Acta orthop. scand. 45, 399–411, 1974

Department of Orthopaedics and Traumatology, University Central Hospital, Helsinki, Finland.

COXA VARA FOLLOWING IMMOBILIZATION OF THE KNEE IN EXTENSION IN YOUNG RABBITS

JARL-ERIK MICHELSSON & ANDERS LANGENSKIÖLD

Accepted 30.viii.73

In a previous paper (Michelsson & Langenskiöld 1972) we reported that after a sufficiently long immobilization (more than three weeks) of one hind limb with only the knee in extension, but the hip free and flexible, in young rabbits (less than three weeks old), a dislocation or subluxation of the hip developed as a rule on the immobilized side. However, after discission of the hamstring muscles and a subsequent immobilization of the knee in extension no marked changes in the hip developed. Other dysplastic changes also developed in the experimental animals in connection with the immobilization of the knee in extension i.e. coxa plana and coxa vara. In this paper we shall refer especially to the pathological condition of the hip in which the angle between the shaft and the neck of the femur diminished. This phenomenon, coxa vara, developed in many of the older animals (aged more than three weeks at the beginning of immobilization) in the investigations regarding the effect of the immobilization on the joints of growing rabbits.

MATERIAL AND METHODS

For these investigations seventy growing rabbits (two to twelve weeks old) were used. One of the hind limbs was immobilized with the knee in extension, but with the hip free to move. The immobilization was accomplished either by a plastic tube fixed proximally to the skin of the femur (sixty-two rabbits) or by a metal pin applied dorsally in the soft tissues of the limb (eight rabbits). These methods have been more fully described in another of our papers (Michelsson & Langenskiöld 1972).

In another twenty-five growing rabbits the hamstring muscles were cut proximally or distally just before the immobilization of the knee in extension of the same limb was performed.

Table 1. Final results in seventy young rabbits following immobilization of one hind limb with the knee in extension (c.f. Figures 1, 2 and 3).

Age of rabbit in weeks at the beginning of immobilization	Duration of immobilization in weeks			Coxa vara on the immobilized side				Other changes of the hip on the immobilized side		No deformity of the hip	Total
	Shortest	Longest	Average	C. V. only	C. V. and subluxation	C. V. and dislocation	Total C. V.	Dislocation	Subluxation		
2	3	4	3.3	–	–	2	2	1	–	–	3
3	3	4	3.7	2	1	2	5	2	–	–	7
4	3	4	3.4	13	5	7	25	5	–	–	30
5	3	6	4.1	2	2	2	6	1	2	–	9
6	3	8	4.4	4	1	2	7	–	1	–	8
8	4	5	4.3	–	1	–	1	–	1	1	3
10	4	6	4.5	3	–	–	3	–	–	3	6
12	3	4	3.7	1	–	–	1	–	–	3	4
Total				25	10	15	50	9	4	7	70

The immobilization of the knee was stopped by the removal of the plastic tube after at least three weeks, usually after three to four weeks, but in some cases up to eight weeks (c.f. Table 1).

During the immobilization of the knee the rabbit kept the hip of the immobilized side in normal flexion in a sitting and resting position.

The condition of the hips was recorded radiographically at regular intervals after the procedures, in some cases to adult age.

The hips of twenty-five of these rabbits were prepared for micro- and macroscopic investigations.

RESULTS

Of the seventy rabbits that had the knee of one hind limb immobilized in extension, sixty-three had some abnormality of the hip whereas seven had no permanent changes (Table 1). These abnormalities have been defined on the basis of radiological and pathologic-anatomical findings as coxa vara, dislocation and subluxation. By coxa vara we mean a condition whereby the angle between the neck and the shaft of the femur is diminished.

Twenty-five of these seventy-five rabbits had coxa vara only (Figure 1), ten had coxa vara and subluxation of the hip (Figure 2), fifteen coxa vara and dislocation of the hip (Figure 3), nine dislocation only and four subluxation of the hip only.

Marked pathological changes of the hip including coxa vara occurred most frequently in those rabbits that were three to six weeks old when the immobilization was begun. Of the fifty-four rabbits in these age groups, twenty-one had coxa vara only and twenty-two coxa vara and dislocation or subluxation of the hip on the immobilized side. In the oldest rabbits (eight to twelve weeks old) usually no changes or only slight ones developed in the hip of the immobilized limb.

These experiments showed that the development of the changes in the hip were dependent upon the age of the rabbit when the immobilization was begun. The younger the animal was the more frequent was the development of serious and permanent pathological changes in the hip. Progression of the coxa vara deformity and a pathological position of the head of the femur (dislocation or subluxation) usually developed, after sufficiently long immobilization, gradually and simultaneously during the period of growth (c.f. Figures 1, 2 and 3).

In the experimental coxa vara it was possible to find not only a diminishing of the angle between the femur and the neck of the femur, but also the following pathological changes in both the acetabulum and

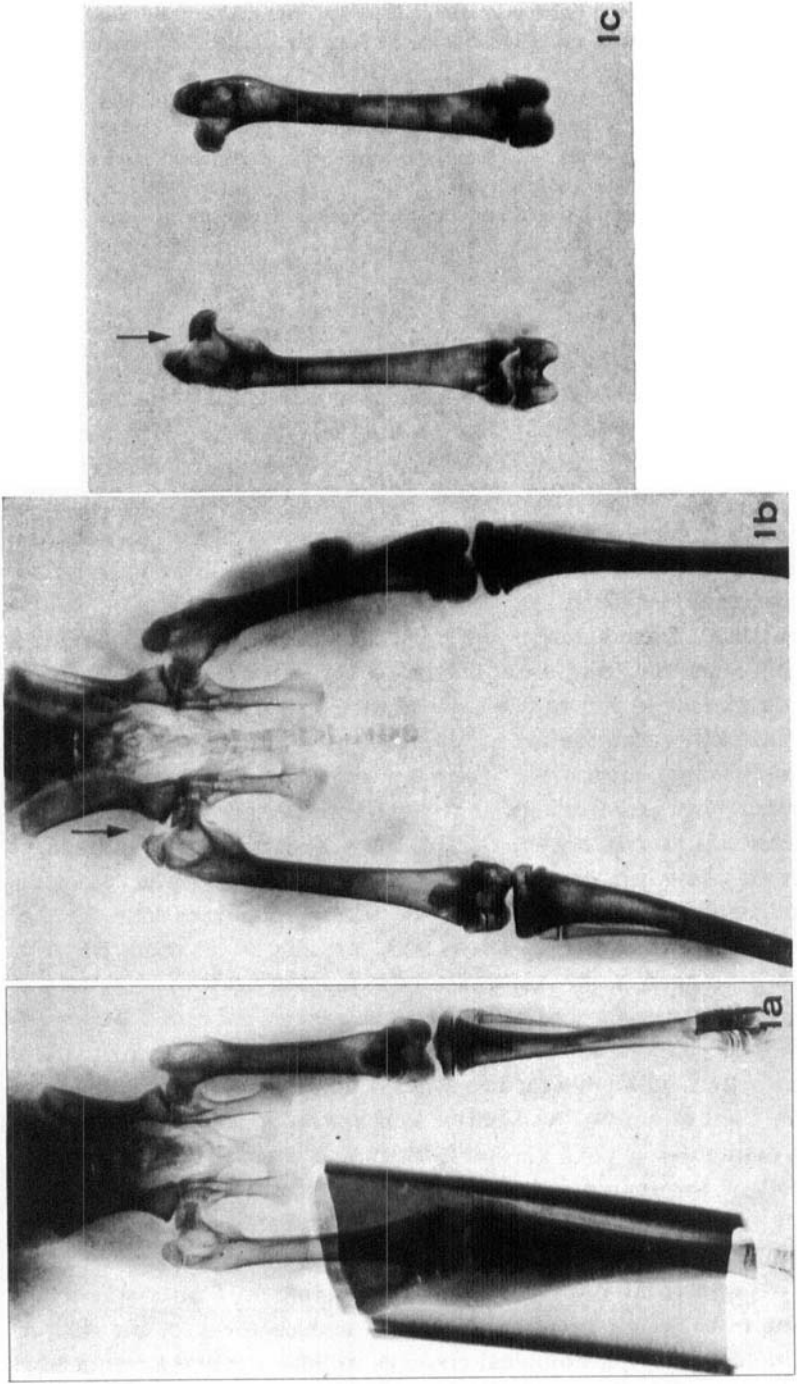


Figure 1 (a–c). A four-week-old rabbit was immobilized with the right hind limb in a plastic tube holding the knee in extension. Two weeks after the procedure a slight coxa vara was visible on the right side. (Figure 1a). The plastic tube was removed 3 weeks after the procedure. A progressive coxa vara deformity was observed 6 weeks after the procedure (Figure 1b). The femurs one week later (Figure 1c).

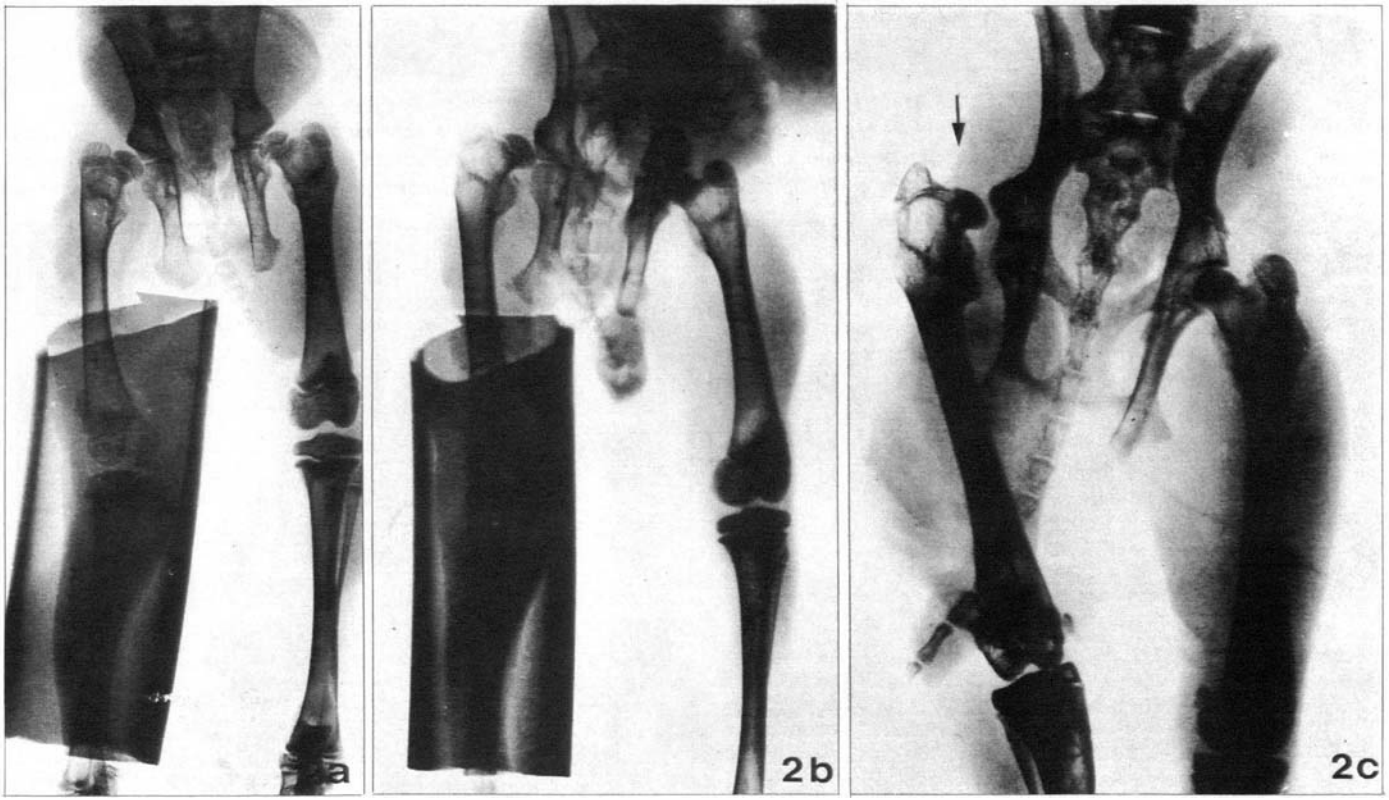


Figure 2 (a–c). A four-week-old rabbit was immobilized with the right hind limb in a plastic tube holding the knee in extension. Two weeks after the procedure subluxation of the right hip was observed (Figure 2a) and two weeks later subluxation and a slight coxa vara deformity had developed (Figure 2b). The plastic tube was then removed. Four months after the immobilization was started subluxation and marked coxa vara were visible (Figure 2c).

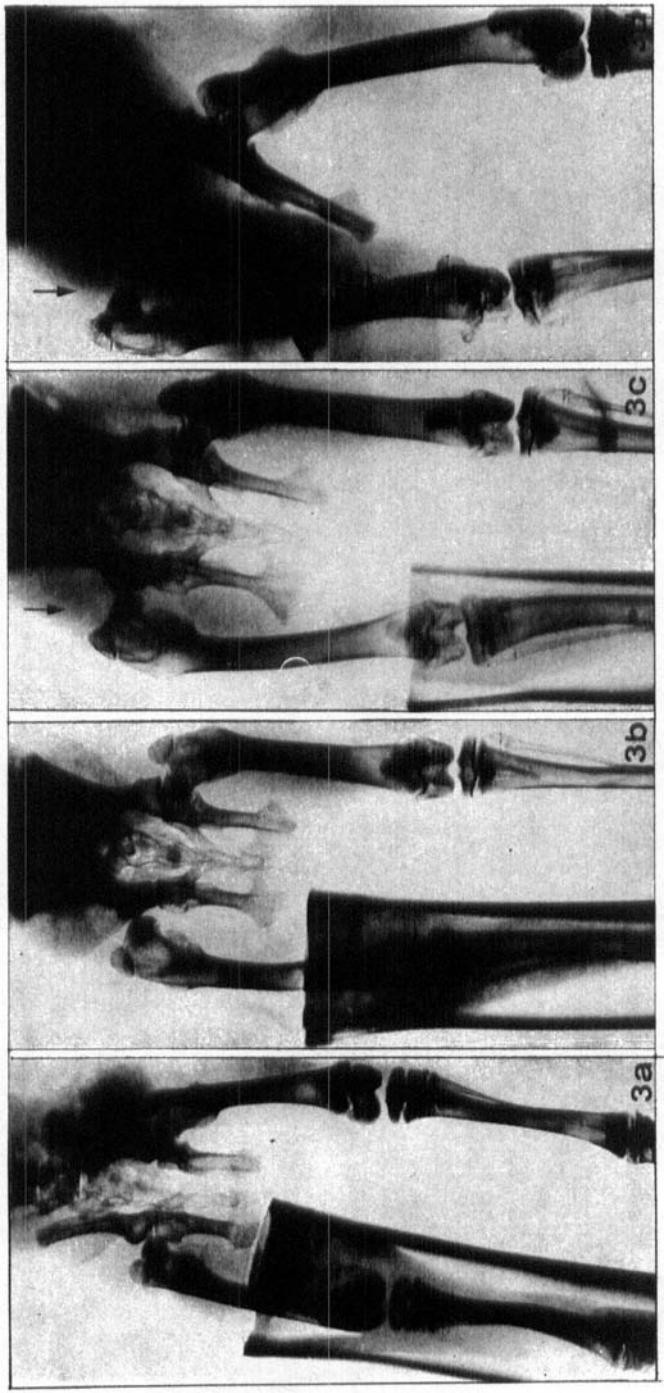


Figure 3 (a–d). A three-week-old rabbit was immobilized with the right hind limb in a plastic tube holding the knee in extension. One week after the procedure subluxation of the right hip was observed (Figure 3a), two weeks (Figure 3b) and six weeks later (Figure 3c) a progressive coxa vara deformity also developed. Three months after the procedure dislocation and coxa vara were observed (Figure 3d).

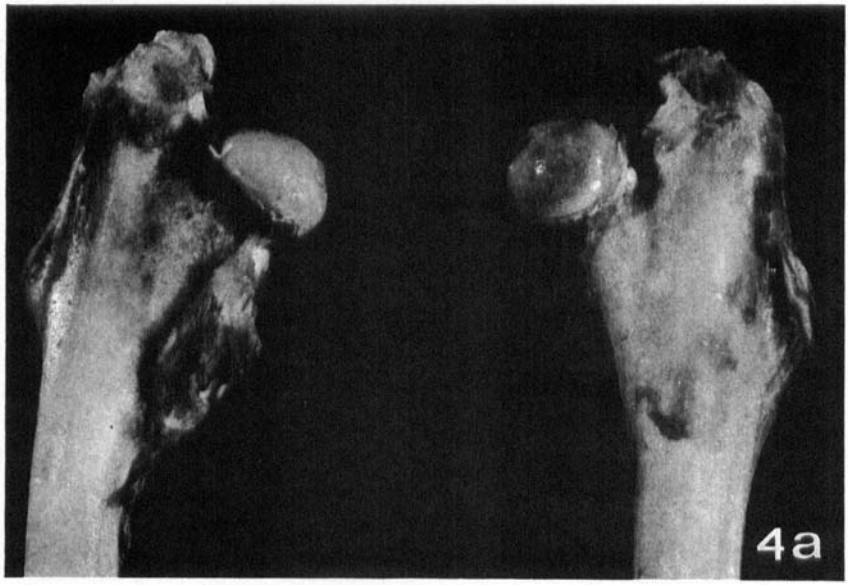


Fig. 4–a *Fig. 4–a$_1$*

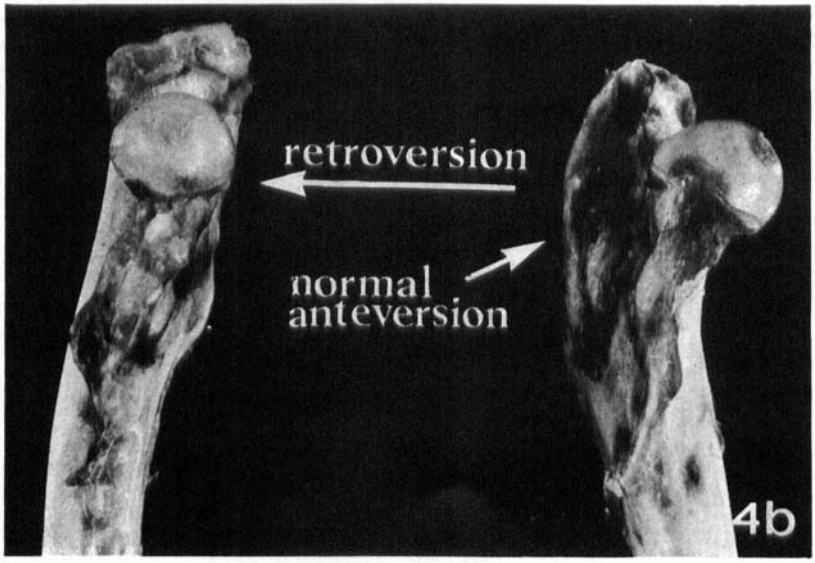


Fig. 4–b *Fig. 4–b$_1$*

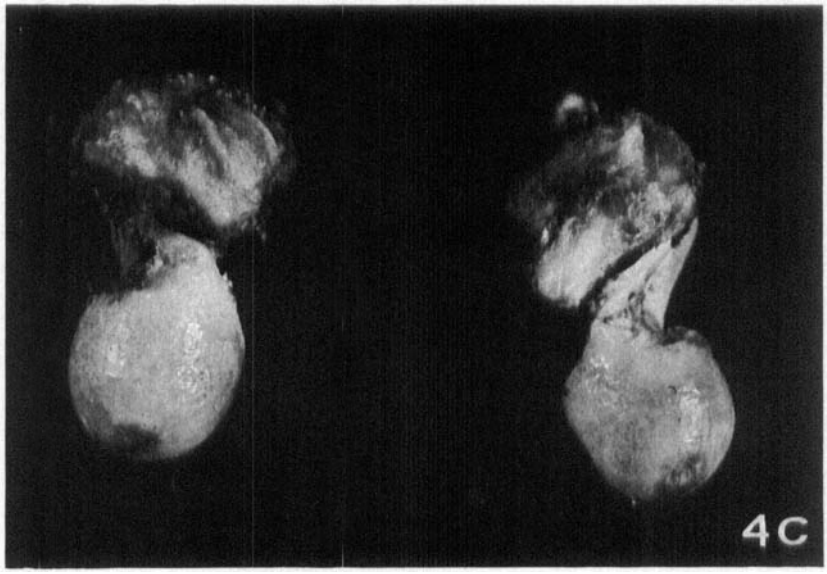


Fig. 4–c *Fig. 4–c_1*

Figure 4 (a–c). Specimens of the proximal ends of the femurs of a rabbit. This four-week-old animal was immobilized with the right hind limb in extension for three weeks and killed three months after the immobilization was started. In the right hip (a, b and c) a coxa vara deformity including a retroversion of the head and neck of the femur were observed but the left hip (a_1, b_1 and c_1) was normal (the head and neck of the femur were in a normal, anteversion position).

all parts of the proximal end of the femur (c.f. Figures 1, 2, 3, 4, 5 and 6):

- The acetabulum was often deformed in outline and more shallow than normal.
- The head of the femur was often lower and broader and situated more posteriorly and inferiorly than normal.
- The epiphyseal plate of the head of the femur was in some cases more vertical than normal.
- The neck of the femur was usually shorter than normal and retroverted compared with the normal.
- The greater trochanter was situated more cranially than normal and the superior part of it was often bowed medially.
- The lesser trochanter was often situated nearer the head of the femur than normal.
- The ossification centres of the femoral head and the greater trochant-

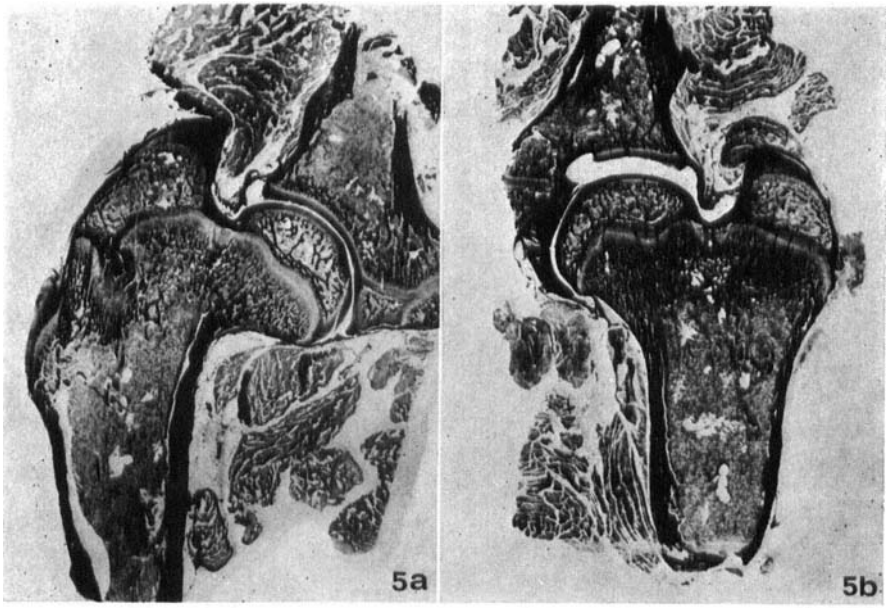


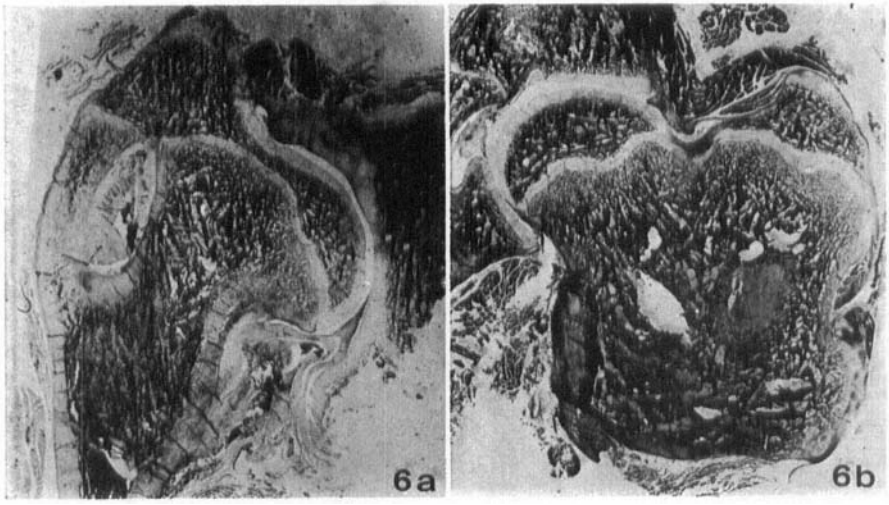
Figure 5 (a, b). A four-week-old rabbit was immobilized with the right knee in extension. Three weeks later a coxa vara deformity was observed on the right side (Figure 5a), but the left hip was normal (Figure 5b).

er were joined by a bridge of bone in some rabbits with coxa vara (Figure 6).
- The proximal end of the femur was often bowed medially and on its medial side more sclerosis than normal was visible.
- The movement of the hip was usually decreased, especially abduction and rotation.

All these pathological findings are described similarly in human coxa vara (Amstutz & Wilson 1962, Blockey 1969, Marchetti & Faldini 1968, Pylkkänen 1960).

DISCUSSION

Both the aetiology and pathogenesis in many of the most common diseases of the hip in childhood i.e. coxa vara, coxa valga, coxa plana, and congenital dislocation of the hip are rather obscure. It is known that coxa vara may develop in children after fractures or infection of the hip and after treatment of dislocation of the hip, but in most cases of



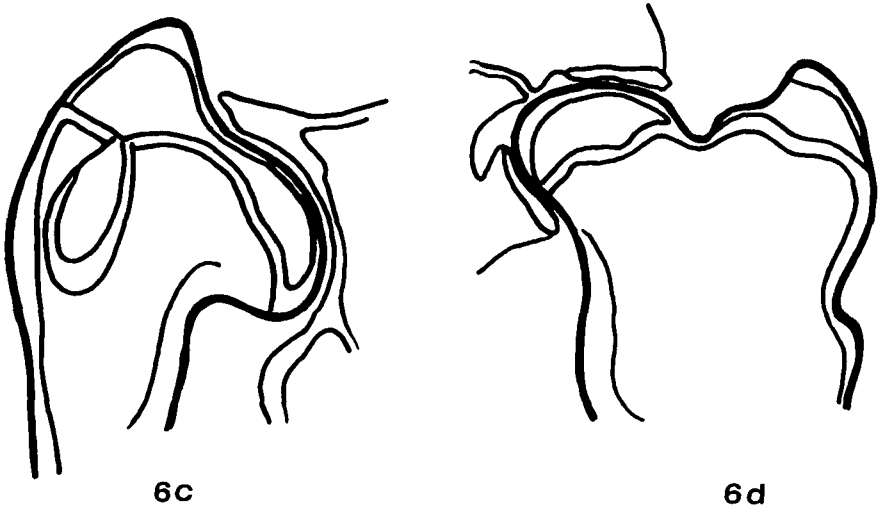


Figure 6 (a–d). A six-week-old rabbit was immobilized with the knee of the right hind limb in extension. One month after the procedure the animal was killed. In the sections a coxa vara deformity and a bony fusion between the ossification centres of the femoral head and the greater trochanter were observed in the right hip (Figure 6a), but the left hip was normal (Figure 6b). Figure 6c: Explanatory drawing of the section in Figure 6 a. Figure 6 d: Explanatory drawing of the section in Figure 6b.

coxa vara the aetiology is unknown (Amstutz & Wilson 1962, Pylkkänen 1960). Many theories have been formulated to explain the development of both the infantile and adolescent forms of coxa vara and these are based on clinical and radiographical investigations. Among other possible aetiological factors, traumata, infections, rickets, vascular disturbances and mechanical changes have been proposed. These theories are reported for instance in a thesis of Pylkkänen (1960). Previously many experimental investigations have been made to clarify the pathogenesis of coxa vara. After destruction of the epiphyseal plate of the head of the femur in growing animals, coxa vara often developed (Burckhardt 1948, Compere et al. 1940, Nagura & Kosuge 1938, Nagura 1940, Salenius & Videman 1970). Following destruction of the epiphyseal plate of the greater trochanter, coxa valga has developed (Compere et al. 1940, Langenskiöld & Salenius 1967, Laurent 1959) and this method has been used in the treatment of some forms of coxa vara (Langenskiöld & Salenius 1967, Pylkkänen 1960). The above-mentioned methods of provoking coxa vara have all been traumatic. In our experiments we have induced deformities of the hip, e.g. coxa vara, without any direct trauma to the hip, but instead created a muscular imbalance of the hip by the immobilization of the knee in extension. The immobilization of the knee in extension led to an increased tension on the hamstring muscles when the animal kept the hip in flexion. Therefore we cut the hamstring muscles in twenty-five animals and thereafter the same limb was immobilized with the knee in extension. None of these animals developed any marked coxa vara or other dysplastic changes of the hip, which shows that the increased tension of the hamstring muscles played an essential role in the development of coxa vara and dislocation of the hip in our experiments (Michelsson & Langenskiöld 1972). The experimental coxa vara proved to have similar pathological features as are described in human coxa vara. A regression of the pathological changes in the hip was noticed in some animals, especially after a short period of immobilization. In some cases of human coxa vara the pathological changes have disappeared, especially if the child has been kept at rest (Lindemann 1941, 1949, Pylkkänen 1960, Rettig et al. 1970). These facts and other experimental evidence support the theory that, as in our experiments, mechanical factors affecting the growth of the capital epiphyseal plate play an important role and may also be essential factors in the development of the human coxa vara.

The therapy is usually also directed towards changing the loading

forces of the hip by osteotomy, and many cases of infantile coxa vara have developed more normally after osteotomy (Pylkkänen 1960).

The type of coxa vara seen in our experiments is very similar to that seen in connection with coxa plana or as a complication following treatment of congenital dislocation of the hip.

These experiments show that both a coxa vara deformity and a dislocation of the hip may develop as a result of mechanical factors; a change of the forces normally acting on the hip. The pathological changes of the skeleton may be explained by the laws of Wolff and Hueter-Volkmann regarding the transformation of cartilage and bone in relation to the forces acting upon these tissues.

SUMMARY

In seventy growing rabbits, two to twelve weeks old, one of the hind limbs was immobilized with the knee in extension but with the hip free and able to be flexed. In fifty of the rabbits a coxa vara deformity developed and in twenty-five of these subluxation or dislocation of the hip occurred in addition to coxa vara (c.f. Table 1). These phenomena of experimental dislocation and subluxation were described in a former article (Michelsson & Langenskiöld 1972). The coxa vara deformity in our experiments was connected with similar features as are described in human coxa vara of different aetiology. Both the acetabulum and the proximal end of the femur were deformed and the head and the neck of the femur were usually retroverted.

The experiments show that in growing rabbits an atraumatically provoked change of the forces acting on the hip may lead to growth disturbance of the capital epiphyseal plate and progressive coxa vara.

The similarity in the experimental and the human coxa vara justify our thinking that the infantile human coxa vara may also develop as an adaptive result of a change in the forces acting on the hip, which may, for instance, be provoked by a long-lasting change of the position of the hip or knee.

REFERENCES

Amstutz, H. C. & Wilson, R. D. Jr. (1962) Dysgenesis of the proximal femur (coxa vara) and its surgical management. *J. Bone Jt Surg.* **44**-A, 1.

Blockey, N. J. (1969) Observations of infantile coxa vara. *J. Bone Jt Surg.* **51**-B, 106.

Burckhardt, E. (1948) Perthes, Osteochondritis dissecans und Coxa Vara infantum im Tierexperiment. *Helv. chir. Acta* **1**, 3.

Compere, E. L., Garrison, M. & Fahey, J. (1940) Deformities of the femur resulting from arrestment of growth of the capital and greater trochanteric epiphyses. *J. Bone Jt Surg.* **22**, 909.

Langenskiöld, A. & Salenius, P. (1967) Epiphyseodesis of the greater trochanter. *Acta orthop. scand.* **38**, 199.

Langenskiöld, A. & Sarpio, O. (1957) Patologin vid kongenital höftledsluxation belyst genom experimentell imitation av deformiteten. (A preliminary report). *Finska Läk.-Sällsk. Handl.* **100**, 111.

Langenskiöld, A. & Sarpio, O. (1958) Primary and secondary changes in congenital dislocation of the hip. *Transactions of the Seventh Congress of the Societé Internationale de Chirurgie Orthopédique et de Traumatologie,* Barcelone, September 16–21, p. 911.

Langenskiöld, A., Sarpio, O. & Michelsson, J.-E. (1962) Experimental dislocation of the hip in the rabbit. *J. Bone Jt Surg.* **44**-B, 209.

Laurent, L. E. (1959) Growth disturbances of the proximal end of the femur in the light of animal experiments. *Acta orthop. scand.* **28**, 255.

Lindemann, K. (1941) Das erbliche Vorkommen der angeborenen Coxa Vara. *Z. Orthop.* **72**, 326.

Lindemann, K. (1949) Zur Morphologie der Coxa Vara congenita. *Z. Orthop.* **78**, 47.

Marchetti, P. G. & Faldini, A. (1968) *The surgical treatment of coxa vara in childhood and adolescence.* Carlo Erba, Milan.

Michelsson, J.-E. & Langenskiöld, A. (1972) Dislocation or subluxation of the hip; regular sequels of immobilization of the knee in extension in young rabbits. *J. Bone Jt Surg.* **54**-A, 1177.

Nagura, S. & Kosuge, S. (1938) Die Pathogenese und das Wesen der Perthesschen Krankheit. *Langenbecks Arch. klin. Chir.* **191**, 347.

Nagura, S. (1940) Zur Ätiologie der Coxa Vara, zugleich Beitrag zur Kenntnis der Transformation der Knochen. *Langenbecks Arch. klin. Chir.* **199**, 533.

Nagura, S. (1940) Perthessche Krankheit und Coxa Vara. *Langenbecks Arch. klin. Chir.* **199**, 613.

Pylkkänen, P. (1960) Coxa vara infantum. *Acta orthop. scand.*, Suppl. 48.

Rettig, H., Eichler, J. & Oest, O. (1970) *Hüft Fibel.* Georg Thieme Verlag, Stuttgart.

Salenius, P. & Videman, T. (1970) Growth disturbances of the proximal end of the femur. *Acta orthop. scand.* **41**, 199.

Correspondence to:

Jarl-Erik Michelsson
Department of Orthopaedics and Traumatology
University Central Hospital
Topeliuksenkatu 5, Helsinki 26, Finland