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A METHOD OF ESTIMATING ADDUCTION AND ABDUCTION OF THE LEG IN HIP DISEASE.

BY ROBERT W. LOVETT, M.D., OF BOSTON.

THE presence of adduction or abduction of the diseased limb in hip-joint disease is one of the commonest and most troublesome of the complications of that affection, and the estimation of the amount of malposition present is a matter of much importance, both during the acute stage of the disease, as an index of the progress of the case, and after the arrest of the disease, where a return of the adduction and a consequent increase of the limp and discomfort is always to be feared. It has been customary to calculate in degrees the amount of malposition present either by a rough guess or by the use of the goniometer, an instrument not often at hand, and always clumsy and inaccurate.

The following article is a purely mathematical deduction from certain evident anatomical relations, by which it has been possible to construct a simple and practical table for working purposes in the estimation of the amount of this malposition. The method is, in a word, the estimation of the angle of malposition of the diseased limb by the varying differences between what we may call the real and the apparent shortening of that leg. Real shortening is the term to be applied to the difference in the length of the legs, measuring from the anterior superior spines of the ilium to the external or internal malleoli — the common measurement.[1] Practical shortening will be

[1] Stimson. Treatise on Fractures, 1883, p. 511.

used to denote the difference in the length of the legs when the measurement is taken from the umbilicus to the malleoli while the patient lies straight, with the legs parallel,[2] and represents, of course, the amount of shortening which will be present when the patient

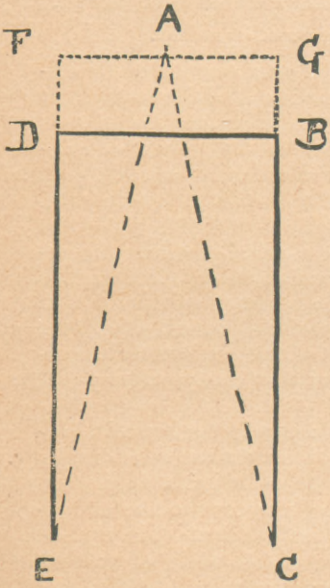

Fig. I.

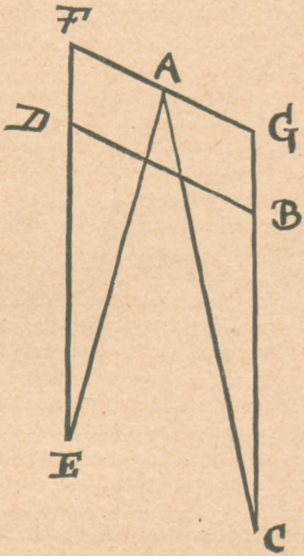

Fig. II.

stands or walks, for the legs must then necessarily be made parallel, even if the pelvis has to be tilted to make them so. Practically, real shortening may be the same as apparent shortening; it may be greater, or it may be less, and I had noted that it varied in

[2] Gibney. Diseases of the Hip, 1884, p. 28.

proportion to the amount of deformity present, but I was unable to express this variation as degrees of malposition, and I am wholly indebted to Mr. G. L. Kingsley, of the Harvard Medical School, for the mathematical assistance which has made it possible to work out and prove the practical usefulness of the method.

When the patient lies straight and neither leg is adducted, it hardly needs mathematical proof to show that the real shortening is equal to the practical shortening (Figure I). Here E and C represent the malleoli, D and B the anterior superior spines, and A the umbilicus. A glance shows that the difference in the length of A E and A C will be the same as the difference between D E and B C (both differences in this case being zero) so long as the pelvis is square.

The mathematical proof of this is: Since F E and G C are parallel in this case, and F D = G B (F G being parallel to D B) and F A = A G, and A F E and A G C are right angles,

$$\text{sec. } GAC = \frac{AC}{AG} \qquad \text{sec. } AFE = \frac{AE}{AF}$$

$$\text{tan. } GAC = \frac{GC}{AG} \qquad \text{tan. } AFE = \frac{FE}{AF}$$

$$\left.\begin{array}{l} GC = AC.\text{ sine } GAC \\ FE = AE.\text{ sine } AFE \end{array}\right\} GC - FE = AC.\text{ sine } GAC - AE.\text{ sine } AFE$$

that is, practically differing only by the difference in the sines of the angles A C G, and A E D and since the angles in the class of cases under observation are very nearly equal, the error is not appreciable, for the maximum error would be 0.03 inches.

If, however, one leg is held adducted or abducted by muscular spasm or anchylosis, the pelvis must necessarily be tilted when the legs are made parallel, as in standing or walking, and the state of affairs is represented by Figure II. It is obvious that now the distances from B to C and D to E are the same as before, whereas A C has grown very much longer than A E; the practical shortening of the leg D E has, in fact, become greater than the real shortening because the leg is adducted. It is, moreover, evident that this must vary in proportion to the amount of adduction and consequent pelvic tilting, for, by the latter, one leg must be carried up and the other down, while the umbilicus remains stationary, so that as the pelvis tilts more and more, A E grows shorter and A C longer.

It is not quite correct practically, to assume that D E = B C in figure II, for Dr. Halstead[3] has pointed out that a leg in adduction has not the same real length when measured from the anterior superior spines to the malleoli, as the same leg in the normal position or abducted, but the difference is to be expressed in milimetres and practically does not enter into this method as an error, it is too small to be of any account.

Of course it is not assumed that the anterior superior spines are the same distance apart as the acetabula, but the practical centre of motion of the leg in adduction and abduction is not at the acetabulum but outside of it, as can easily be seen in the skeleton. This is of course on account of the angle that the shaft makes with the neck of the femur. So far as could be determined, it was well enough represented by saying that it was in the lines of the anterior superior spines. The only inaccuracy likely to be caused by this, would be possibly in the adult female pelvis where the flare was extreme and even here the error would be small and of little account.

The problem was to make this variation express in degrees the angular deformity of the adducted or abducted leg which caused this pelvic tilting; and for working purposes Figure III had to be constructed, where the original position of the pelvis is represented by dotted lines, and the tilted pelvis by heavy lines. Of course, a working triangle must be found, and such a triangle is L F B, for F L B is the angle to be measured, for it is the angle of pelvic tilting which is equal to the lateral variation of the diseased leg from the normal.

For, letting D B = pelvis in new position, and G F = pelvis when square, D E = position of leg, and D M = position leg should have if still at right angles to pelvis, and M D E = adduction angle.

A L G = 90°, L D M 90°, E D L = D L A (since A N and D E are parallel and cut by the line D L).

$$\left.\begin{array}{l} 90° = ALG = ALD + DLG \\ 90° = LDM = LDE + MDE \end{array}\right\} \text{Cut } ALD = LDE$$

$\therefore$ D L G = M D E = abduction or adduction angle.

[3] New York Medical Journal, 1884, page 317.

Now of this right-angled triangle, L F B, two sides are known: L B, which is equal to half the distance between the anterior superior spines of the ilium; and B F, which is equal to half the difference between the real and apparent shortening. The pelvis tilts, and one foot is carried up and the other down, and the practical shortening is the sum of these excursions.

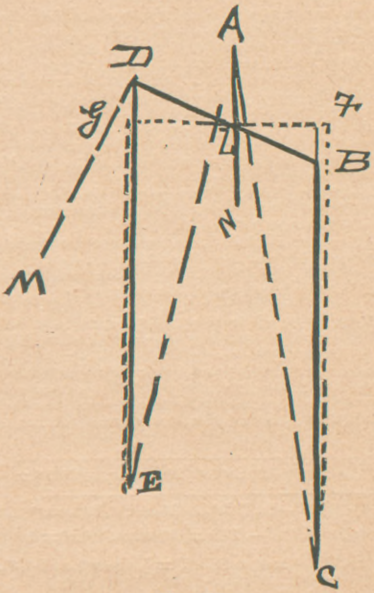

Fig. III.

First, when the legs are of equal length.

In this case the problem becomes — to prove that twice the sine of the angle of ad- or abduction is equal (or very nearly so) to the difference between the distances from the umbilicus to the internal malleoli.

In Figure 4 if we suppose D and E to be the positions of the anterior superior spines of the ilium, A the umbilicus, B and C the internal malleoli, then the angle D R D′ (which equals B R′ B′) will be equal to the angle of duction (as proven in Figure 3), D′ and E′ are the positions which the anterior superior spines would have if there was no ad- or abduction.

The Figure D′ E′ C′ B′ will be a rectangle. Suppose a circle with a radius B R′ to be described on R′ as a centre ; then the points B′, C″, C and C′ will lie in the circumference of this circle, since they are points all equally distant from R′.

It is to be proved that

$$AC - AB = BC'' \left(\frac{AC - AB}{2} = \frac{BC''}{2} = BT\right)$$

or if there is an error in the equality, to show that the same is so small as to be inappreciable in the estimation of the ultimate result.

Suppose the triangle A R′ C to be rotated on A R′ as an axis. Then C will fall at C″ and the arc B B′ will equal the arc B′ C″. On A as a centre with a radius equal to A B described an arc which shall cut A C″ at S and therefore make A B equal to A S. Now C″ S will equal the difference between A B and A C″.

From observation in a large number of typical cases the angle of ab- or adduction is found not to exceed 30°. It has also been ascertained from observations that the ratio of A R′ to B′ R′ lies within the limits of six to one and eight to one.

It is evident that the smaller the angle of duction and the larger the ratio of A R′ to B′ R′ the less will be the error arising from the assumption that C″ B equals C″ S.

Therefore if it is computed, in the case where the angle of duction is greatest (equal to 30°) and the ratio is smallest (equal to 6 : 1), the value of C″ B and C″ S, the quantity by which these two lines differ in length, should be the largest possible error entering into the computation.

Suppose B′ R′ to be equal to one, A R′ equal to 6 (the smallest ratio), B R′ B′ equal to 30° (the largest angle) ; then A R′ B′ equals 90°, B R′ B′ = B′ R′ C″, A R′ C″ = 120° and A R′ B = 60°.

Since by trigonometry in oblique angle triangle when two sides and the included angle are given the third side is equal to the square root of the sums of the squares on the two given sides diminished by twice the product of these sides into the cosine of the included angle. The formula is

$$C''A = \sqrt{\overline{C''R'}^2 + \overline{R'A}^2 - 2 \,.\, C''R' \,.\, R'A \,.\, \cos.\ AR'C''} = \sqrt{43} = 6.557$$

$$BA = \sqrt{\overline{BR'}^2 + \overline{AR'}^2 - 2 \,.\, BR' \,.\, AR' \cos.\ AR'B} = \sqrt{37} = 5.567$$

$$\text{Therefore } C''A - BA = .01 \text{ when } B'R' = 1$$

$$\text{But } BT\left(=\frac{BC''}{2}\right) = \text{sine } BR'T = \tfrac{1}{2}, \text{ therefore } BC'' = 1$$

Since the greatest pelvic measurement which would have to be dealt with would not exceed 14 inches, and therefore one-half of it not more than 7, therefore the error arising from considering $BT = \frac{C''S}{2}$ (= sine duction angle) could not exceed .035 of an inch in any case and usually would not exceed .02 of an inch which is a quantity far too small to have any influence in the computing of the table where single degrees only are considered and measurements considered only accurate to the nearest one-eighth inch.

The same relation is easily proved by a similar figure, to exist where the legs are of unequal length. It hardly seems worthwhile to add it here.

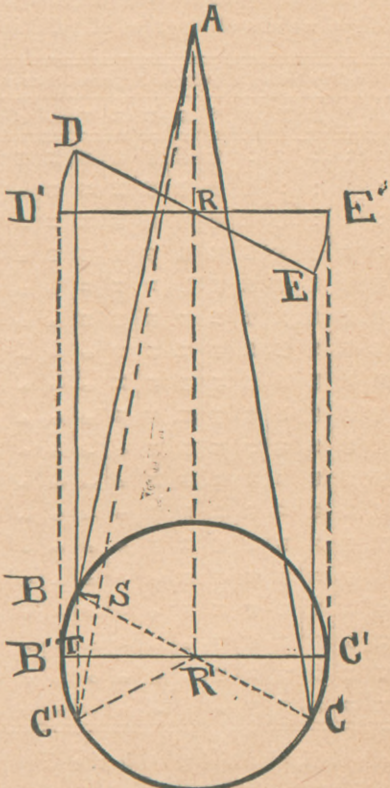

Fig. IV.

Having, then, a right-angled triangle with two known sides, the angle F L B was calculated by the formula, sine $FLB = \frac{FB}{LB}$, and from the results obtained, the following table was constructed for all breadths of pelvis and all degrees of variation.

Difference in inches between Real and Apparent Shortening.	Distance between Anterior Superior Spines in inches.																	
	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	11	12	13
¼	5°	4°	4°	3°	3°	2°	2°	2°	2°	2°	2°	2°	2°	1°	1°	1°	1°	1°
½	10	8	7	6	5	5	4	4	4	4	4	4	4	3	3	3	3	2
¾	14	12	11	10	8	8	7	7	6	6	5	5	5	4	4	4	3	3
1	19	17	14	13	11	10	9	9	8	7	7	7	6	6	6	5	5	4
1¼	25	21	18	16	14	13	12	11	10	9	9	8	8	7	7	7	6	6
1½	30	25	22	19	17	15	14	13	12	12	11	10	10	9	9	8	7	7
1¾	36	30	26	23	20	18	17	15	14	13	13	12	11	10	10	9	8	8
2	42	35	30	26	23	21	19	18	16	15	14	14	13	12	12	10	10	9
2¼	..	40	34	30	26	24	21	20	19	17	16	15	14	14	13	12	11	10
2½	..	..	39	34	29	27	24	22	21	19	18	17	16	15	14	13	12	11
2¾	..	..	..	38	32	29	27	25	23	21	20	19	18	17	16	14	13	12
3	..	..	..	42	35	32	29	27	25	23	22	21	19	18	18	16	14	13
3¼	..	..	..	..	39	36	32	30	27	26	25	22	21	20	19	17	15	14
3½	..	..	..	..	..	40	35	33	30	28	26	24	23	22	21	19	17	16
3¾	..	..	..	..	..	..	38	35	32	30	28	26	25	23	22	20	18	17
4	..	..	..	..	..	..	42	38	35	32	30	28	26	25	23	21	19	18

The patient lies straight, with the legs parallel. Real shortening is measured with the ordinary tape-measure, and then apparent shortening is obtained in the same way. The difference between the two shortenings is seen at a glance. The only additional measurement necessary is the distance between the anterior superior spines, which is taken with the tape. Turning now to the table, if the line which represents the amount of difference in inches between the real and apparent shortening is followed until it intersects the line which represents the pelvic breadth, the angle of deformity will be found in degrees where they meet. *If the practical shortening is greater than the real shortening, the diseased leg is adducted; if less than the real shortening, it is abducted.* Take an example: Length (from anterior superior spine) of right leg, 23; left leg, 22½; length (from umbilicus) of right leg, 25; left leg, 23; difference between real and practical shortening, 1½ inches; pelvic measurement, 7 inches. If we follow the line for 1½ inches until it intersects the line for pelvic breadth of 7 inches, and we find 12° to be the angular deformity, as the practical shortening is greater than the real, it is 12° of adduction of the left leg.

Certain objections which are likely to be made may be formulated and dismissed:

(1) That inequality in the length of the legs, congenital or acquired, would vitiate the result. Any such inequality would appear in both the real and the apparent shortening, and not affect the difference between the two.

(2) That the co-existence of flexion of the thigh upon the pelvis would render the method inaccurate. A moment's consideration will show that the flexion of the thigh upon the pelvis makes no difference, for the measurements here considered depend wholly upon certain relations in a horizontal plane between the iliac spines and the malleoli, and that this relation remains the same, unaffected by the movement of the

anterior superior spines in another plane so long as they move together.

(3) It may be urged that individual measurers vary. But both measurements are taken each time by the same man, skilled or not; and in the measurement for practical shortening he will use the same method, and make the same error that he made in measuring for real shortening, and it will not appear in the difference between the two. It is not unreasonable to expect a moderate amount of care to be taken in any such measurements.

Next and last, as to the practical accuracy of the method: It has been used by the writer and others for some weeks in a large number of cases of hip-joint disease in the Surgical Out-patient Department of the Children's Hospital, and afterward a very careful measurement has been taken independently with a fairly accurate goniometer, and the results have always coincided within one or two degrees.