

A radiographic study of growth plate closure compared with age in the Korean native goat

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Abstract : This study was performed to assess the growth plate closure time with aging in the Korean native goat. Radiographs of proximal and distal epiphysis of humerus, radius, ulna, femur and tibia were obtained at 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 17, 18, 20, 21, 30, 43 and 52 weeks after birth in 30 Korean native goats. The secondary ossification centers were scrutinized and assessed the maturity process on the basis of the criteria (stage 0 to 10). The secondary ossification centers of proximal and distal epiphysis of humerus, radius, femur and tibia and proximal ulna epiphysis appeared immediately after birth. While, that of distal ulna epiphysis appeared during the 1st to 2nd week of life. The fusion of distal humeral epiphysis occurred during the period from 8 to 12 months. The fusion of proximal radial epiphysis and distal tibial epiphysis were found at 1 year. The fusion of proximal and distal epiphysis of ulna and femur, proximal epiphysis of humerus and tibia and distal epiphysis of radius were found at 1 year or more than 1 year. As a result, growth plate closure was highly related to age in the Korean native goat and it is suggested that the estimation of animal's age might be useful by illustration of maturity process of the secondary ossification centers in the Korean native goat.

Key words : growth plate closure, Korean native goat, radiography

Introduction

Normal development of bones is very important to estimate the age in experimental animals and diagnose the skeletal diseases in growing animals. Several indicators for the age estimation, such as body weight and bone length, were used but they were tough criteria due to large variation [1].

The development of the secondary ossification centers in human bone normally follow a fairly definite pattern and time schedule [22]. Stevenson [21] also described that the epiphysis of long bones was the most reliable indicator for the age estimation as characterized by its remarkably constant growing state during the period of active body growth in man. The ages at which the ossification centers appear in the man have been reported by many investigators [5, 7, 8, 10, 11, 12, 13, 14, 15].

Many authors have already reported on the secondary ossification centers in several experimental animals [1, 2, 3, 4, 6, 17, 18, 23]. However, few studies have been reported with the sheep [9] and goat [19].

The purpose of this study was to determine when the ossification centers appear and fuse in the Korean native goat whose age was exactly known and to clarify the whole process of maturation of the secondary ossification centers to provide basic information for the estimation of body maturation by radiography.

Materials and Methods

Animals

In this study, healthy growing 30 Korean native goats (*Capra hircus aegagrus*) were used. The age of experimental animal ranged from 2 to 52 weeks and classified in Table 1.

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Table 1. Number of goats examined

Week	2	3	4	5	6	7	8	9	11	
No.	5	4	7	15	4	9	2	9	1	
Week	12	13	14	17	18	20	21	30	43	52
No.	1	5	1	1	2	1	1	1	5	3

Table 2. Classification method by Owada and Sutow¹⁶

Stage	Criteria
0	absence of differentiation
1	obscure appearance
2	developing ossification center
3	delimiting line
4	ossification center width < bone length
5	ossification center width = bone length
6	“capping” and narrowing of gap
7	commencing fusion
8	more than half fusion
9	recent fusion (remaining clear epiphyseal line)
10	almost or perfect fusion

Radiography

The X-Omat[®] regular film (Kodak Co., U.S.A) was used with intensifying screen. Radiography were performed on the proximal and distal end of humerus, radius, ulna, femur and tibia by mediolateral and craniocaudal projection. The right extremities were closely fixed onto the table in mediolateral position.

In order to explore the maturation process of the secondary ossification centers, the images of the proximal and distal epiphysis of long bones on the film were scrutinized. The developmental state of the secondary ossification center at each age was judged on the basis of the criteria (stage 0 to 10) proposed by Ohwada and Sutow [16] (Table 2).

Illustration

The maturity process of secondary ossification centers were illustrated at each stage.

Results

The state of postnatal development of each ossification center is shown graphically in Fig. 1 and 2. The curve showing the maturation process of each secondary

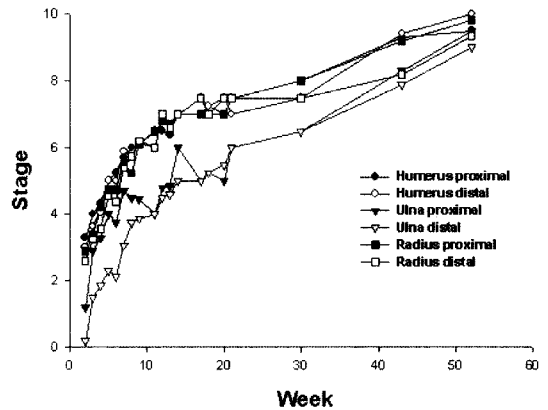


Fig. 1. Maturity process of secondary ossification center of age at fore limb in the Korean native goat. The longitudinal axis of the figure represents the score proposed by Ohwada and Sutow¹⁶ and horizontal axis represents the age.

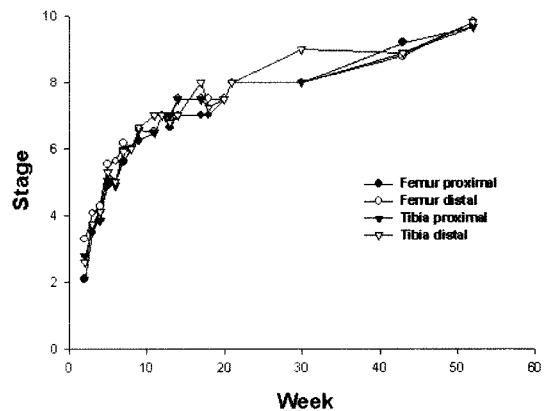


Fig. 2. Maturity process of secondary ossification center of age at hind limb in the Korean native goat. The longitudinal axis of the figure represents the score proposed by Ohwada and Sutow¹⁶ and horizontal axis represents the age.

ossification center presented in Fig. 1 and 2 has been plotted out of the average values in each age group. The time of appearance and fusion of the secondary ossification centers in the extremities were summarized in Table 3.

The secondary ossification centers of proximal

Table 3. The time of appearance and fusion of secondary ossification center

	Appearance		Fusion
Humerus	p	birth	more than 1y
	d	birth	8 m ~ 1y
Radius	p	birth	1y
	d	birth	more than 1y
Ulna	p	birth	more than 1y
	d	2w	more than 1y
Femur	p	birth	1y or more than 1y
	d	birth	1y or more than 1y
Tibia	p	birth	more than 1y
	d	birth	1y

p: proximal epiphysis, d: distal epiphysis, w: weeks, m: months, y: year

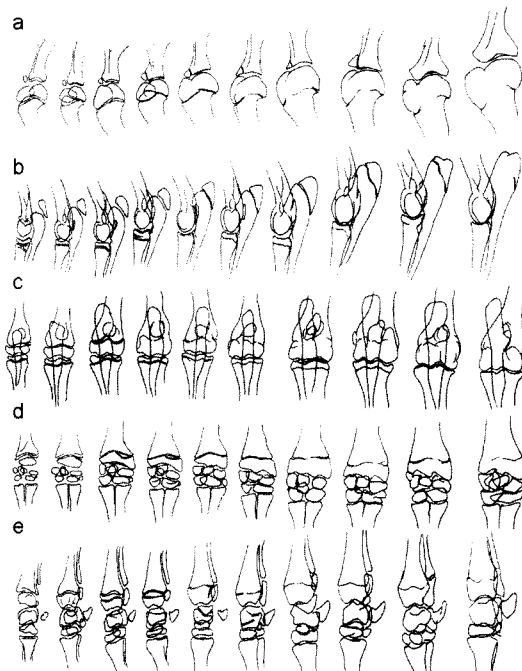


Fig. 3. Maturity process of secondary ossification center of age at fore limb in the Korean native goat. a: shoulder joint (mediolateral view), b: elbow joint (craniocaudal view), c: elbow joint (mediolateral view), d: carpal joint (craniocaudal view), e: carpal joint (mediolateral view).

epiphysis of ulna, humerus, and radius, and distal epiphysis of humerus and radius observed immediately after birth. The secondary ossification center of distal epiphysis of ulna was observed during the 1st to 2nd

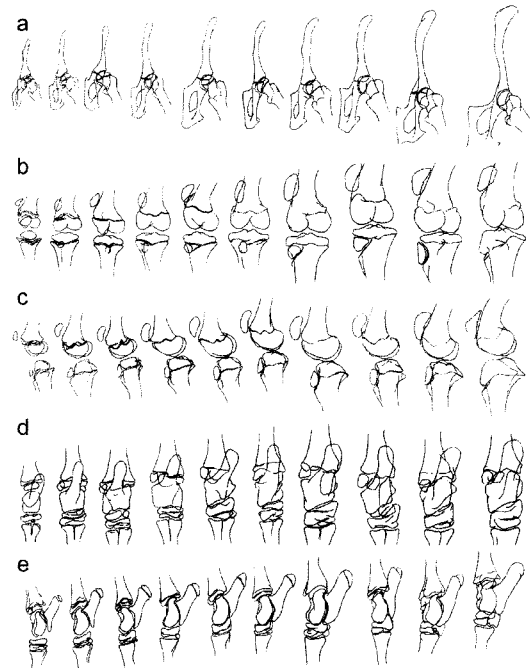


Fig. 4. Maturity process of secondary ossification center of age at hind limb in the Korean native goat. a: hip joint (craniocaudal view), b: stifle joint (craniocaudal view), c: stifle joint (mediolateral view), d: tarsal joint (craniocaudal view), e: tarsal joint (mediolateral view).

week of life. The fusion of proximal epiphysis of humerus was found after one year. However, the fusion of distal epiphysis of humerus appeared during the period from 8 to 12 months. The fusion of proximal epiphysis of radius was found at 1 year. The fusion of proximal and distal epiphysis of ulna and distal epiphysis of radius were found 1 year or more than 1 year.

The secondary ossification centers of proximal and distal epiphysis of femur and tibia were observed immediately after birth. The fusions of proximal and distal epiphysis of femur and proximal epiphysis of tibia were found at 1 year or more than 1 year. The distal epiphysis of tibia was found at 1 year.

The development of secondary ossification centers of the fore and hind limb was illustrated (Fig. 3 and 4). Most of the secondary ossification centers of the fore and hind limb appeared immediately after birth, except that the distal epiphysis of ulna appeared at 2 weeks. By 4 weeks, most of the secondary ossification centers developed to be in the range between the 3rd and 5th stage, except that the distal ulnar epiphysis developed

to be 2nd stage. By 9 weeks, most of the secondary ossification centers developed to be in the range between the 5th and 7th stage, except that the proximal and distal epiphysis of ulna developed to be 4th stage. Each secondary ossification center of both extremities gradually developed during 4 weeks to 43 weeks, and at 43 weeks all the secondary ossification centers were beyond 8th stage. Almost all the secondary ossification centers fused at 1 year or more than 1 year.

Discussion

The validity of the investigation of secondary ossification centers in determining an animal's age has been well known [1-4, 6, 17, 18]. Further available method that the score was given by assessing the maturity process of the secondary ossification centers was introduced [16, 24]. Many investigators have already reported on the secondary ossification centers in several experimental animals [1-4, 6, 17, 18, 23]. For example, It has been reported that the development of secondary ossification centers in the mouse, rat, and cynomolgus monkey [1, 3, 4]. Rajtova [19] reported the postnatal development of the bones of limbs in sheep and goat.

Recently, the Korean native goat is widely used as ruminant model animal in Korea. However, there was no study on evaluation of age using growth plate closure time in the Korean native goat. Therefore, we investigated about growth plate closure compared with age in the Korean native goat. Our limitations are that the longer follow up period and clarification of differences in sex were thought to be required to standardize growth plate in the Korean native goat.

The fusion of distal epiphysis of humerus appeared at 9 months in sheep and 11 months in goat [19]. It was similar to the result of our study in Korean native goat. Also, the fusion of proximal epiphysis of radius completed at 8 months and the fusion of distal epiphysis of tibia completed at 2 years [19]. The proximal epiphysis of humerus, ulna and femur and distal epiphysis of ulna and femur closed during the period from 2 years 6 months to 3 years 6 months and the fusion of distal radius epiphysis completed at 5 years in goat study [19]. In the Korean native goat, almost all the fusion of the epiphysis was found at 1 year or more than 1 year. It is clearly faster than in goat [19], except proximal epiphysis of radius. The fusion of proximal epiphysis of the radius was completed 4 months later

than in goats [19].

The earliest epiphyseal fusion was observed at the distal humeral epiphysis, while the latest was at the distal ulna in the Korean native goat. It is similar that previous investigators reported about mouse [4], rat [3], cynomolgus monkey [1] and Japanese black beef cattle [17].

In the present study, the observation was performed until 1 year age that sexual maturity was completed. However, further study was required to determine the closure time of the secondary ossification centers of the ulna and tibia that didn't fuse until 1 year in the Korean native goat.

In this study, the rate of development of secondary ossification center and fusion increased with age. It was shown most of the secondary ossification centers developed to be in the range between the 6th and 8th stage by 12 weeks, except that the distal epiphysis of ulna developed to be 4th stage in the Korean native goat. At 43 weeks, almost the secondary ossification centers were beyond 8th stage. After all, we can see the rapid increase of skeletal development from birth to third month and slow increase from third month to twelfth month (Fig. 1 and 2).

Conclusion

In conclusion, radiographic estimation of secondary ossification centers of the Korean native goat was clarified. Most of the secondary ossification centers had appeared immediately after birth and the time of fusion was about one year of age in the Korean native goat. These results containing illustrations will be the reference data for the age estimation or diagnosis of the immature skeletal disease in Korean native goats.

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