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Stimulation of the Longitudinal Growth of the Long Bones

By

E. LØSSL NORDENTOFT

and

E. HJORT GULDHAMMER

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From the Orthopaedic Hospital, Copenhagen, Denmark. Dept. 1 (Head: Professor A. Bertelsen), Dept. 2 (Head: E. Hjalmar Larsen), Dept. 3 (Head: A. Monberg).

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1. Review of the Literature

A. *Introduction.*

It is generally known that the longitudinal growth of the diaphyses of long bones takes place only by apposition from the epiphysial plates.

The histology and cytology of the epiphysial plate has been rather thoroughly studied. On the other hand, the detailed mechanisms which condition normal, symmetrical longitudinal growth and the pathogenetic factors which may stimulate or retard longitudinal growth are practically unknown. However, a number of clinical and experimental findings indicate that changes in the blood supply of the epiphysial plates play an important role in growth intensity.

The blood supply of the long bones has been investigated int. al. by *Weinmann & Sicher* (1947), *Trueta & Harrison* (1953), *Trueta* (1958), *Trueta & Cavadias* (1955), *Lewis* (1956), *Trueta & Morgan* (1960), *Trueta & Little* (1960), *Trueta & Amato* (1960), and *Trueta & Trias* (1961). The epiphyses receive their blood supply from epiphysial vessels. The metaphysis is supplied primarily by the nutrient arteries, but during the growing phase also to an increasing extent by metaphysial vessels. Between epiphysial and metaphysial vessels there are ample extraosseous anastomoses along the periphery of the epiphysial plate, but endosteal anastomoses are not present between these two vascular systems until growth has been completed.

It has been known for a long time that in a large number of diseases abnormal stimulation of the longitudinal growth of long bones may occur.

This has been observed *e.g.* in congenital anomalies, vascular diseases, systemic diseases, and following infections, traumas, and sympathetic denervation.

In arteriovenous anastomoses (*Broca* 1856, *Horton* 1932, *Betrand & Trillat* 1948, *Bertelsen & Dohn* 1953) and in "systemic haemangiomas" (*Servelle* 1948, *Harris & McDonald* 1936) considerable overgrowth of the affected limb may be observed. Severe overgrowth has been reported in Recklinghausen's neurofibromatosis.

Cases of overgrowth have also been reported to be due to osteomyelitis, chronic suppurative infections of soft tissues and joints (*v. Langenbeck* 1869, *Trueta* 1953) and to fractures as well as other skeletal lesions (*Ollier* 1867, *Emneus* 1957, *Levander* 1929, *Aitken* 1940, *Blomquist & Rudström* 1943, *Hedberg* 1944–45, *Barfod & Christensen* 1959, *Guldhammer* 1963).

Following sympathectomy overgrowth has occasionally been observed in the denervated area (*Bidder* 1874, *Harris & McDonald* 1936).

These findings have stimulated a large number of experimental and clinical attempts at reproducing the growth-stimulating mechanisms with the purpose of working out a clinically applicable method for growth stimulation. *Ollier* (1867–73) appears to have been the first to perform growth stimulation experiments on a larger scale. From a number of more or less specified experiments he concluded that all agents which irritate the periosteum and bone, such as incisions, excisions, dilacerations, cauterizations, perforations of the medullary cavity, and inplantation of foreign material resulted in intensified longitudinal growth.

Ollier's observations inspired to a large number of studies of a similar nature.

Below follows a review of the various methods used in the attempt to stimulate the longitudinal growth of the long bones experimentally or clinically.

B. *Periosteal Stripping:*

1. *Animal experiments.*

After periosteal stripping on infant rabbits *Wu & Miltner* (1937), *Lacroix* (1947), and *Langenskiöld* (1957) found a growth stimulation of from 1–3 mm., while *Sousa Pereira* (1937) was unable to demonstrate any effect. The most extensive and most thoroughly analysed experimental material in this respect is *Brodin*'s (1955). Following periosteal stripping proximally on the tibiae of 44 infant rabbits he found during the first post-operative week stimulation of both epiphysial plates on the tibia, but at the end of one week the growth intensity from the proximal epiphysial zone fell to below normal and remained so until the completion of growth, while distally the intensity continued to be a little above normal. The end result, thus, was only a slight increase in the growth rate.

2. *Clinical experience.*

Bertrand & Trillat (1948), *Zanoli* (1949), and *Taillard* (1959) performed periosteal stripping on children with shortening of a lower limb. All found mild stimulation of growth or mild retardation of the progression of anisomelia. However, the results cannot be assessed owing to the inaccuracy of the measurement and the inaccuracy in evaluating the spontaneous course.

C. *Implantation of Foreign Material.*

In animal experiments *Meisenbach* (1910), *Königswieser* (1925, 1926), *Pitzen* (1928), *Bohlmann* (1929), *Kischikawa* (1936), *Wu & Miltner* (1937), *Bertrand & Trillat* (1948), *Chapchal & Zeldenrust* (1948), and *Herndorn & Spencer* (1953) implanted a large number of different organic and inorganic substances in the vicinity of the epiphysial plates. This resulted in a maximum stimulation of a few millimetres, and frequently in inhibition of growth. *Langenskiöld* (1957) and *Haas* (1958) found no growth stimulation following injection of pituitary growth hormone into the medullary cavity.

Wilson & Percy (1956) found an unreliable and varying growth stimulation following implantation of dissimilar metals into the metaphyses of animals. When applied clinically this method gave no effect.

von Langenbeck (1869) reported growth stimulation following implantation of an ivory screw into the femur of a dog.

Chapchal & Zeldenrust (1948) found on the average a slight and extremely varied stimulation by ivory implants in rabbits.

In 10 patients with anisomelia *Pease* (1952) inserted screws of various metals or of ivory into the metaphyses at the knee. The results are reported only for 7 of the patients. Assuming that if untreated the shortening would have progressed in proportion to time at an unchanged rate, *Pease* calculated that by the ivory screws he had obtained a stimulation of from 0.8–1.1 cm. and by metal screws 0.0–2.2 cm. The methods of measurement or the technique of the procedure are not specified. The inaccuracy of the measurement cannot be assessed, and the follow-up period was in some cases not longer than 6 months. *Pease* recommended insertion of ivory screws for clinical use, but in 1956 he had abandoned this technique and recommended instead the introduction of dissimilar metal compounds.

Blount & Zeier (1952) as well as *Kramer* (1955) claimed to have observed positive results with Pease's method of inserting ivory screws.

On the other hand, *Montgomery & Ingram* (1956) found growth stimulation to be less common and did not feel that the clinical use of Pease's method was justified. In 12 out of 16 patients with progressive shortening, *Tupman* (1960) found a decreased rate of progression following implantation of ivory screws or ox bone into the metaphyses at the knee, but no real decrease in the anisomelia.

D. *Occlusion of the Medullary Cavity.*

Ferguson (1933) made drill holes into the metaphyses and cut the bone marrow at the knee in 16 children with anisomelia. He reported the results only for 4 who showed a stimulation of 1.6–3.2 mm. in a follow-up period of 2–5 months. It is not stated how this was demonstrated.

Ferguson's method was tested experimentally on rabbits by *Compere & Adams* (1937) and by *Wu & Miltner* (1937) without demonstrable effect and on puppies by *Hutchison & Burdeaux* (1954) who found an average growth stimulation of 1 mm. in half of 10 treated animals and none in the others.

This method has been employed clinically in a modified form by *Carpenter & Dalton* (1956). In addition to making drill holes in the metaphyses and curetting the bone marrow, they packed the defect with ivory chips. In 26 out of 28 children they obtained an average stimulation of 0.7 cm.

On the basis of clinical experience of growth stimulation following fractures and osteomyelitis, *Trueta* (1953) believes that the stimulation appears chiefly when the lesions are localized to the diaphyses and that it is active only while the medullary cavities are occluded.

E. *Occlusion of the Nutrient Arteries.*

Haas (1917) found no alteration in longitudinal growth after severing the nutrient arteries in dogs and cats.

Trueta (1953) found no growth stimulation after severing the nutrient arteries of rabbits, while blocking of their lumina with wax or periosteal stripping around the nutrient foramen resulted in a growth stimulation which is not further specified.

Brookes (1957), closing the nutrient arteries of 1-day-old rabbits, found no alteration in growth until towards its completion which was premature.

F. *Arteriovenous Anastomoses.*

Bertrand & Trillat (1948) suggested trying surgical formation of arteriovenous anastomoses in the treatment of anisomelia.

In 5 out of 8 patients in whom arteriovenous anastomosis had been established on the lower limbs, *Janes & Jennings* (1961) found an average decrease of the existing anisomelia of 2.7 cm. after an average follow-up period of 4.4 years. In the other 3 patients the shortening progressed. All the patients developed considerable cardiac dilatation which, however, subsided when the anastomosis was closed. A number of the patients developed varicose veins.

Hiertonn (1961) set up an anastomosis between the femoral artery and vein proximally on the femur of 5 children suffering from the sequaelae of poliomyelitis and progressive anisomelia. After the anastomosis had been open for periods ranging from 5.3 to 7.5 years the anisomelia had decreased by 3.0–6.5 cm. All the patients developed varicose veins and 3 ulcer of the leg which healed after normal circulation had been re-established. There was no instance of demonstrable cardiac complications or permanent late sequelae. Arteriography after the procedure showed extremely ample vascularization around the epiphysial zones at the knee.

G. *Venous Stasis.*

The earliest reports on a growth-stimulating effect of venous stasis were *Helferich*'s (1887), *Schüller*'s (1889), and *Bier*'s (1905).

In rabbit experiments *Bergmann* (1931), using venous stasis and *Kishikawa* (1936), using external stasis or ligation of the femoral vein, found mild growth stimulation in some of the animals.

Ligating the femoral vein, the great saphenous, or the popliteal vein on 7 puppies *Servelle* (1948) found a growth stimulation of 2.6–7.6 per cent. However, he does not describe his measuring method.

Hutchison & Burdeaux (1954), applying stasis to the forelegs of 11 dogs, found no alteration in growth intensity. Using the same procedure on the hind legs of 6 dogs, they found an average growth increment of 1.45 per cent, both on the femora and tibiae, although the stasis had been applied immediately above the knee.

On the other hand, *Wu & Miltner* (1937), ligating the femoral artery on 11 rabbits and *Dickinson* (1953), ligating the popliteal and iliac veins in a very carefully studied material of 8 dogs, found no demonstrable growth stimulation during the treatment.

H. *Sympathetic Denervation.*

1. *Animal experiments.*

Bidder (1874) observed considerable hypertrophy of a rabbit ear following cervical sympathectomy.

Kishikawa (1936) obtained mild growth stimulation following lumbar sympathectomy on puppies.

Gullickson, Kubicek & Kottke (1951) applied electrical stimulation to the sympathetic trunk of 10 puppies through 23–70 days. Measurements on post-mortem specimens thereafter showed an average shortening of 2.8 mm. on the stimulated side. In 6 puppies treated by lumbar sympathectomy they found invariably a lengthening on the denervated side of 2.7–14.0 mm. average 6.5 mm. In a normal control series the maximum value was 1 mm. and the average difference in length 0.2 mm.

Cannon et al. (1929), *Simon* (1930), *Bacq* (1930), *Bergmann* (1931), *Bisgard* (1933), and *Harris & McDonald* (1936) found no definite growth stimulation following sympathectomy on animals.

Goetz, du Toit & Swart (1955) found a mild lengthening of the paw, but no alteration in the length of the femur or tibia following lumbar sympathectomy on 2 rabbits.

Ring (1961), performing total lumbar sympathectomy on 11 puppies, found mild lengthening in only 3, and no influence upon growth in the others.

Troupp (1961) found inhibition of longitudinal growth in rabbits in which ischaemia had been induced on a hind limb. Lumbar sympathectomy was unable to compensate for this inhibition of growth.

2. *Clinical experience.*

Harris & McDonald (1936) had followed 46 polio patients after lumbar sympathectomy. In 21 an existing anisomelia decreased—in 2 cases by more than 2.5 cm., in 4 by more than 1.9 cm., and in the remaining 15 by less than 1.3 cm. The results are based on the clinical measurement of the shortening. In 1945, *Harris & McDonald,* in a discussion, reported that they had performed more than 400 lumbar sympathectomies on polio patients. They found that further progression was arrested and that frequently the anisomelia decreased, in one case from 4.25 cm. to 0.6 cm.

In one patient with progressive, congenital anisomelia *Bertrand & Trillat* (1948) found a reduction of the shortening of 1.5 cm. 2 years after lumbar sympathectomy.

Barr et al. (1950) had followed 23 polio patients after lumbar sympathectomy. These patients showed an average reduction of the shortening of 0.3 cm. as compared with an average increase of 1.8 cm. in a control group. The age at onset of the disease in the control group not being stated, it cannot be seen whether the two groups are comparable. When considering the inaccuracy of the measurement, only 3 patients obtained a definite reduction of the shortening.

Fahey (1936) found no alteration of longitudinal growth after lumbar sympathectomy on 2 children with Hirschsprung's disease.

Steward (1937), following 6 children with cerebral palsy after lumbar sympathectomy, found in 6 years a growth increase, of half an inch (1.2 cm.), in only 2 children.

I. *Effect of Short-wave Diathermy.*

The influence of short-wave diathermy upon the longitudinal growth has been studied by *Buchtala* (1948, 1949), *Wise et al.* (1949), *De Forest et al.* (1953), and *Vaughen & Bender* (1959). In no case was there a growth-stimulating effect, but on high doses they found extensive destructions of bone, epiphysial plate, and joint cartilage.

J. *Effect of Heat.*

This was studied by *Ring & Lee* (1958). In 4 children suffering from the sequelae of poliomyelitis, they maintained a temperature of 40° C around the epiphysial zones at the knee. No influence upon longitudinal growth was demonstrated.

Upon electrical heating of the epiphysial regions of animals *Richards & Stofer* (1959) found a growth increment of 2–6 per cent.

K. *Effect of X-radiation.*

X-radiation has been suggested for stimulating growth. Its effect has been studied by *Brooks & Hillstrom* (1933), *Bisgard & Hunt* (1936), and *Barr et al.* (1943). None of these authors found a growth-stimulating effect, but on the contrary growth retardation on high dosage.

L. *Discussion.*

This review does not include investigations comprising at the same time several different procedures aiming at growth stimulation, as in such cases it is impossible to evaluate the effect of the individual components.

Periosteal stripping has not given definite growth stimulation in animal experiments. The clinical results cannot be assessed with certainty.

The reported results of implanting foreign material have varied. However, most investigators have found a slight effect which cannot be evaluated in relation to the spontaneous course.

Occlusion of the medullary cavity has not afforded a definite effect in animal experiments, but in clinical use it appears to have resulted in some slight stimulation of growth.

Most authors have found no or only negligible stimulatory effect of venous stasis.

Surgical establishment of arteriovenous anastomoses entailed striking stimulation of growth in both of the reports published so far, but gave rise to severe cardiac and vascular complications.

The effect of sympathetic denervation has been extremely varied according to the different authors, both in experimental and in clinical use. Some have found a striking effect, others a milder effect, and others again no definite effect.

Long-continued application of heat to the epiphysial zones may possibly result in slight growth stimulation, while X-radiation, short-wave diathermy, and occlusion of the nutrient arteries do not appear to be of definite effect.

Thus, most of the methods studied have afforded little or no definite effect and have been used only sporadically for clinical cases.

Surgical establishment of arteriovenous anastomoses appears to involve such severe complications as to prohibit its clinical use.

Implantation of ivory screws into the metaphyses, as introduced by *Pease* (1952), still seems to be in use, but on the basis of the literature it seems impossible to evaluate the effect of this procedure with accuracy.

Lumbar sympathectomy is reported by some authors having experience of large series to exert a striking growth-stimulating effect. Others have found the effect to be nil or so slight that the obtained growth stimulation was of no clinical value.

Accordingly, we felt prompted to study the growth-stimulating effect obtained by Pease's procedure and by lumbar sympathectomy on a series of patients from the Orthopaedic Hospital, Copenhagen.

2. Present Investigations

Our patient material for evaluating the growth-stimulating effect of ivory implants is larger than any published before. On the other hand, the material for assessing the effect of lumbar sympathectomy is small compared with a number of previous series. However, both studies are based upon radiological measurement, and both series are of a size which permits statistical evaluation of the results.

A. *Material.*

The Pease procedure was done on 26 patients, 12 boys who had the operation in the age range 5 years 7 months to 13 years, average 9 years 10 months, and 14 girls in the age range 4 years 11 months to 9 years 10 months, average 7 years 6 months. The operation was carried out on 23 femora and 21 tibiae, a total of 44 bones.

The anisomelia which indicated growth stimulation had been caused by the sequelae of acute anterior poliomyelitis in 22 patients and by congenital diseases in 4.

Lumbar sympathectomy was done on 11 patients. In 6 it was impossible to assess the effect, either in the femur or in the tibia, because of operations upon the contralateral bone during the follow-up period. Thus, the effect could be assessed in the case of 16 bones. All these patients were suffering from the sequelae of poliomyelitis which had occurred 3–11 years, average 6 years 1 month, before the procedure. Four patients were boys who had the operation at ages ranging from 6 years 7 months to 11 years 11 months, average 9 years 6 months, and 7 were girls operated upon during the age range 8 years 11 months to 12 years 6 months, average 11 years 0 month.

In both series we included only patients on whom the procedure was performed a minimum of 3 years after the onset of the disease and a maximum of 3 years before the completion of growth. We excluded any patients who had had the Pease operation as well as lumbar sympathectomy and those subjected to other operations on the treated or the untreated contralateral bone during the follow-up period.

B. *Methods.*

The *Pease operation* was carried out according to the technique described by *Pease* (1952). After making drill holes 1 or 2 ivory screws were inserted into the metaphysis distally on the femur or proximally on the tibia. The screws were applied transversely through the metaphysis in its entire width and as close as possible to the epiphysial cartilage plate without injuring it.

In the *lumbar sympathectomy* 2 or 3 ganglia were removed. This was confirmed by histological study.

On all patients spot-orthoradiographic measurement was performed prior to the procedure. Patients having the Pease procedure were followed for a minimum of 3 years and patients having lumbar sympathectomy for a minimum of 2 years by regular spot radiographic measurements.

Calculation of Results.

On the basis of the spot-orthoradiographic measurements growth curves were plotted in all cases for the femora and tibiae as a function of age. By means of these curves the difference between the femora and tibiae in each individual patient was measured at the time of the operation and postoperatively at 12-month intervals.

All operations were done on patients having progressive anisomelia. Thus, a stimulation of growth may have occurred, even though decreasing anisomelia could not be demonstrated after the operation.

Apparently there are marked individual variations in the spontaneous course of anisomelia following poliomyelitis (*Green* 1949, *Ring* 1958, *Ratliff* 1959), and there seem to have been no previous studies on the course of anisomelia in congenital diseases. It was impossible, therefore, to carry out accurate calculations of how far the anisomelia would have progressed, if the operations had not been done.

It appears to be generally agreed, however, that the anisomelia following poliomyelitis does not start until a year or two after the onset of the disease and then rapidly progresses during the subsequent 3–4 years. From 4–5 years after the onset and until the completion of growth, however, the anisomelia seldom seems to progress as rapidly as previously.

In order to assess the effect of the operations in relation to the spontaneous course, the results obtained by both methods were calculated in two ways:

A: As the actual equalization obtained within the individual postoperative years by deducting the measured anisomelia 12, 24 and (after the Pease intervention) also 36 months after the operation from the anisomelia found one year previously. Thus, negative results indicate continued progression of the anisomelia.

B: The expected anisomelia at the times of follow-up was calculated on the basis of the anisomelia at the time of operation and the duration of the disease, the progression rate being presumed to be equal during the postoperative and preoperative period. From this computed anisomelia we deducted the measured anisomelia. The results are given as progression within the 1st, 2nd, or 3rd postoperative year. Positive statements thus mean that the progression rate has been less than that presumed in relation to the duration of the disease.

The methods of calculation are illustrated graphically in Fig. 1. Values a_1, a_2, a_3 indicate the actual equalization obtained during the 1st, 2nd, and 3rd postoperative year. b_1, b_2, and b_3 indicate the difference between the calculated and measured progression of anisomelia within the 1st, 2nd, and 3rd postoperative year.

C. *Results.*

1. *Pease Procedure.*

The results are given in Tables 1 and 2. It will be seen that during the first postoperative year the anisomelia progressed by an average of 0.77 mm., in the second year by 2.11 mm., and in the third year by 2.02 mm.

This means that—assuming that the anisomelia would have increased in proportion to the duration of the disease (Fig. 3)—there had been an average stimulation during the first year of 1.57 mm., in the second year 0.61 mm., and in the third year 0.57 mm.

Thus, after the operation the shortening showed an average increase, but not as rapid as in the preoperative period, especially not during the first preoperative year. The spontaneous course being unknown, it is impossible to decide whether this course represents real stimulation or a spontaneous course.

The difference between the progression of anisomelia during the first and the subsequent two postoperative years may be indicated by the formula (cf. Fig. 1):

$$2a_1 - (a_2 + a_3)$$

This value was calculated for all bones in the Pease series.

TABLES 1, 2, 4 and 5

Distribution of the results of growth-stimulating operations.

(For explanation see text and Fig. 1.)

	Equalization obtained, mm.		—																	+	Total No. of obs.	Equalization	
			9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10		mean value ($\bar{x}$) mm.	standard deviation (s_x) mm.
Table 1	Real	a_1				2	2	1	7	4	7	8	3	5	5								44	— 0.77	± 2.5
Pease	equalization	a_2			1	3	5	4	5	7	8	7	2	1				1					44	— 2.11	± 2.5
operation	(No. of obs.)	a_3	1			3	1	6	6	5	10	9	1	2									44	— 2.02	± 2.3
Table 2	Computed	b_1						1	2	2	3	8	3	10	5	6	2	1		1			44	+ 1.57	± 2.5
Pease	equalization	b_2						2		7	4	3	14	10	2	1					1		44	+ 0.61	± 2.2
operation	(No. of obs.)	b_3					1		2	2	4	14	8	7	3	2	1						44	+ 0.57	± 1.9
Table 4	Real																								
Lumbar	equalization	a_1			1	2		2	2	1	2	4	1			1							16	— 2.00	± 2.9
sympath-	(No. of obs.)	a_2				2		1	1	1	5	5				1							16	— 1.38	± 2.5
ectomy	Computed																								
Table 5	equalization																								
Lumbar	(No. of obs.)	b_1						1	1		3	1	2	3	3			2					16	+ 1.19	± 2.8
sympath-		b_2						1		1	2	2		4	3	2						1	16	+ 1.69	± 3.2
ectomy																									

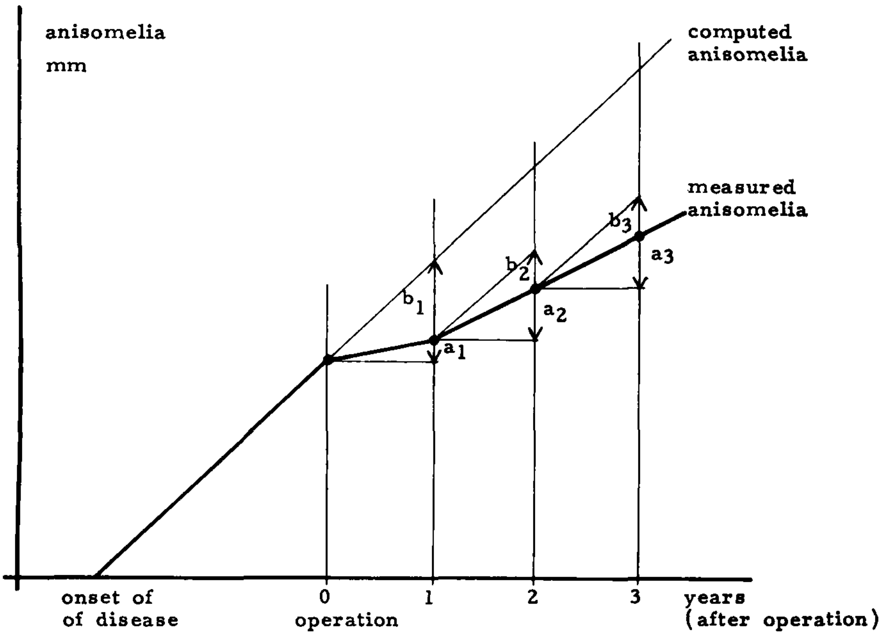

Fig. 1.
Graphic representation of the methods used for calculating the results a_1, a_2, a_3 and b_1, b_2, b_3.

TABLE 3

Difference between progression of anisomelia during the 1st and during the 2nd + 3rd years after the Pease operation.
(For explanation see text and Fig. 1.)

$2\,a_1 - (a_2 + a_3)$ mm.	— 15	12	9	6	3	0	+ 3	6	9	Total	mean value ($\bar{x}$) mm.	standard deviation (s_x) mm.
No. of obs.	1	2	3	8	10	9	9	1	1	44	— 2.32	± 5.0

The distribution of the results may be read from Table 3.

The standard deviation (s_x) for the results is ± 5.0 mm. and the mean value –2.32 mm. The mean value differs significantly from 0 ($p<1$ per cent).

In other words, the average annual progression of the anisomelia has been 2.32 mm. greater during the second and third than during the first postoperative year.

It has been demonstrated, then, that the progression rate was significantly slower during the first postoperative than the subsequent 2 postoperative years. This course must represent a growth-stimulating effect of the operations during the first postoperative year since according to the experience gained so far regarding the spontaneous course of anisomelia following poliomyelitis it is hardly conceivable that a material of the present size would show a temporary average spontaneous reduction in the progression rate.

Of course, a spontaneous decrease in the progression rate might be imagined during the first 2 or 3 years after the onset of the disease and during the last 2 or 3 years before the completion of growth, but none of the operations was carried out during these periods. Nor is a temporary spontaneous reduction in the progression rate in the middle of the growing period likely in the 4 cases of congenital diseases.

On the other hand, the course during the 2nd and 3rd postoperative years may represent a spontaneous course, the progression of the anisomelia having been almost as rapid as during the preoperative period.

Investigation of the inaccuracy of the measurement in spot orthoradiographic measurement revealed a standard deviation of ± 2.5 mm. on the results in measuring the difference between 2 of the bones in the lower limbs (*Nordentoft*, in press). Since the results in the present study are based upon the measurement of the difference between 2 different times, the error might result in a standard deviation of

$$\pm\ 2.5^2 + 2.5^2 = \pm\ 3.54 \text{ mm.}$$

Presuming a normal distribution of the results, maximum variations from the mean value of twice the standard deviation might be expected, *i.e.* about 7 mm. merely as a result of the inaccuracy of measurement. In calculating the results b_2 and b_3, the inaccuracy of the measurement of the difference at the time of operation must also influence the results which will consequently differ by more than 7 mm. from the mean value—merely because of the inaccuracy of measurement.

When this inaccuracy of the measurement is taken into consideration in assessing the individual results, none of the latter can be taken to represent a growth stimulation greater or lesser than the average.

2. *Lumbar Sympathectomy.*

The results were calculated in the same way as after the Pease procedure, but it was impossible to follow the effect in a sufficient number of patients for more than 2 postoperative years.

Tables 4 and 5 give the results. They show that the anisomelia increased by an average of 2.00 mm. during the first and by 1.38 mm. during the second postoperative year. The increment in anisomelia was during the first year an average of 1.19 mm. and during the second year an average of 1.69 mm. less than would have corresponded to a progression proportional to the duration of the disease. When related to the standard deviation on the results and the inaccuracy of the measurement, the average and individual results do not differ significantly from 0.

The course may easily represent a spontaneous course, and thus the results cannot be taken to stand for a growth-stimulating effect.

However, it can also not be excluded on the basis of the results of this study that lumbar sympathectomy may reduce the progression rate of anisomelia following poliomyelitis. However, the present results make it seem unlikely that this intervention might in some cases entail a real reduction of existing anisomelia of several centimetres—as reported by a few authors.

A further analysis of the influence of lumbar sympathectomy upon the longitudinal growth of the lower limbs would seem to be obtainable only by a statistical evaluation of a larger series and "pair au pair" comparison with a definitely comparable control series.

3. Conclusion

It must be justified, therefore, to conclude that insertion of ivory screws into the metaphyses at the knee entailed a significant growth stimulation of an average magnitude of 2 mm. during the first post-operative year. No case showed a growth stimulation significantly exceeding the average effect. The effect has disappeared, completely or very nearly, in 1 year.

Therefore, the effect obtained is so slight that it does not justify a continued clinical application of this procedure.

From the present results it must be permitted to conclude that the growth stimulating effect of lumbar sympathectomy is so uncertain that it is not justified to use the method in the treatment of anisomelia. This is not saying, of course, that the procedure cannot be indicated for the treatment of vascular disturbances in poliomyelitis patients.

4. Summary

In a study of the effect of inserting ivory screws into the metaphyses of 44 long bones in the lower limbs of 26 patients the authors found a significant average growth stimulation of the magnitude 2 mm. during the first postoperative year. On the other hand, no growth stimulating effect could be demonstrated during the subsequent 2 years, and the growth stimulation was in no case significantly greater than the average effect.

The effect of lumbar sympathectomy was followed on 16 long bones in 11 patients. No definite stimulation of growth was found, although it cannot be ruled out that the procedures may have inhibited the development of further anisomelia.

It is concluded that the effect of implanting ivory screws into the long bones of the lower limbs as well as the effect of lumbar sympathectomy upon longitudinal growth is so slight and uncertain that these procedures are not justified in the treatment of anisomelia.

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