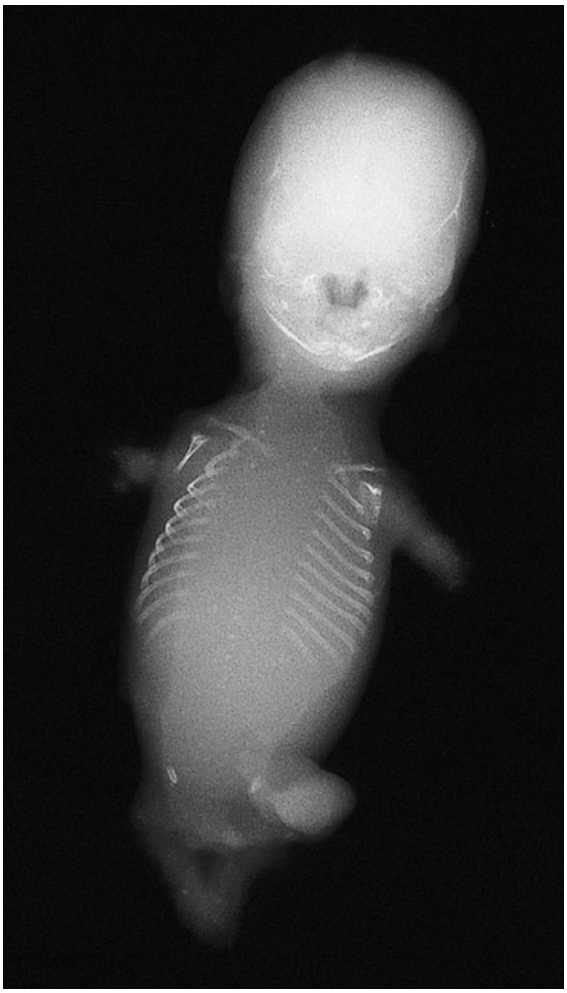

Fig. 2.5. ***10th gestational week.*** Short limbs. Roberts syndrome. Absent ossification of most tubular bones and age related absent ossification of the vertebrae

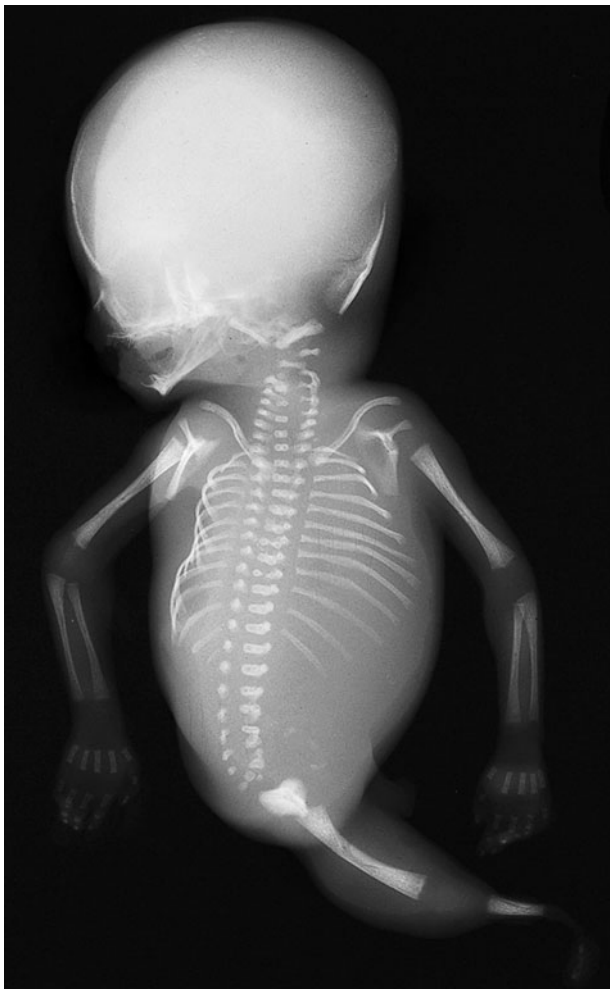

Fig. 2.6. ***19th gestational week.*** Monopodic sirenomelia. Pelvic fusion, sagittal cleft defects of the thoracic vertebral bodies. Accessory rib on the right at L1

Diagnosis	Accessory radiological findings in the fetus
Femur-Fibula-Ulna complex (FFU-syndrome) [7] MIM 228200	Asymmetric absent upper and/or lower limbs, phocomelia, absent or hypoplastic femur, fibula, ulna, humero-ulnar/-radial synostosis, oligodactyly.
Limb/pelvis hypoplasia/aplasia syndrome Includes: Schinzel phocomelia [8] MIM 268300 AL-Awadi/Raas-Rothschild syndrome [9, 10] MIM 276820 Fuhrmann syndrome MIM 228930	Variable and possibly asymmetric lower limb deficiency including primarily femur, tibia and fibula; absent toes; upper limb defects including absent/hypoplastic radius, ulna; radio-humeral synostosis; abscence of carpals, metacarpals, and phalanges; hypoplastic pelvis including irregular pubis, ischium; hip dislocation; thoracic involvement including wide or fused ribs, pectus carinatum
Oromandibula-limb hypogenesis syndromes (incl. Hanhart syndrome) [11] MIM 103300 **Fig. 2.4**	Nearly symmetric terminal limb reduction anomalies, micrognathia, hypoglossia
Roberts (pseudothalidomide) syndrome [12] MIM 268300 **Fig. 2.5**	Tetraphocomelia, severe limb shortening, radial defects, oligodactyly, nuchal cystic hygroma, cleft palate, sometimes craniostenosis

Diagnosis	Accessory radiological findings in the fetus
Sirenomelia [13] (part of caudal regression sequence); MIM 182940 **Fig. 2.6**	Fusion and varying degrees of hypoplasia of lower extremities; pelvic bone fusion; fusion of femurs, sometimes both tibiae and fibulae rotated by 180 degrees (see Fig. 2.38), spinal segmentation anomalies, bladder exstrophy, meningomyelocele, hypoplastic/absent radius
Splenogonadal fusion – limb defects [14] MIM 183300	Micrognathia, caudal regression, spinal dysraphism, transverse limb reduction with or without digits
Tetraamelia with multiple malformations [15] MIM 301090	Anencephalus, hydrocephalus, facial cleft, segmentation defects of spine, aplasia of pelvic bones, severe reduction defects of upper and lower limbs, no digits; other defect: anal atresia
Thalidomide embryopathy [16]	Amelia, proximal phocomelia, fingers present, often attached directly to the shoulders
Thrombocytopenia-absent radius (TAR) syndrome (severe form) [17] MIM 274000	Bilateral severe phocomelia of the upper limbs with hands, including thumbs, attached to the shoulders
Vacterl association [18] MIM 192350	Acronym of associated malformations: *V*ertebral malsegmentation, *a*nal atresia, *c*ardiac malformation, *t*racheoesophageal fistula, *e*sophageal atresia, *r*adial/*r*enal anomalies, *l*imb anomalies (absent upper limb, ray defects such as hypoplasia of fibula, tibia, aplasia of metatarsals, oligo-/preaxial polydactyly of fingers)

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Radius and/or Thumb: Aplasia, Hypoplasia [1]

Entities with isolated aplasia of the radius or radial ray without other radiological apparent defects are not listed.

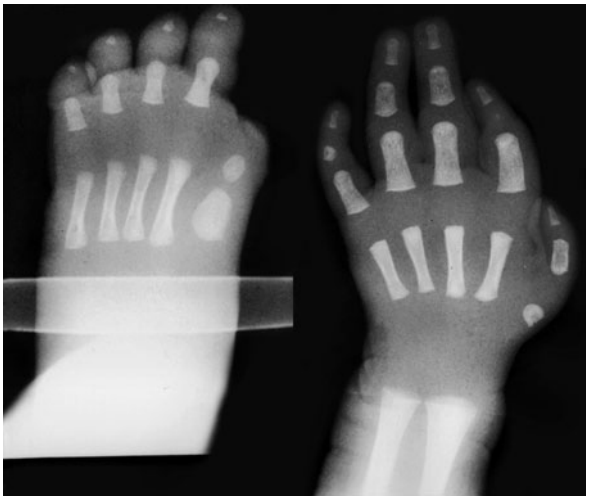

Fig. 2.7. ***Newborn.*** Isolated hypoplasia of metacarpal and phalanges of thumb; Brachymesophalangy II and V. Hypoplasia of metatarsal and aplasia of terminal phalanx of hallux in fibrodysplasia ossificans progressiva

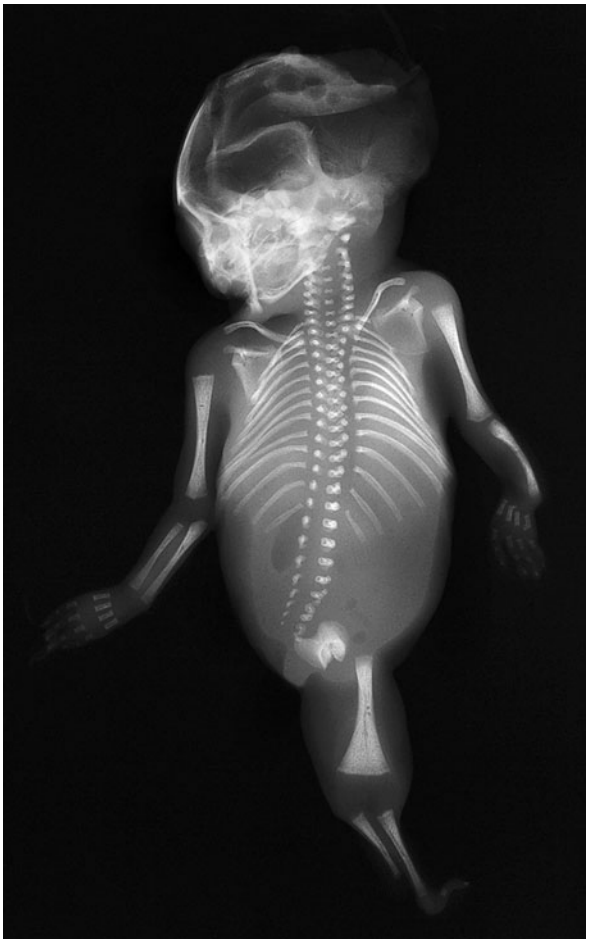

Fig. 2.8. ***19th gestational week.*** Dipodic sirenomelia. Aplasia of the thumb in both hands, aplasia of the left radius, 13 pairs of ribs, and accessory cervical ribs. Fusion of femora, aplasia of fibulae, hypoplastic tibiae. (Postmortem laceration of the neurocranium)

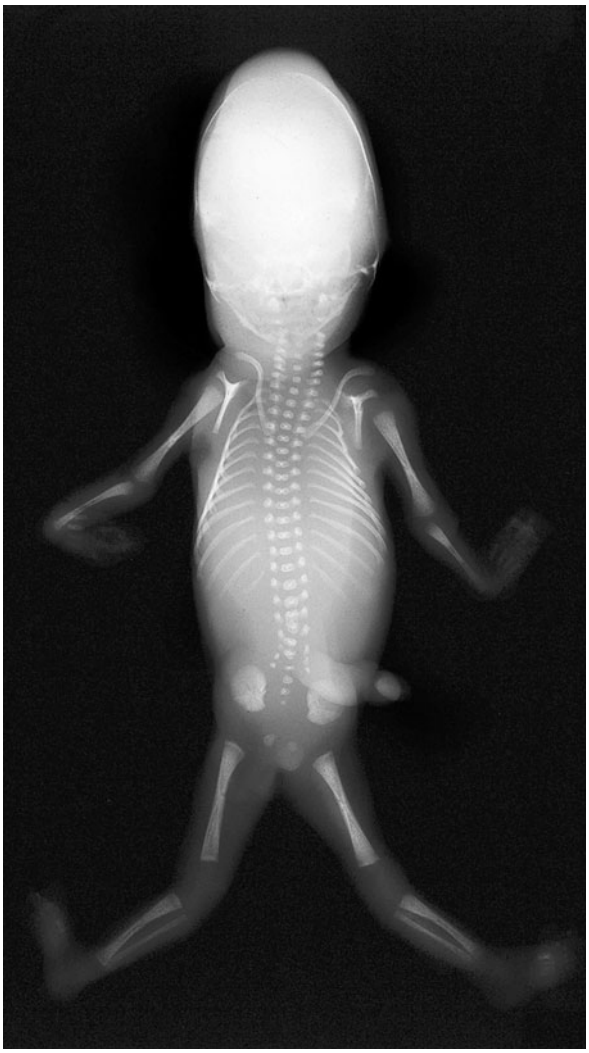

Fig. 2.9. ***18th gestational week.*** Aplasia of radius on both sides in VACTERL association. Segmentation defects of the lumbar and sacral vertebrae. Vertebral fusion. Hyperextended knees are a sequelae of intrauterine malposition due to anhydramnios. Asymmetric shape and narrow position of the ischia suggest an underlying urethral pathology – see "Pelvic-Sacral Abnormalities". Other findings: esophageal atresia Vogt II; urethral atresia; multicystic, dysplastic horseshoe kidney

Diagnosis	Accessory radiological findings in the fetus
Aase syndrome [2] MIM 205600 Blackfan-Diamond syndrome [3]	Radio-ulnar synostosis
Acrofacial dysostosis, type Rodriguez [4, 5] MIM 263750	Micrognathia, forearm anomalies mostly on the radial side, short forearm, radio-ulnar synostosis, preaxial polydactyly, fibular hypoplasia
Amniotic band/disruption sequence ADAM complex (Amniotic Deformity, Adhesions, Mutilations) [6] Limb-body wall complex MIM 217100	Terminal limb defects, constriction bands, distal lymphedema, different degree of mutilations, craniofacial clefts, ectopia cordis, cephalocele/anencephaly, body wall defects
Baller-Gerold Syndrome [7] MIM 218600	Asymmetric radial defect; shortened, bowed ulna; variable premature craniosynostosis; preferable coronal suture
Brachmann-de Lange Syndrome [8] MIM 122470	Primordial dwarfism; hand with ray reduction, mainly ulnar aplasia

Diagnosis	Accessory radiological findings in the fetus
Cerebro-cardio-radio-rectal community [9] MIM 223340 Overlap with VATER + hydrocephalus Association	Microcephaly, absent or hypoplastic humerus, radius, ulna, metacarpals, thumb; oligodactyly; syndactyly of fingers
Chromosome abnormality Trisomy 18 (Edwards' disease) [10]	Slender ribs (11 pairs), vertical iliac bones, limb reduction, radioulnar synostosis, rocker-bottom foot, typical flexion deformity of fingers and overlapping of 2nd finger (see Fig. 2.41b,c), omphalocele
Chromosome 13 q- syndrome [11] see Fig. 2.32	Growth retardation, absent thumb, proximal synostosis of metacarpals/tarsals 4 and 5
Duane anomaly-radial defects [12] MIM 126800	Fusion of verteba, hypolplastic or absent fibula
Fanconi pancytopenia [1] MIM 227650 Thrombocytopenia-absent radius (TAR) syndrome [1] MIM 274000	Range from aplastic thumb to duplication Bilateral aplasia of radius but present thumbs
Fetal valproate syndrome [13, 14]	Prominent metopic ridge, bifrontal narrowing, clinodactyly, distal phalangeal hypoplasia, absent or hypoplastic radius, absent or hypoplastic thumb, talipes equinovarus
Fibrodysplasia ossificans progressiva [15] MIM 135100 **Fig. 2.7**	Isolated aplasia/hypoplasia of metacarpal and phalanges of thumb and metatarsal and phalanges of hallux
Fryns syndrome – acral defects [16] MIM 229850	Distal ray hypoplasia; other finding: diaphragmatic hernia
Goldenhar syndrome (oculo-auriculo-vertebral dysplasia) [17] MIM 164210 see Fig. 2.33	Sporadic, unilateral malformation syndrome of the first and second branchial arches (hypoplastic mandible and maxilla), vertebral anomalies, radial hypoplasia
Holt-Oram (cardiomelic) syndrome [1] MIM 142900	Triphalangeal thumb, radio-ulnar synostosis, absent radius, absent ulna, hypoplastic humerus
Mesomelic dyspiasias [18] see p. 173 ff	Symmetric mesomelic (forearm, shank) shortening of the extremities, different types
MURCS association [19] MIM 601076 see Fig. 2.35	Acronym of associated malformations: Mullerian duct aplasia/hypoplasia, renal aplasia/ectopia, cervical somite (spinal) dysplasia; upper limb defects
Nager acrofacial dysostosis [20] MIM 154400	Forearm anomalies, aplasia/hypoplasia on the radial side, radio-ulnar synostosis, micrognathia
OPD II (oto-palato-digital syndrome II) [21] See p. 136 MIM 304120	Curved long bones, wavy ribs, platyspondyly, omphalocele, overlapping of 2nd finger (trisomy 18-like; see Fig. 2.41b,c) narrow pelvis
Poland syndrome [22] MIM 173800	Different degrees of finger and radius defects, vertebral anomalies; other defect: aplasia of pectoralis muscle
Roberts (pseudothalidomide) syndrome [23] MIM 268300 see Fig. 2.5	Tetraphocomelia, severe limb shortening, radial and ulnar defects, oligodactyly, nuchal cystic hygroma, sometimes craniostenosis
Sirenomelia [24] (part of caudal regression sequence); MIM 182940 **Fig. 2.8**	Fusion and varying degrees of hypoplasia of lower extremities, pelvic bone fusion, fusion of femurs; overlap with VACTERL association
VACTERL Association [1] MIM 192350 **Fig. 2.9**	Acronym of associated malformations: *V*ertebral malsegmentation, *a*nal atresia, *c*ardiac malformation, *t*racheoesophageal fistula, *e*sophageal atresia, *r*adial/*r*enal anomalies, *l*imb anomalies (ray defects such as hypoplasia of fibula, tibia, aplasia of metatarsals, oligo-/preaxial polydactyly of fingers)
XK-aprosencephaly [25] MIM 207770	Anencephaly, absent radius, radio-ulnar synostosis

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Radio-ulnar Synostosis (Fig. 2.10)

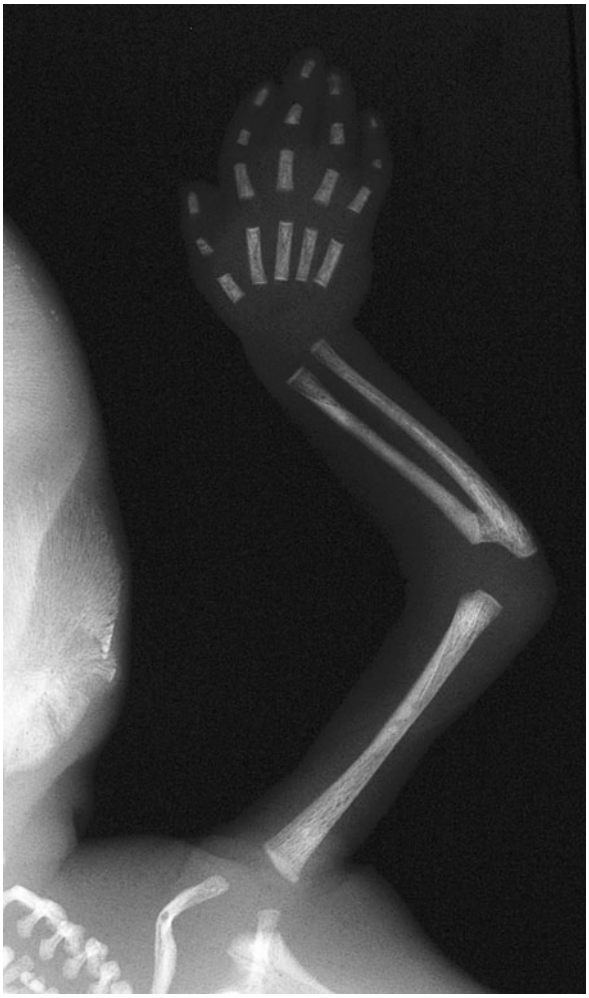

Fig. 2.10. ***19th gestational week.*** Radioulnar synostosis in Triploidy. Bone bridge between the proximal parts of radius and ulna

Diagnosis	Accessory radiological findings in the fetus
Aase syndrome [1] MIM 205600 Blackfan-Diamond syndrome [2]	Triphalangeal thumb, duplication of thumb
Antley-Bixler syndrome MIM 207410 see p. 126	Craniosynostosis, multiple synostoses.
Cenani-Lenz syndrome [3] MIM 212780	Extensive phalangeal synostosis and proximal metacarpal fusion; oligodactyly; thoracic hemivertebrae
Cloverleaf skull – limb anomaly, type Holtermüller-Wiedemann [4] MIM 148800	Trilobed skull deformity (congenital cranial synostosis), ankylosis of elbow
Chromosome abnormality Trisomy 18 [5]	Slender ribs (11 pairs), vertical iliac bones, rocker-bottom foot, hypoplasia of first metacarpal, typical flexion deformities and overlapping 2nd finger (see Fig. 2.41b,c), omphalocele, limb reduction

Diagnosis	Accessory radiological findings in the fetus
Chromosome (Sex-) abnormality Klinefelter syndrome [6]	No specific radiologic signs in the fetus
Ectrodactyly AD [7] MIM 183600, 600095 Ectrodactyly AR [7] MIM 225300	Cleft hand/foot, reduction deformity of arms or legs, triphalangeal thumbs
Fetal alcohol syndrome [8]	Intrauterine growth retardation, vertebral segmentation defects, Klippel-Feil syndrome, reduction deformity of upper extremities, hypoplasia! aplasia of ulna, tetradactyly; clubfoot
Genitopatellar syndrome [9] MIM 606170	Dislocation of hip, hypoplasia of ischia and pubic rami, brachydactyly
Holt-Oram syndrome (cardiomelic syndrome) [10] MIM 142900	Triphalangeal thumb, hypoplastic/absent radius, hypoplastic/absent ulna, hypoplastic humerus
Larsen syndrome MIM 150250, 245600 see p. 161	Multiple luxations of great joints, especially of hips, knees, elbows, coronal vertebral cleft
Nager acrofacial dysostosis [11] MIM 154400	Forearm anomalies: aplasia/hypoplasia on the radial side, radio-ulnar synostosis; micrognathia
Radio-ulnar synostosis, autosomal dominant [12] MIM 179300	Bilateral or single-sided proximal synostosis
XK-aprosencephaly [13] MIM 207770	Anencephaly, absent/hypoplastic thumb and radius,

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Ulna: Aplasia, Hypoplasia

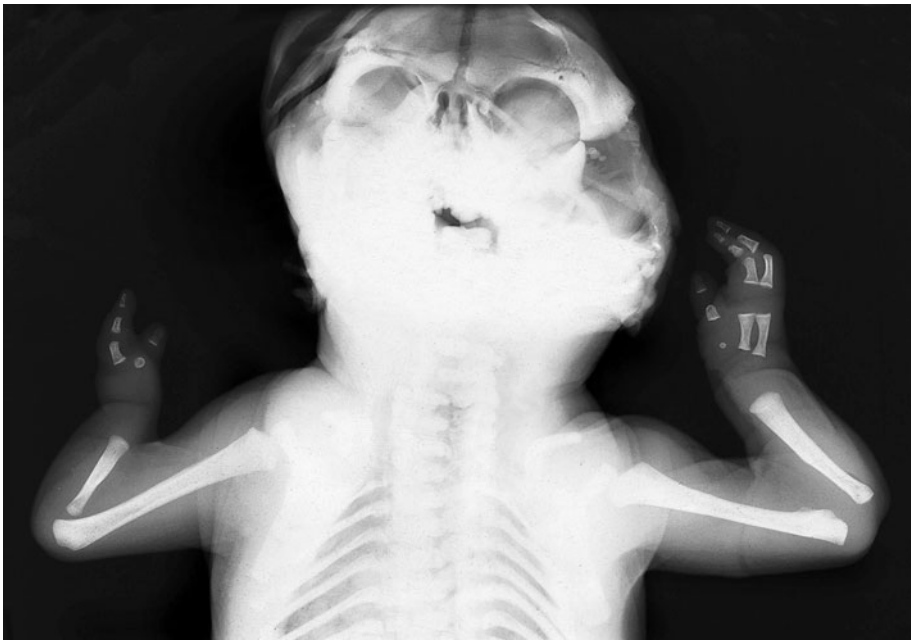

Fig. 2.11. ***33rd gestational week.*** Complex tubular bone aplasia/hypoplasia in Brachmann-De Lange syndrome: bilateral aplasia of the ulna and ulnar rays of the hands, aplasia of the middle finger and proximal phalanx of the thumb on the right side. Hypoplastic radii. Luxation of the left humeroradial joint

Diagnosis	Accessory radiological findings in the fetus
Acrofacial dysostosis with post-axial defects [1] MIM 263750	Different degrees of postaxial hypoplasia in all four limbs, shortened forearm
Acrofacial dysostosis, type Rodriguez [2] MIM 263750	Micrognathia, forearm anomalies mostly on the radial side, short forearm, radio-ulnar synostosis, preaxial polydactyly, fibular hypoplasia
Brachmann-de Lange syndrome [3] MIM 122470 **Fig. 2.11**	Variable reduction deficiency of upper limb, including ulna, humerus, radius, carpals; ectrodactyly
Femur-fibula-ulna complex (FFU syndrome) [4] MIM 228200	Asymmetric hypoplasia/aplasia of femur, fibula, humerus, ulna; humero-ulnar/-radial synostosis; oligodactyly
Fetal alcohol syndrome [5]	Intrauterine growth retardation, vertebral segmentation defects, Klippel-Feil syndrome, reduction deformity of upper extremities, hypoplasia/aplasia of ulna, radioulnar synostosis, tetradactyly, clubfoot
Grebe syndrome [6,7] and related osteochondrodyspiasias; see p. 177 MIM 200700	Dislocated radial heads, aplasia/hypoplasia of ulna, radius, femur; absent or hypoplastic proximal and middle phalanges; syndactyly; absent or hypoplastic metacarpals; absent or hypoplastic carpals; carpal fusion; very short tubular long bones (lower limbs more severe than upper limbs), hypoplastic tarsals, short and broad metatarsals
Holt-Oram-Syndrome (cardiomelic syndrome) [8] MIM 142900	Asymmetric aplasia of radius, triphalangeal thumb, hypoplasia of humerus
Humero-radial synostosis-ulnar defects [9] MIM 236400	Humero-radial synostosis, fibular aplasia, patellar aplasia
Lethal osteochondrodyspiasias [10] see p. 167	For example, atelosteogenesis II (de la Chapelle dysplasia)

Diagnosis	Accessory radiological findings in the fetus
Leri-Weill dyschondrosteosis [11] MIM 127300	Mesomelia, bowed radius, hypoplasia of tibia
Mesomelic dysplasias [11] see p. 173 ff	Severe mesomelic i.e, forearm, shank) shortening of the extremities, different types
Mietens-Weber syndrome [12] MIM 249600	Proportionate short stature, hypo-/aplasia of ulna, radius, fibula, elbow dislocation, hip dislocation, mesomelia of upper limb
Neu-Laxova syndrome [13] MIM 256520	Severe microcephaly, hypoplasia of radius/ulna, postaxial oligodactyly
Neurofibromatosis 1 [14] MIM 162200	Pseudarthrosis; pathologic fracture of the diaphysis due to focal fibrous dysplasia; most often in the tibia
Odontotrichomelic syndrome [15] MIM 273400	Spilt hand, oligodactyly,
Pfeiffer Absent ulna/fibula with oligodactyly [16] MIM 228930	Bowed femur, split hand
Roberts (pseudothalidomide) syndrome [17] see Fig. 2.5 MIM 268300	Tetraphocomelia, severe limb shortening' radial defects, oligodactyly, nuchal cystic hygroma, sometimes craniostenosis
Thrombocytopenia-absent radius (TAR) syndrome [18] MIM 274000	Bilateral aplasia of radius but present thumbs
Ulnar-mammary syndrome type Pallister [19] MIM 181450	Ulnar ray deficiency, aplasia of phalanges, bowed radius, hypoplasia of humerus; other: anal atresia/stenosis
Weyers syndrome of deficiency of ulnar and fibular rays [20] MIM 602418 (similar with De la Chapelle syndrome? see p. 167) MIM 256050)	Hypoplasia of ulna and fingers, split hand, absent clavicles, cleft palate; see also "Fibula: Aplasia. Hypoplasia"

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Humerus: Aplasia, Hypoplasia

Diagnosis	Accessory radiological findings in the fetus
Acrofacial dysostosis, type Rodriguez [1] MIM 201170	Phocomelia of arms, defective ulnar ray, short humerus and fibula, hypoplastic scapula
Atelosteogenesis 1 [2–4] and related osteochondrodyspiasias; see p. 163 MIM 108720, 108721, 112310	Hypoplastic vertebral bodies, especially of cervical and thoracic spine; hypoplastic and tapered (distal) humerus and femur; bowed radius, ulna and tibia; absent or hypoplastic fibula; absent or hypo-ossified metacarpals and phalanges
Brachmann-de Lange syndrome [5] see Fig. 2.11 MIM 122470	Variable reduction deficiency of upper limb, including ulna, humerus, radius, carpals; ectrodactyly
CHILD syndrome [6] (Congenital hemidysplasia, ichthyosiform erythroderma, limb defects) MIM 308050	Unilateral hypoplasia of limb(s) including absent or hypoplastic scapula, humerus, radius, ulna, femur, tibia, fibula; joint contracture or pterygium; punctate epiphyseal calcification; other features: congenital ichthyosiform erythroderma ipsilateral to limb deficiency, visceral anomalies
Chondrodysplasia punctata, rhizomelic type [7, 8] see p. 159 MIM 215100	Punctate calcifications primarily around the ends of the long bones, hypoplasia of humerus and femur, wide or splayed metaphyses, platyspondyly
Chondrodysplasia punctata, tibia-metacarpal type [9] MIM 118651	Stippling of sacrum and carpals; dislocation of hip, knee, elbow; short tibia, femur, metacarpals, phalanges; asymmetry
DK phocomelia [10] Phocomelia-encephalocele-thrombocytopenia-urogenital malformation von Voss-Cherstvoy syndrome MIM 223340	Microcephaly; absent or hypoplastic humerus, radius, ulna, metacarpals, thumb; oligodactyly; syndactyly of fingers; other features: genitourinary, cardiac anomalies, platelet abnormalities
Femur-fibula-ulna complex (FFU syndrome) [11] MIM 228200	Asymmetric hypoplasia/aplasia of femur, fibula, humerus, ulna; humero-ulnar/-radial synostosis; oligodactyly
Fetal thalidomide syndrome [12]	Amelia; proximal phocomelia; fingers present, often attached direct to the shoulders
Fetal valproate syndrome [13, 14]	Prominent metopic ridge, bifrontal narrowing, clinodactyly, distal phalangeal hypoplasia, absent or hypoplastic radius, absent or hypoplastic thumb, talipes equinovarus
Holt-Oram syndrome [15, 16] Cardiomelic syndrome MIM 142900	Absent or hypoplastic humerus, radius, ulna, first metacarpal, thumb; triphalangeal thumb; absent or hypoplastic carpals; delayed ossification or fusion of carpals; other polydactyly; radioulnar synostosis; hypoplasia of the clavicle, scapula; Sprengel anomaly; pectus excavatum or carinatum; rib hypoplasia or fusion; vertebral fusion or hemivertebra, scoliosis; other anomalies: cardiac defects (secundum-type atrial septal defect most commonly)
Omodysplasia [17 – 19] see p. 161, 170 MIM 164745, 251455	Rhizomelia of upper limbs by distal hypoplasia of humeri, milder such involvement of lower limbs; dislocation of radial heads
Oromandibular – limb hypogenesis syndromes; see Fig. 2.20 Aglossia-adactylia, hypoglossia-hypodactylia Hanhart syndrome [20, 21] MIM 103300	Asymmetric, variably absent or hypoplastic humerus, radius, ulna, carpals, metacarpals, femur, tibia, fibula, tarsals, metatarsals; oligodactyly; syndactyly; microretrognathia; aplasia/hypoplasia of tongue
Thrombocytopenia-absent radius (TAR) syndrome (severe form) [22] MIM 274000	Bilateral severe phocomelia of the upper limbs with hands attached to the shoulders, thumbs present
Ulnar-mammary syndrome type Pallister [23] MIM 181450	Ulnar ray deficiency; aplasia of phalanges; bowed radius; hypoplasia of humerus; other feature: anal atresia

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Tibia: Aplasia, Hypoplasia

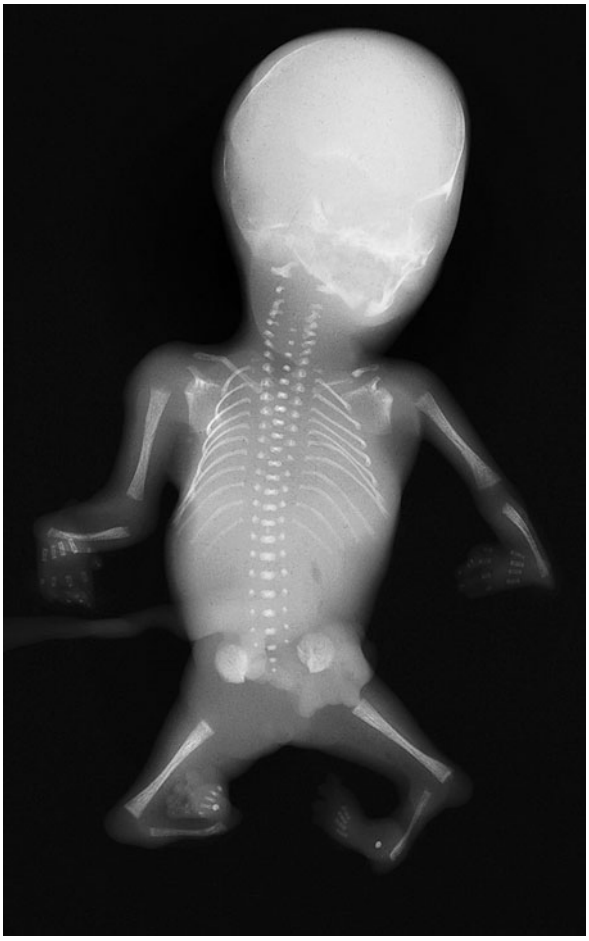

Fig. 2.12. ***18th gestational week.*** Aplasia of both radii and tibiae in Trisomy 18. Aplasia of the first ray of the left hand and foot. Punctate calcifications in the calcaneus. 11 pairs of slender ribs. (Note retarded maturation!)

Diagnosis	Accessory radiological findings in the fetus
Acro-renal-mandibular syndrome [1] MIM 200980	Severe mandibular hypoplasia, variable and asymmetric limb reduction defects incl. hypoplastic or absent radius, oligodactyly, syndactyly, vertebral segmentation defects
Amniotic band disruption sequence ADAM complex (Amniotic Deformity, Adhesions,Mutilations) Limb-body wall complex [2] see Fig. 2.24 MIM 217100	Usually asymmetric transverse terminal limb reductions/amputations and variable terminal syndactyly/pseudosyndactyly; sometimes also oligodactyly, hypoplasia of long bones, craniofacial and ventral wall disruption
Chondrodysplasia punctata, tibia-metacarpal type [3] MIM 118651	Stippling of sacrum and carpals; dislocation of hip, knee, elbow; short tibia and femur; short metacarpals and phalanges; asymmetry
Chromosome abnormality Trisomy 18 [4]; **Fig. 2.12**	In rare cases tibial aplasia is present; for Trisomy 18 see "Aplasia, Hypoplasia of Radius and Thumb"
Grebe syndrome [5] see p. 177 MIM 200700	Severe, proportionate shortening of extremities, mild shortening of trunk, absent proximal phalanges, distal phalanges always present, oligo/polydactyly
Leri-Weill dyschondrosteosis [6] MIM 127300	Mesomelia, bowed radius, hypoplasia of tibia and ulna

Diagnosis	Accessory radiological findings in the fetus
Mesomelic dyspiasias [6] see p. 173 ff	Different types and degree of mesomelic shortening of the extremities combined with or without phalangeal involvement.
Mesomelic dwarfism of hypoplastic tibia-radius type [7] MIM 156230	Isolated bilateral shortening of radius and tibia
Neurofibromatosis 1 [8] MIM 162200	Tibial pseudarthrosis; pathologic fracture of the diaphysis due to a focal mesenchymal defect; rare in other long bones
Split hand/foot, tibial defect [9] MIM 119100	Split hand and/or foot; hypoplasia of ulna, femur; bifurcation of distal femur; postaxial polydactyly
Tibial hemimelia [10] MIM 275220	Isolated aplasia of the tibia, clubfoot
Tibial hypoplasia, polydactyly and triphalangeal thumb (Werner syndrome) [11] MIM 188770	Triphalangeal thumb, (multiple) preaxial polydactyly of feet, polydactyly of hands, radio-ulnar synostosis. In rare cases tibial aplasia is present
VACTERL association	For VACTERL association see: "Radius and Thumb: Aplasia, Hypoplasia"

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Fibula: Aplasia, Hypoplasia

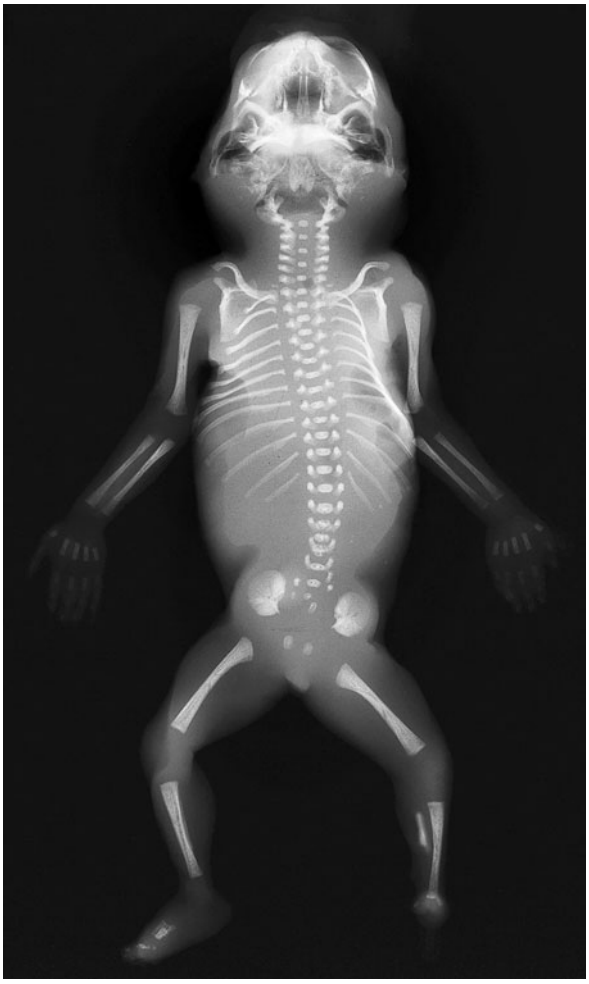

Fig. 2.13. ***18th gestational week.*** Hypoplasia of left fibula in VACTERL association. Small left foot with only one ray. Fused vertebrae L3–5 Segmentation errors and hypoplasia of the sacrum (caudal regression). Urethral pathology is suggested by narrow and asymmetric pubic bones. Other findings: esophageal atresia Vogt IIIb; anal atresia; absent urethra, bladder, and kidneys

Diagnosis	Accessory radiological findings in the fetus
Acrofacial dysostosis, type Rodriguez [1] MIM 201170	Phocomelia of arms, defective ulnar ray, short humerus, hypoplastic scapula
Atelosteogenesis 1 [2–4] and related osteochondrodyspiasias; see p. 163 MIM 108720, 108721, 112310	Hypoplastic vertebral bodies, especially of cervical and thoracic spine; hypoplastic and tapered (distal) humerus and femur; bowed radius, ulna and tibia; absent or hypo-ossified metacarpals and phalanges
Campomelic dysplasia; see p. 124 MIM 114150	Bowing of femur and tibia, pear-shaped iliae; hypoplasia of claviculae, scapulae; cervical kyphosis
Chondroectodermal dysplasia Ellis-van Creveld [5] see p. 153	Postaxial polydactyly; narrow chest; short, thick, bowed humeri and femurs; hypoplasia/aplasia tibiae; triradiate acetabula
Chromosome abnormalities	Rare
De la Chapelle dysplasia [6] including atelosteogenesis II; see p. 167 MIM 256050	Deficiency of fibular and ulnar rays; hemivertebrae; platyspondyly; coronal clefts; thin, short ribs

Diagnosis	Accessory radiological findings in the fetus
Du Pan brachydactyly, fibular aplasia [7] see Grebe dysplasia p. 177 MIM 228900	Dislocation of elbow, knee, or hip; complex brachydactyly
Ectrodactyly-fibular aplasia [8] MIM 113310	Variable absence or hypoplasia of ulna, carpals, metacarpals, phalanges, fibulae, tarsals, metatarsals; brachydactyly; syndactyly; triphalangeal thumb
Femoral hypoplasia, unusual facies syndrome [9] MIM 134780	Small mandible, cleft palate, bowing of femur, hypoplastic/absent fibula or tibia, hypoplastic acetabula, preaxial polydactyly
Femur-fibula-ulna complex (FFU syndrome) [10] see Fig. 2.14 MIM 228200 Fibular aplasia – oligodactyly – camptomelia MIM 246570	Asymmetric hypoplasia/aplasia of femur, fibula, humerus, ulna; humero-ulnar/radial synostosis; oligodactyly
Fibular aplasia/hypoplasia [11] Limb/pelvis-hypoplasia/aplasia syndrome [12] MIM 276820	Isolated defect of the fibula Hypoplastic femurs and feet; aplastic fibulae; oligodactyly; short, bent ulnae
Leri-Weill dyschondrosteosis [13] MIM 127300	Mesomelia, bowed radius, hypoplasia of tibia and ulna
Mesomelic dyspiasias [13] see p. 173	Different types and degrees of mesomelic shortening of the extremities with or without phalangeal involvement
Seckel syndrome [14] MIM 210600	Severe intrauterine growth retardation; microcephaly; craniosynostosis; radial head luxation, absent ribs
VACTERL association; **Fig. 2.13**	Aplasia of fibula in rare cases (see: "Aplasia, Hypoplasia of Thumb and Radius")

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Femur: Aplasia, Hypoplasia

Aplasia or hypoplasia of the femur is rare, most often associated with other radiological signs helping to solve the differential diagnosis. See "Amelia, Amputation, Phocomelia"

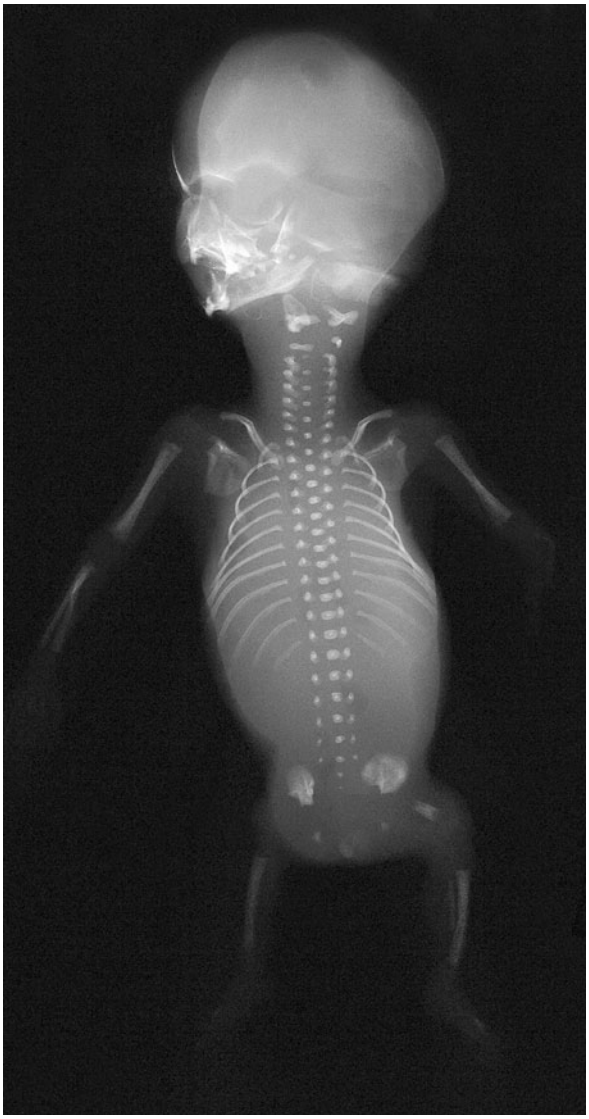

Fig. 2.14. ***17th gestational week.*** Complex tubular bone aplasia/hypoplasia in femur-fibula-ulna complex. Aplasia of the right femur, hypoplasia of the left femur, hypoplastic fibulae, aplasia of left radius, hypoplasia of the left ulna, two triphalangeal digits on the left

Diagnosis	Accessory radiological findings in the fetus
Atelosteogenesis I [1–3] and related osteochondrodysplasias; see p. 163 MIM 108720, 108721, 112310	Hypoplastic vertebral bodies, especially of cervical and thoracic spine; hypoplastic and tapered (distal) humerus; bowed radius, ulna and tibia; absent or hypoplastic fibula; absent or hypo-ossified metacarpals and phalanges
Diabetic embryopathy [4] see Fig. 2.37	Caudal regression, segmentation defects of the spine, defects of ulna and tibia
Ectrodactyly-tibial hypoplasia [5] MIM 119100	Split hand and/or foot, polydactyly, ulnar hypoplasia, tibial hypoplasia, bifid femur
Femoral hypoplasia, unusual facies syndrome [6] MIM 134780	Small jaw, cleft palate, radio-ulnar synostosis, absent fibula, absent tibia, hypoplastic acetabula, preaxial polydactyly of feet

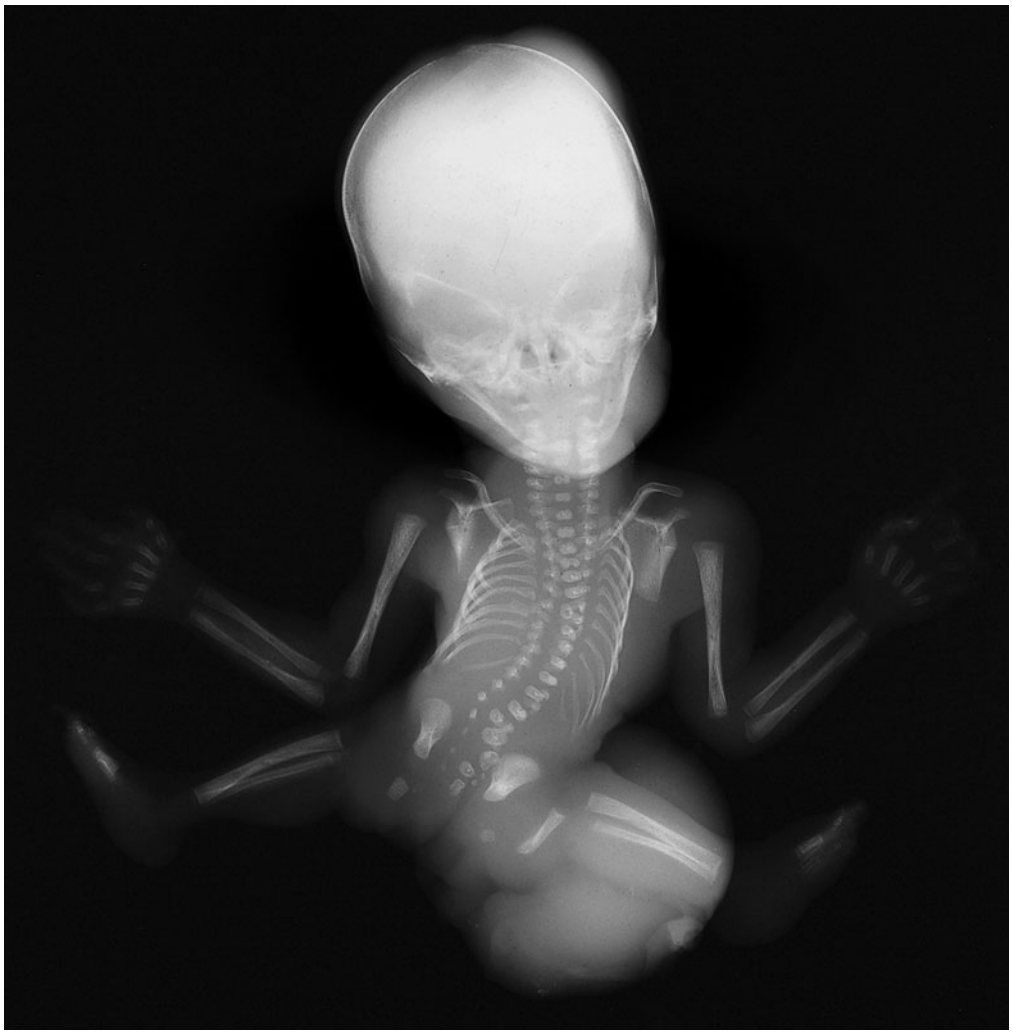

Fig. 2.15. ***20th gestational week.*** Femoral aplasia/hypoplasia in limb-body wall complex. Aplasia of the right femur, hypoplasia of left femur. Disproportionately short trunk. vertebral segmentation defects. Abdominal wall defect and bladder exstrophy. The upper extremities are normal

Diagnosis	Accessory radiological findings in the fetus
Femur-fibula-ulna syndrome (FFU complex) [7] **Fig 2.14** MIM 228200	Asymmetric hypoplasia/aplasia of femur, fibula, humerus; humero-ulnar/-radial synostosis; oligodactyly
Limb, body wall complex [8] **Fig. 2.15** MIM 217100	Defect of lower abdominal wall, bladder exstrophy, pubic diastasis, segmental defects of lower extremities, spinal segmentation defects
Limb/pelvis-hypoplasia/aplasia syndrome [9] MIM 276820	Hypoplastic femur; aplasia of fibula; hypoplastic feet; oligodactyly; short, bent ulnae
Omodysplasia [10–12] see p. 170 MIM 164745, 251455	Rhizomelia of upper limbs by distal hypoplasia of the humeri, milder involvement of lower limbs; dislocation of radial heads
Proximal focal femoral deficiency [13] MIM 228200	Unilateral short femur due to proximal reduction defect, hip joint preserved

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Femur: Bowing

Bowing of the femur is a quite common sign. It is helpful to evaluate at first whether length and structure are normal or not.

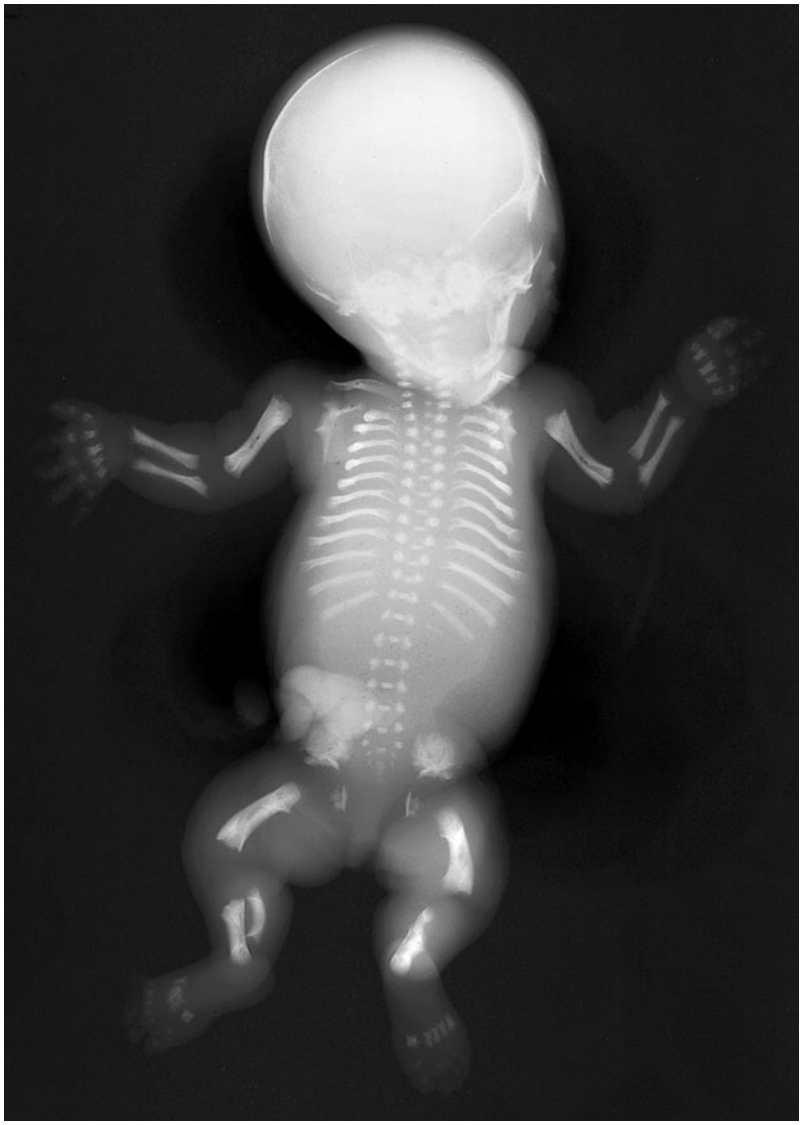

Fig. 2.16. ***23rd gestational week.*** Short bowed femora in thanatophoric dysplasia I. Narrow thorax, platyspondyly. All short and long tubular bones are markedly short and broad with flared and cupped metaphyses. Postaxial polydactyly right foot

Structure of femur	Diagnosis
A: short, thick, metaphyseal abnormalities but normal bone structure; **Fig. 2.16**	Mostly lethal osteochondrodyspiasias [4] (see Chap. 3, "Skeletal Dysplasias with Shortened Tubular Bones", p. 100 ff, "Skeletal Dysplasias with Congenital Bowing", p. 120 ff); exception: kyphomelic dysplasia [1]
B: normal structure, slight to moderate bowing; **Fig. 2.17**	Unspecific radiological sign in many syndromes and chromosomal abnormalities with otherwise normal skeleton or luxations [3]; exceptions: Antley-Bixler syndrome MIM 207410; campomelic dysplasia MIM 211970 (see p. 124), OPD II MIM304120 (see p. 136)

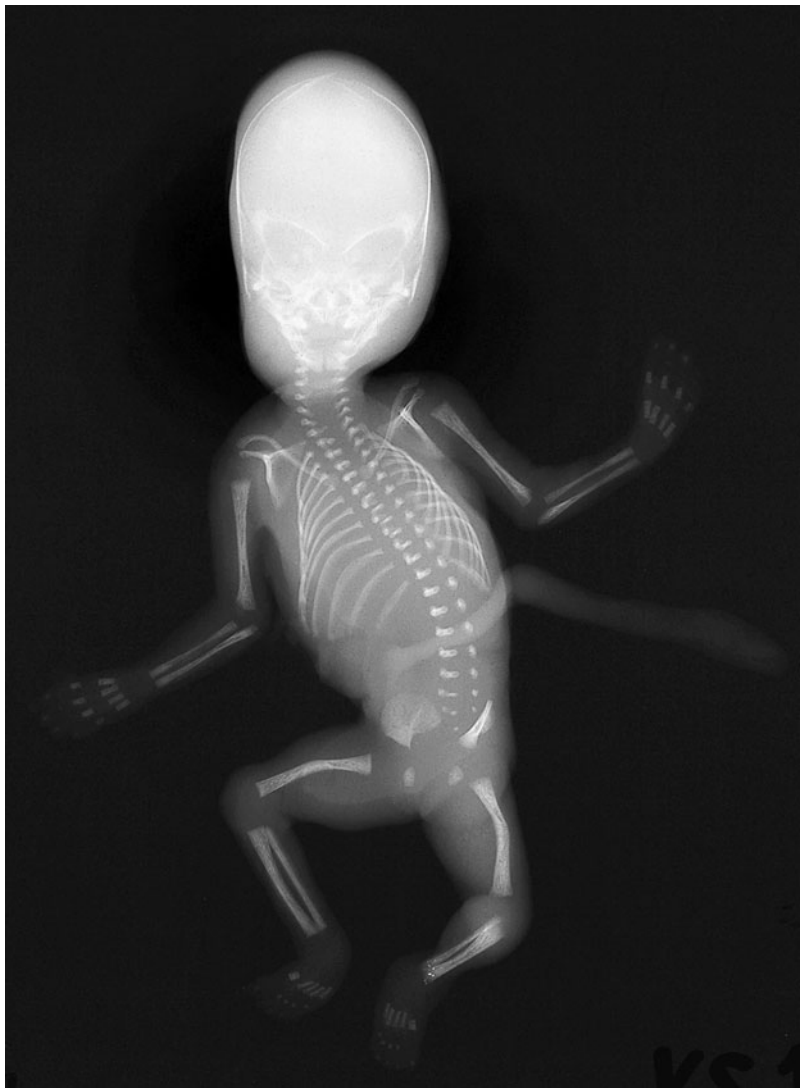

Fig. 2.17. ***15th gestational week.*** Mild femoral bowing of the normally structured femora in Trisomy 18. Eleven pairs of ribs. Disharmonic skeletal maturation: absent ossification of the cervical vertebrae but well-ossified ischia

Structure of femur	Diagnosis
C: abnormal structure (fractures, abnormal density), any size	
Osteogenesis imperfecta II [4] see p. 128 MIM 120150, MIM 166200	– broad irregular diaphyses due to multiple fractures, multiple rib fractures, hypo-ossified calvarium
Hypophosphatasia, infantile form [2] **Fig. 2.18** MIM 241500	– bowing of long bones (rectangular), metaphyseal ossification defects, transverse midshaft spurs, hypo-ossified calvarium, erratic ossification of vertebrae
Neurofibromatosis 1 [5] MIM 162200	– pseudarthrosis of femur (more often tibia)

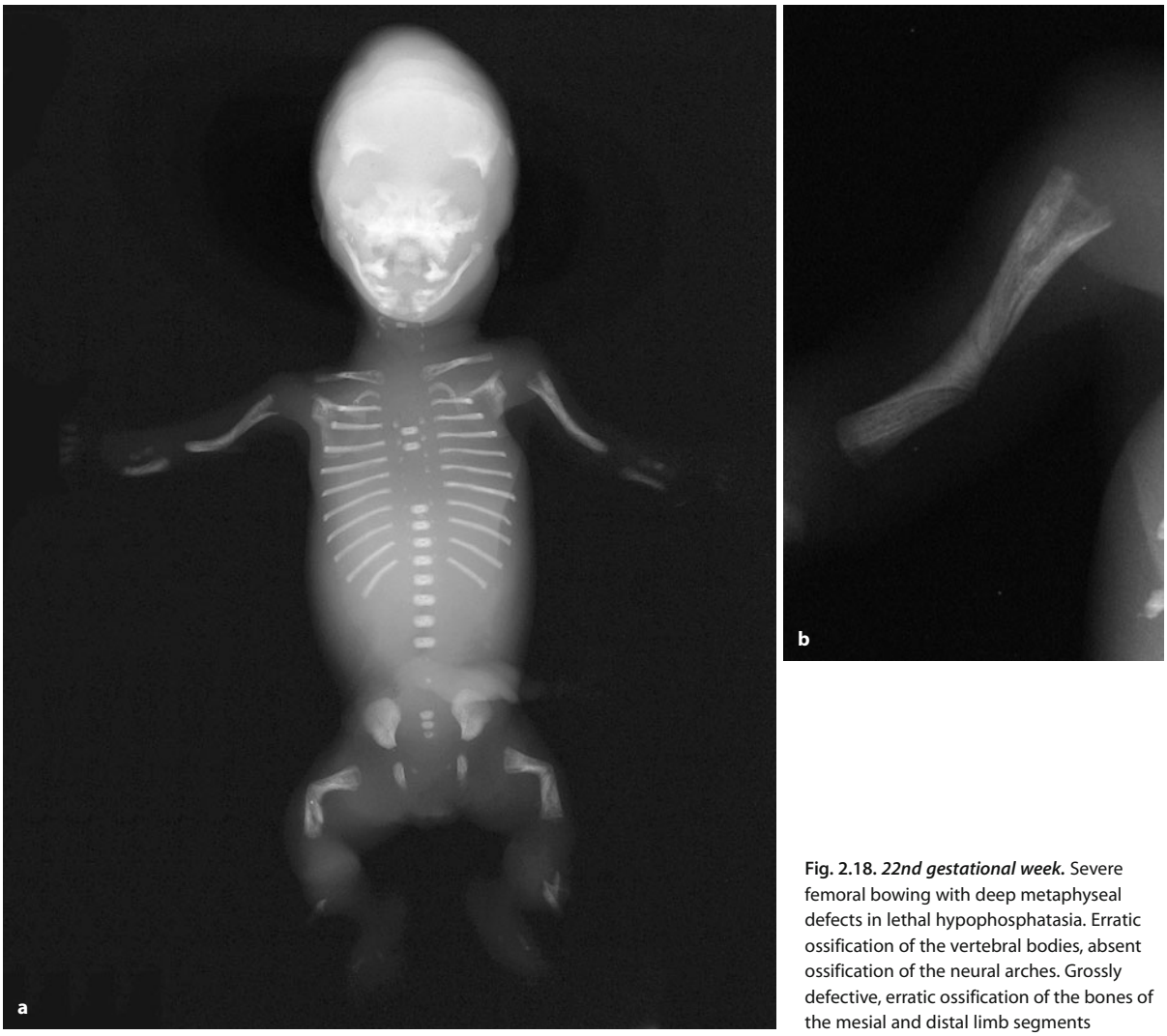

Fig. 2.18. ***22nd gestational week.*** Severe femoral bowing with deep metaphyseal defects in lethal hypophosphatasia. Erratic ossification of the vertebral bodies, absent ossification of the neural arches. Grossly defective, erratic ossification of the bones of the mesial and distal limb segments

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Stippled Epiphyses – Stippled Ossification of Cartilage

For skeletal dysplasias with punctuate calcification see p. 155 ff (Greenberg dysplasia; dappled diaphysis dysplasia; chondrodysplasia punctata, different types; CHILD syndrome)

Definition

– Syndromatic or symptomatic premature stippled calcification of epiphyses or apophyses of high radiographic density

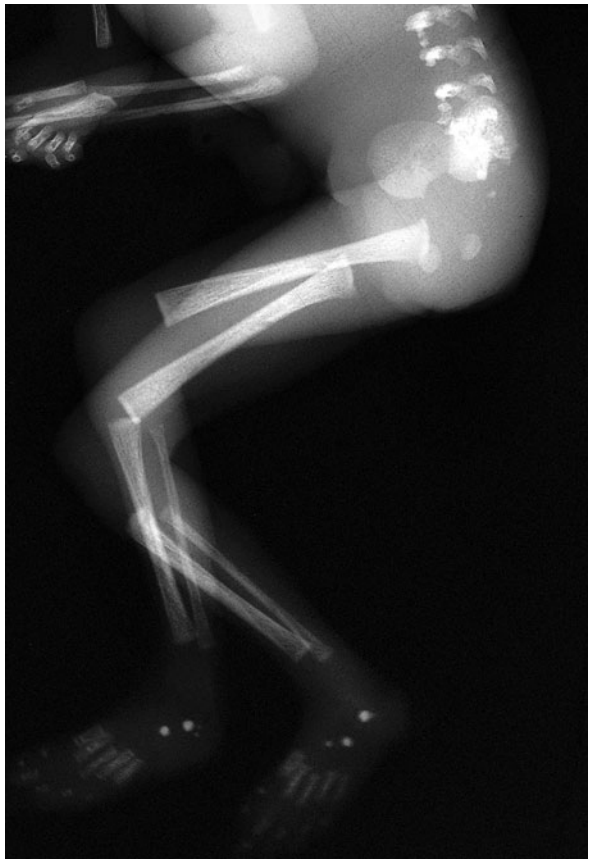

Fig. 2.19. ***22nd gestational week.*** Short femora in triploidy: femur length of 18th gestational week. Puncta in the tarsus and intervertebral disks

Diagnosis	Accessory radiological findings in the fetus
Chromosome abnormalities: Triploidy Trisomy 13 Trisomy 18 Trisomy 21 [1] Turner syndrome, X-Y translocation **[2]**	Besides the other signs which specific disorders expose (such as dystrophy, hypo-ossified calvaria, hypotelorism, nuchal cystic hygroma, umbilical hernia, radius aplasia, coronal vertebral clefts) most often only the calcaneus with a premature, dot-like, very dense ossification; especially in triploidy, intervertebral disks with a central calcification (see Fig. 2.19)
Fetal alcohol syndrome [3]	Intrauterine growth retardation, microcephaly, hemivertebra, Klippel-Feil syndrome
Hydantoin embryopathy [4] MIM 261720	Microcephaly, distal hyperphalangism or hypoplasia
Smith-Lemli-Opitz syndrome [5] MIM 270400	Growth retardation, microcephaly, postaxial polydactyly, split hand, clubfoot
Warfarin embryopathy [6, 7]	Short, broad hand; calcification of larynx and trachea; shortened limbs; occipital encephalocele
Zellweger syndrome [8] (cerebro-hepato-renal syndrome) MIM 214100	Microcephaly, no specific radiologic signs, stippled calcifications of the patella and mostly grouped around the pelvis

Chromosome 16p duplication, DeBarsy-Syndrome (progeroid syndrome), show, except for stippled epiphyses, no other radiologic signs in the fetus helping to solve the differential diagnosis.

Single cases of undetermined origin have been published.

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Hands/Feet: Absent

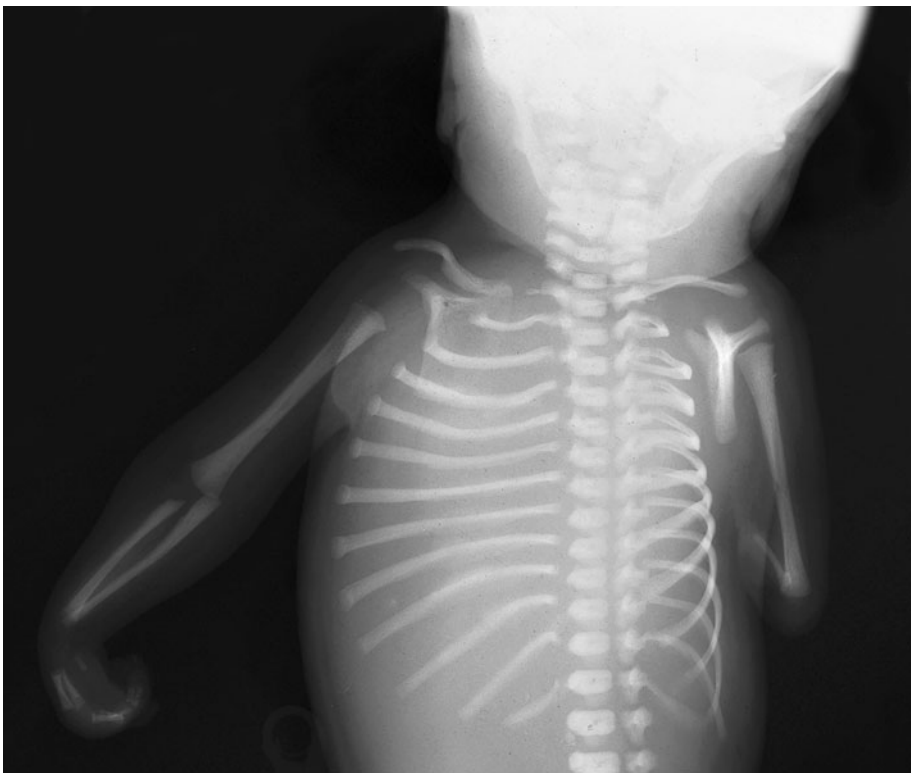

Fig. 2.20. ***30th gestational week.*** Complex aplasia/hypoplasia: aplasia of the left radius and hand in oromandibular-limb hypogenesis syndrome, hypoplasia of the left ulna. On the right side, slightly dysplastic radius and ulna, absent ossification of the 4th and 5th digits and of the phalanges of the 3rd digit

Diagnosis	Accessory radiological findings in the fetus
Acheiropodia [1] MIM 200500	Transverse terminal limb reductions, usually involving all extremities with variable deficiency of radius, ulna, humerus, tibia, and fibula; variable presence of Bohomoletz bone (hypoplastic bone at the tip of the upper limb stump with triphalangeal component)
Adams-Oliver syndrome [2,3,4] MIM 100300	Occipital skull and/or scalp defect associated with highly variable clinical findings; variable transverse limb reduction including phalanges, metacarpals, metatarsals. and occasional tubular long bones, ectrodactyly, syndactyly
Amniotic band disruption sequence [5] ADAM complex (Amniotic Deformity, Adliesions, Mutilations) MIM 217100	Usually asymmetric transverse terminal limb reductions/amputations and variable terminal syndactyly/pseudosyndactyly; may also include oligodactyly, hypoplasia of long bones, craniofacial and ventral wall disruption
Brachmann-de Lange syndrome [6,7] MIM 122470 see Fig. 2.11, Fig. 2.21	Asymmetric and variable upper limb deficiency including absent or hypoplastic humerus, radius or ulna, carpals, metacarpals, and phalanges; other skeletal findings including microcephaly, micrognathia, supernumerary ribs, fused ribs, hemivertebrae, or vertebral fusion
Femur-fibula-ulna complex [8] MIM 228200	Asymmetric hypoplasia/aplasia of femur, fibula, ulna, humerus; humero-ulnar/-radial synostosis; oligodactyly
Holoprosencephaly-transverse limb defect [9]	Quadrilateral transverse terminal limb defects, holoprosencephaly

Diagnosis	Accessory radiological findings in the fetus
Oromandibular – limb hypogenesis syndromes; **Fig. 2.20** Aglossia-adactylia Hypoglossia-hypodactylia Hanhart syndrome [10,11] MIM 103300	Asymmetric and variable absent or hypoplastic humerus, radius, ulna, carpals, metacarpals, femur, tibia, fibula, tarsals, metatarsals; oligodactyly; syndactyly; microretrognathia; aplasia/hypoplasia of the tongue

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Hands/Feet: Split/Cleft/Ectrodactyly

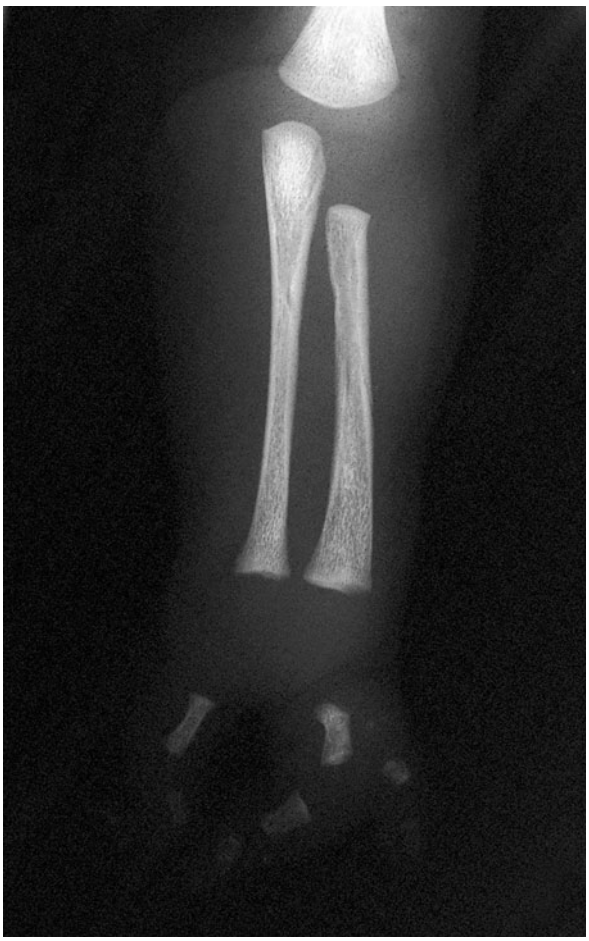

Fig. 2.21. ***32nd gestational week.*** Split hands with three incomplete rays bilaterally in Brachmann-de Lange syndrome

Diagnosis	Accessory radiological findings in the fetus
Acro-renal-mandibular syndrome [1] MIM 200980	Severe mandibular hypoplasia; variable and asymmetric limb reduction defects including hypoplastic or absent radius or tibia, oligodactyly, syndactyly, vertebral segmentation defects; other defects including renal agenesis/renal dysplasia, diaphragmatic hernia
Brachmann-de Lange syndrome [2]; **Fig. 2.21** MIM 122470	Asymmetric and variable upper limb deficiency including absent or hypoplastic humerus, radius or ulna, carpals, metacarpals, and phalanges; other skeletal findings including microcephaly, micrognathia, supernumerary ribs, fused ribs; hemivertebrae or vertebral fusion
Chromosome abnormality trisomy 13 [3]	Microcephaly, hypotelorism, small orbits, hypo-ossification of calvarium, spinal dysraphism, hemivertebrae, absent/supernumerary/fused ribs, hypoplasia of pelvis, oligodactyly, polydactyly, syndactyly, camptodactyly, vertical talus; other defects including cardiac anomalies, omphalocele, holoprosencephaly, neural tube defect, cystic hygroma, hydrops fetalis

Diagnosis	Accessory radiological findings in the fetus
Chromosome abnormality trisomy 18 [4 – 7]	Microcephaly, hypo-ossification of calvarium, hypoplasia of maxilla and/or mandible, microretrognathia, absent or thin ribs, short sternum, spinal dysraphism, hypoplasia of pelvis, hypoplasia of first metacarpal, flexion deformities and overlapping fingers, vertical talus, short first toe, hammertoes; other defects: intrauterine growth retardation, cardiac anomalies, omphalocele, neural tube defect
Cleft palate-cardiac defect-genital anomalies and ectrodactyly [8] Acrocardiofacial syndrome, ACFS MIM 600460	Proximal placed thumb, short first metacarpal, syndactyly of toes, hypoplasia of metatarsal, absent phalanges, cleft lip +/- palate, congenital heart defect, genital anomalies
DK phocomelia [9, 10] Phocomelia-encephalocele-thrombocytopeniaurogenital malformation von Voss-Cherstvoy syndrome MIM 223340	Microcephaly; encephalocele; absent or hypoplastic humerus, radius, ulna, metacarpals, thumbs; oligodactyly; syndactyly
Ectodermal dysplasia-ectrodactyly-macular dystrophy [11] EEM syndrome MIM 225280	Syndactyly, camptodactyly, phalangeal agenesis/hypoplasia, duplication of phalanges, sparse scalp hair, eyebrows and eyelashes, macular dystrophy
Ectrodactyly-Ectodermal dysplasia – Clefting syndrome [12] MIM 129900, 604292	Cleft lip ± palate; variable absence or hypoplasia of carpais, metacarpals, tarsals, metatarsals, phalanges; variable oligodactyly; variable syndactyly; other finding: renal dysplasia
Ectrodactyly-fibular aplasia [13] MIM 113310	Variable absence or hypoplasia of ulna, carpals, metacarpals, phalanges, fibulae, tarsals, metatarsals; brachydactyly; syndactyly; triphalangeal thumb
Ectrodactyly, isolated malformation MIM 183600, MIM 313350, MIM 600095, MIM 605289, MIM 606708	Variable and usually asymmetric absence or hypoplasia of phalanges, metacarpals and/or metatarsals, carpals and/or tarsals, radius, dna, tibia, and fibula
Ectrodactyly-tibial aplasia [14, 15] MIM 119100	Variable absence or hypoplasia of radius, ulna, carpals, metacarpals, phalanges, tibia, tarsals, metatarsals; bifid distal femur; bowed tibia, absent or hypoplastic patella; preaxial or postaxial polydactyly; variable oligodactyly; variable syndactyly; may present as four-extremity monodactyly or transverse hemimelia
Femur-fibula-ulna complex [15] MIM 228200	Asymmetric hypoplasia/aplasia of femur, fibula, ulna, humerus; humero-ulnar/radial synostosis; oligodactyly
Holoprosencephaly-ectrodactyly and bilateral cleft lip/palate [16] MIM 300571	Craniosynostosis, hypertelorism, absent or hypoplastic radius, ulna phalanges; other defects: cleft lip ± palate, holoprosencephaly, neural tube defect
Monodactylous ectrodactyly and bifid femur Wolfgang-Gollop syndrome [17, 18] MIM 228250	Variable absence or hypoplasia of radius, ulna, carpals, metacarpals, phalanges, tibia, patella, tarsals, and metatarsals; bifid femur; talipes equinovarus; vertebral body fusion; hemivertebrae
Oromandibular – limb hypogenesis syndromes: aglossia-adactylia, hypoglossia-hypodactylia, Hanhart syndrome [19,20]; see Fig. 2.4 MIM 103300	Asymmetric and variably absent or hypoplastic humerus, radius, dna, carpals, metacarpals, femur, tibia, fibula, tarsals, and metatarsals; oligodactyly; syndactyly; microretrognathia

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20. KelIn EE, Bennet CG, Klingberg WG (1968) Aglossia-adactylia syndrome. Am J Dis Child 116:549–552

Hands/Feet: Preaxial Polydactyly

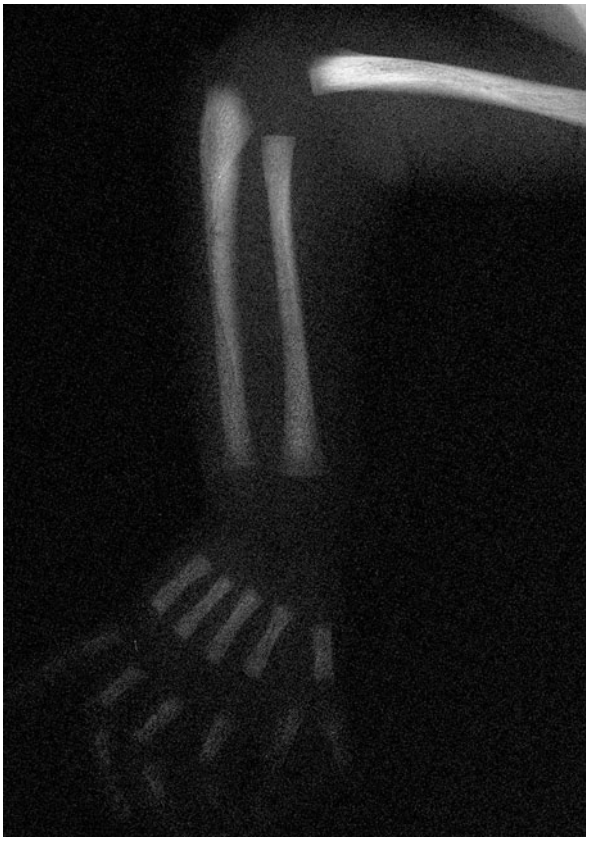

Fig. 2.22. ***24th gestational week.*** Preaxial polydactyly in Townes-Brock syndrome. Duplication of triphalangeal thumbs; defective ossification of the middle and distal phalanges. Other findings: imperforate anus, triphalangeal thumbs, ear anomalies

Diagnosis	Accessory radiological findings in the fetus
Aase syndrome [1] MIM 205600 Blackfan-Diamond syndrome Anemia and triphalangeal thumbs [2]	Broad thumb, triphalangeal thumb, hypoplastic thumb, radial hypoplasia, abnormal clavicles; other features: cleft palate, congenital heart defect, congenital hypoplastic anemia
Acrocallosal syndrome [3, 4] MIM200990	Macrocephaly, prominent forehead, large fontanelles, hypertelorism, bifid terminal phalanges of thumbs, duplicated hallux, syndactyly, brachydactyly, postaxial polydactyly; other features: absent corpus callosum, other brain defects, cleft palate, heart defect
Carpenter syndrome [5, 6] Acrocephalopolysyndactyly, type 2 MIM 201000	Craniosynostosis, Kleeblattschädel (cloverleaf skull), absence or hypoplasia of middle phalanges, double ossification center of proximal phalanx of thumb, postaxial polydactyly, broad first metatarsal, syndactyly, coxa valga, genu vara, pes varus
Chromosome abnormalities	Variable according to specific segmental aneuploidy
Diabetic embryopathy [7]	Hemivertebrae, absent or hypoplastic femora, hypoplastic tibia, postaxial polydactyly, spinal dysraphism, neural tube defect, congenital heart defect
Greig cephalopolysyndactyly [8,9] MIM 175700	Macrocephaly, prominent forehead, large fontanelles, hypertelorism, postaxial polydactyly of hands (rarely of feet), broad thumbs, broad hallux

Diagnosis	Accessory radiological findings in the fetus
Holt-Oram syndrome [10, 11] Cardiomelic syndrome MIM 142900	Absent or hypoplastic humerus, radius, ulna, first metacarpal, and thumb; triphalangeal thumb; absent or hypoplastic carpals; delayed ossification or fusion of carpals; other polydactyly; radioulnar synostosis; hypoplasia of the clavicle and scapula; Sprengel anomalyr; pectus excavatum or carinatum; rib hypoplasia or fusion; vertebral fusion or hemivertebra and scoliosis; other anomalies:cardiac defects (secundum type atrial septal defect the most common)
Hydrolethalus syndrome [12, 13] MIM 236680	Macrocephaly, keyhole-shaped deformity of foramen magnum, severe micrognathia, postaxial polydactyly of hands, tibial hypoplasia, bowing of tubular long bones, duplicated hallux, hallux varus, short first metatarsal; other anomalies: major brain defects including hydrocephalus, cleft lip/palate, laryngotracheobronchial malformation, pulmonaryr hypoplasia
Isolated defect MIM 174200, 174400, 174500,174600, 174700	May include postaxial polydactyly and syndactyly
Laurin-Sandrow Syndrome [14] MIM 135750	Ulnar duplication, fibular duplication, absent radius, absent tibia, accessory metacarpals, capral fusion, preaxial and postaxial polydactyly, triphalangeal thumb, syndactyly, hypertelorism, broad nose with cleft of nares
Orofacial digital syndromes [15] Type 1 MIM 311200 Type II MIM 252100 Type IV MIM 258860 Type VI MIM 277170 Type VIII MIM 311200	Absence or hypoplasia of phalanges, metacarpals, metatarsals; clinodactyly; camptodactyly; forked or bifid metacarpals; duplication of hallux; postaxial polydactyly; irregular modeling of bones in hands and feet; syndactyly; tibial hypoplasia; talipes equinovarus; other features: microcephaly, lobulated or cleft tongue, cleft lip/palate, malformations of brain and other organs
Pfeiffer syndrome [16, 17] Acrocephalopolysyndactyly, type 5 MIM 101600	Craniosynostosis, Kleeblattschädel, hypertelorism, ocular proptosis/shallow orbits, broad first metacarpals and phalanges of the thumb, radial deviation of thumb, syndactyly, broad first metatarsals and phalanges of hallux, deviation of hallux, absence or hyrpoplasia of other phalanges, symphalangism, radioulnar or radiohumeral synostosis
Pseudo-trisomy 13 syndrome [17] MIM 264480	Microcephaly, micrognathia, hemivertebrae, absent or hypoplastic radius or ulna, postaxial polydactyly, absent or hypoplastic tibia, broad hallux, talipes equinovarus; other defects: omphalocele, malformations of brain and other organs
Short rib-polydactyly syndromes [19, 20], different types; see p. 147 ff MIM 269860, 263520	In common: short horizontal ribs, short tubular bones, postaxial polydactylyr, hypoplastic ilia
Townes-Brocks syndrome [21, 22]; **Fig. 2.22** MIM 107480	Bifid or broad thumb, triphalangeal thumb, syndactyly, clinodactyrly, hyrpoplasia or absent carpals, carpal and/or tarsal fusion, pseudoepiphyses of metacarpals, metatarsal fusion other features: ear anomalies, imperforate anus
VATER Association [23] VACTERL Association MIM 192350	Vertebral fusion, hemivertebrae, missing or extra ribs, rib fusion, absent or hypoplastic radius, absent or hypoplastic thumb, triphalangeal thumb, other limb deficiencies are reported less commonly. Other defects include anal atresia, esophageal atresia, tracheoesophageal fistula, cardiac defect, renal agenesis or dysplasia.
VATER Association with hydrocephalus [24] (MIM 276950, 314390)	Macrocephaly secondary to hydrocephalus, hydranencephaly, vertebral fusion, hemivertebrae, missing or extra ribs, rib fusion, absent or hypoplastic radius, absent or hypoplastic thumb, triphalangeal thumb, other limb deficiencies are reported less commonly. Other defects include anal atresia, esophageal atresia, tracheoesophageal fistula, cardiac defect, renal agenesis or dysplasia.

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Hands/Feet: Postaxial Polydactyly

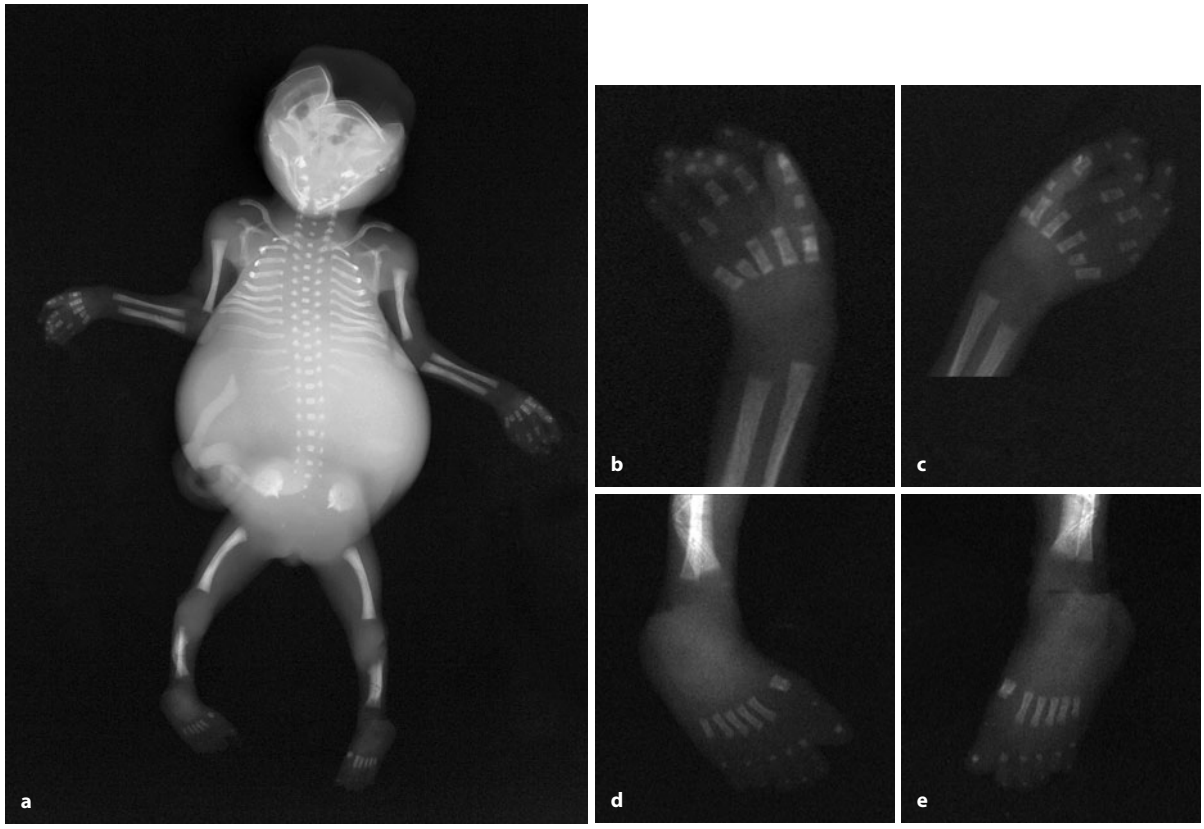

Fig. 2.23. ***16th gestational week.*** Postaxial polydactyly in Meckel-Gruber syndrome. Six toes, shortened tibia and fibula (mesomelia), slight bowing of femora. Ruptured encephalocele

Fig. 2.23b – e. (Detail) Postaxial polydactyly

Diagnosis	Accessory radiological findings in the fetus
Acrocallosal syndrome [1] MIM 200990	Macrocephaly, prominent forehead, large fontanelles, hypertelorism, bifid terminal phalanges of thumbs, duplicated hallux, preaxial polydactyly, syndactyly, brachydactyly: other features: absent corpus callosum, other brain defects, cleft palate, heart defect
Asphyxiating thoracic dystrophy [2, 3]; see p. 150 Jeune syndrome MIM 208500	Long narrow thorax with short, horizontal ribs, irregular costochondral junctions; short and flared iliac bones; triradiate acetabulae; ischial and pubic bones with medial and lateral spurs; premature ossification of the capital femoral epiphysis; shortened long tubular bones with irregular metaphyses; short and/or broad phalanges
Carpenter syndrome [4, 5] Acrocephalopolysyndactyly, type 2 MIM 201000	Craniosynostosis, Kleeblattschädel, absence or hypoplasia of middle phalanges, double ossification center of proximal phalanx of thumb, preaxial polydactyly, broad first metatarsal, syndactyly, coxa valga, genu vara, pes varus
Chromosome abnormality, trisomy 13 [6]	Microcephaly, hypotelorism, small orbits, hypo-ossification of calvarium, spinal dysraphism, hemivertebrae, absentlsupernumerary/fused ribs, hypoplasia of pelvis, oligodactyly, syndactyly, camptodactyly, vertical talus: Other defects: heart defects, omphalocele, holoprosencephaly, neural tube defect, cystic hygroma, hydrops fetalis

Diagnosis	Accessory radiological findings in the fetus
Chromosome abnormality, other [6]	Variable according to specifsc segmental aneuploidy
Elejalde syndrome [7] Acrocephalopolydactylous dysplasia MIM 200995	Craniosynostosis, hypertelorism, shortening of all long bones: Other features: generalized overgrowth, cystic hygroma, hydrops fetalis, omphalocele
Ellis-van Creveld syndrome [8]; see p. 153 Chondroectodermal dysplasia MIM 225500	Mild narrowing of thorax with short ribs, small and flared ilia, triradiate acetabulae, short tubular long bones, bowing of humerus and femur, premature ossification of capital femoral epiphysis, hypoplasia of proximal tibial ossifscation center, genu valgum, short fibula, carpal fusion, short and broad middle phalanges, hypoplasia of distal phalanges, cone-shaped epiphyses of phalanges; other features: heart defect, sparse hair, hypoplastic nails, oral frenula
Focal dermal hypoplasia [9, 10] Goltz syndrome MIM 305600	Absent or hypoplastic clavicles; clavicular pseudoarthrosis; bifsd or fused ribs; asymmetric oligodactyly; ectrodactyly; syndactyly; preaxial polydactyly; bifid thumb; bifid hallux; hemimelia; short phalanges, metacarpals, metatarsals; osteopathia striata; other features: skin, eye, and visceral malformations
Grebe syndrome [11,12]; see p. 177 MIM 200700	Absent or hypoplastic proximal and middle phalanges; syndactyly; absent or hypoplastic metacarpals and carpals; carpal fusion; very short tubular long bones (lower limbs more severe than upper limbs); dislocated radial heads; aplasia/hypoplasia of ulna, radius, and femur
Greig cephalopolysyndactyly [13, 14] MIM 175700	Macrocephaly, prominent forehead, large fontanelles, hypertelorism, preaxial polydactyly of feet, broad thumbs, broad hallux
Hydrolethalus syndrome [15, 16] MIM 236680	Macrocephaly, keyhole-shaped deformity of foramen magnum, severe micrognathia, preaxial polydactyly, tibial hypoplasia, bowing of tubular long bones, duplicated hallux, hallux varus, short first metatarsal; other anomalies; major brain defects including hydrocephalus, cleft lip/palate, laryngotracheobronchial malformation, pulmonary hypoplasia
Isolated defect MIM 174200	May include preaxial polydactyly, syndactyly
Laurin-Sandrow syndrome [17] MIM 135750	Ulnar duplication, fibular duplication, absent radius, absent tibia, accessory metacarpals, capral fusion, preaxial and postaxial polydactyly, triphalangeal thumb, syndactyly, hypertelorism, broad nose with cleft of nares
Meckel-Gruber syndrome [18,19]; **Fig. 2.23** MIM 249000	Rarely preaxial polydactyly or bifsd thumb, talipes equinovarus; other features: polycystic kidneys; CNS anomalies including microcephaly, occipital encephalocele (most common), Dandy-Walker malformation, hydrocephalus
McKusick-Kaufman syndrome [20] MIM 236700	Mesoaxial polydactyly, syndactyly, congenital heart defect, hydrometrocolpos, vaginal stenosis/atresia, polycystic kidney. Some cases may be allelic with Bardet-Biedl syndrome (MIM 209900)
Orofacial digital syndromes [21] Type II MIM 252100 Type III MIM 258850 Type IV MIM 258860 Type V MIM 174300 Type VI MIM 277170 Type VIII MIM 300484	Absent or hypoplastic of phalanges, metacarpals, metatarsals; clinodactyly; camptodactyly, forked or bifid metacarpals; duplication of hallux; preaxial polydactyly; irregular modeling of bones in hands and feet; syndactyly; tibial hypoplasia; talipes equinovarus; other features: microcephaly, lobulated or cleft tongue, cleft lip/palate, malformations of brain and other organs

Diagnosis	Accessory radiological findings in the fetus
Pallister-Hall syndrome [22] MIM 146510	Central polydactyly, bifid third metacarpal, hypoplastic fourth metacarpal, metacarpal synostosis, syndactyly, subluxation or dislocation of radial head, mild shortening of long tubular bones, bifid hallux;. other features: hypothalamic hamartoma, imperforate anus, laryngeal cleft, visceral defects
Pseudo-trisomy 13 syndrome [23] MIM 264480	Microcephaly, micrognathia, hemivertebrae, absent or hypoplastic radius or ulna, preaxial polydactyly, absent or hypoplastic tibia, broad hallux, talipes equinovarus; Other defects: include omphalocele, malformations of brain and other organs
Short rib-polydactyly syndromes, different types [24 – 28]; see p. 147 ff MIM 263530, 263510, 263520, 269860	In common: relative macrocephaly, very short horizontal ribs, short tubular long bones, hypoplasia of scapula, small ilia, preaxial polydactyly
Simpson-Golabi-Behmel syndrome [29] MIM 312870	Macrocephaly, supernumerary ribs, vertebral anomalies, hypoplasia of distal phalanges, syndactyly, clinodactyly, broad hallux other features: hepatosplenomegaly, congenital heart defect, diaphragmatic hernia, renal dysplasia, and hydrops fetalis
Smith-Lemli-Opitz syndrome [30, 31] MIM 270400	Microcephaly, micrognathia, thin ribs, hypoplastic first metacarpal, brachydactyly, syndactyly, talipes equinovarus, vertical talus; other features include CNS anomalies, cleft palate, heart defect, renal dysplasia, hydrops fetalis, genital hypoplasia, sex reversal
Synpolydactyly [32, 33] MIM 186000	Syndactyly of third and fourth fingers, mesoaxial polydactyly, camptodactyly and/or clinodactyly of fifth finger, accessory metacarpal and/or metatarsal, Y-shaped metacarpal, syndactyly of fourth and fifth toes, preaxial polydactyly, mid-phalanx hypoplasia, triangular shaped distal phalanges of feet

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Skull

Premature Cranial Synostosis/Cloverleaf Skull

Fibroblast growth factor receptor mutations cause some of the main short-limb skeletal dysolasias and craniosynostosis syndromes, of which some present a cloverleaf skull (Kleeblattschädel) [1]

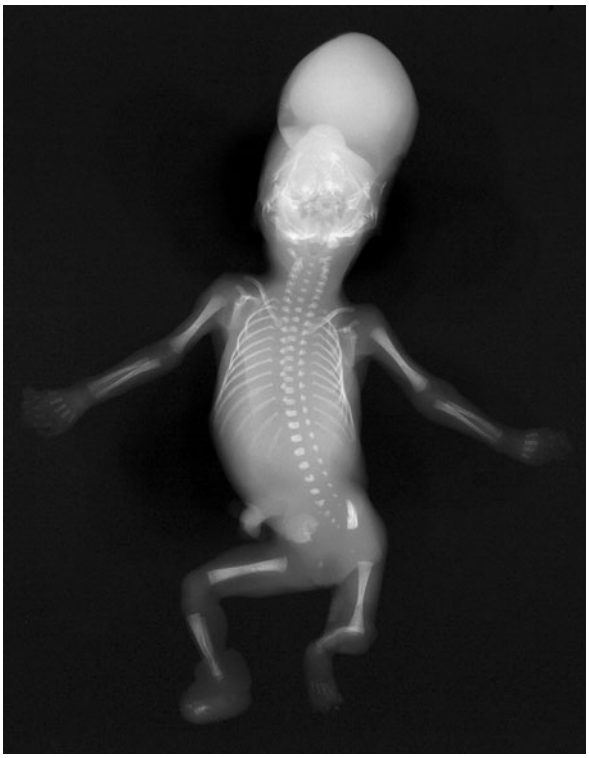
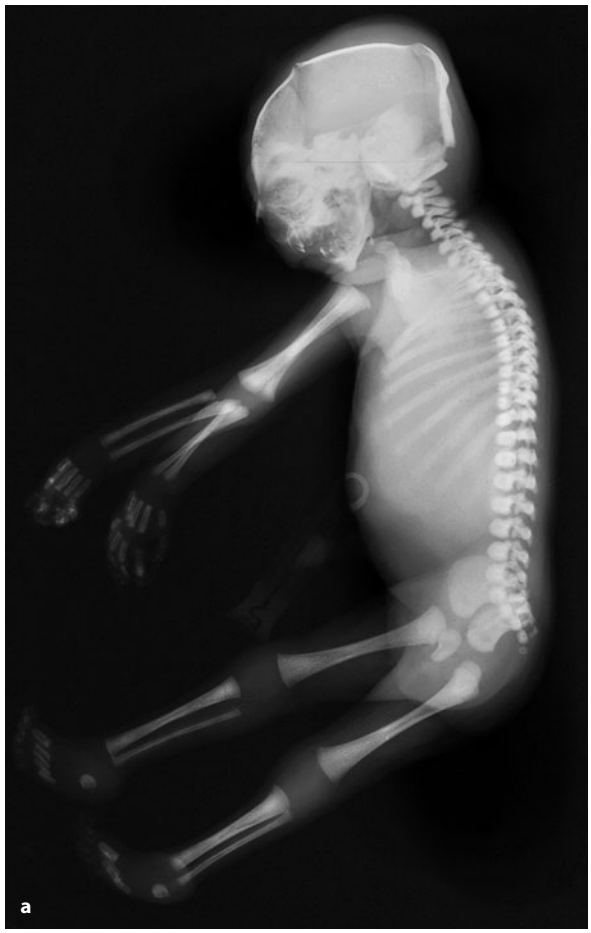


Fig. 2.24. ***17th gestational week.*** Cloverleaf skull in amnion band disruption sequence. Amputation of distal phalanges, aplasia of left tibia, ring constriction at the right shank with distal edema



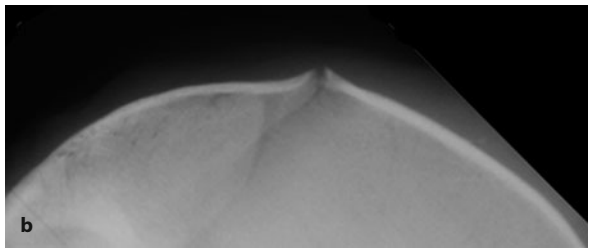


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Fig. 2.25a–c. ***29th gestational week.*** **a** Premature craniosynostosis (donkey's back deformity of the coronal suture) in microcephalic Seckel syndrome with lissencephaly. Very thick calvaria
b (Detail) Ogee arch-like deformation of the ridged, nonfunctional coronal suture
c Orgee arch (Lintel from Jewish Chapel in Mainz, 19th century)

Diagnosis	Accessory radiological findings in the fetus
Acrocephalosyndactyly 1 (Apert) [1] Acrocephalosyndactyly V (Pfeiffer) [1] Acrocephalopolydactyly II (Carpenter) [1] MIM 101200,101600,201000	Distal bony syndactyly of hands and feet Occasionally duplication of first toe Preaxial poly-syndactyly of feet
Amniotic band/disruption sequence ADAM complex (Amniotic Deformity, Adhesions and Mutilations) [2]; **Fig. 2.24** Limb-body wall complex MIM 217100	Usually asymmetric transverse terminal limb reductions/amputations and variable terminal syndactyly/pseudosyndactyly; may also include oligodactyly, hypoplasia of long bones, craniofacial and ventral wall disruption
Antley-Bixler syndrome [3]; see p. 126 MIM 207410	Synostosis of coronal and lambdoid sutures, depression of nasal bridge, frontal bossing, radiohumeral synostosis, bowing of ulnae and femora, fractures
Baller-Gerold Syndrome [4] MIM 218600	Asymmetric radial defect; shortened bowed ulna; variable premature craniosynostosis (coronal suture most commonly)
Cloverleaf skull-limb anomalies, type Holtermüller-Wiedemann [5] MIM 148800	Trilobed skull deformity, ankylosis of the elbows
Craniosynostosis, nonsyndromic isolated	No further radiologic signs
M. Crouzon [6,7] MIM 123500	Coronal and lambdoid suture synostosis, frontal bossing, midface hypoplasia, brachycephaly
Microcephaly: Holoprosencephaly with fetal akinesia/hypokinesia sequence [8] MIM 306990 Fetal brain disruption sequence [9]	Due to reduced intracranial pressure: growth failure of the brain i.e. migrational disorder or intruterine brain destruction
Osteocraniostenosis [10, 11, 12]; see p. 140	Intrauterine dwarfism, thin ribs, slender long bones with diaphyseal fractures, hypo-ossified calvaria, craniostenosis with mild cloverleaf skull appearance
Osteoglophonic dysplasia [13, 14] MIM 166250	Bizarre premature cranial synostosis, rhizomelia, metaphyseal defects
Seckel syndrome [15]; **Fig. 2.25** MIM 210600 Lissencephaly syndromes [16] MIM 247200	Severe intrauterine growth retardation, microcephaly, craniosynostosis, absent fibula
Short rib (polydactyly) syndrome Beemer-Langer type [17]; see p. 149 MIM 269860	Intrauterine dwarfism; short ribs; narrow thorax; marked bowing of long bones, especially radius and ulna; hydrops; pre-postaxial polydactyly
Thanatophoric dysplasia II [1]; see p. 102 MIM 187600	Short stature, short ribs, platyspondyly, mild shortening of long bones, straight femora

Such malformations can also be seen in some partial trisomy syndromes of chromosome **4, 9, 13**.

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Unossified and Hypo-ossified Calvaria

Some skeletal dysplasias, such as atelosteogenesis, boomerang dysplasia, dappled diaphysis dysplasia, lethal male Melnick-Needles syndrome, and others, show a hypo-ossification of the calvaria. These all show striking additional skeletal findings (see p. 136, 163).

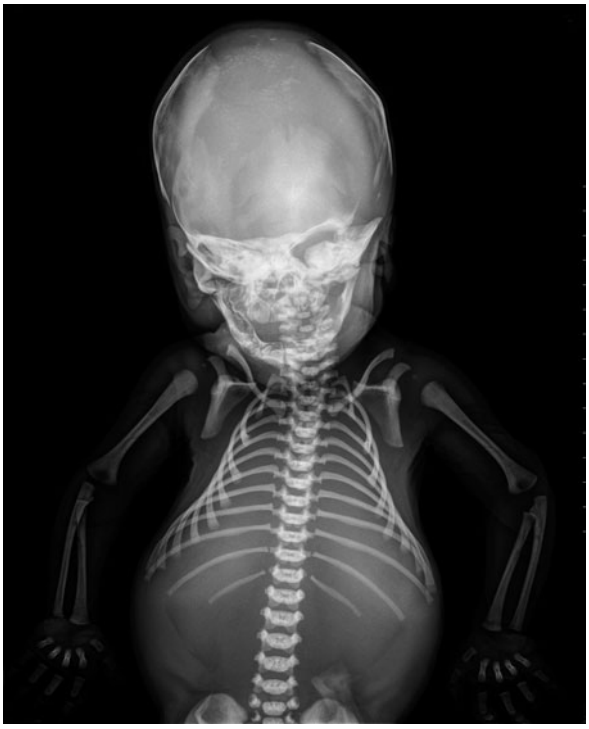

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Fig. 2.26. ***Renal tubular dysplasia. Stillborn, 40 GW.*** Hypocalvaria, broad sutures, bell shaped thorax (lung hypoplasia)

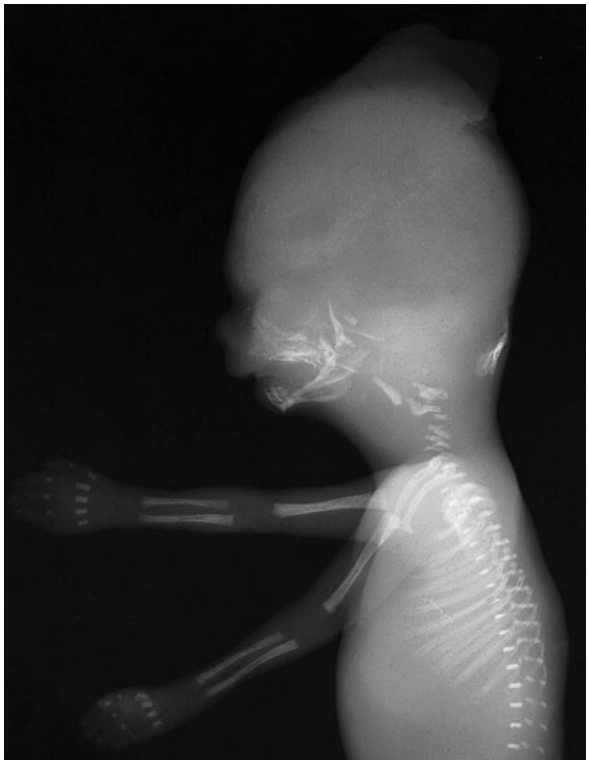

Fig. 2.27. ***15th gestational week.*** Unossified calvaria. in Trisomy 18

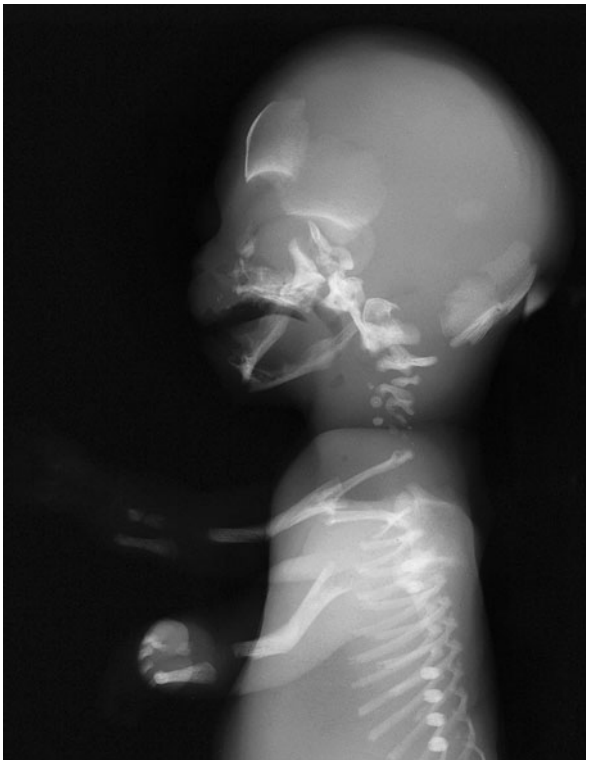

Fig. 2.28. ***22nd gestational week.*** Deficient calvarial ossification in lethal hypophosphatasia. Absent ossification of a major part of the spine. Incomplete or missing ossification of metacarpals and phalanges. Bowing of humeri with deep metaphyseal defects

Diagnosis	Accessory radiological findings in the fetus
Acalvaria [1]	May be associated with omphalocele, spina bifida
Aminopterin/methotrexate fetopathy [2] MIM 600325	Retardation, mesomelia of upper limbs
Angiontensin converting enzyme (ACE) inhibitor fetopathy [3] Same pathomechanism: Renal tubular dysplasia [4]; **Fig.2.26** MIM 267 430	Renal insufficiency, oligohydramios, hypoplasia of lungs, bell shaped thorax, severely underossified calvarial bones (wide sutures), growth retardation, otherwise normal skeleton, perinatal death
Chromosome abnormality [5]; Trisomy 13 and 18 **Fig. 2.27**, see Fig. 2.41	Intrauterine growth retardation microcephaly, hypo- ossification of calvarium, hypoplasia of maxilla and/or mandible, microretrognathia, absent or thin ribs, short sternum, spinal dysraphism, omphalocele
Hyperparathyroidism, neonatal familial [6] MMI 239200	Gross underossifscation, subperiosteal bone resorption, metaphyseal fractures (resembling mucolipidosis type II)
Hypophosphatasia, infantile form [7]; **Fig. 2.28** see p. 131 MIM 241500	Poorly ossifled skeleton, erratic ossification of vertebrae, deep metaphyseal defects, angulation of long bones, especially femur (see Femur: Bowing)
Mucolipidosis type II (I-cell disease) [8] MIM 252500 see p. 145	Decreased bone mineralization, short vertebral bodies, diaphyseal cloaking, signs of hyperparathyroisism, pelvic dysplasia.
Osteocraniostenosis [9, 10]; see p. 140	Intrauterine dwarfism, thin ribs, slender long bones with diaphyseal fractures, hypo-ossified calvaria, craniostenosis with mild cloverleaf skull appearance
Osteogenesis imperfecta II [11]; see p. 128 MIM 120150, 166200	Multiple fractures of ribs and long bones, shortening and angulation of long bones. Hypo-ossification present in all types

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Encephalocele

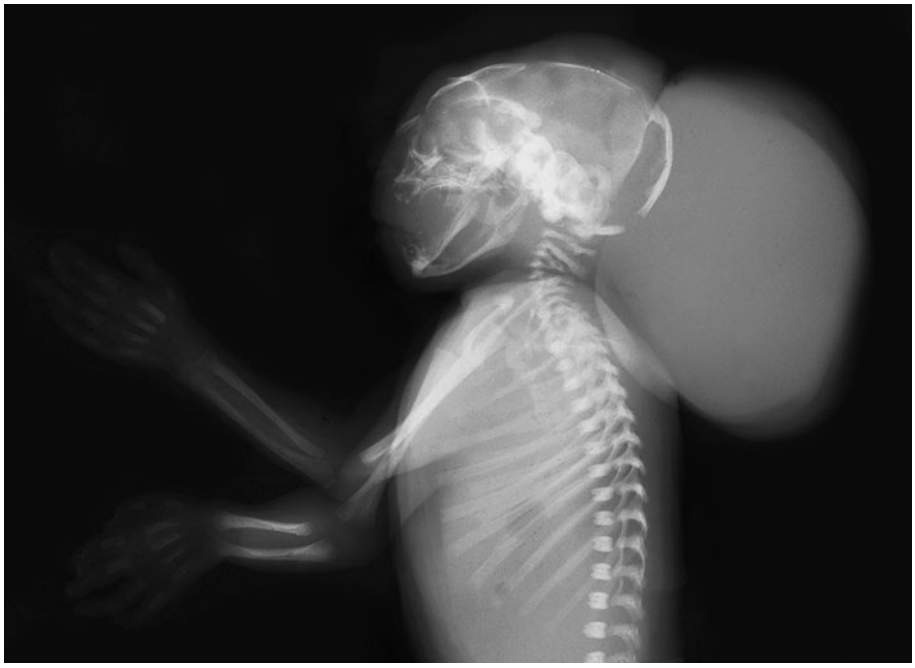

Fig. 2.29. ***23rd gestational week.*** Microcephaly with encephalocele. Note lückenschädel (craniolacunia)

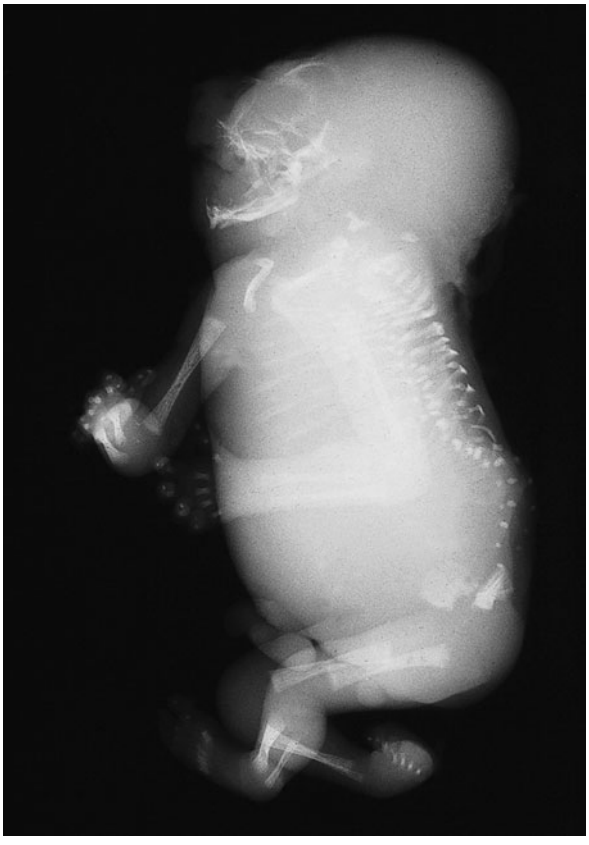

Fig. 2.30. ***15th gestational week.*** Iniencephaly. Retroflexion of head, "missing" neck by fusion of the soft tissue of the head and the shoulders. Defective ossification of the spine. Thoracolumbar kyphosis

Diagnosis	Accessory radiological findings in the fetus
Amniotic band/disruption sequence [1] ADAM complex (*A*mniotic *D*eformity, *A*dhesions, *M*utilations) Limb-body wall complex MIM 217100	Usually asymmetric transverse terminal limb reductions/amputations and variable terminal syndactyly/pseudosyndactyly. Mayr also include oligodactyly, hypoplasia of long bones, craniofacial and ventral wall disruption
Chromosome abnormalities	Variable according to specific segmental aneuploidy
DK phocomelia [2] Phocomelia-encephalocele-thromobocytopeniaurogenisal malformation von Voss-Cherstvoy syndrome MIM 223340	Microcephaly; absent or hypoplastic humerus, radius, ulna, metacarpals, thumb; oligodactyly; syndactyly of fingers; other features: genitourinary, cardiac anomalies, platelet abnormalities
Dyssegmental dysplasia; see p. 120 Silverman-Handmaker type [3, 4] MIM 224410	Severe irregularity in shape and size of vertebral bodies; hypoplastic thorax with short ribs; short and wide, bowed tubular long bones with wide metaphyses (dumbbell-shaped); hypoplasia ofbasilar portions of ilia; broad and thick ischium and pubis
Fukuyama congenital muscular dystrophy [5] MIM 253800	Hydrocephalus, neuronal migration defect, optic atrophy, retinal detachment, myocardial fibroelastosis
Isolated finding; **Fig. 2.29**	Isolated encephalocele, microcephalus, no other radiologic findings
Iniencephaly [6]; **Fig. 2.30**	Cervical spinal retroflexion, elevated face, occipito-spinal association, cervical spina bifida, rhizomelia of upper limbs, omphalocele
Joubert syndrome and related cerebellooculorenal syndromes [7] MIM 213300	Macrocephaly, enlarged cisterna magna hypoplasia or Aplasia of cerebellar vermis, hypoplasia of cerebellar hemispheres and/or brainstem, postaxial polydactyly, renal cysts
Knobloch syndrome [8] MIM 120329	Occipital skull defect, cerebellar hypoplasia, vermian agenesis or hypoplasia, neuronal heterotopia, vitreoretinal degeneration, high myopia
Laryngeal atresia, encephalocele and limb anomalies (LEL syndrome) [9] MIM 607132	Fetal hydrops, anterior and/or parietal skull defect, facial cleft, enlarged echogenic lungs, laryngeal atresia, hypoplasia or aplasia of radius and/or tibia, aplasia of metacarpals, metatarsals and phalanges, syndactyly, renal anomaly
Meckel-Gruber syndrome [10]; see Fig. 2.23 MIM 249000	Post-axial polydactyly, rarely pre-axial polydactyly, talipes equinovarus; other features: polycystic kidneys; CNS anomalies including microcephaly, anencephaly, Dandy-Walker malformation, hydrocephalus
Roberts syndrome [11] Roberts-SC phocomelia syndrome Pseudothalidomide syndrome see Fig. 2.5 MIM 268300	Microcephaly, wormian bones, sometimes craniostenosis, hypertelorism, cleft lip and palate, variable absence or hypoplasia of tubular bones (usually asymmetric, and upper limbs typically more severe than lower limbs), fusion of tubular long bones, bowing of tubular long bones, contractures of large joints, absent carpals, absent first metacarpal and thumb, absent fifih metacarpal and phalanges, clinodactyly, syndactyly, talipes equinovarus or equinovalgus, calcaneovalgus: anomalies common in GNS, heart, kidneys
Sakoda complex [12] MIM 610871	Microcephaly, cerebral dysgenesis, agenesis of corpus callosum, cleft lip +/- palate, microphthalmia, hemivertebrae, scoliosis, heart defect, bifid thumb
VACTERL association with hydrocephalus [13] MIM 276950	See “Aplasia, Hypoplasia of Thumb and Radius”
Walker-Warburg syndrome [14] Hydrocephalus, agyria, retinal dysplasia-encephalocele HARD ± E syndrome MIM 236670	Microcephaly, wide or delayed fusion of cranial sutures, joint contractures, talipes equinovarus; other features: retinal dysplasia, cataract, ear anomalies, Dandy-Walker malformation, hydrocephalus, heart defect

Diagnosis	Accessory radiological findings in the fetus
Warfarin embryopathy [15] Coumadin embryopathy Fetal warfarin syndrome	Frontal bossing; depressed nasal bridge; very small/short anteverted nose; short tubular long bones; short metacarpals, metatarsals, and phalanges; stippling or punctate calcification of epiphyses, spine, proximal femur, and calcaneus

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Anencephaly/Myelomeningocele/Spina Bifida

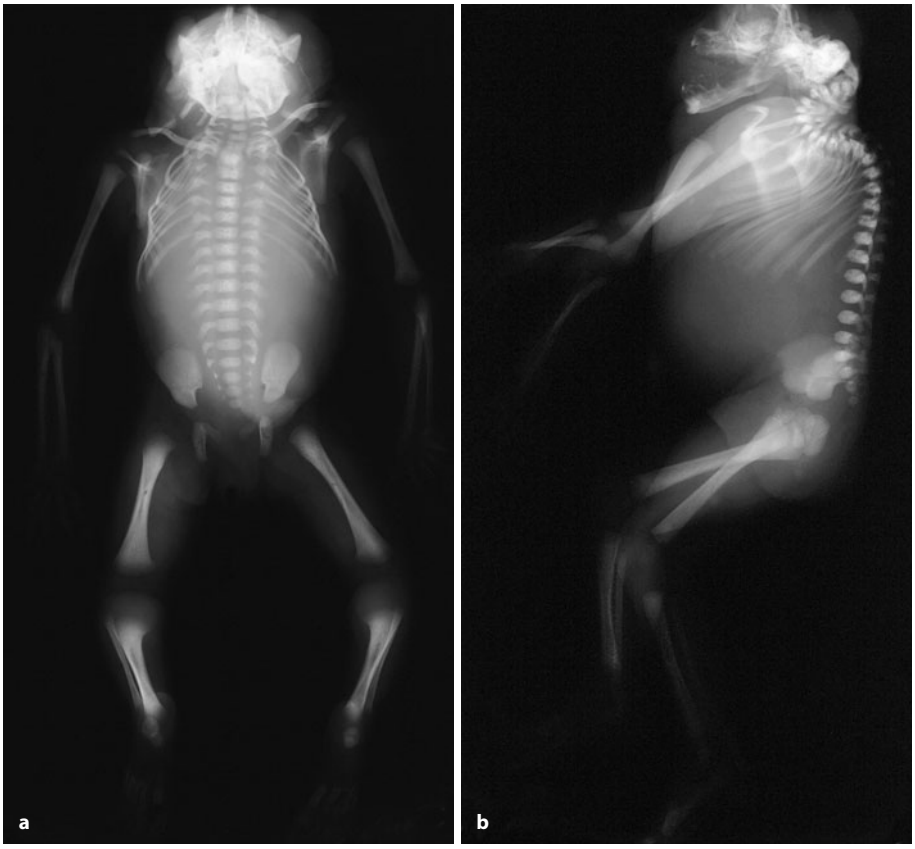

Fig. 2.31a, b. ***29th gestational week.*** Anencephaly with total craniorachischisis, aplasia of the cranial vault. Wide open spinal canal, severe kyphosis and swan's neck deformity of the cervical spine resulting in a disproportionately short trunk

Diagnosis	Accessory radiological findings in the fetus
Amniotic band/disruption sequence ADAM complex (Amniotic Deformity, *Adhesions, Mutilations)* Limb-body wall complex [1] MIM 217100	Usually asymmetric transverse terminal limb reductions/amputations and variable terminal syndactyly/pseudosyndactyly; may also include oligodactyly, hypoplasia of long bones, craniofacial and ventral wall disruption
CHILD syndrome [2] (Congenital hemidysplasia, ichthyosiform erythroderma, limb defects) MIM 308050	Unilateral hypoplasia of limb(s) including absent or hypoplastic scapula, humerus, radius, ulna, femur, tibia, fibula; joint contracture or pterygium; punctate epiphyseal calcification; other features: congenital ichthyosiform erythroderma ipsilateral to limb deficiency, visceral anomalies
Chromosome abnormality trisomy 18 (Edward syndrome) [3]	Intrauterine growth retardation; microcephaly; prominent occiput; micrognathia; thin or absent ribs; short sternum; absent or hypoplastic radius, first metacarpal, thumb; camptodactyly; vertical talus; talipes equinovarus; short or dorsiflexed great toe; other defects: tracheoesophageal fistula, heart defect, absent or cystic kidneys, omphalocele
Chromosome abnormalities, other	Variable according to specific segmental aneuploidy
Diabetic embryopathy [4]	Hemivertebrae, absent or hypoplastic femora, hypoplastic tibia, preaxial or postaxial polydactyly, spinal dysraphism, neural tube defect, congenital heart defect
Disorganisation-like syndrome [5] MIM 223200	Anencephaly, asymmetry, pre-/postaxial polydactyly, lower limb aplasia/duplication
Fetal aminopterin syndrome Folate antagonist chemotherapeutic agents [6]	Delayed mineralization of calvarium, craniolacunae, craniosynostosis, hypertelorism, micrognathia, rib anomalies including fusion, joint contractures, absence or hypoplasia of digits including thumbs, syndactyly, talipes equinovarus

Diagnosis	Accessory radiological findings in the fetus
Fetal valproate syndrome [7, 8]	Prominent metopic ridge, bifrontal narrowing, clinodactyly, distal phalangeal hypoplasia, absent or hypoplastic radius, absent or hypoplastic thumb, talipes equinovarus
Iniencephaly [9]	Severe retroflexion of the head, occipital encephalocele, spinal defects, mandibular aplasia, cleft palate
Isolated defect with or without rachischisis [10]; **Fig. 2.31a, b**	No other radiological signs
Laterality sequence [11] MIM 304570	Visceral heterotaxy, sacral agenesis.
Meckel-Gruber syndrome [12, 13]; see Fig. 2.23 MIM 249000	Post-axial polydactyly, rarely pre-axial polydactyly, talipes equinovarus;. other features include polycystic kidneys; CNS anomalies including microcephaly, occipital encephalocele (most common), Dandy-Walker malformation, hydrocephalus
Omphalocele-exstrophy of the bladder-imperforate anus-spinal defects (OEIS) complex [14] MIM 258040	Hemivertebrae, absent sacrum, widely spaced pubic bones, spinal dysraphism, talipes equinovarus, ventral wall defect
Pentalogy of Cantrell [15] Thoracoabdominal syndrome; see Fig. 2.40 MIM 313850	Sternal defects including agenesis, clefting or bifid sternum, absence of lower third of sternum; other defects include supraumbilical midline defect (omphalocele), central diaphragmatic hernia, pericardial defect, congenital heart defect
Short-rib polydactyly syndrome, type II (Majewski type) [16, 17]; see p. 152 MIM 263520	Relative macrocephaly, prominent forehead, thoracic hypoplasia with protuberant abdomen, short and horizontal ribs, short tubular long bones, ovoid tibia smaller than fibula, preaxial or postaxial polydactyly; other features include hydrops fetalis, cleft or lobulated tongue, multiple visceral and brain anomalies
X-linked neural tube defects [18] MIM 301410	Dysraphias within families as an X-linked condition.

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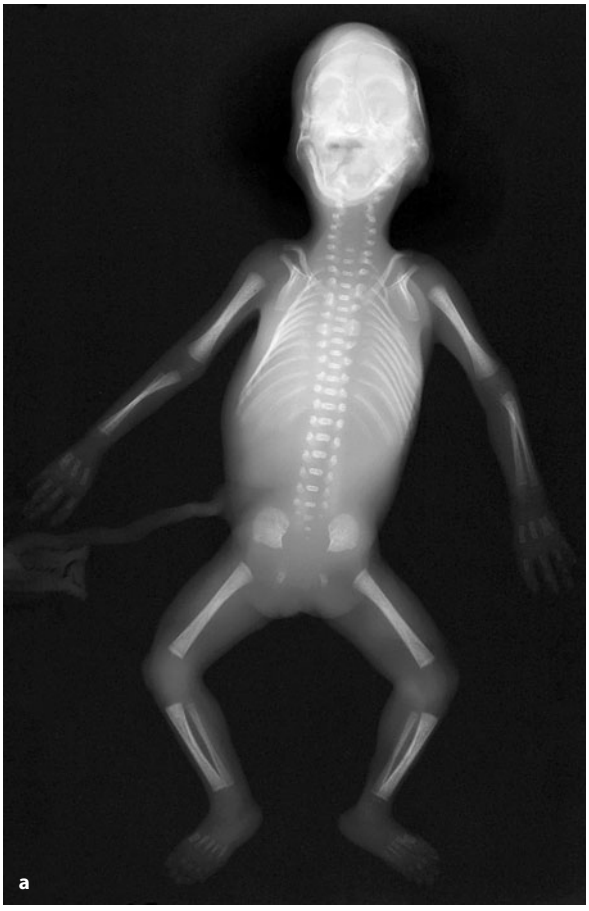
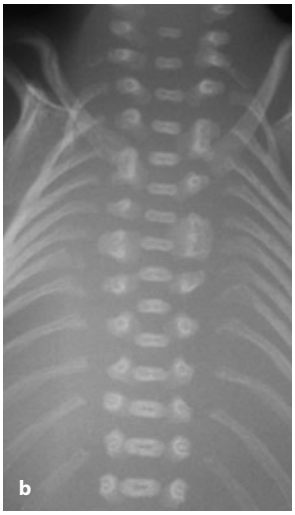
Spine

Vertebral Segmentation Defects/Hemivertebrae/Vertebral Fusion





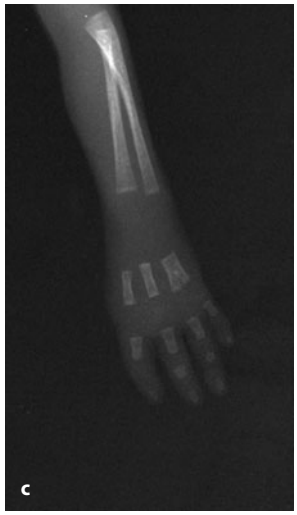
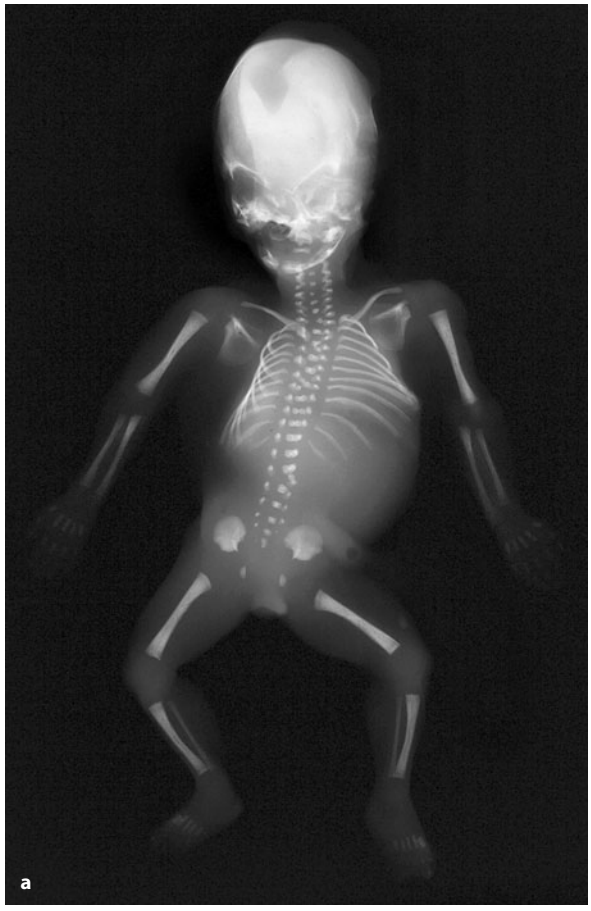
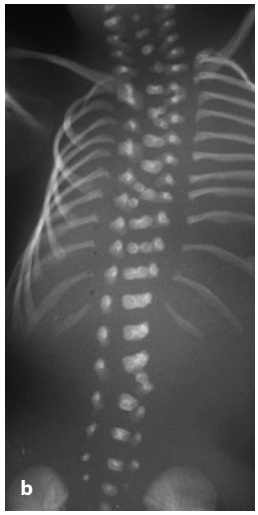


Fig. 2.32. ***18th gestational week.*** Fusion of neural arcs in the upper half of the thoracic spine in partial monosomy 13 q-. Microcephaly, defective ossification C1–C5. Oligodactyly; aplasia of thumb. Proximal fusion of metacarpals 4 and 5. **b** (Detail) Segmentation defects in the thoracic spine. **c** (Detail) Preaxial oligodactyly





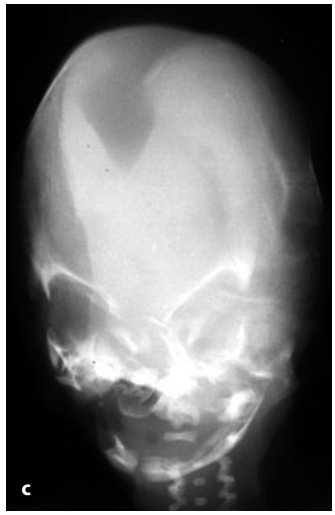


Fig. 2.33. ***18th gestational week.*** Multiple vertebral segmentation defects with hemivertebrae and butterfly vertebrae in Goldenhar syndrome. Mandibular hemihypoplasia (absence of the right corpus mandibulae). **b** (Detail) Hemivertebrae in the thoraxic spine. **c** (Detail) Aplasia of the right corpus mandibulae

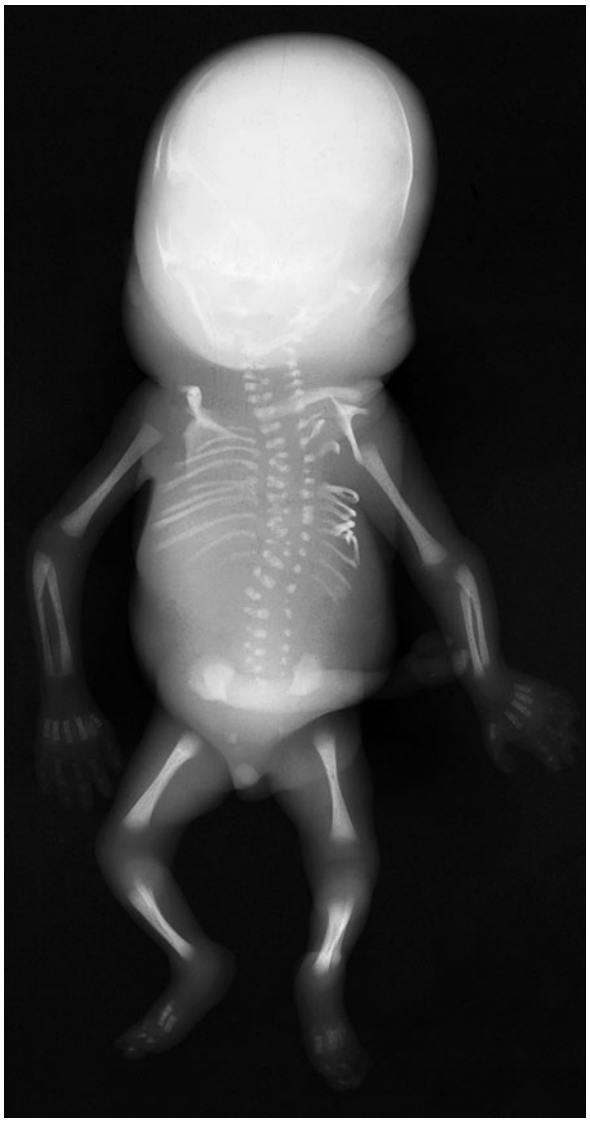


Fig. 2.34. ***17th gestational week.*** Multiple vertebral segmentation defects in the dorsal and upper lumbar spine in spondylothoracic dysostosis. Fusion of ribs (10 ribs on the right, 12 on the left). Short thorax. Nuchal lymphedema

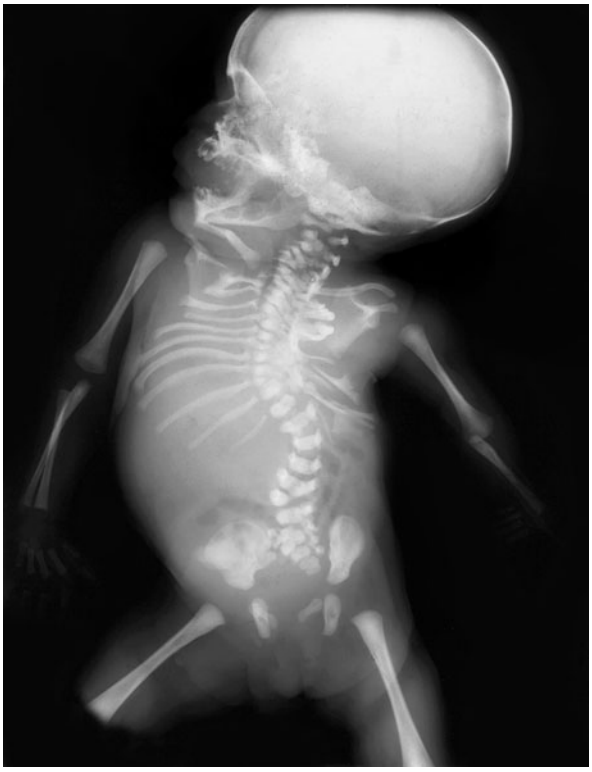


Fig. 2.35. ***30th gestational week.*** Multiple segmentation defects of the vertebrae in MURCS association. Asymmetric vertebral aplasia/hypoplasia, left-sided rib fusions, resulting in an S-shaped scoliosis. Aplasia of the radius and right thumb

Classification of vertebral segmentation defects has considerably changed during the last few years. Spondylocostal dysplasias cover all phenotypes with the characteristics of the 3 molecularyly defined types. Spondylothoracic dysplasia is used for the specific phenotype with "crab-like" chest. Diagnoses like Jarcho-Levin, Klippel-Feil should no longer be used: Their indiscremenate use refers erroneously to a whole variety of heterogenous phenotypes that should be named specifically.

Diagnosis	Accessory radiological findings in the fetus
Acro-renal-mandibular syndrome [1] MIM 200980	Severe mandibular hypoplasia, variable and asymmetric limb reduction defects including hypoplastic or absent radius or tibia, oligodactyly, ectrodactyly, syndactyly
Aicardi Syndrome [2] MIM 304050	Absent, extra and/or fused ribs, scoliosis, microcephaly, cleft lip +/- palate, central nervous system defects, microphthalmia, coloboma, chorioretinal lacunae, cataract

Diagnosis	Accessory radiological findings in the fetus
Alagille syndrome [3] MIM 118450	Mostly butterfly vertebrae, further: rib anomalies, short ulnae, short distal phalanges
Butterfly vertebrae, isolated	Can be seen in Alagille syndrome, Aicardi syndrome
Campomelic dysplasia [4]; see p. 124 MIM 114290	Mandibular hypoplasia; hypoplastic scapulae;, small, bell-shaped thorax; absent ribs; hypoplastic vertebrae; usually short and bowed femur and tibia; joint dislocation may include hip and radial head; absent or delayed ossification of distal femur, proximal tibia, sternum, ischium, pubis; hypoplasia of ischium and pubis; talipes equinovarus
CHARGE association [5] MIM 214800	Aconym of associated malformations: *C*oloboma, *H*eart anomaly, choanal *A*tresia, *R*etardation, *G*enital and *E*ar anomalies. Small mandible, cleft palate, hemivertebra, rarely limb anomalies (ectrodactyly, bifid distal femur)
Chromosome abnormalities [6, 7] Trisomy 13 Partial monosomy 13 q; **Fig. 2.32** Trisomy 18 Triploidy	Growth retardation, hypo-ossified calvaria, hypotelorism, nuchal cystic hygroma, umbilical hernia, radial aplasia, hemivertebrae (especially fusion of the vertebral arches), coronal clefts in the lumbar spine; see Fig. 2.38
Diabetic embryopathy [8]; see Fig. 2.36	Hemivertebrae, absent or hypoplastic femora, hypoplastic tibia, preaxial or postaxial polydactyly, spinal dysraphism, caudal dysplasia
Duane anomaly-radial defects [9] MIM 126800	Hypolplastic or absent fibula
Dyssegmental dysplasia [10]; see p. 120 Silverman-Handmaker type [11], MIM 224410 Rolland-Desbuquois type, MIM 224400	Severe irregularity in shape and size of vertebral bodies, hypoplastic thorax with short ribs, short and wide bowed tubular long bones with wide metaphyses (dumbbell shaped), hypoplasia of basilar portions of ilia, broad and thick ischium and pubis
Fetal alcohol syndrome [12]	Intrauterine growth retardation, microcephaly, vertebral segmentation defects, cervical ald thoracic segmentation anomaly, reduction deformity of upper extremities, hypoplasia/aplasia of ulna tetradactyly, clubfoot
Goldenhar syndrome/hemifacial dysplasia (oculo-auriculo-vertebral dysplasia) [13,14] see **Fig. 2.33** MIM 164210	Sporadic, unilateral malformation syndrome of the first and second branchial arches (hypoplastic mandible and maxilla), vertebral anomalies, radial hypoplasia
Klippel-Feil syndrome [15]; MIM 148900) Better use specific diagnoses.	Spectrum of cervical and upper thoracic spinal fusions; hemivertebrae and occipitoatlantal fusion; Sprengel deformity; spina bifida; may be a part of Mayer-Rokitansky-Küster syndrome, MURCS association (Fig. 2.34), alcohol embryopathy, Duane anomaly-radial defects, or Goldenhar syndrome (Fig. 2.32)
Limb/pelvis hypoplasia/aplasia syndrome Includes: Schinzel phocomelia, Al-Awadi/Raas-Rothschild syndrome [16, 17, 18, 19, 20], MIM 276820 Fuhrmann syndrome MIM 228930	Variable and possibly asymmetric lower limb deficiency including primarily femur, tibia and fibula; absent toes; upper limb defects include absent/hypoplastic radius, ulna, carpals, metacarpals, and phalanges; radio-humeral synostosis; hypoplastic pelvis including irregular pubis, ischium; hip dislocation; thoracic involvement including wide or fused ribs, pectus carinatum
(Jarcho-Levin syndrome [21]); see: spondylothoracic dysostosis **Fig. 2.34**	Severe vertebral defects including block vertebrae; butterfly vertebrae; hemivertebrae; ribs that: have sagittal clefts with malsegmentation including fusion, are bifid, are absent or hypoplastic, appear "fan-like" or "crablike"; spinal dysraphism; neural tube defects; congenital heart defects; and other visceral anomalies frequently reported

Diagnosis	Accessory radiological findings in the fetus
Lethal multiple pterygium syndrome [22] MIM 253290 X-linked lethal multiple pterygium syndrome [23] MIM 312150	Fusion of cervical vertebrae, hypoplastic scapulae, wide ribs, contractures of large joints with pterygia formation, radio-ulnar synostosis, camptodactyly of fingers, talipes equinovarus; other features: cystic hygroma and hydrops fetalis, diaphragmatic hernia
Microphthalmia-esophageal atresia [24] Anophthalmia-esophageal-genital AEG syndrome MIM 206900	Absent, extra or fused ribs, hypoplastic vertebrae, microcephaly, anophthalmia/microphthalmia, congenital heart defect, esophageal atresia, genital defects, central nervous system defects
MURCS association [25]; MIM 601076 **Fig. 2.35**	Acronym of associated malformations: *M*ullerian duct aplasia/hypoplasia, *R*enal aplasia/ectopia, *C*ervical *S*omite (spinal) dysplasia, and upper limb defects
Omphalocele-Exstrophy of the bladder- Imperforate anus-Spinal defects (OEIS) complex [26] MIM 258040	Hemivertebrae, absent sacrum, widely spaced pubic bones, spinal dysraphism, talipes equinovarus
Robinow syndrome, autosomal recessive [27] Costovertebral segmentation defects with mesomelia COVESDEM MIM 268310	Macrocephaly, large fontanelle, frontal bossing, hypertelorism, depressed nasal bridge, pectus excavatum, absent or fused ribs, scoliosis, mesomelia, brachydactyly, brachymesophalangism, broad thumbs and halluces, bifid terminal phalanges, congenital heart defect, umbilical hernia, genital defects, renal duplication, hydronephrosis
Simpson-Golabi-Behmel syndrome [28] MIM 312870	Macrocephaly, supernumerary ribs, hypoplasia of distal phalanges, syndactyly, clinodactyly, broad hallux, postaxial polydactyly, hydrops fetalis
Spondylocostal dysostosis 1 (DLL3) [29,30] MIM 277300 Spondylocostal dysostosis 2 (MESP2) MIM 608681 Spondylocostal dysostosis 3 (LFNG) MIM 609813	Diffuse segmentation disorder (whole spine). no scoliosis, rib anomalies. Pebble beach sign Diffuse segmentation disorder (whole spine), pronounced in cervico-thoracic region, block vertebrae Diffuse segmentation disorder (whole spine), multiple hemivertebrae and rib anomalies, kyphoscoliosis
Spondylothoracic dysostosis (AR) [31] MIM 277300 (formerly covered by Jarcho-Levin syndrome)	Severe trunk shortening, fan-like or crab-like thorax, rib fusion at their origin, spinal dysraphism
Sprengel deformity [32] MIM 184400	Clavicular anomalies, rib segmentation defects, omovertebral bone, scoliosis, diastematomyelia, cleft palate, may be associated with Klippel-Feil syndrome
Spinal dysraphism	Vertebral segmentation defects (such defects are also part of Arnold-Chiari II malformation, hydrocephalus)
Urorectal septum malformation sequence [33]	Vertebral fusion, hemivertebrae, extra or missing ribs, absent or hypoplastic sacrum, hypoplastic radius, absent or hypoplastic thumb; other defects: megacystis ("prune belly"), anal atresia, esophageal atresia, tracheoesophageal fistula, cardiac defect, renal agenesis or dysplasia, absent or ambiguous external genitalia
VATER Association [34] MIM 192350 VACTERL Association	Vertebral fusion, hemivertebrae, missing or extra ribs, rib fusion, absent or hypoplastic radius, absent or hypoplastic thumb, triphalangeal thumb, preaxial polydactyly, other limb deficiencies less commonly; other defects: anal atresia, esophageal atresia, tracheoesophageal fistula, cardiac defect, renal agenesis or dysplasia

Diagnosis	Accessory radiological findings in the fetus
VATER Association with hydrocephalus [35] MIM 276950,314390	Macrocephaly secondary to hydrocephalus, hydranencephaly, vertebral fusion, hemivertebrae, missing or extra ribs, rib fusion, absent or hypoplastic radius, absent or hypoplastic thumb, triphalangeal thumb, pre-axial polydactyly, other limb deficiencies less commonly; other defects: anal atresia, esophageal atresia, tracheoesophageal fistula, cardiac defect, renal agenesis or dysplasia

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Pelvic-Sacral Abnormalities

Sacral Agenesis/Hypogenesis/Caudal Dysplasia; Pubic Bone Dysgenesis

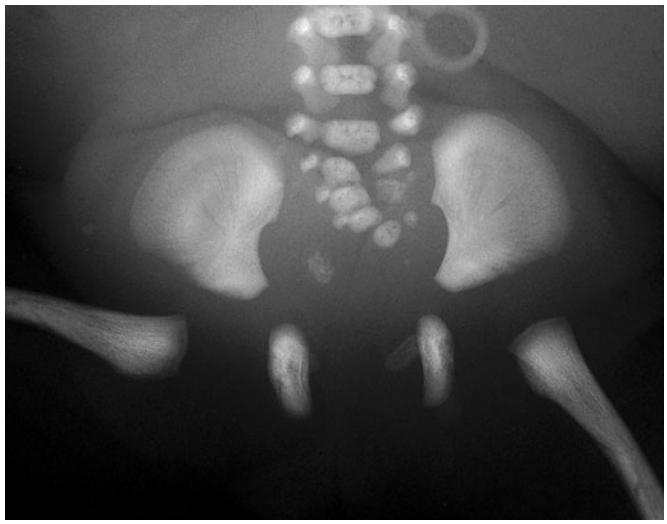

Fig. 2.36. ***34th gestational week.*** Semilunar dysostosis of the sacrum (scimitar shape) due to an anterior meningocele. (Currarino triad)

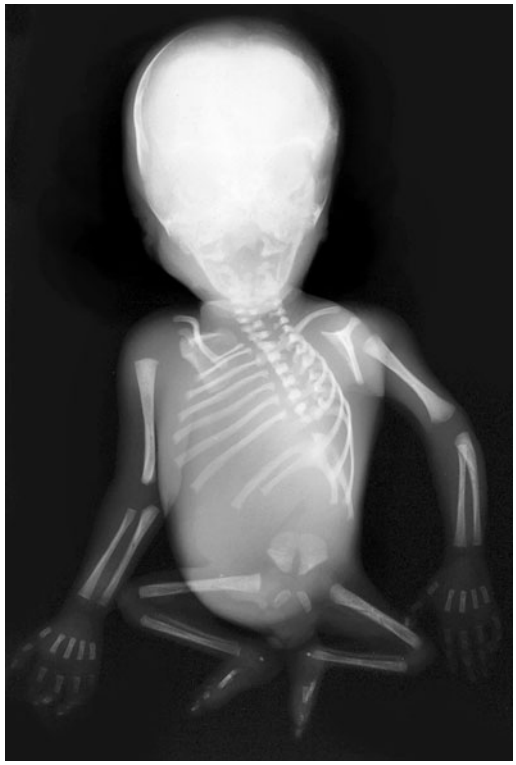

Fig. 2.37. ***22nd gestational week.*** Aplasia of the lower spine in Diabetic embryopathy. Posterior, fork-like fusion of the 8th and 9th ribs, partial fusion of iliac bones, narrow pelvis. Slender tibia and fibula due to hypokinesia. Stippled ossification of calcaneus

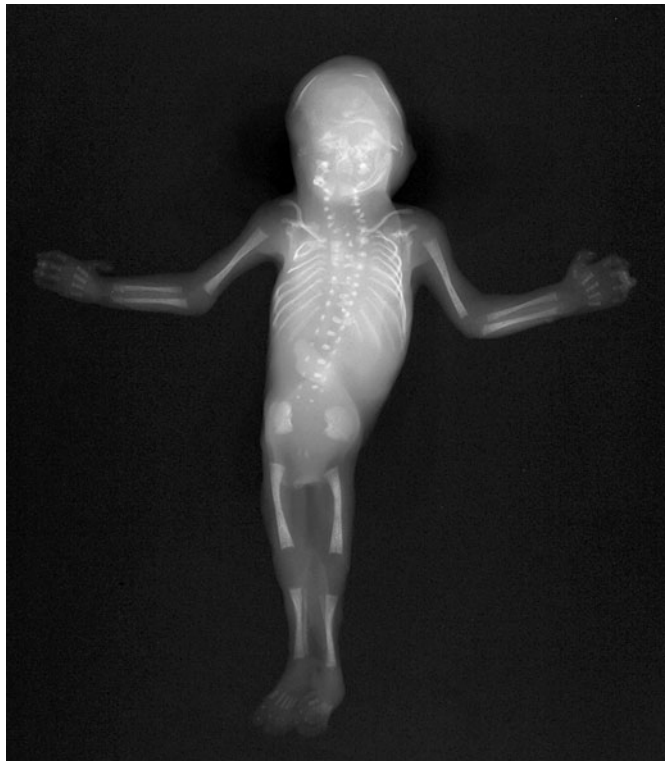

Fig. 2.38. ***16th gestational week.*** Narrow pubic distance in dipodic sirenomelia. Multiple vertebral segmentation defects and fusion of neural arches. Desmal fusion of lower legs. Mirroring of shanks and feet (tibia and hallux on the outside). Sacrum not ossified, narrow ossa ischii

Diagnosis	Accessory radiological findings in the fetus
Achondrogenesis, type 2; see p. 114 Hypochondrogenesis MIM 200600 Lethal type II collagenopathies [1] MIM 200610	Absent or severely delayed ossification of vertebral bodies, short and horizontally oriented ribs, absent or delayed ossification of pubic and ischial bones, small iliac bones with concave borders, small scapulae, very short long bones with cupped metaphyses, fetal hydrops
Boomerang dysplasia[a] [2]; see p. 163 MIM 112310	Similar to atelosteogenesis 1, hut more severe; hypoossification of calvarium; relative macrocephaly; micrognathia; absent or severely retarded ossification of vertebral bodies; long clavicles with normal ossification; narrow interpedicular distance of the thoracic spine with widening in the lumbar spine; very short and deformed long tubular bones (the femur may be fan- or boomerang-shaped); absent pubic ossification centers; hydrops fetalis
Campomelic dysplasia[a] [3]; see p. 124 MIM 211970	Mandibular hypoplasia; hypoplastic scapulae; small bell-shaped thorax; absent ribs; hypoplastic vertebrae; usually short and bowed femur and tibia; joint dislocation may include hip and radial head; absent or delayed ossification of distal femur, proximal tibia, sternum, ischium, pubis; hypoplasia of ischium and pubis; talipes equinovarus
Cleidocranial dysostosis [4]; see p. 171 MIM 119600	Partially absent clavicles, delayed ossification of the pubic bones, cleft mandible, cleft palate
Currarino triad [5, 6, 7]; MIM 176450 **Fig. 2.36**	Sickle-shaped sacrum, presacral mass, anterior meningocele
Diabetic embryopathy [8]; **Fig. 2.37**	Hemivertebrae, absent or hypoplastic femora, hypoplastic tibiae, preaxial or postaxial polydactyly, spinal dysraphism, rib fusion in the midline
Axial mesodermal dysplasia spectrum [9]	Caudal dysplasia, hemivertebrae, scoliosis, absent or bifid ribs, lower limb contractures, talipes equinovarus, hemifacial microsomia
Isolated defect [10]	Variable lumbar vertebral agenesis; fused iliac wings; lower limb contractures with pterygia; hypoplasia of femur, tibia, fibula; talipes equinovarus
Limb-body wall complex [11]; MIM 217100 see Fig. 2.15	Defect of lower abdominal wall, bladder exstrophy, pubic diastasis, segmental defects of lower extremities, spinal segmentation defects
Limb/pelvis hypoplasia/aplasia syndrome [12,13,14,15,16] Includes: Schinzel phocomelia syndrome, MIM 268300 Al-Awadi/Raas-Rothschild syndrome MIM 276820 Fuhrmann syndrome MIM 228930	Parieto-occipital skull defect, femoral hypoplasia, bowing, absent ulnae and fibulae, radial agenesis, oligodactyly, preaxial polydactyly, diaphragmatic hernia, absence or coalescence of tarsal and metatarsal bones
Omphalocele-Exstrophy of the bladder-Imperforate anus-Spinal defects (OEIS) complex[a] [17] MIM 258040	Hemivertebrae, widely spaced pubic bones, spinal dysraphism, talipes equinovarus
Opsismodysplasia[a] [18] MIM 258480	Delayed skeletal maturation, shortening of hand bones. rhizomelic shortening of limbs, severe platyspondyly. absent ossification of vertebrae, narrow thorax, delayed ossification of ischiopubic bones
Pubic distance, extended[a] see Fig. 2.15	Hint of an underlying epispadia, bladder exstrophy, ventral wall defect; syndromatic or non-syndromatic
Pubic distance, narrow[a] see Fig. 2.13	Hint of an underlying urethral aplasia/atresia, prune belly syndrome; syndromatic or non-syndromatic

Diagnosis	Accessory radiological findings in the fetus
Sacral defect with anterior meningocele [7] MIM 600145	Caudal regression, in case of urinary tract obstruction: narrow pubic distance
Sirenomelia [19]; **Fig. 2.38** MIM 182940	Hemivertebrae, fusion of vertebrae, bifld or fused ribs. spinal dysraphism, single or fused lower limb with single or fused femora and tibiae, variable foot abnormalities depending on degree of fusion, sometimes both tibiae and flbulae rotated by 180 degrees, hypoplastic/absenT radius
Spondyloepiphyseal dysplasia congenita[a] [1, 20]; see p. 118 MIM 183900 Spondylometepiphyseal dysplasia (Strudwick)[a] [21, 22] MIM 184250	Short trunk, short limbs; similar radiologic signs of both diseases during fetal period; growth retardation, ovoid vertebrae; no ossification of pubic rami
Urorectal septum malformation sequence[a] [23]	Hemivertebrae, hypoplasia of femur and/or tibia, talipes equinovarus, polydactyly, radial agenesis, megacystis ("prune belly")
VATER Association[a] [24] MIM 192350 VACTERL Association; see Figs. 2.9, 2.13	Vertebral fusion, hemivertebrae, missing or extra ribs. rib fusion, absent or hypoplastic radius, absent or hypoplastic thumb, triphalangeal thumb, preaxial polydactvly, other limb deficiencies less common; other defects include anal atresia, esophageal atresia, tracheoesophageal fistula, cardiac defect, renal agenesis or dysplasia
X-linked visceral heterotaxy syndrome [25,26] MIM 306955	Dextrocardia, heart defect, situs inversus, visceral heterotaxy, gastrointestinal atresia, malrotation, meningomyelocele

[a] Syndromes with pubic bone dysgenesis/a- hypoossified pubic bones

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Coronal Clefts of Vertebral Bodies

Coronal clefts of vertebral bodies in the fetus may be a temporal variation of normal enchondral ossification [1]. In our experience this type is most often seen in chromosomal aberrations. (Fig. 2.38 b,c)

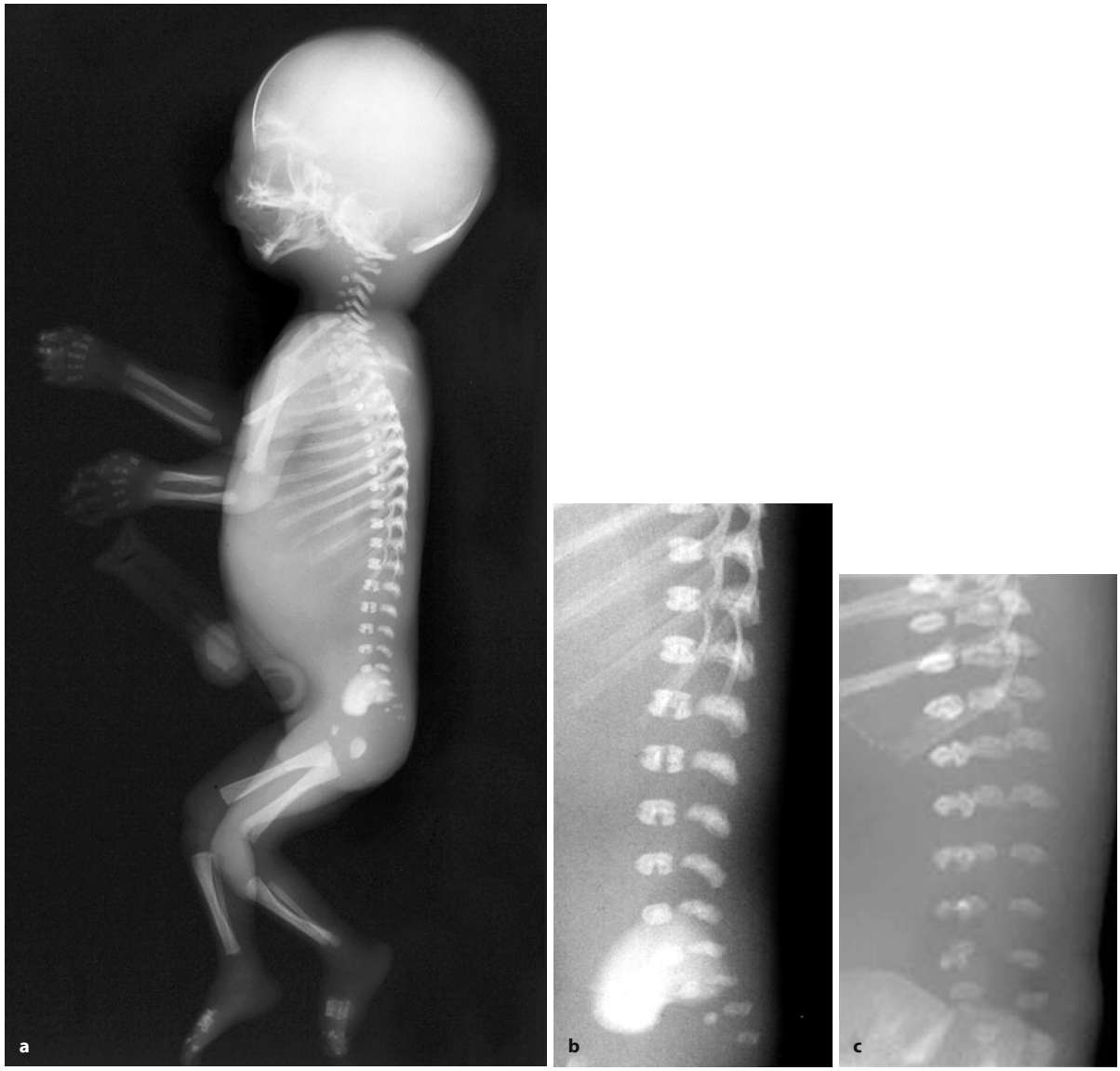

Fig. 2.39. ***18th gestational week.*** Coronal clefts of the thoracic and lumbar vertebral bodies in Trisomy 21. Otherwise normal skeleton **b** (Detail) Coronal clefts of the lumbar vertebrae. **c** Coronal clefts in another fetus, illustrating the spectrum of clefting

Diagnosis	Accessory radiological findings in the fetus
Atelosteogenesis 1 [2 – 4] and related osteochondrodyspiasias; see p. 163 MIM 108720, 108721, 112310	Hypoplastic vertebral bodies, especially of cervical and thoracic spine; hypoplastic and tapered (distal) humerus and femur; bowed radius, ulna, tibia; absent or hypoplastic fibula; absent or hypo-ossified metacarpals and phalanges
Chondrodysplasia punctata, rhizomelic type [5,6]; see p. 159 MIM 215100	Punctate calcifications primarily around the ends of long bones, hypoplasia of humerus and femur, wide or splayed metaphyses, platyspondyly

Diagnosis	Accessory radiological findings in the fetus
Chondrodysplasia punctata, tibia-metacarpal type [7]; see p. 159 MIM 118651	Stippling of sacrum and carpals; dislocation of hip, knee, elbow; short femur, tibia, metacarpals, phalanges; asymmetry
Chromosome abnormalities Trisomy 13 [8] Trisomy 18 [9] Trisomy 21 [10]; **Fig. 2.39** Triploidy [11] Turner syndrome	Besides the other signs (such as growth retardation, hypo-ossified calvaria, hypotelorism, nuchal cystic hygroma, umbilical hernia, radius aplasia), hemivertebrae (especially fusion of the vertebral arches), coronal clefts in the lumbar spine
CODAS (cerebral-ocular-dental-auricular-skeletal syndrome) [12] MIM 600373	Hip dislocation, delayed ossification of pubic bones
De la Chapelle dysplasia [13] see p. 167 MIM 256050	Short tubular bones, deficiency of ulna and to a lesser degree radius, hemivertebrae, platyspondyly, short ribs
Desbuquois syndrome [14, 15]; see p. 165 MIM 251450	Mild platyspondyly, hypoplasia of the ilia (base), short femoral neck and greater trochanter ("monkey wrench" appearance), mild shortening of long bones with flared metaphyses, multiple large and small joint dislocations, advanced carpal and tarsal ossification, accessory ossification centers of metacarpals and metatarsals (digits 1 and II)
Fibrochondrogenesis [16, 17]; see p. 108 MIM 228520	Micrognathia; absent or hypo-ossification of vertebral bodies, especially posteriorly; platyspondyly; short ribs with splayed ends; short, broad ilia with basilar spurs, short long tubular bones with metaphyseal flaring ("dumbbell-shaped")
Larsen syndrome [18]; see p. 161 MIM 150250, 245600	Multiple joint luxations, bifid calcaneus,
Lethal Kniest-like dysplasia [19], MIM 245190 Kniest dysplasia [20], MIM156550; see p. 118	Relative macrocephaly, micrognathia, platyspondyly, broad ilia with hypoplasia of the base, short tubular bones with wide metaphyses, short femoral neck, hydrops fetalis
OPD II (oto-palato-digital syndrome type II) [21] MIM 304120	Curved long bones, wavy ribs, platyspondyly, absent frist digits, omphalocele, overlapping of 2nd finger (trisomy 18-like; see Fig. 2.41b,c) narrow pelvis in case of infravesical obstruction
Oto-spondylo-megaepiphyseal dysplasia (OSMED)[a] [22,23,24] see p. 118 MIM 215150	Micrognathia, depressed midface, rhizomelic shortening of long bones, dumbbell-shaped femora, square or broad iliac wings, brachydactyly, platyspondyly, anterior vertebral wedging, absent-small capital femoral epiphyses (newborn), enlarged epiphyses (late)
Short rib-polydactyly syndrome, type 1 (Saldino-Noonan) [25]; see p. 147 MIM 263530	Relative macrocephaly, very short horizontal ribs, hypoplasia of scapula, small ilia, very short femur and humerus with pointed ends, absent or hypo-ossification of other long tubular and short tubular bones, postaxial polydactyly, hydrops fetalis
Weissenbacher-Zweymüller syndrome[a] [22,26] MIM 277610	Micrognathia, midface hypoplasia, rhizomelic shortening of long bones, dumbbell-shaped femora and humeri, broad iliac wings, enlarged epiphyses

[a] related disorders due to defects in type 11 collagen genes and/or type II collagen

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Platyspondyly

This is an unspecific radiographic sign most often recognized in skeletal dysplasias (see chapter 3). It becomes only diagnostic with a combination of other findings (e.g. short extremities, unossified pubic bone, multiple fractures, unossified calvaria, coronal clefts of vertebral bodies...).

Ventral Body Wall Defects

Ectopia Cordis

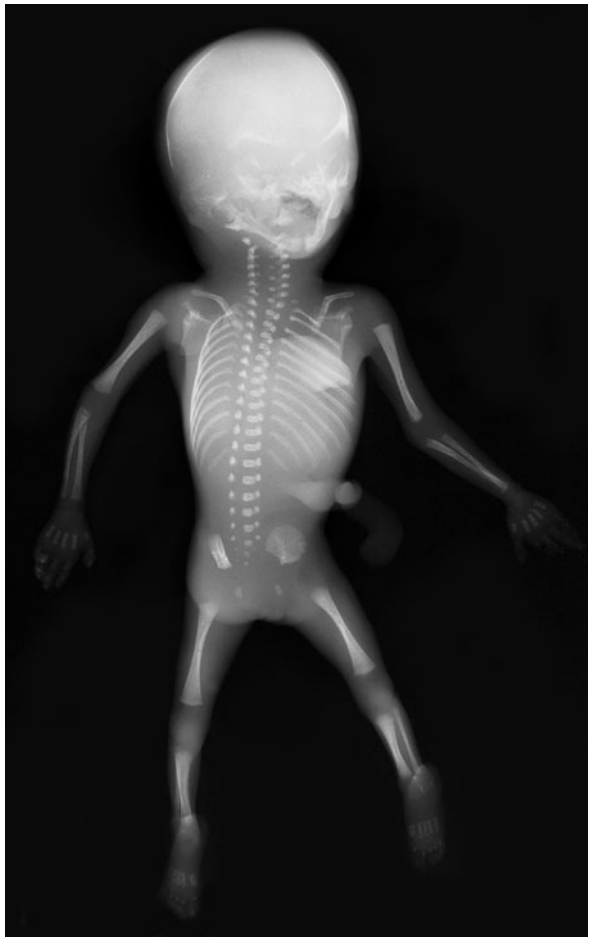

Fig. 2.40. ***18th gestational week.*** Body wall defect: ectopic heart in pentalogy of Cantrell. The shadow of the ectopic heart projects onto the upper part of the left hemithorax. Slender abdomen. Otherwise normal

Diagnosis	Accessory radiological findings in the fetus
Amniotic band/disruption sequence [1, 2]; ADAM complex (Amniotic Deformity, Adhesions, Mutilations) Limb – body wall complex MIM 217100	Usually asymmetric transverse terminal limb reductions/amputations and variable terminal syndactyly/pseudosyndactyly; may also include oligodactyly, hypoplasia of long bones, craniofacial and ventral wall disruption.
Pentalogy of Cantrell [3] Thoracoabdominal syndrome; MIM 313850 **Fig. 2.40**	Sternal defects including agenesis, clefting or bifid sternum, absence of lower third of sternum; other defects include supraumbilical midline defect (omphalocele), central diaphragmatic hernia, pericardial defect, congenital heart defect
Sternal malformation-vascular dysplasia association [4] Sternal clefts-telangiectasia/hemangiomas Hemangiomas – midline abdominal raphe [5] MIM 140850	Absent or bifid sternum, pectus excavatum, absent or hypoplastic clavicles; micrognathia, cleft mandible; other features include midline hemangiomas of face and/or chest, midline supraumbilical raphe

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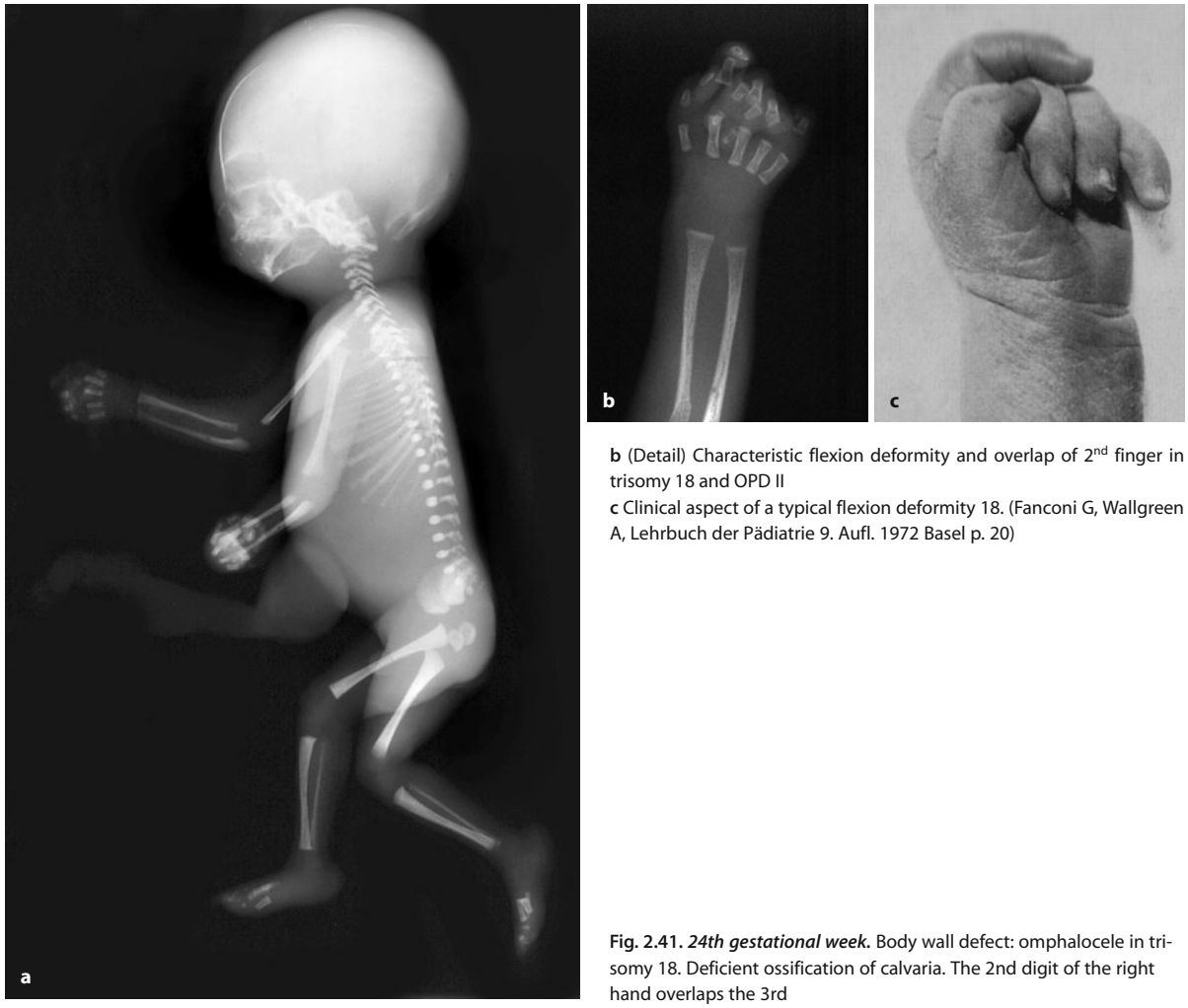
Ventral Wall Defects/Omphalocele/Gastroschisis



b (Detail) Characteristic flexion deformity and overlap of 2nd finger in trisomy 18 and OPD II

c Clinical aspect of a typical flexion deformity 18. (Fanconi G, Wallgreen A, Lehrbuch der Pädiatrie 9. Aufl. 1972 Basel p. 20)

Fig. 2.41. ***24th gestational week.*** Body wall defect: omphalocele in trisomy 18. Deficient ossification of calvaria. The 2nd digit of the right hand overlaps the 3rd

Diagnosis	Accessory radiological findings in the fetus
Amniotic band/disruption sequence ADAM complex (*Amniotic* Deformity, *Adhesions*,Mutilations) Limb-body wall complex [1]; MIM 217100 see Fig. 2.15	Usually asymmetric transverse terminal limb reductions/amputations and variable terminal syndactyly/pseudosyndactyly; may also include oligodactyly, hypoplasia of long bones, craniofacial and ventral wall disruption
Arthrogryposis multiplex congenita Amyoplasia [2] MIM 108110	Extension contractures of elbows and knees, dislocated or adducted hips, flexion of wrists and hands, slender long bones, metacarpophalangeal and interphalangeal joint contractures, pterygia, absent patellae, hypoplastic genitalia, gastroschisis, nonduodenal intestinal atresia
Beckwith-Wiedemann syndrome [3] MIM 130650	Macrosomia, cardiomegaly, omphalocele, abdominal visceromegaly

Diagnosis	Accessory radiological findings in the fetus
Boomerang dysplasia [4,5]; see p. 163 MIM 112310	Similar to atelosteogenesis 1, but more severe; hypoossification of calvarium; relative macrocephaly; micrognathia; absent or severely retarded ossification of vertebral bodies; long clavicles with normal ossiflcation; narrow interpedicular distance of the thoracic spine with widening in the lumbar spine; very short and deformed long tubular bones (the femur may be fan- or boomerang-shaped); hydrops fetalis
Chromosome abnormality, trisomy 13 [6]	Microcephaly, hypotelorism, small orbits, hypo-ossification of calvarium, spinal dysraphism, hemivertebrae, absent/supernumerary/fused ribs, hypoplasia of pelvis, oligodactyly, polydactyly, syndactyly, camptodactyly, vertical talus; other defects: heart ahnormalities, omphalocele, holoprosencephaly, neural tube defect, cystic hygroma, hydrops fetalis
Chromosome abnormality, trisomy 18 [6, 7]; **Fig. 2.41**	Microcephaly, hypo-ossification of calvarium, hypoplasia ofmaxilla and/or mandible, microretrognathia, absent or thin ribs, short sternum, spinal dysraphism, hypoplasia of pelvis, hypoplasia of first metacarpal, flexion deformities and overlapping fingers, vertical talus, short first toe, hammertoes; other defects: intrauterine growth retardation, heart abnormalities, omphalocele, neural tube defect
Donnai-Barrow syndrome [8] MIM 222448	Macrocephaly, wide metopic suture, large anterior fontanelle, agenesis of corpus callosum, hypertelorism, heart defect, diaphragmatic hernia or eventration, omphalocele, intestinal malrotation, bicornate uterus
Elejalde syndrome [9] MIM 200995	Craniosynostosis, hypertelorism, shortening of all long bones, postaxial polydactyly; other features include generalized overgrowth, cystic hygroma, hydrops fetalis.
Fryns syndrome [10] MIM 229850	Macrocephaly, wide metopic suture, large anterior fontanelle, agenesis of corpus callosum, hypertelorism, heart defect, diaphragmatic hernia or eventration, omphalocele, intestinal malrotation, bicornate uterus
Melnick-Needles osteodysplasty [11, 12] MIM 309350 Oto-palato-digital syndrome, type II [13, 14]; see Fig. 2.41b,c see p. 136 MIM 304120	Hypo-ossification of calvarium, sclerosis of skull base, large anterior fontanelle, micrognathia, thin/wavy/beaded ribs with irregular cortex, hypoplastic scapula, flared ilia with hypoplastic base, kyphosis, scoliosis, lordosis, S-shaped bowing of long bones, metaphyseal flaring, coxa valga, genus valga, short distal phalanges, absent or hypoplastic metacarpals and metatarsals, absent or hypoplastic thumb and/or hallux; other defects: urinary obstruction, multiple joint dislocations
*O*mphalocele-*E*xstrophy of the cloaca-*I*mperforate anus-*S*pinal defects (*OEIS* complex) [15] MIM 258040	Absent or hypoplastic sacrum, hemivertebrae, scoliosis, spinal dysraphism, pubic diastasis, talipes equinovarus
Omphalocele, diaphragmatic hernia and radial ray defects [16] Gershoni-Baruch syndrome MIM 609545	Diaphgramatic hernia, bell-shaped chest, scoliosis, hepatic cysts, radioulnar synostosis, absent thumb, triphalangeal thumb, absent metacarpal
Osteopathia striata with cranial sclerosis [17] OSCS MIM 300373	Macrocephaly, trapezoidal shaped skull, hypertelorism, frontal bossing, cleft lip +/- palate, cleft palate, linear striations of long bones, scoliosis, increased bone density, cranial sclerosis, absent or hypoplastic fibulae, talipes equinovarus, camptodactyly, hydrocephalus, heart defect, omphalocele, intestinal malrotation, multicystic kidney, Males are more severely affected.
Pseudotrisomy 13 syndrome [18, 19] MIM 264480	Microcephaly, micrognathia, hemivertebrae, absent or hypoplastic radius or ulna, postaxial polydactyly, preaxial polydactyly, absent or hypoplastic tibia, broad hallux, talipes equinovarus

Diagnosis	Accessory radiological findings in the fetus
Short rib-polydactyly, Beemer-Langer type [20]; see p. 149 MIMIM 269860	Short horizontal ribs, short tubular bones, tibia short but longer than fibula, bowed radius and ulna, preaxial or postaxial polydactyly, hypoplastic ilia; other defects: CNS abnormalities, cleft lip, heart, kidneys, hydrops fetalis
Tetraamelia [21] MIM 273395	Tetraamelia, microphthalmia, cleft lip +/- palate, choanal atresia, diaphragmatic defect, abnormal lung lobation, gastroschisis, agenesis of kidney, adrenal, spleen, absence or malformation of external and internal genitalia, persistent cloaca,
Thoracoabdominal syndrome Pentalogy of Cantrell [22, 23] MIM 313850	Short, cleft or bifid sternum, central/anterior diaphragmatic hernia; other defects include ectopia cordis, congenital heart defect

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