MEASUREMENT OF TESTICULAR VOLUME

ITS APPLICATION TO ASSESSMENT OF MATURATION, AND ITS USE IN DIAGNOSIS OF HYPOGONADISM

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(RECEIVED FOR PUBLICATION JUNE 12, 1962)

During a cross-sectional survey of growth and maturation of mentally defective adolescents, the need was felt for a method of assessing the degree of maturation in the male based on an objective measurement rather than subjective indices such as breaking of the voice or pubic hair development.

It was also felt that such a method might have value in screening patients for abnormally small testes in a search for cases of Klinefelter's syndrome and thus be analogous to the use made of coarctation of the aorta in Turner's syndrome (Polani, Hunter and Lennox, 1954).

There is very little information in the literature on the size of the normal testis, particularly in the living patient. Spangaro (1902) gave the measurements of the testes of 10 corpses as length 40 to 50 mm., breadth 20 to 27 mm. and thickness 25 to 35 mm. Roessle and Roulet (1932) quote Schultze's (1913) measurements of adult testes to be 40 to 45 mm. length, 20 to 25 mm. breadth and 18 to 24 mm. thickness. The same authors quote Mita (1914) as 38, 24, 23 mm. respectively. The majority of the workers who have examined living subjects have used models to indicate size, e.g. Engberg (1948) divided the adult range into six sizes, ranging from a pea to normal adult size. Nordlander adopted the same principle (1948). Hurxthal (1948) had eight models made for comparison, with volumes ranging from 2 ml. to 18 ml. and stated that the latter was normal from the age of 18 years.

From Hansen (1949) measured the length and breadth of the testis and calculated the volume on the assumption that the testis was the shape of an ellipsoid of revolution. He found the mean testicular volume of the normal adult to be 23·5 ml., S.D. 7 ml. Lambert (1951) compared the size of normal adult testes with subjects who had suffered from mumps. He showed that the formula for the rotation of an ellipsoid gave results that were inaccurate, and devised an empirical formula as follows:

Testicular volume $= 0{\cdot}71 \times \text{length} \times \text{breadth} \times \text{depth}$.

More recently From Hansen and With (1952) reported a series of testicular measurements of boys and men, the measurement here being the sum of the largest widths of the two testes. These authors give the mean total volume (corrected according to Lambert) as 34·7 ml. The figures reported by these authors on boys are in agreement with those of Reich (1924) and also those of Quaade (1955), who showed a relatively constant testicular volume until 12 years of age, followed by a rapid increase until the adult form is achieved at about 17 years.

Patient Material

All the subjects of this investigation were permanently resident in a large mental deficiency hospital, under constant medical supervision; all were in good health and free from spastic deformities. The selection was a random one; any subjects suspected to be suffering from an endocrine anomaly were not discarded as it was felt that if the method was to prove of value, these patients should be obvious in the analysis of the results. In this series, no cases of hydrocele, varicocele, hernia or tumorous tissue were encountered. The total number investigated was 265 of whom 50 had mongolism. For the purposes of this communication only those not suffering from mongolism have been reported. A comparison between those with and those without mongolism is being reported elsewhere (Rundle and Sylvester, 1962).

Methods

The length and breadth of the left testis was measured using a Harpenden Skinfold Caliper as described by Edwards, Hammond, Healy, Tanner and Whitehouse (1955). It was felt necessary to modify the caliper by

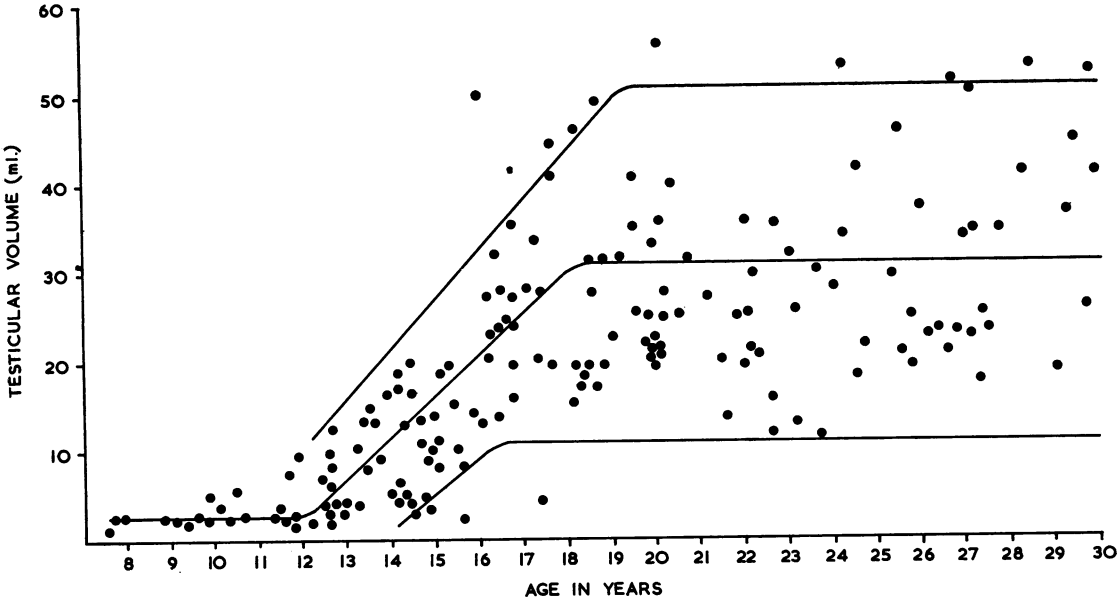

FIG. 1.—The effect of chronological age on testicular volume.

replacing the usual 10 g./mm.^{2} spring with one of 2 g./mm.^{2} at full extension, in order to reduce errors created by compression of the testis. The skin duplicature was found to be relatively constant (2 to 3 mm.), but unlike the methods of many of the previous authors, this was not subtracted from the measurements as the scrotum was stretched during the actual measuring, and subtraction of the scrotal duplicature would introduce a variable error.

Manipulations necessary to exclude the epididymis introduced greater errors than the assumption that the breadth and thickness were the same, and for this reason, only the length and breadth were measured. The volume of the left testis in ml. was obtained using the empirical formula of Lambert, i.e.

Volume (in ml.) = $0 \cdot 71 \times$ length $\times$ breadth^2.

The genital development stages I to V were those described by Reynolds and Wines (1951) and were as follows:

Stage I: infantile.
Stage II: enlargement of scrotum, first reddening and texture change.
Stage III: first 'sculpturing' and enlargement of penis.
Stage IV: pronounced 'sculpturing' and darkening.
Stage V: essentially adult, reddish brown colour, loose penile skin, loss of sharp 'sculpturing'.

Buccal smears of all subjects of this investigation were examined for the sex-chromatin body (Klinger and Ludwig, 1957). In three chromatin-negative patients whose testicular volumes suggested Klinefelter's syndrome, subsequent karyotype analysis was shown to be normal.

Radiographs of the left wrist were compared with the normal standards of Greulich and Pyle (1959). Each radiograph was read blind on two occasions; a third reading was necessary in five cases in which the disagreement between readings was greater than six months.

Results

Fig. 1 shows the testicular volume of all subjects plotted against chronological age; the mean and 2 S.D. above and below the mean are also indicated. It can be seen that from the ages 7 to 12 years there is very little increase in testicular volume, and that a volume of 5 ml. or less can be considered as infantile, i.e. completely undeveloped. After 12 years there is a sudden increase in size until the 17th year is reached, 12 to 17 years corresponding to the pubertal spurt. After 17 years the adult form is achieved. The mean adult volume of the left testis is 31·1 ml.

Fig. 2 shows the testicular volume of 68 cases aged 7 years to adult plotted against bone age. The age scale finished at 18 years, that being the upper limits of the standards of Greulich and Pyle (1959). A typical S-shaped growth curve was obtained.

The coefficients of correlation r between testicular volume and chronological age, and between testicular volume and bone age, were determined for these cases on the linear part of the curve, i.e. between 12 and 17 years (33 cases). These were found to be as follows:

Testicular volume: chronological age $= 0 \cdot 68$
Testicular volume: bone age $= 0 \cdot 60$

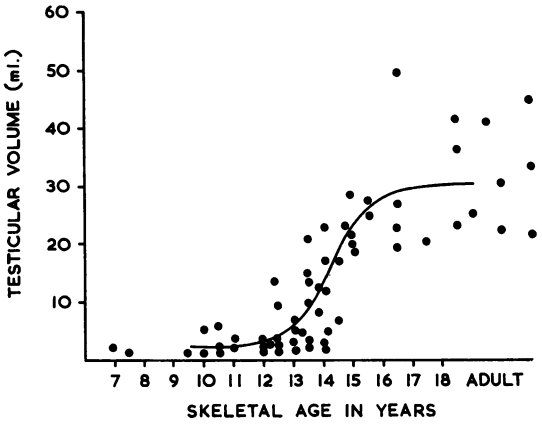

FIG. 2.—The effect of bone age on testicular volume.

Table 1 compares the results of the testicular volume of all patients (18 years of age was taken in this context to be adult, in order to be clear of the pubertal spurt) with the values reported in the literature, and also with those patients whose bone age was 18 years or more. In all cases the volume has been estimated by applying Lambert's formula to the original data.

TABLE 1

COMPARISON OF TESTICULAR VOLUMES REPORTED BY VARIOUS AUTHORS WITH (A) PATIENTS AGED 18 YEARS AND OVER IRRESPECTIVE OF BONE AGE, AND (B) PATIENTS WITH BONE AGE OF 18 AND OVER IRRESPECTIVE OF CHRONOLOGICAL AGES

Author	Mean (ml.)	Range
Spangaro (1902)	20·8	35·2–49·2
Schultze (1913)	25	15 –40
Mita (1914)	22	—
From Hansen (1949)	13·3	31·5–65
Lambert (1951)	19·2	41·6–64
From Hansen and With (1952)	16	34·7–76
Barr *et al.* (1960)	31·1	—
Present investigation* A	31·1	12·0–54·5
B	31·0	20·4–45·3

* Single testis only.
All results determined by application of Lambert's formula (1951).

TABLE 2

COMPARISON OF 20 AND 80 PERCENTILES OF TESTICULAR VOLUME AND AGE OF FOUR GENITAL DEVELOPMENT STAGES*

	Testicular Volume (ml.)		Age (years)	
	20%	80%	20%	80%
Stage I	2·0	10·1	9·8	13·6
Stage II	10·2	16·5	13·4	15·2
Stage III	17·2	28·1	15·0	17·3
Stages IV and V	21·0	38·0	16·6	19·7

* Stages IV and V are combined.

Table 2 compares the 20 and 80 percentiles of age and testicular volume for each of the genital development stages. Stages IV and V have been combined as the difference between these two stages is small and most open to observer error.

Discussion

Any method for the evaluation of the maturational status of an individual must satisfy several criteria. It must be applicable to persons of all ages from pre-adolescence, through the pubertal spurt to full maturity. It should be simple to estimate and as free from observer error as possible, and there should be a high degree of correlation with other observable landmarks.

The method described, although not ideal, satisfies all these criteria. Only the left testis was measured as this is generally the smaller of the two. Lambert showed, in adults, that of 56 cases the right testis was larger than the left in 30 cases and of equal size in a further 11 cases. In a group of 68 adults we found 36 with the left smaller than the right, which is in close agreement with the figures of Quaade (1955), and it was felt that the error introduced by the measurement of only one testis would not be significant.

The limits of the pubertal spurt of 12 to 17 years found in this investigation are in agreement with the findings on normal boys of Reich (1924), From Hansen and With (1952) and Quaade (1955) that there is little change in size of the testes before 12 years and after 16 years.

Other criteria for assessing the pubertal spurt, e.g. range of ages of first ejaculation (Ramsey, 1950), occurrence of voice breaking (Quaade, 1955; Scott, 1961) and appearance of pubic and axillary hair and moustache (Quaade, 1955) all reflect a similar pubertal spurt.

Within our sample, there was good correlation between genital development ratings and testicular volumes.

The coefficients of correlation between testicular volumes and chronological age and between testicular volumes and bone age, indicate that there is no advantage in choosing one method of assessment over the other.

It was concluded that measurement of the testis would give an accurate indication of the adolescent maturity state as well as an accurate assessment of the degree of hypogonadism in the adult when this exists. Three males in our series had testes below the limits of 2 S.D. for their age. Each patient was chromatin negative—as were all the cases in this series—and examination of the chromosomes in each

case showed no abnormality. Subsequently, it was found that two of these youths had mumps at the age of 11 and 12 years and the smallness of their testes was assumed to have resulted from mumps orchitis. The cause of the third youth's small testis is obscure, but this together with five cases of testicular volume above 2 S.D. of the normal are under investigation.

Recently, several types of sex-chromosome abnormalities have been reported in which hypogonadism is a feature. Barr, Shaver, Carr and Plunkett (1960) measured the testicular size in 10 patients with Klinefelter's syndrome (chromosome complement XXY) and found the mean to be $2{\cdot}4 \times 1{\cdot}7 \times 1{\cdot}3$ cm. (i.e. a volume of 3·84 ml.) compared with a normal mean $4{\cdot}5 \times 3{\cdot}9 \times 2{\cdot}5$ cm. (31·1 ml.). The same authors also describe three atypical cases of Klinefelter's syndrome in which double sex-chromatin was a feature, Barr, Shaver, Carr and Plunkett (1959). In two of these cases the testicular volume was below 5 ml. Ferguson-Smith, Johnstone and Handmaker (1960) described two males with a sex-chromosome complement of XXXY and reported the length of the testis in each case to be 1·8 cm. This corresponds to a volume of less than 5 ml.

The results of this series suggest that an adult with a volume of 12 ml. or less (i.e. below 2 S.D.) should be suspected as suffering from hypogonadism, and any below 5 ml. should be considered as infantile and should be investigated further. It is further suggested that estimation of testicular volume may be a useful means of screening adult patients for hypogonadism, particularly when more specialized techniques such as steroid estimations or testicular biopsy are not available.

Conclusions

It was found in a sample of young mental defective males that the measurement of testicular volume is a simple but reliable and objective method for assessing the degree of maturation of an individual.

Using the method described it was found that a pubertal spurt of growth in testicular size occurred between the ages of 12 to 17 years, whether the age was assessed chronologically or skeletally; a mean adult size of 31·1 ml. (range 12 to 54·5 ml.) was achieved, and that the changes in the size of the testis reflected changes in other criteria of maturity.

Summary

A simple but reliable method for the estimation of the testicular volume and its application to assessing the degree of maturation is described. The use of this method for the diagnosis of hypogonadism is discussed. The method was applied to 215 mentally subnormal males aged 7 to 30 years, and it was found that a pubertal spurt in testicular size occurred between 12 and 17 years. A mean adult size of 31·1 ml. (range 12 to 54·5 ml.) was achieved.

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