Acta orthop. scand. 45, 225–234, 1974

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GROWTH OF THE UPPER END OF THE FEMUR

Experimental Investigation in the Rabbit

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Accepted 5.vii.73

Pathological conditions of the hip involving the epiphysis of the femoral head may lead to growth disturbances which affect the shape and the length of the upper end of the femur. Acute infections of the hip in infants, epiphyseal changes following reduction of congenital dislocation of the hip, Perthes' disease or fractures of the femoral neck in children may be followed by the occurrence of a coxa vara deformity and a variable amount of shortening of the femur.

The shortening is the direct outcome of the deceleration and eventual cessation of growth at the epiphyseal plate of the capital epiphysis. The coxa vara deformity too results from the cessation of growth of the capital epiphysis but also from the continued growth of the unaffected trochanteric epiphysis, with subsequent rise of the tip of the trochanter above the level of the head.

Such elevation of the greater trochanter reduces the efficiency of the abductor muscles of the hip and thus produces a gluteal limp. In order to prevent this occurrence early surgical epiphysiodesis of the trochanter has been recommended by Edgren (1965) and Langenskiöld & Salenius (1967). This step was justified by the studies of Laurent (1959) which showed that the epiphysis of the trochanter does not contribute to the length of the femur and therefore could be dispensed with easily. However, the observations of Morgan & Somerville (1960) indicated that the trochanteric epiphysis was active in maintaining the length of the femur in conditions affecting the capital epiphysis such as those mentioned above.

It seems therefore that there is still some uncertainty with regard to the contribution of the trochanteric epiphysis to the length of the femur. Nevertheless, the implications thereof are important. By performing an epiphysiodesis of the trochanter in cases of progressing coxa vara deformity we may well prevent the occurrence of a gluteal limp. It is not at all certain, however, that through such action we may not aggravate the existing shortening by discarding the sole remaining and active epiphysis of the upper end of the femur.

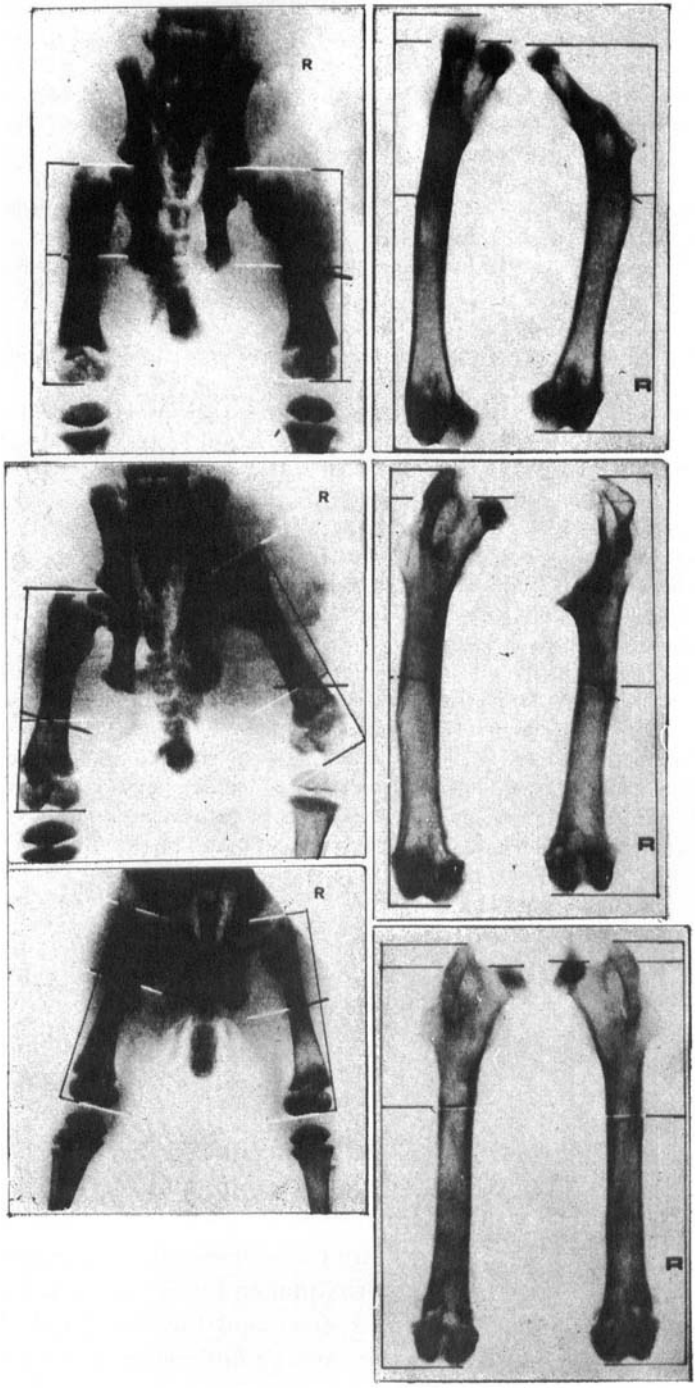
This report concerns an experimental study undertaken in order to ascertain the changes in length of the femur occurring after resection of the capital epiphysis, a situation somewhat similar to that existing in the above-mentioned pathological conditions. In addition it was thought that a resection of the trochanteric epiphysis and the study of the subsequent changes in length of the femur may throw some light on its importance as a growth centre of that bone.

METHODS

Rabbits of both sexes about twelve days old with average weight of 230 grams were used. All rabbits belonged to eighteen parturitions of eighteen dams. The siblings of each parturition were divided into three groups. In the first group (group T) the right trochanteric epiphysis was resected through a small incision in the gluteal region. The muscles were cut from the trochanter, the trochanteric epiphysis was exposed and sharply resected, encroaching upon the bony metaphysis. Only the skin was sutured by interrupted stitches. In the second group (group H) the right capital femoral epiphysis was resected. The skin incision was similar, the gluteal muscles were split, the joint capsule was exposed and opened dorsolaterally. The femoral head was dislocated after severance of the ligamentum teres and through external rotation of leg, the cartilagenous head was sharply resected encroaching upon the bony metaphysis and the skin closed by interrupted sutures. The third group (group C) was kept as controls.

All operations were performed under open ether anaesthesia. While the rabbits were under anaesthesia, a bone marker was introduced percutaneously into the femoral shaft. The marker was the sharp end of a stainless steel hypodermic needle 27 gauge and 1.8 cm long (B-D Yale Luer-Lok, Becton, Dickson and Company, Rutherford, N.J.) Bone markers were introduced into both femurs of all the animals.

Figure 1. Measurements used in each of the three groups on the first and last roentgenograms:
Top row: trochanter resected group.
Middle row: head resected group.
Bottom row: control group.
For details see text.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Roentgenograms were taken within forty-eight hours following operation (or following marking for the control animals). A mobile x-ray apparatus was used (Picker X-Ray Corporation, Cleveland, Ohio). Exposure time was 0,08 second and the distance between tube and x-ray cassette was 113 cm. Each rabbit was radiographed dorsoventrally, strapped to a special board, with hindlimbs fully extended and symmetrical as far as possible.

During the ensuing months additional roentgenograms were taken mainly in order to ascertain that there was no change in the position of the markers. These radiograms were not used for measurements.

The animals were killed at the age of six months. Each pair of femurs was dissected free of the soft tissue and a final roentgenogram was taken in the same conditions.

The measurements were performed on the initial and final roentgenograms between the following points (Figure 1):

For group T in which the trochanteric epiphysis was resected, the total length was measured from the uppermost point of the femoral head to the lowest point of the longest femoral condyle and the lengths of the upper and lower parts were measured from these points to the marker inserted into the shafts;

For group H in which the capital epiphysis was resected, the total length was measured from the uppermost point of the trochanter to the lowest point of the longest femoral condyle and the lengths of the upper and lower parts were measured from these points to the marker inserted into the shaft;

For the control group (group C) all the preceding measurements were taken.

The effect of specific operation on the growth of the femur was evaluated by way of comparing growth in the operated group with that observed in the control group, using the t-distribution for significance tests.

The dam was considered as the sampling unit (Weil 1970). Therefore the comparison was made between mean growth of each dam's siblings in the operated group with the mean of the same dam's siblings in the control group.

In addition the difference in growth within pairs of femurs was evaluated for each group. For this evaluation t-tests were also carried out, using the young rabbits as the sampling unit.

RESULTS

Averages of femoral growth are presented by siblings and groups (operated and control) in Table 1 (for the proximal end) and Table 2 (for the distal end).

Table 3 and Figure 2 present the average differences in longitudinal growth between siblings in the control group and in each of the two operated groups.

In group T in which the trochanter was resected, as compared to the control group, the growth of the proximal end was significantly smaller (the average difference was — 4.2 mm) and the growth of the distal end was significantly greater (the average difference was 4.4 mm). No

Table 1. Averages by siblings of longitudinal growth (in mm) in the proximal end of the femur.

Serial no. of dam	Operated groups						Control group		
	No. of siblings	Unoperated femur (LT)	Trochanter resected femur (RT)	No. of siblings	Unoperated femur (LT)	Head resected femur (RT)	No. of siblings	LT	RT
1				3	34.7	29.0			
2	2	29.5	24.0	3	34.7	32.0	1	26.0	31.0
3	2	21.5	22.0	2	29.0	31.0	2	27.0	27.0
4	2	28.5	23.5				1	34.0	30.0
5	3	23.7	21.7	2	28.0	26.5	2	21.5	24.5
6	1	24.0	26.0						
7				1	34.0	30.0	2	29.5	29.0
8	2	26.5	21.0	1		25.0	1	25.0	27.0
9	2	26.0	22.5	2	30.0	28.0	1	27.0	
10	2	28.0	22.5	2	32.0	25.0	1	30.0	27.0
11	2	25.0	20.5	1	26.0	24.0	2	21.5	20.5
12	1	24.0	22.0	1	33.0	25.0	1	23.0	23.0
13	1	22.0	20.0						
14				1	27.0	25.0	2	22.5	25.5
15	2	24.0	18.0	3	28.7	20.0			
16	2	20.5	22.0	2	26.0	23.5	2	23.0	22.5
17	3	20.7	18.7	2	28.5	25.5	2	25.5	24.0
18	1	26.0	19.0	2	30.5	28.0	2	27.0	26.5

significant difference was found between the unoperated femur in this group and the corresponding left femur of the control siblings.

In group H, in the femurs in which the femoral head was resected there were no significant differences in longitudinal growth from femurs in the control group, neither in the proximal nor in the distal ends (the average difference was 1.1 mm for the proximal end and 1.5 mm for the distal end). However, a significant difference was found between the unoperated femur in this group and the corresponding left femur of the control siblings in that the proximal end of the unoperated femur grew significantly longer (the average difference was 4.6 mm).

Table 4 presents the average differences in growth within pairs of femurs in each group. In group T and in group H growth of the proximal end of the operated femur was significantly smaller than in the unoperated left femur (the average difference was 3.1 mm in group T and 3.7 mm in group H). In group T, the growth of the distal end was

Table 2. Averages by siblings of longitudinal growth (in mm) in the distal end of the femur.

Serial no. of dam	Operated groups						Control group		
	No. of siblings	Un-operated femur (LT)	Tro-chanter resected femur (RT)	No. of siblings	Un-operated femur (LT)	Head resected femur (RT)	No. of sib-lings	LT	RT
1				3	51.0	49.7			
2	2	46.0	51.0	3	47.3	47.3	1	40.0	37.0
3	2	46.5	44.5	2	37.0	30.5	2	41.5	42.0
4	2	44.5	48.0				1	42.0	43.0
5	3	42.3	43.0	2	41.5	39.5	2	43.0	39.5
6	1	37.0	38.0						
7				1	45.0	50.0	2	58.5	46.0
8	2	49.5	50.5	1		44.0	1	46.0	44.0
9	2	45.0	45.5	2	45.0	44.5	1	46.0	
10	2	45.5	52.0	2	45.5	47.5	1	49.0	50.0
11	2	38.5	42.5	1	40.0	41.0	2	36.0	37.5
12	1	36.0	37.0	1	39.0	42.0	1	36.0	34.0
13	1	45.0	44.0						
14				1	37.0	36.0	2	41.0	38.5
15	2	35.0	35.0	3	32.7	39.3			
16	2	35.5	38.0	2	34.5	37.0	2	33.5	33.0
17	3	37.7	40.7	2	40.5	44.5	2	43.0	41.5
18	1	43.0	47.0	2	45.5	46.0	2	45.0	44.5

significantly greater in the operated femur (the average difference was 2.1 mm).

The difference in total length between right (operated) and left (un-operated) femurs in group T was negligible (average 1.1 mm). The

Table 3. Averages (and standard errors) of differences in femoral growth (in mm) between operated and control siblings.

End of femur	Unoperated femur		Operated femur	
	Trochanter resected vs control group	Head resected vs control group	Trochanter resected vs control group	Head resected vs control group
Proximal	− 0.9 (3.3)	4.6 (2.6)*	− 4.2 (2.7)*	1.1 (1.9)
Distal	0.8 (3.4)	− 1.2 (5.2)	4.4 (3.7)*	1.5 (5.6)
Whole femur	− 0.1 (5.3)	3.4 (6.8)	0.2 (4.2)	2.6 (5.8)

Significant at 5% level.

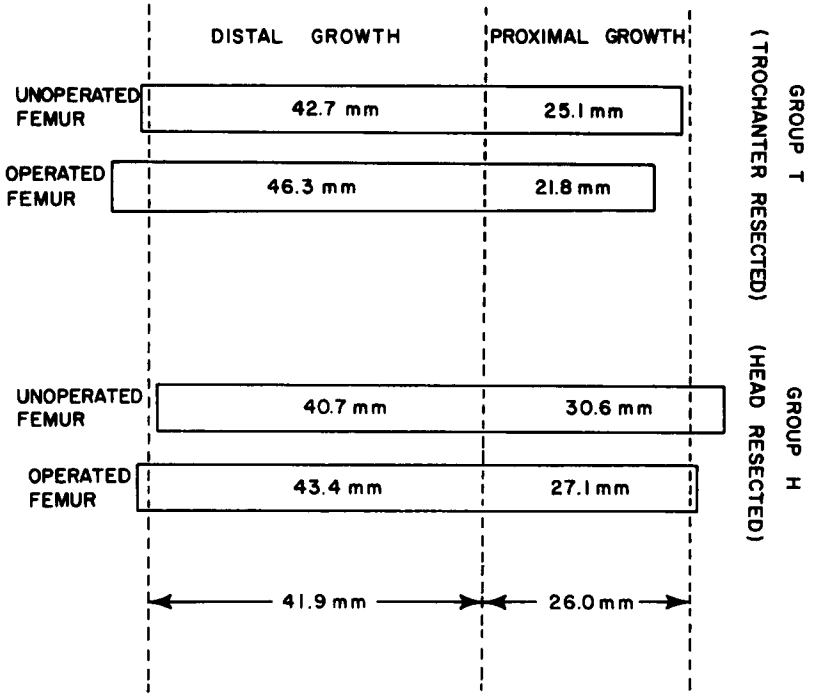

Figure 2. Diagram demonstrating the average differences in femoral growth between operated and control siblings. The distances from the middle horizontal broken line to the upper and lower broken lines each represent respectively the growth in proximal and distal ends in the control group.

value of this difference was significantly greater in group H, the unoperated femur in group H being longer that the operated one (average 3.2 mm).

DISCUSSION

The roentgenological method of measurement used in this study is similar to those used by Langenskiöld (1957), by Elo (1960) and by Ryöppy (1965). According to Langenskiöld (1957) such technique permits calculations to an accuracy of 1 mm.

When the operated femurs were compared with those of the control group, it became apparent that neither resection of the head nor that of the trochanter produced any significant reduction in the total length of the bone. However, the mechanism by which the total longitudinal growth was preserved or perhaps even somewhat enhanced (in group H) was different for each resection.

Table 4. Averages (and standard errors) of differences in longitudinal growth (mm) within pairs (left minus right side) in each group.*

End of femur	Group C (control)	T (trochanter resected)	H (head resected)
Proximal	−0.2 (2.7)	3.1 (3.5)§	3.7 (4.2)§
Distal	0.6 (2.5)	−2.1 (2.9)§	−0.5 (4.8)
Whole femur	0.4 (2.6)	1.1 (3.6)	3.2 (2.9)§

* Right is the operated side in groups T and H.

§ Significant at 5% level.

In animals in which the trochanter was resected the proximal end grew significantly less but the distal end grew significantly more. Thus, because of the compensatory growth of the distal end no change occurred in the total longitudinal growth. In animals in which the femoral head was resected the proximal end as well as the distal one of the operated femur grew even a little more than femurs in the control siblings. It may be assumed that growth of the proximal end was preserved or perhaps even enhanced through compensatory growth from the trochanteric epiphysis, and therefore no reduction occurred in the final length of the femur.

It appears therefore that resection of one of the upper femoral epiphyses produced enhanced growth in other epiphyses of that femur. A similar effect was observed by Hall-Craggs & Lawrence (1969) who found a reduction in the normal decelaration of the distal epiphysis in rabbits whose proximal epiphysis was stapled.

An enhanced growth was observed in the unoperated femurs in group H in which the head was resected, due to the activity of the proximal epiphyses of these femurs. Therefore, while growth of the operated femurs in this group was quite similar to that of femurs in control siblings, growth of the contralateral, unoperated femurs was greater and a significant difference in growth within the pairs of femurs resulted.

Thus, by using control siblings, an enhanced growth effect was also found in one epiphysis of the contralateral, unoperated, femur. Such controls are not mentioned in the work of Hall-Craggs & Lawrence (1969) and no explanation can be forwarded in this respect.

The fact that neither the resection of the capital nor that of the trochanteric epiphysis produced any shortening of the operated femur

appears to unite the seemingly opposite views of Laurent (1959) and that of Morgan & Sommerville (1960). Laurent (1959) stated that the trochanteric epiphysis did not contribute to the length of the bone, because injury to that epiphysis produced either insignificant shortening in the experimental animal or even lengthening in children operated upon because of unilateral congenital dislocation of the hip. It is permissible to think, in the light of our experiments, that these results may have been due to a compensatory enhanced growth of the distal femoral epiphysis of the operated femur. Morgan & Sommerville (1960) have observed that in cases of destruction of the capital epiphysis, the trochanteric epiphysis was active in maintaining the length of the femur. This view is corroborated by our findings of uninhibited growth occurring in the operated femur after resection of the capital epiphysis.

With regard to the advisability of epiphysiodesis of the greater trochanter mentioned at the beginning, it must be pointed out that, although this study has shown that there can be quite efficient compensatory growth when one epiphysis is made deficient, it is still questionable whether such growth will occur when both upper femoral epiphyses are deficient, as is the case when growth disturbances of the capital epiphysis are treated by epiphysiodesis of the trochanteric epiphysis. We feel that as long as this question remains unanswered, some circumspection should be exercised before deciding on the performance of such an epiphysiodesis.

SUMMARY

Changes occurring in the length of the femur were studied after resection of the capital epiphysis or of the trochanteric epiphysis performed in young rabbits.

No shortening of the operated femur occurred in either one of these resections.

It could be ascertained that normal length was preserved through compensatory enhanced growth from other, unaffected, femoral epiphyses.

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