THE ACCURACY OF MEASURING LEG-LENGTH DIFFERENCES

AN "OBSERVER ERROR" EXPERIMENT

BY

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The assessment of the differences in leg lengths is of importance in many aspects of medicine, and is a technique taught to all medical students. Because of appreciable differences between the recorded measurements of different observers it was decided to investigate the accuracy of this technique. The proportion of patients for whom all observers agree is a useful guide to the "observer error," but this criterion is somewhat limited —even if sufficiently reliable results for clinical purposes are being obtained—as "observer error" tends to increase with the accuracy of the measuring (e.g., the proportion of disagreements will be greater when measurement is to the nearest millimetre than when it is to the nearest inch). A statistical method is described for estimating the "observer error" in a more satisfactory manner.

Material and Method

The investigation was carried out at the Royal Air Force Medical Rehabilitation Unit, Collaton Cross. Of the 200 patients at the unit at the time, 50 were selected at random. The cases included in the investigation were: knee injuries (23), upper limb injuries (12), spinal injuries (8), leg injuries (5), effort syndrome (1), pes planus (1).

This group gives a reasonable selection of the conditions met at the unit, and might be expected to provide for the appearance of idiopathic and post-traumatic leg-length differences.

Leg lengths were measured by four doctors without reference to each other's results. They used the same metal-ended tape-measure. The patients were dressed in singlets and shorts, and were lying on an examination couch. Care was taken to ensure that the patient's heels were resting on the couch and that the knees were not flexed. The measurements were made from the anterior superior iliac spine to the tip of the medial malleolus. The tape-measure lay evenly along the inner border of the patella. Although the method is a standard one, there is no doubt that the conditions of the investigation led to a higher degree of accuracy than might be found in routine clinical practice. Differences in leg lengths were recorded to the nearest ¼ in. (6 mm.), the lower reading being taken in the case of intermediate values.

Results

Accepting ¼ in. (6 mm.) as the criterion for the diagnosis of "short leg," there was complete agreement in 20 (40%) of the 50 cases. When the criterion is changed from ¼ in. to ½ in. (12.5 mm.), the proportion of cases showing disagreement drops from 60% to 14%. In the cases that showed disagreement there was considerable variation in the number of doctors recording a short leg. When ¼ in. was accepted as the criterion, in many cases three or four doctors recorded "short leg," but their measurements differed from each other by ¼ in. or more. The results are summarized in Table I.

This method of describing the "observer error" is not entirely satisfactory, though it may be used as a general guide. In the first place, the estimate of error will increase if more accurate measuring is attempted. Secondly, it makes no distinction between systematic differences between observers and the variation which might result from repeated measurements by one observer on a single patient.

TABLE I

	Complete Agreement between All Observers		Disagreement between One or More Observers				Observer Error (Percentage Disagreement)
	Leg Lengths Equal	Leg Lengths Unequal	No. of Observers Finding Short Leg: 1	2	3	4	
No. of cases: ¼ in. (6 mm.) criterion	17	3	11	8	7	4	60%
½ in. (12·5 mm.) criterion	40	3	4	3			14%

A Statistical Method of Measuring "Observer Error"

For the purpose of analysis, the difference in leg length to the nearest ¼ in., given by the length of the left leg minus the length of the right, is taken as the basic measurement. Thus short right legs yield positive differences and short left legs negative ones.

If the average of all four observers for each of the patients is taken, there is a good deal of variation between patients, as expected. Alternatively, by averaging over all patients for each observer mean values are obtained (Table II).

TABLE II.—*Mean Values for Recording Leg-length Differences*

Observer	Mean Values (in inches)	Mean Values (in mm.)
1	$+0{\cdot}065\pm0{\cdot}017$	$+1{\cdot}65\pm0{\cdot}43$
2	$+0{\cdot}010\pm0{\cdot}017$	$+0{\cdot}25\pm0{\cdot}43$
3	$+0{\cdot}045\pm0{\cdot}017$	$+1{\cdot}14\pm0{\cdot}43$
4	$+0{\cdot}005\pm0{\cdot}017$	$+0{\cdot}13\pm0{\cdot}43$
General mean	$+0{\cdot}036\pm0{\cdot}009$	$+0{\cdot}91\pm0{\cdot}23$

Note.—The quantities following the ± signs are the standard errors of the means.

The standard errors have been derived from the analysis of variance given in Table III.

TABLE III.—*Analysis of Variance*

Source of Variation	Degrees of Freedom	Mean Square	Components of Variance
Between patients	49	0·1870	$v + 4v_P$
" observers	3	0·0470+	$v + 50v_O$
Residual	147	0·0155	v
Total	199		

$F^{+}_{3,147} = 3{\cdot}0.\ P < 5\%.$

Table III may be used in another way. Each measurement is assumed to consist of the sum of four quantities, which can be calculated from the third and fourth columns: (*a*) an overall average value; (*b*) a term representing the true leg-length difference of a particular patient (variance $v_P = 0.0429$); (c) a term representing the systematic bias of the observer in measuring the difference (variance $v_O = 0.0006$); (*d*) a residual experimental error (variance $v = 0.0155$).

Discussion

Clinical observations may be very unreliable. Schilling *et al.* (1955) found observer errors ranging from 4 to 30% in the diagnosis of certain respiratory conditions. In measuring the blood pressure they found that two observers disagreed in 43% of patients by 10 mm. of mercury or more in reading the systolic blood pressure, and in 22% in reading the diastolic blood pressure. In measuring the chest expansion, a technique more comparable with the measuring of leg lengths, they found that two observers disagreed by ½ in. or more in 42% of cases.

The present investigation into the measurement of leg lengths also finds difference between four observers making estimates on 50 patients. Analysis of variance shows that the difference between observer means is significant at the 5% level (Table III). This is rather surprising, as observed differences in leg lengths might be expected to be free from any systematic bias affecting a single measurement. The bias could depend on the order of the two measurements or on the handedness of the observers; but Observer 3 was left-handed and measured the left leg first, whereas the other three observers were right-handed and measured the right leg first.

The departures from the general mean are small, though significant, and are judged unimportant. The general mean (+0.036 in.—0.91 mm.), having a standard deviation of only ±0.009 in. (±0.23 mm.), is significantly greater than zero, but again is small. It is not possible from the data to say to what extent it is due to a real average difference in the patient's leg lengths or to a persistent bias in the observers.

The systematic differences between observers, though significant, are small, the main source of variation being an experimental error which would arise even with repeated determinations by one observer. What is much more important from the clinical standpoint is that the variations between observers are negligible compared with the residual variation, since the latter measures the variation to be expected if a single observer continued to make independent measurements on the same patient. This experimental error has a standard deviation of about ⅛ in. (3 mm.), so that once in 20 times a single reading will be more than ¼ in. (6 mm.) out. Greater accuracy could be achieved by taking the average of several independent readings.

Conclusion

The overall degree of accuracy of the measurement of leg lengths is such that differences of ½ in. (12.5 mm.) or more may be accepted as diagnostically significant, but differences of less than ½ in. are not reliable unless based on the average of at least four measurements.

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REFERENCE

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TREATMENT OF SEVERE SHOCK BY NORADRENALINE

REPORT OF FOUR CASES

BY

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L-Noradrenaline bitartrate ("levophed") is a powerful peripheral vasoconstrictor drug which produces a rise in both systolic and diastolic pressures (Swan, 1949). The clinical indications for its use include the treatment of hypotensive circulatory states due to a lowering of the peripheral resistance (Churchill-Davidson, 1951). In the following four cases the intravenous infusion of L-noradrenaline caused a dramatic sustained rise in blood pressure and appeared to be a major factor in the recovery from seemingly irreversible shock.

Case 1

A man aged 57 had a partial gastrectomy for duodenal ulcer performed by Mr. J. W. M. Sutherland in May, 1950. He was well until 4 a.m. on February 12, 1953, when he suddenly developed a severe haematemesis and was admitted to hospital. He was transfused with 7 pints (4 litres) of blood, and the blood pressure rose satisfactorily to 120/70. In the evening he collapsed again, and the blood pressure fell to 70/40. Surgical intervention seemed imperative, and at operation an hour later a stomal ulcer was found at the site of anastomosis and a second higher gastrectomy done. The operation lasted two and a half hours and 4 pints (2.3 litres) of blood was given intravenously. Forty minutes after operation the blood pressure was 60/40, and the patient was severely shocked. Methylamphetamine hydrochloride (15 mg. intravenously, 15 mg. intramuscularly) had no effect.

Half an hour later, in a last attempt to raise the blood pressure, intravenous noradrenaline was started, 4 ml. in 1,000 ml. of glucose-saline. At a rate of 20 drops a minute the blood pressure rose to 100/50 within a few minutes. The drip rate was increased to a maximum of 40 drops a minute within the next half-hour and the blood pressure rose steadily to 130/70. Thereafter ten-minute blood-pressure readings were taken and the drip rate was adjusted to keep the systolic pressure at 130. For an hour the rate varied between 20 and 30, and then gradual "weaning" from the drip was begun until it was finally stopped six hours after its commencement. Slow but steady improvement followed, but on the seventh post-operative day a phlebothrombosis developed in the right leg. Anticoagulants were given and the swelling subsided, but unfortunately on March 14 he developed sudden pain in the chest and died in two hours. Post-mortem examination revealed a large pulmonary embolus.

Comment.—Initial shock due to haemorrhage aggravated by operation.

Case 2

A man of 78 was admitted to hospital on October 26, 1954, with acute retention of urine. On examination he was fit and active for his age. The tongue was clean, and the heart and lungs were clinically normal. The blood pressure was 166/96. The bladder was distended to 2 in. (5 cm.) below the umbilicus. Rectal examination revealed an adenomatous enlargement of the prostate.

A self-retaining Foley catheter was inserted and the patient underwent a retropubic prostatectomy the following morning. The operation was without incident and lasted fifty minutes. Approximately 10 oz. (285 ml.) of blood was lost. The blood pressure at the conclusion was 140/80.

Two hours after operation bladder lavage was carried out and some clots were removed. The pulse rate was 86 and the blood pressure 136/78. Two hours later there was a marked deterioration. The patient was pale and sweating, pulse rate 120, blood pressure 80/60. A pint (570 ml.) of blood was given rapidly intravenously. Since there was no significant improvement a second pint was given intra-arterially. Preoccupied by the resuscitative measures, it was not noticed until after the intra-arterial transfusion that the bladder was distended and not draining. Manipulation of the catheter soon produced about 20 oz. (570 ml.) of heavily blood-stained fluid. Following the transfusions and release of tension in the bladder there was a moderate improvement. At 7 p.m. the blood pressure was 130/70 and the pulse rate 100. During the evening there was persistent blood-stained soakage from the wound followed by a further deterioration in the general condition.

A third pint of blood was started intravenously, and at 11 p.m. the wound was reopened under general anaesthesia. There was some venous oozing from the prostatic veins, which was controlled by a pack. At the end of the operation the blood pressure was only 60/40 and the patient seemed unlikely to survive. A noradrenaline drip, 4 ml. in 1,000 ml. of glucose-saline, was started. Within ten minutes, at a drip rate of 30 drops a minute, the blood pressure rose to 110/80 and was maintained at over 100 systolic by a drip rate varying between 20 and 25 a minute. Blood pressure readings were taken at 10-minute intervals throughout the night. At 10.30 a.m. the drip was stopped. Within five minutes the blood pressure fell to 70/40. Five minutes