Skeletal Radiol (1983) 9:157–169

Skeletal
Radiology

Radiology of Postnatal Skeletal Development

VII. The Scapula

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Abstract. Twenty-four pairs of scapulae from fetal specimens and 35 pairs of scapulae from postnatal cadavers ranging in age from full-term neonates to 14 years, were studied morphologically and roentgenographically. Air-cartilage interfacing was used to demonstrate both the osseous and cartilaginous contours. When the entire chondro-osseous dimensions, rather than just the osseous dimensions, were measured, the scapula had a height-width ratio ranging from 1.36 to 1.52 (average 1.44) during most of fetal development. The exceptions were three stillborns with camptomelic, thanatophoric, and achondrogenic dwarfism in which the ratio averaged 0.6. At no time during fetal development was the glenoid cavity convex; it always had a concave articular surface. However, the osseous subchrondral countour was often flat or slightly convex.

In the postnatal period the height-width ratio averaged 1.49. The ratio remained virtually unchanged throughout skeletal growth and maturation. In a patient with unilateral Sprengel's deformity the ratio for the normal side was 1.5, while the abnormal was 1.0. The cartilaginous glenoid cavity was always concave during postnatal development, even in the specimens with major structural deformities, although the subchondral osseous contour was usually flat or convex during the first few years of postnatal development. Ossification of the coracoid process began with the development of a primary center at three to four months. A bipolar physis was present between the primary coracoid center and the primary scapular center until late adolescence.

Key words: Acromion – Acromioclavicular joint – Coracoid – Glenoid – Scapula – Sprengel's deformity

Unlike other components of the appendicular skeleton, the complete scapula is not well visualized in standard roentgenographic projections. Accordingly, it is difficult to attain familiarity with its overall developmental morphology, particularly the normal patterns of secondary ossification center formation within the vertebral margin, inferior tip, acromion, and coracoid process. Special projections such as transthoracic or transaxillary views become more difficult to interpret when unfamiliar physeal contours and linear secondary ossification centers are seen. Reference studies of postnatal skeletal development that might assist in interpretation of this particular bone are nonexistent.

The scapula is injured infrequently in the child, but when there is direct trauma, differentiation of an undisplaced fracture line, the most common manifestation of injury, from a normal developmental pattern may be extremely difficult [12, 24]. Congenital abnormalities such as Sprengel's deformity, while relatively uncommon, may present confusion in diagnosis, especially when an omovertebral segment is present or the superior vertebral margin is deformed [1, 3]. The morphologic contours of the scapula are altered in the Sprengel's abnormality, although supportive, correlative roentgenographic anatomic data are minimal [6, 23, 24]. Ogden et al. described a complete specimen (scapula, omovertebral bone, and deformed cervicothoracic spine) from a patient with concomitant Sprengel and Klippel-Feil deformities [17].

This study continues the presentation of data concerning the radiographic appearance of the developing cartilaginous epiphyses and secondary ossification centers [8, 9, 14–16, 18]. The specific patterns within the acromion and coracoid process will be assessed. A series of prenatal radiographs also were analyzed to show that the basic contours and height/width ratio of the scapula are present early in prenatal development, and do not change

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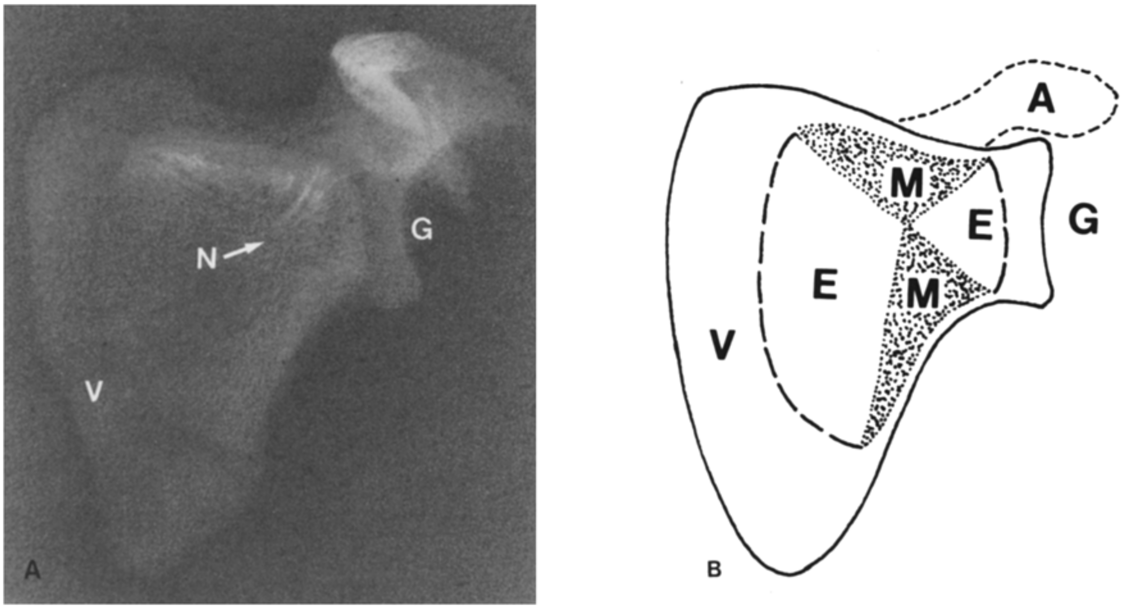

Fig. 1. A Anteroposterior (AP) view of scapula from a 26-week-old fetus. Note that the overall cartilaginous contour, especially along the vertebral border, is comparable to the final osseous contour at skeletal maturity. The pattern of ossification from a central nutrient artery (N, *arrow*) radiating toward the vertebral (V) border and glenoid (G) is comparable to the ossification pattern retained in marine mammals (see Fig. 16). However, in the human this is rapidly remodeled during fetal growth, so that minimal to no roentgenographic evidence remains postnatally. **B** Schematic of fetal scapula, showing how different patterns of endochondral (E) ossification toward the vertebral and glenoid margins establishes the primary endochondral cones. The region between the cones superiorly and inferiorly subsequently fill in with membranous (M) bone. A – acromion; G – glenoid; V – vertebral border

substantially with subsequent fetal and postnatal growth.

Materials and Methods

Twenty-four fetuses ranging in crown-rump length from 8 to 28.5 cm were studied; these corresponded to developmental ages of twelve to twenty-nine weeks [21]. These fetuses were obtained from either spontaneous or elective abortions. None of the fetuses had gross structural abnormalities affecting the pectoral girdle. Thirty-five pairs of scapulae were removed from a series of skeletally immature cadavers. The ages of the cadavers ranged from full-term stillborn to fourteen years. There were 23 males and 12 females. Included were examples of camptomelic, thanatophoric, and achondrogenic dwarfism (all stillborn) and Sprengel's deformity (13-year-old).

All prenatal and postnatal scapulae were dissected free of non-skeletal soft tissues and disarticulated at the acromioclavicular and glenohumeral joints. The gross specimens were roentgenographed in standard anteroposterior projections using Kodak RP-M2 (mammography) film. This technique, using air/cartilage interfacing, allowed excellent radiographic visualization of the hyaline cartilage of the epiphyses, as well as the articular contours. Specimens were placed directly on the film to avoid magnification errors. The gross specimens also were immersed completely in water and roentgenographed. Such a technique, using a water/cartilage interface, reasonably duplicated the clinical situation of the radiolucent epiphyseal cartilage. A "lateral" projection duplicating the transaxillary view visualized the angular relationships of the scapular spine, supraspinous and infraspinous portions, acromion, and coracoid. In order to adequately visualize the glenoid, acromion, and coracoid, without superimposition of the scapular blade, several specimens were sectioned through the region of the scapular spine and glenoid in the sagittal plane, and radiographed using air/cartilage and water/cartilage interfacing. Additional oblique views were taken, as indicated, to visualize coracoid and acromial ossification. A "superior" view was taken looking down the scapula from its superior margin; this view allowed good visualization of coracoid development and the buttressing ("wrap-around") of the coracoid and acromion anterior and posterosuperior to the glenoid. All specimens were documented photographically.

Height-to-width ratio was determined by measuring the longest distance from the apex of the supraspinous portion to the inferior angle of the body and dividing it by the distance across the scapular body measured along the spine and glenoid. These measurements included the normally radiolucent cartilage of the glenoid and vertebral border of the scapula, and thus represent true measurements of the entire chondro-osseous unit, rather than simply the osseous measurements.

Results

Fetal

The initial area of primary scapular ossification is located closer to the glenoid than the vertebral border. The endochondral ossification process expands toward the glenoid to produce a slightly convex subchondral plate, and toward the vertebral border, initially establishing a radiate pattern

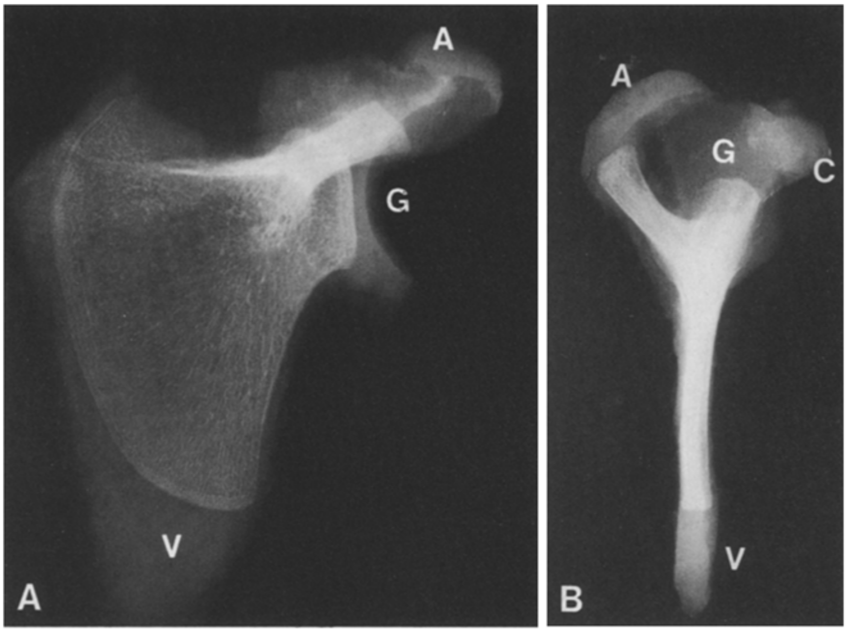

Fig. 2A, B. Two months. **A** AP view. **B** Transcapular (lateral) view. The bulk of the vertebral (V) margin is unossified. Similarly the ends of the acromion (A), coracoid (C), and glenoid (G) are unossified. The glenoid cartilage is concave, in contrast to the slightly convex appearance to the subchondral bone of the glenoid

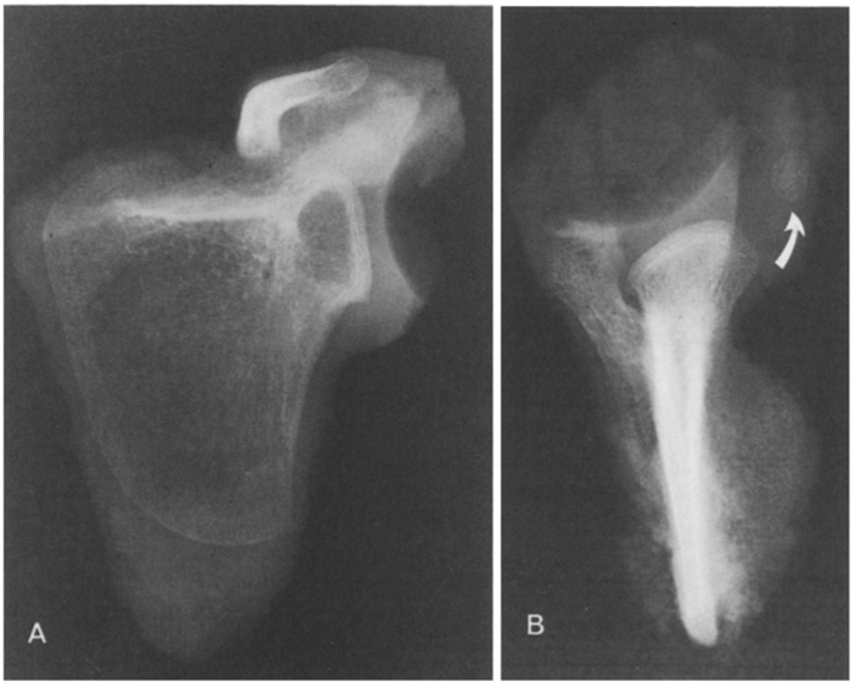

Fig. 3A, B. Three months. **A** AP view. **B** Superior view. The vertebral osseous contour does not completely follow the cartilaginous contour, especially at the inferior margin. The coracoid process is just beginning to ossify (*arrow*). This is not readily evident in the AP view, but is quite obvious in the superior view. The glenoid subchondral plate is still slightly convex

to the endochondral bone. This leads to the creation of a "proximal" epiphysis along the vertebral border and a "distal" epiphysis comprising glenoid and acromion (Fig. 1). Separate primary ossification in the coracoid was not evident in any of the fetal scapulae in this series.

The height-width ratio was fairly constant from 12 weeks of fetal development to term, ranging from 1.36 to 1.52, with an average of 1.44. The camptomelic, thanatophoric, and achondrogenic dwarf specimens (all stillborn) averaged 0.6. All were characterized by relatively normal width, but variably decreased height (relative to a scapula from a comparably-sized fetus). This height decrease was most evident in the scapulae from the fetus with camptomelic dwarfism, in which the ratio was 0.48.

The cartilaginous glenoid had a concave shape

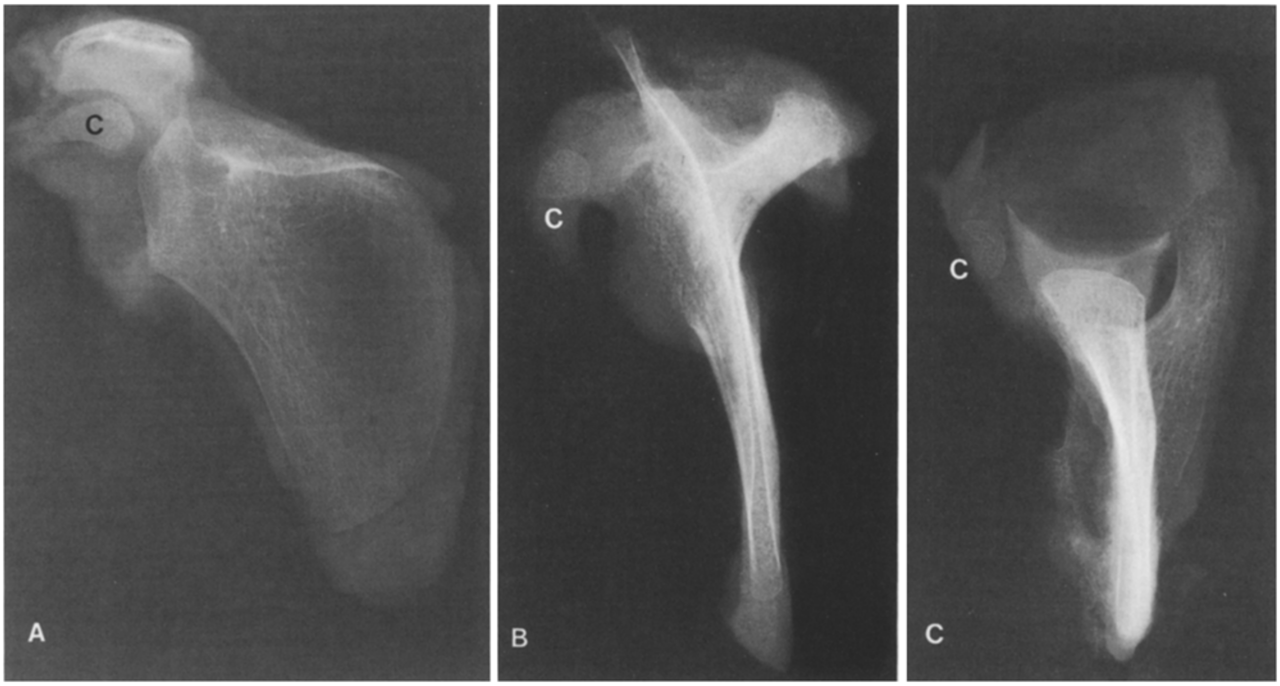

Fig. 4A–C. One year. **A** AP view. **B** Lateral view. **C** Superior view. The acrominal and vertebral contours have not shown any major changes. However, the ossification center of the coracoid process (C) has enlarged. Note, in the superior view, the slightly retroverted appearance of the glenoid cartilage and ossification margin

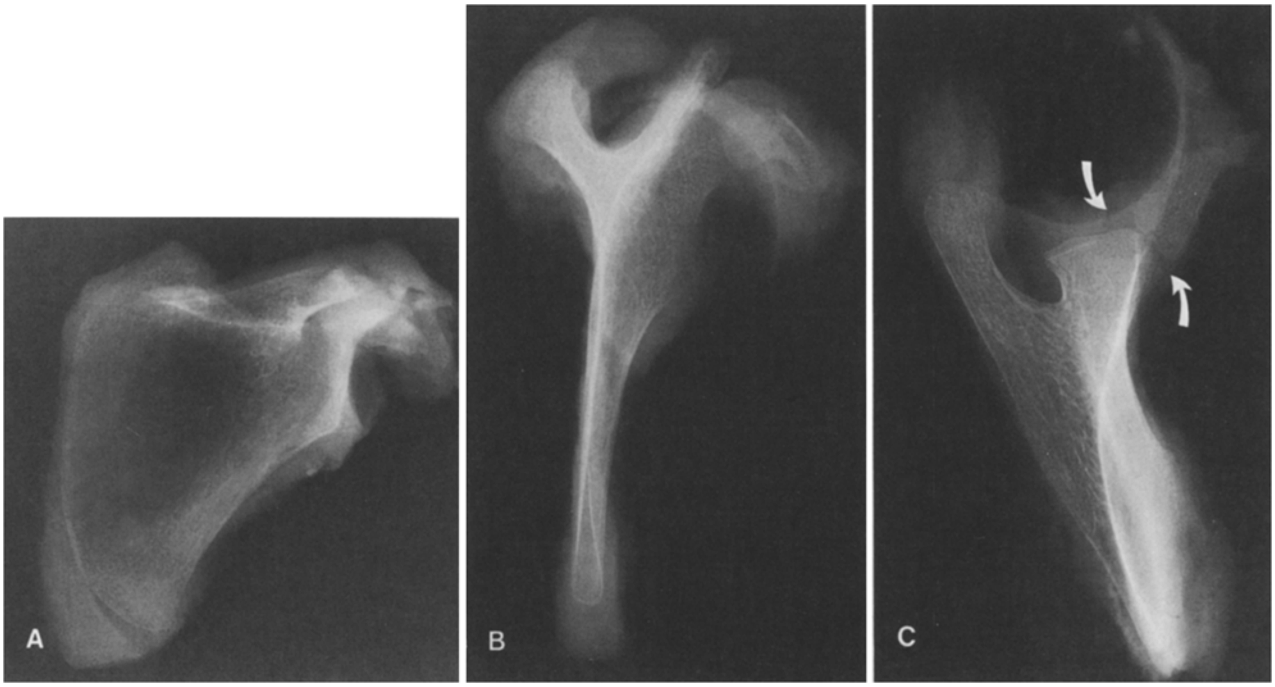

Fig. 5A–C. Two years. **A** AP view. **B** Lateral view. **C** Superior view. The primary change is further development of the coracoid ossification center, leading to demarcation of a growth region (physis) for the base of the coracoid process, where it originates from the anterior glenoid (*arrows*)

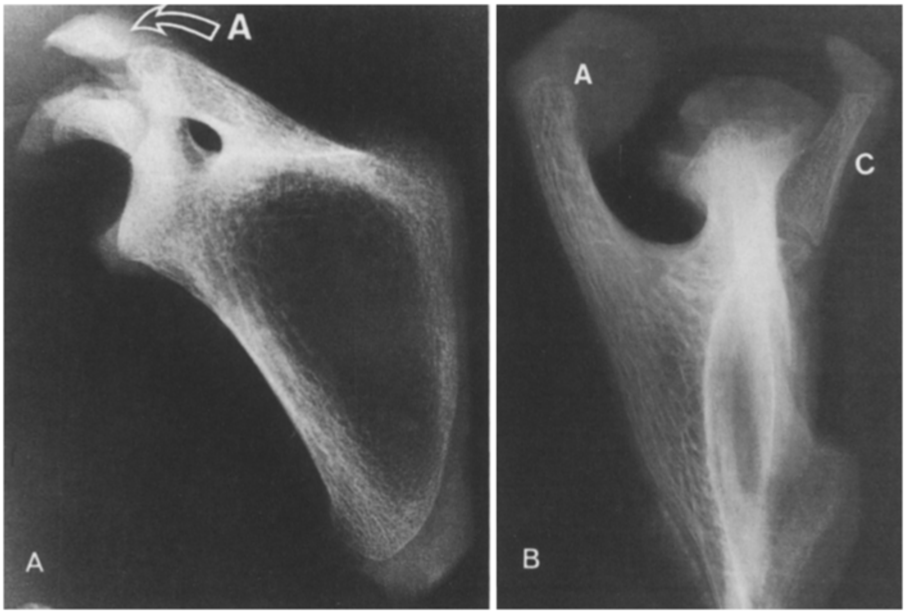

Fig. 6A, B. Seven years. **A** AP view. **B** Superior view. The vertebral ossification margin has expanded toward the cartilaginous edge, except at the inferior tip. Growth rate slowdown leads to a demarcation of a subchondral plate along this vertebral margin. Coracoid ossification shows elongation distally. A – acromion; C – coracoid

in all specimens. Even the youngest fetal specimen (approximately 12 weeks gestation) had a concave glenoid articular surface congruent with the convex humeral head. However, the subchondral osseous contour of the glenoid was either flat or slightly convex.

Thus, the contours and height-width ratio of the scapula are present by 12–14 weeks of fetal development, and change very little from then until birth. Roentgenographic measurements that incorporate only the osseous contours do not reflect the true overall dimensions of the cartilage and bone.

Neonatal/Postnatal

At two months a wide vertebral border epiphysis was present (Fig. 2), the coracoid process had no ossification center, and the acromion was a large cartilaginous epiphysis. Remodeling continued to rapidly rearrange the initially radiate pattern of endochondral bone deposition, especially along the vertebral border.

The first major change was the appearance of the primary ossification center in the coracoid process (Fig. 3). The earliest it appeared was three months after birth. The glenoid cavity was well formed, concave, and with the rotator cuff and capsule, surrounded the humeral head. In contrast, the subchondral bone contour was minimally convex and retroverted.

At one year the acromial and vertebral contours remained essentially unchanged. The primary ossification center of the coracoid process had enlarged. The glenoid was retroverted (Fig. 4), with this being evident in both the cartilage as well as the subchondral bone orientation.

At two years the coracoid ossification center expanded further (Fig. 5), establishing a true bipolar growth region between the main portion of the scapula and the coracoid process (reflecting the independence of scapula and coracoid, from an evolutionary standpoint, in most vertebrates except mammals).

Over the next five years minimal changes occurred, the most noticeable being progressive replacement of the vertebral border epiphyseal cartilage by the advancing endochondral ossification process (Fig. 6). This occurred along the entire vertebral margin except inferiorly. Such a process, if measured roentgenographically, would indicate a slightly greater increase in width relative to increase in height during this period.

Throughout postnatal development from stillborn to 14 years the height-width ratio ranged from 1.42 to 1.56, with an average ratio of 1.49. The exception was the patient with unilateral Sprengel's deformity; the unaffected side had a ratio of 1.51, whereas the affected side was 1.04. Thus, there is no significant alteration of the basic morphology during postnatal growth.

The vertebral margin matured over the next two to three years, demarcating a subchondral plate. Such a well established subchondral plate indicated a greater amount of transversely oriented bone deposition in the primary spongiosa, indica-

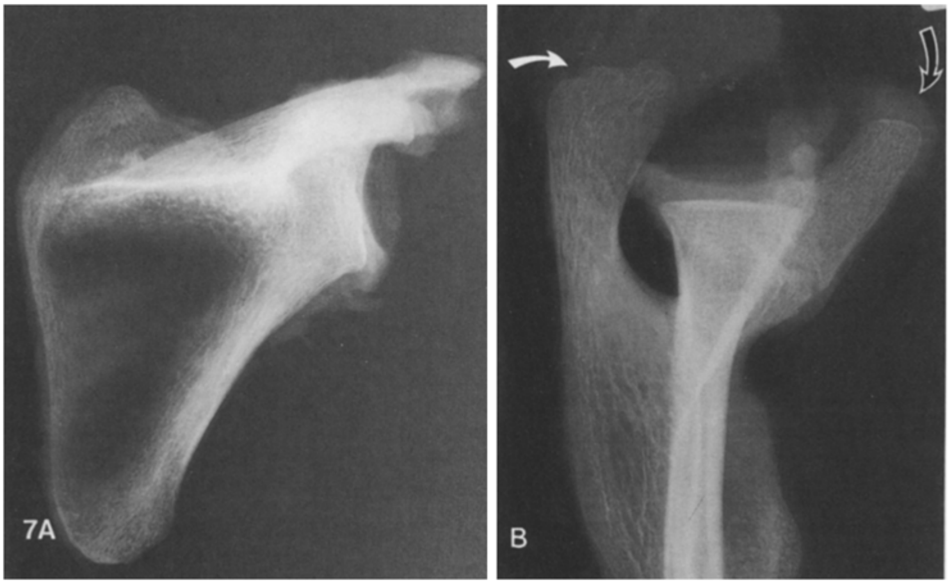

Fig. 7A, B. Ten years. **A** AP view **B** Superior view. The acromial chondro-osseous interface is beginning to develop undulations (*solid arrow*). The coracoid physis has thinned, and an epiphyseal tip (unossified) is still evident (*open arrow*). The supraspinous segment has become more prominent ("peaked")

Fig. 8. Ten years, AP view. Undulations (*arrow*) develop along the inferior scapular ossification margin. These appear prior to secondary ossification in the region

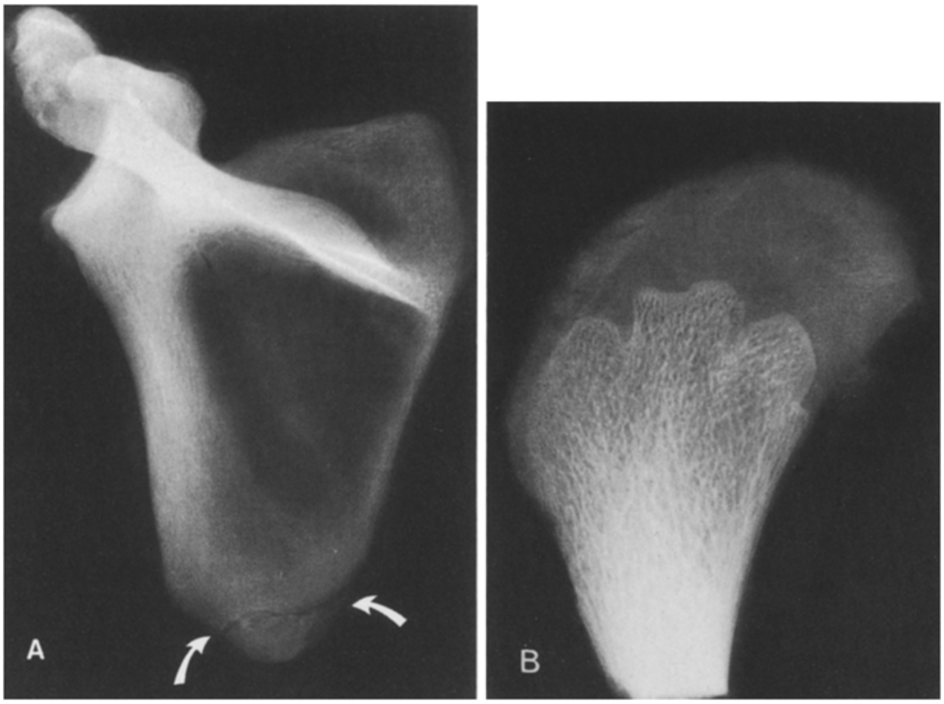

Fig. 9A, B. Thirteen years. **A** A secondary ossification center has developed at the inferior tip of the scapula. The coracoid bipolar physis has closed. The peak in the supraspinous portion has matured. **B** The acromion develops significant undulations

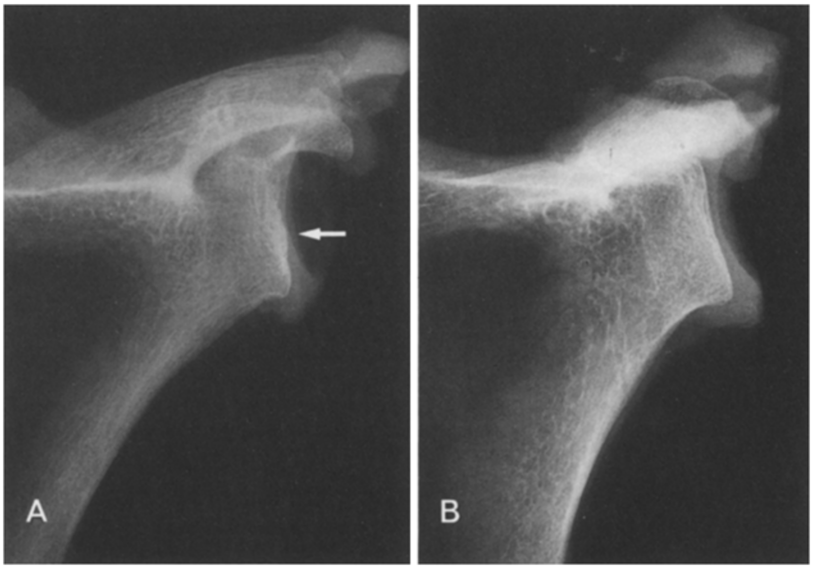

Fig. 10. A By nine years the glenoid subchondral ossification margin is developing some undulations (*arrow*). **B** At ten to eleven years the margin begins to develop a concave contour

tive of a relative slowing down of growth rates along the vertebral border (in contrast, more rapid rates of growth are reflected in a more longitudinal orientation to the trabecular bone in the primary spongiosa [11]).

At about ten years undulations developed at the cartilage-bone interfaces of the acromion (Fig. 7) and inferior scapular margin (Fig. 8). These represent microscopic and macroscopic reorientation of the physeal regions to accommodate changing stress-strain relationships from the surrounding musculature.

During adolescence a distinct ossification center appeared at the inferior tip of the scapular vertebral epiphysis (Fig. 9). The coracoid bipolar physis closed. In none of the scapulae from adolescents were other smaller secondary ossification centers noted.

The subchondral bone of the glenoid, in the anteroposterior view, was usually flat or slightly convex in the first decade, and then gradually assumed a concave contour comparable to the articular surface (Fig. 10). Marginal ossification (i.e., a secondary ossification center), similar to the os acetabuli, was not evident in any of these specimens.

The superior vertebral margin of the supraspinous portion varied significantly in its contour, ranging from a relatively smooth curve to a sharply peaked appearance (Fig. 11). Such a peaked appearance or elongation of the superior vertebral margin may be present with Sprengel's deformity (Fig. 13), but one must be careful in such attribution in view of the significant morphologic variation of this region.

Coracoid ossification began from a single (primary) center that progressively enlarged (Fig. 3). As the primary center enlarged toward the scapula, an epiphyseal zone became demarcated and physes developed on each side, establishing a bipolar physis similar to those in the acetabular triradiate cartilage arms. In none of the specimens was there evidence of a secondary ossification center at the tip of the coracoid, nor a secondary center within the bipolar physis (bipolar secondary ossification usually is superior [2]).

The acromial epiphysis caused progressive longitudinal growth of the scapular spine, with this growth being integrated with elongation of the glenoid and coracoid. Height increase along the scapular spine was due to membranous bone formation from the periosteum.

The acromioclavicular joint appears relatively wide in the small infant or child because of the large amounts of cartilage present in both the acromion and distal clavicle (Fig. 12). With growth the region narrowed as the endochondral ossification process further replaced each of these cartilaginous epiphyses. This process is analogous to replacement of the "non-epiphyseal" ends of the small longitudinal bones of the hand and foot [10, 11]. Because of the apparent "widening" of this region, one must be careful in diagnosing acromioclavicular separation prior to skeletal maturity. In the child widening of this region, as compared to the other side, most likely represents an epiphyseal fracture through the distal clavicular physis, with the acromioclavicular joint itself being intact [12].

There were several examples of pathologically involved scapulae in this series: Figure 13 shows

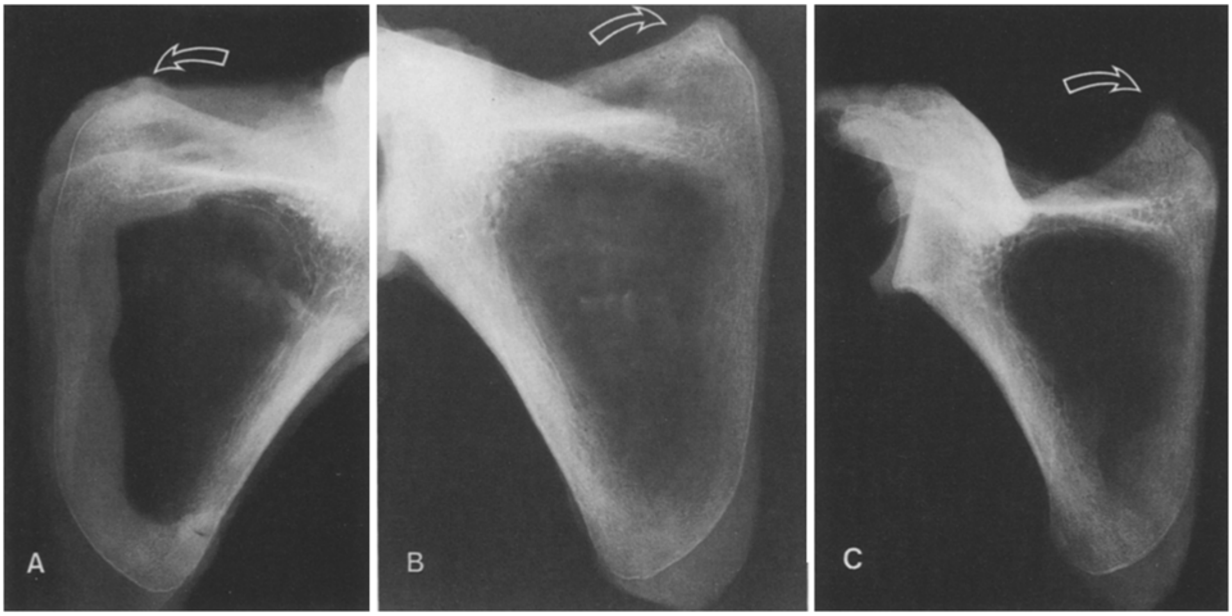

Fig. 11 A–C. Variations in development of supraspinous segment (*arrow*) in scapulae from three 10-year-olds. **A** Smooth rounded appearance. **B** Moderate peaked appearance. **C** Marked elongation of supraspinous segment

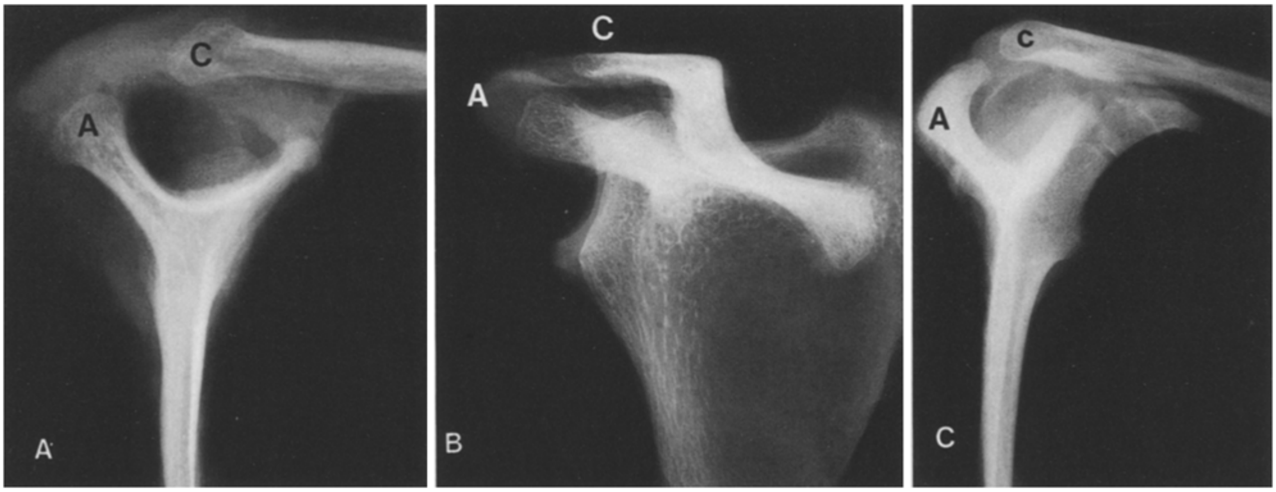

Fig. 12 A–C. Development of acromioclavicular region. **A** In the infant a wide space exists due to a largely cartilaginous acromion (A) as well as distal clavicle (C). **B** As ossification progresses into the acromion the gap narrows. **C** By six to seven years there is a relatively narrow space. However, great caution must be taken not to overinterpret this gap as an acromioclavicular separation in the child with trauma to the shoulder

the normal and abnormal scapulae from a patient with Sprengel's deformity, a case which has been documented in detail [17]. The uninvolved scapula exhibited normal developmental morphology. In contrast, the involved scapula had approximately equal height and width measurements. The omovertebral bone in this specimen articulated through a definite joint with the infraspinous portion of the vertebral margin. Figure 14 illustrates the scapulae from a patient with widespread metastases (angiosarcoma). This case has been documented in detail [13]. One scapula had a large metastasis along the inferior border. Both exhibited multiple smaller metastases in the vertebral border and subglenoid spongiosa, indicating hematogenous spread to the areas of most active bone turnover. Figure 15 shows the scapula from a child with renal rickets. This bone is severely osteoporotic, and

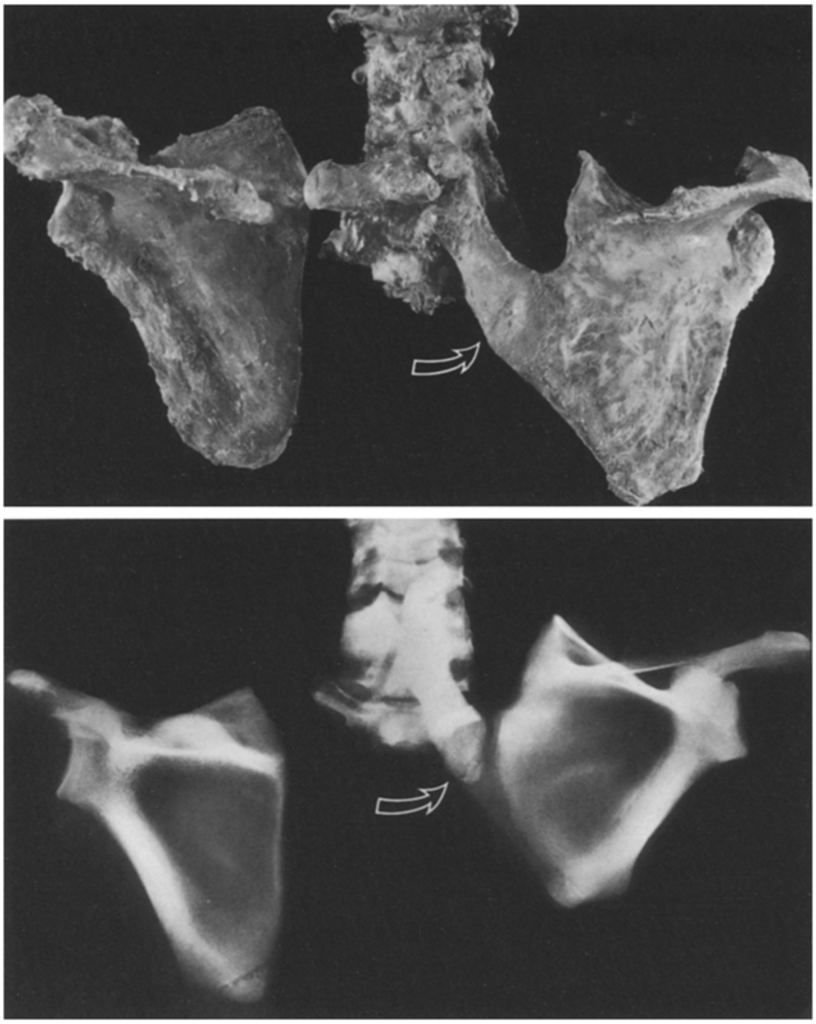

Fig. 13. Normal (*left*) and deformed (*right*) scapulae and cervical spine from a patient with unilateral Sprengel's deformity. In this particular specimen, a large omovertebral bone (*open arrow*) was present, connecting the infraspinous vertebral border to the spinous processes of a deformed spine

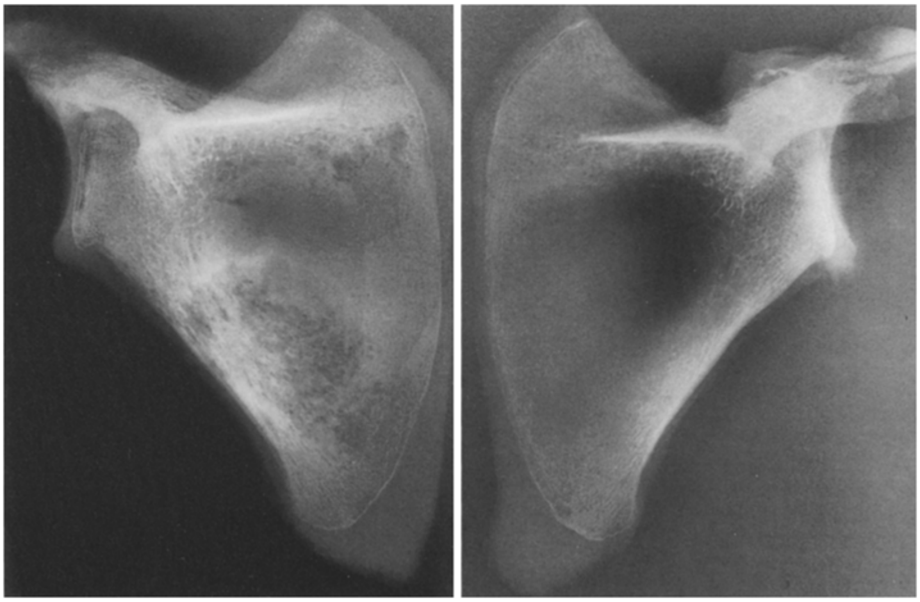

Fig. 14. Right and left scapulae from a 9-year-old with disseminated angiosarcoma. The tumor has metastasized to the comparable metaphyseal regions along the vertebral border and adjacent to the glenoid. The two sides were assymmetrically involved in the degree of osteolytic bone destruction

reflects the complete involvement of this child's skeleton. Unlike long bones, which often manifest epiphyseolysis and/or angular growth deformity in this disease, neither scapula from this patient exhibited any irregular growth at the physes.

Fig. 15. Scapula from a child with rickets. Note the diffuse lack of mineralization and ossification, especially in the diaphyseal analogue, in this specimen from a 14-year-old boy with untreated, primarily dietary deficient disease

Discussion

The glenoid fossa (articular socket), a scapular blade, and a coracoid plate for attachment of musculature are common anatomic features of all vertebrate pectoral girdles. The coracoid plate, which may be extremely large in amphibia and reptiles, decreases in size to a small beak-like process in most mammals [20, 22]. The bipolar growth plate of the coracoid base is a reflection of this previous "independence". The scapular spine and acromion are primarily mammalian features, and reflect changes in limb posture and musculature [7, 20, 22]. The change in scapular form throughout Mammalia is minimal, suggesting that the genetic complex controlling the shoulder is extremely limited and uniform [20].

Understanding the basic pattern of scapular growth is not easy, since initially it appears very different from a long, tubular bone [10, 11]. However, certain comparative situations may help. In marine mammals, because of a generalized lack of (or minimal) trabecular remodeling, the endochondral bone retains its longitudinal orientation, reflecting progressive, constant addition to each elongating column once it is formed (Fig. 16). This retention and constant addition to each endochondral column and the creation of new columns

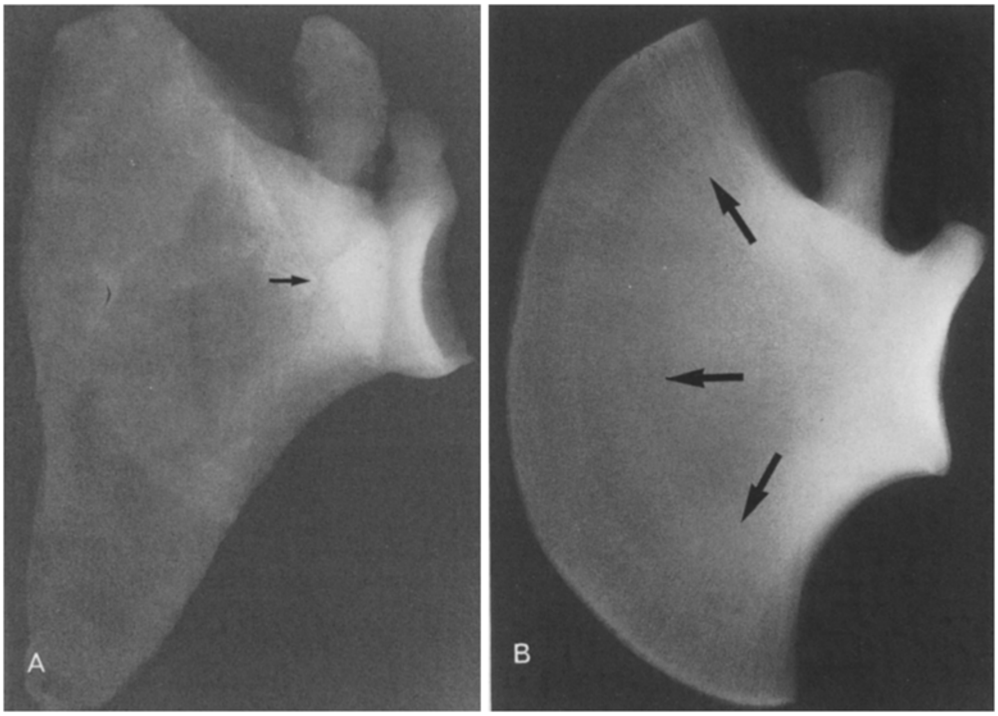

Fig. 16 A, B. A Roentgenograph of a scapula from an immature fin whale (*Balaenoptera physalus*) showing the nutrient artery (*arrow*), a small endochondral cone directed toward the glenoid, and a large cone radiating toward the vertebral border. **B** Roentgenogram of a scapula from a mature dolphin (*Tursiops truncatus*) showing radiating pattern (*arrows*) of endochondral growth due to dominance of the vertebral border epiphysis. Latitudinal growth rates are greater than longitudinal rates

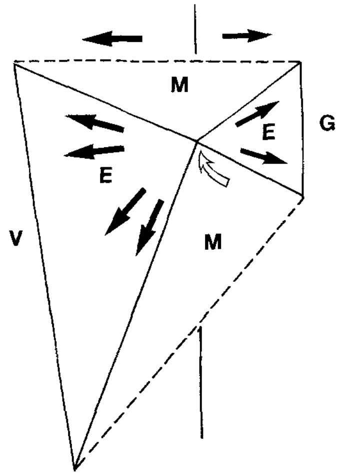

Fig. 17. Schematic of growth patterns of scaupla, which can be considered an analogue of a long bone. Endochondral ossification (E, *arrows*) goes from the initial central focus (*open arrow*) toward the proximal, vertebral (V) epiphysis as well as toward the distal, glenoid (G) epiphysis. The regions above and below the endochondral triangles are filled in by membranous (M) ossification

peripherially (latitudinal growth), establishes a radiating pattern to the vertebral border cone. Such retention thereby allows a better understanding of basic growth in this flat bone. Longitudinal growth rates are rapid, depending upon the size of the scapular plate. These rates certainly are greater for the vertebral than the glenoid cone. More importantly, the scapula exhibits significant latitudinal growth along the vertebral border. This is more dominant in the infraspinous than supraspinous segments.

The basic growth mechanism of the scapula thus can be considered a structural modification of longitudinal bone growth (Fig. 17). The "proximal" epiphysis is the vertebral border cartilage. This growth unit, in turn, can be divided into supraspinous and infraspinous segments with different rates of latitudinal growth. The infraspinous segment is probably more involved in pathologic conditions that lead to height-width ratio changes. The "distal" epiphysis is comprised of the combined glenoid, acromion, and coracoid process. These three physes must grow in an integrated fashion to provide the appropriate support for the developing humeral head and glenohumeral articulation.

The glenoid always has a concave articular surface, whereas the subglenoid plate varies, initially being slightly convex and subsequently becoming concave. These observations support Tachdjian's statement that the glenoid contour (i.e., the roentgenographically evident portion) changes from convex to flat and the concave [24]. When analyzed from the superior view, it is readily evident that the glenoid is slightly retroverted, allowing the anterior glenoid margin to provide a buttress to anterior displacement. Undoubtedly there is anatomic variation in this retroversion, similar to that in the acetabulum, and this variation may be a factor in the predisposition of certain individuals to subluxation or dislocation.

The scapular spine grows by both basic bone growth mechanisms. The acromion uses progressive endochrondral deposition distally, gradually establishing a prominent posterosuperior structure. Increased height of the scapular spine occurs through membranous ossification. Very little growth occurs at the "proximal" end of the scapular spine, and this is undoubtedly due to membranous ossification, rather than endochondral deposition by the vertebral border physis. Caffey describes primary coracoid ossification as occurring at approximately one year [2]. In this study no coracoid ossification was evident in scapulae from neonates to two-month-old cadavers. However, the scapulae from several cadavers between three and twelve months of age all showed coracoid ossiciation. This was best demonstrated with the special "superior" views, and was not readily evident on the anteroposterior view because of superimposed scapular bone (Fig. 3A). Routine clinical views of the scapula, upon which Caffey's observations were based, thus would not readily show coracoid ossification in its early stages.

The coracoid ossification center progressively expands until a physis is established at the tip. This allows progressive elongation. At the other end a bipolar physis is established that allows growth on both the coracoid and scapular sides. This growth plate is similar to that between the dens and body of the second cervical vertebra. The vertebral border epiphysis is relatively wide in the fetus, but rapidly thins due to endochondral ossification, similar to the rapid replacement of the "non-epiphyseal" cartilage at the distal end of the phalanges of the fingers. Latitudinal growth in this physis is most evident at the superior end, which always retains a large amount of cartilage and is the site of the most regularly appearing secondary ossification center. The development of the human scapula has had minimal treatment in the literature [4, 5]. O'Rahilly and Gardner studied the onset of primary ossification in early human embryos [19]. They found that the clavicle ossified first, during stages 18–20 (crown-rump length 13–22 mm), while the humerus ossified during stages 21 to 22 (crown-rump length 22–28 mm). Presumably the

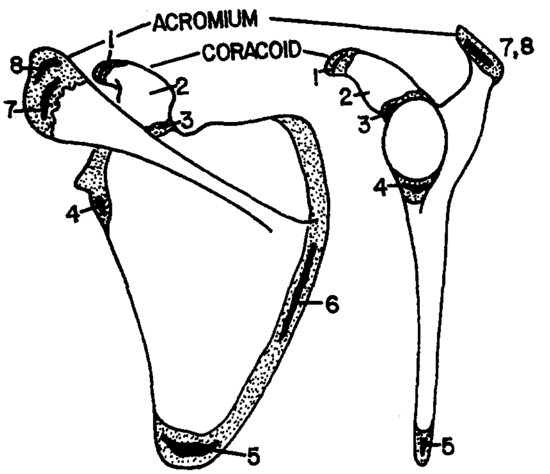

Fig. 18. Schematic of regions associated with secondary ossification centers (*stippled*). (1) distal coracoid; (2) primary ossification center of coracoid process; (3) secondary center in bipolar epiphysis between coracoid and scapula (this may extend to superior glenoid margin); (4) ossification at inferior glenoid margin; (5) most frequent secondary center at inferior margin; (6) ossification along vertebral epiphysis; (7, 8) acromial ossification

scapula, which they did not specifically discuss, ossified somewhere around stages 20 to 21.

In the human the permanent shape of the scapula is present by 12–14 weeks of fetal development, and changes very little from then through chondro-osseous maturity. However, roentgenographic measurements that only incorporate the osseous contours do not reflect the true dimensions. Such development is of clinical interest as it relates to Sprengel's deformity. Tachdjian states that the scapula is larger transversely than longitudinally during fetal development and gradually reverses the length/width ratio as growth takes place [24]. Failure of this morphologic progression is thus postulated as the reason for the scapular shape in Sprengel's deformity. However, this concept was not supported by the fetal, neonatal, and postnatal cadaver scapular measurements in this study. It appears, based upon the normal anatomy, the specific findings in the Sprengel's deformity case, and the aforementioned basic mechanisms of scapular growth, that the altered morphology in Sprengel's deformity is due to (a) a basic structural alteration when the blastemal pectoral girdle is forming, and (b) altered latitudinal growth primarily in the infraspinous portion of the vertebral border physis.

Secondary ossification centers may occur in several regions (Fig. 18). These have been detailed by Caffey [2]. They may be asymmetric, so comparison films to distinguish normal anatomy from traumatic avulsion, especially in adolescence, may not be useful. Secondary centers occur along the vertebral border, appearing first at the inferior tip at 15–18 years and along the remainder at 17–19 years. Both areas fuse with the metaphyseal bone between 20 and 25 years. A secondary center in the coracoid bipolar epiphysis occurs in the superior margin at 15–17 years and, along with the rest of the coracoid, fuses to the scapula between 18 and 21 years. Secondary ossification in the acromion, which is often multifocal, occurs at 15 to 18 years and fuses from 18 to 19 years. Many of these centers would not have been expected in the current series, as the most mature scapulae were from cadaver of 16 years.

A large number of mammals develop a supraglenoid secondary ossification center (Fig. 19). This structure is part of the attachment of the long head of the biceps and may represent a structural analogue of the tibial tuberosity (i.e., a traction-responsive physeal-epiphyseal unit). Similar mar-

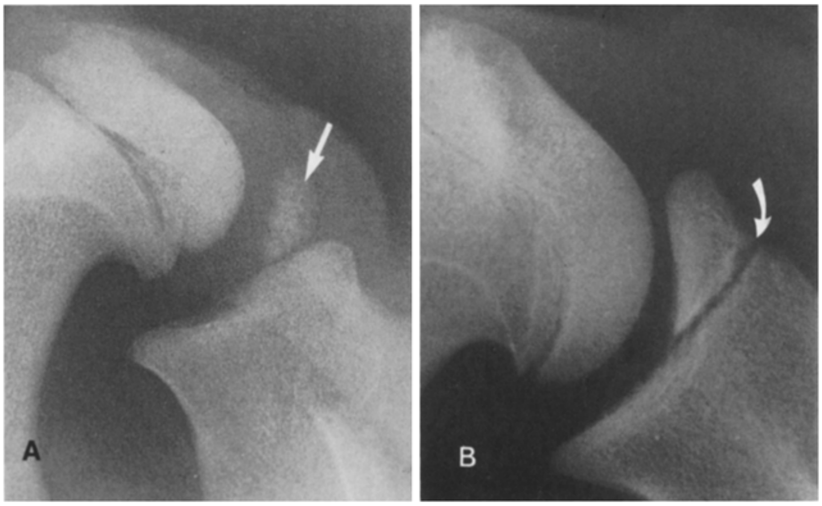

Fig. 19 A, B. Sequential roentgenographic development of the supraglenoid secondary ossification center in the seal (*Phoca vitulina*). **A** Early development of the secondary center is characterized by coalescence of multiple foci at the periphery of the enlarging center (*arrow*). **B** Mature phase, with well-formed bipolar physis (*arrow*)

ginal secondary ossification in the glenoid is usually located inferiorly in the human.

Fractures of the scapula are rare in children. They usually involve the glenoid or subglenoid border, and propagate partially into the spongiosa. The resilient nature of the developing scapular diaphysis and metaphyses favors such incomplete fractures rather than fragmentation or complete propagation across the entire bone. Trauma also may cause, from ossification of subperiosteal hematoma, scapular thickening comparable to and indistinguishable from infantile cortical hyperostosis. Deep radiolucent notches have been described along the scapular border inferiorly; the significance of these is uncertain [2].

Tumor involvement is rare, either as a primary or metastatic spread (Fig. 14). Aneurysmal bone cysts may involve large segments of the metaphyseal bone, especially in the infraspinous region where extensive remodeling occurs. The vertebral border may be variably involved in multiple cartilaginous exostoses; the glenoid is infrequently involved, probably because of the much slower growth rate. The osteochondromata may grow from the outer surface as a relatively small mass, or they may grow toward the chest wall. In the latter case the constant impingement of the aberrant physeal cartilage of the osteochondroma surface against the ribs may stimulate massive overgrowth and outward displacement of the scapula.

Acknowledgements. This work was supported in part by N.I.H. Grants HD-10854 and AM-00300, the Easter Seal Research Foundation, and Skeletal Educational Associates, Inc.

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