Observations on Changes in the Blood Pressure and Blood Volume following Operations in Man. (Preliminary Communication.)

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The cases here investigated were wounded men undergoing operations, and repeated examinations were usually made. Most of the cases showed only slight symptoms of shock.

Methods.—The systolic and diastolic blood pressures were measured before, during, and after operations, a Riva Rocci apparatus being used. The auscultatory method recommended by Oliver was used to determine the two levels. The hæmoglobin was estimated also, as far as possible, at the same time. The actual level of the hæmoglobin value was read by Haldane's method, while the changes in any patient were determined by comparison of the different samples in a Du Borscq colourimeter. For this purpose suspensions of the corpuscles in a dilution of 1 in 200 in saline were used, the volume chosen being 10 c.c., and these samples were hæmolysed with saponin before being read in the colourimeter. For this method I am indebted to Prof. Dreyer, and it has proved more accurate than any other. The blood has been taken always from either the ear or the finger. In estimating the blood volume changes from these readings, it has been assumed that the blood volume varies inversely as the hæmoglobin percentage. During and after operations this will be only relatively true, since hæmorrhage occurs. The amount of blood lost may, however, be roughly estimated by the loss of hæmoglobin in the first 24 hours after operation. In cases of slight shock, equilibrium will probably have been reached in this time. That this is true is indicated by the results obtained and put forward in Case I. In this patient a fair amount of blood was lost during the process of decompression for a fractured skull, and nearly all the blood lost was washed into buckets by a stream of saline running over the wound. The saline in these buckets was collected after the operation and the hæmoglobin content was determined by reading the contents in the Du Borscq colourimeter against a sample of the patient's own blood, taken before operation. In this way it was calculated that he lost 782 c.c. of blood. By the determination of the change in the hæmoglobin value in 24 hours, it was estimated that he lost 17·7 per cent. of his blood volume, and this was reckoned (taking Dreyer's formula for blood volume) to correspond to a loss of 760 c.c. The agreement was therefore remarkable, and it is probable that the methods are moderately accurate. In

all the Tables the calculations of blood volume are made neglecting this factor of hæmorrhage. At the bottom of the Tables the estimated blood lost is given, and in the last column of the Tables corrected values for the blood volume are given in which the hæmorrhage has been approximately allowed for. The results obtained seemed to indicate that the changes in the hæmoglobin percentage of capillary blood do demonstrate the changes seen in the blood volume, provided that the lag due to a slow circulation and partial stasis is allowed for, the hæmoglobin changes following those in the blood pressure.

The results obtained are, briefly, that during the early stages of an operation the pulse rate, systolic, and pulse pressures are all raised, while the diastolic pressure is also usually slightly raised, and at this time the hæmoglobin percentage is slightly reduced, that is to say, the blood volume is probably increased. In the later stages of an operation, or in the post-operative stage, the blood-pressures all fall; the pulse rate may remain fairly fast, and with the fall of blood pressure there is a blood concentration. Thus it is seen that in most cases the blood volume curve runs parallel with the blood pressure, except that it usually lags about half an hour behind the other curve, and when the circulation is sluggish, as in cases of shock, it may lag an hour or more (compare Cases II and III). None the less, the two curves usually show a marked similarity. The cases investigated, as a rule, have shown very slight blood concentration, since nitrous oxide and oxygen anæsthesia was used in all cases in which shock was feared, and with this form of anæsthesia little or no shock was experienced. The pulse in even desperate patients was often actually improved by the amputation of a leg. Any ill effects following operation in these cases with nitrous oxide seemed to be attributable to either loss of blood in the operation or exposure to cold.

In one case (Case III) which was resplinted with no loss of blood, but considerable exposure of both lower limbs, there was a considerable fall of temperature, and this was the only case that showed real blood concentration to any marked degree. This case was anæsthetised with pure chloroform.

Since the curves always showed such a marked similarity, the diurnal variations were investigated to determine if they showed a similar relationship. One chart of these (Case IV) is included, and it will be seen that the relationship still holds good except for a brief half-hour after meals. These diurnal variations cannot be discussed now; I am indebted to Prof. Dreyer, who first drew my attention to these marked diurnal variations in the hæmoglobin percentage, for permission to mention this. He first worked out these diurnal variations in the hæmoglobin percentage, and I only mention

them now in order that they may be compared with these post-operative changes.

Since, then, there appears to be this interdependence of the changes in the blood pressure and blood volume, it seemed necessary to explain it. An artificial schema was used in which a raised reservoir of water supplied the systolic pressure; a tap connected this with the artificial arterial system, this tap (representing the contraction of the heart) being opened at the rate of 30 to 40 times a minute by hand, the time being judged by a pendulum. The arterial system consisted of thin-walled rubber tubing, ending in a resistance created by capillary glass tubes, which could be changed. The water flowing through was collected and measured. It was found that the output per minute (MV) was proportional to the product of the pulse rate and pulse pressure.

$$MV \propto PR \times PP.$$

It was also found that the resistance (R) of the artificial schema arteriole was indicated by the following formula:—

$$R \propto \frac{MP}{(PR \times PP)^2},$$

where MP is the mean pressure and a high figure for R indicates a high resistance—but the proportion is not an arithmetical one. By the use of this formula it was easy to recognise, by the examination of the record, which of a series of capillary tube resistances had been used. Fig. A gives some examples of records obtained. In applying this formula, however, to blood pressure changes it did not appear to give reasonable results in cases where there were big changes of blood pressure.

However, on examination of the average pulse pressures found in man with different systolic pressures, as quoted for instance in Oliver's 'Studies in Blood Pressure,' it is found that the pulse pressure is a function of the square of the systolic pressure, if the blood circulation is otherwise normal. Thus, taking the figures from Oliver's book, a child of 15 has a systolic pressure of 107, and a pulse pressure of 33, a ratio of $PP/(SP)^2$ of 0·00288. On the other hand, an arterio-sclerotic with a blood pressure of 165 has a pulse pressure usually of 75, a ratio $PP/(SP)^2$ of 0·00275. The ratio is therefore remarkably constant. These results are charted in fig. B.

In considering the actual circulation, the viscosity of the blood must also be allowed for. Fig. C shows the probable changes in the viscosity of the blood for man with different percentages of hæmoglobin, this curve being

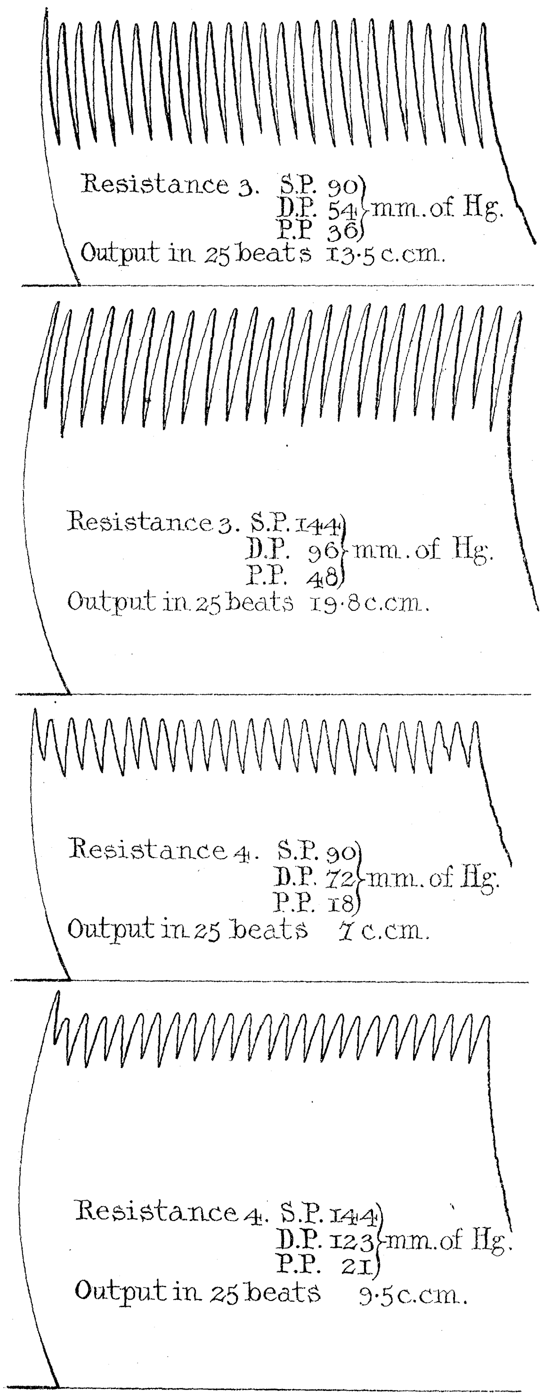

Resistance 3. S.P. 90
D.P. 54 mm. of Hg.
P.P 36
Output in 25 beats 13·5 c.cm.
Resistance 3. S.P. 144
D.P. 96 mm. of Hg.
P.P. 48
Output in 25 beats 19·8 c.cm.
Resistance 4. S.P. 90
D.P. 72 mm. of Hg.
P.P. 18
Output in 25 beats 7 c.cm.
Resistance 4. S.P. 144
D.P. 123 mm. of Hg.
P.P. 21
Output in 25 beats 9·5 c.cm.

Fig. A.

calculated from Arrhenius' formula for the viscosity of suspensions, and some actual figures for blood kindly supplied me by Prof. Bayliss.*

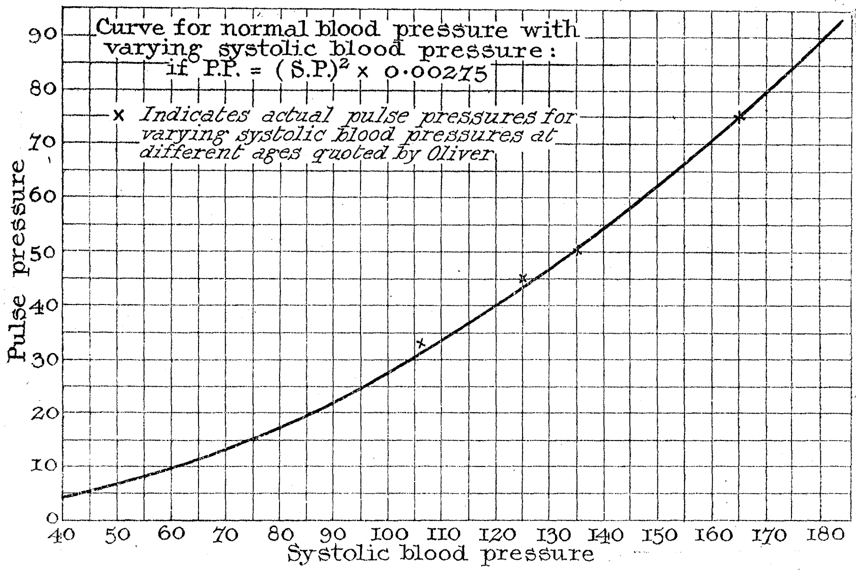


FIG. B.

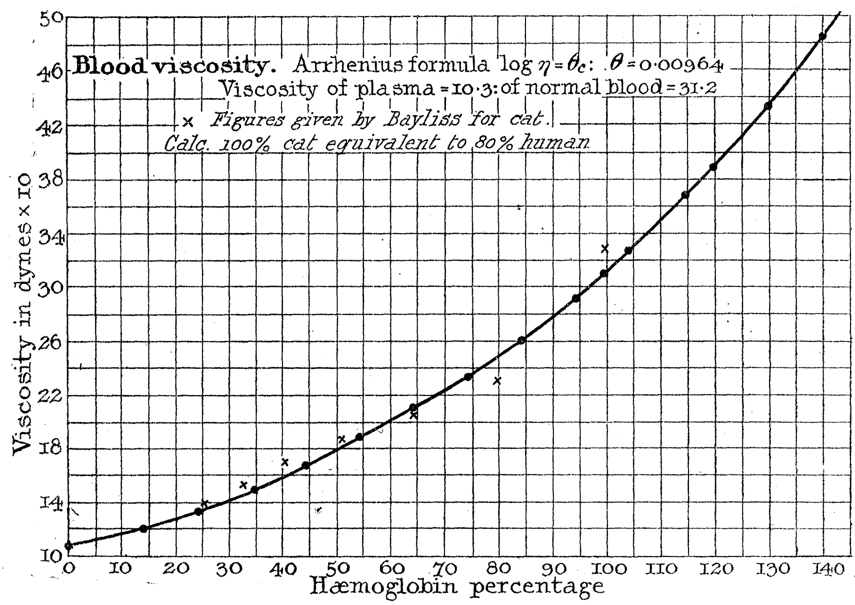


FIG. C.

* Since this was written Trevan has published figures on viscosity changes ('Bio-chemical Journal,' vol. 12, p. 60), and has employed a different formula. His curve lies at a higher level, but is very similar to that given here within the limits of the hæmoglobin values seen in these patients.

So that the output of the heart per minute (MV) may be taken as being proportional to $PP/(SP)^2 \times PR$ with a normal value of 0·225, while the average resistance of the arterioles is represented by the formula

$$A \propto \frac{MP}{\eta \times [PP/(SP)^2 \times PR]^2},$$

where A is the resistance in the arterioles (a high figure indicating an increased contraction), MP is the mean pressure, η is the viscosity of the blood in dynes/1000, and the other figures are as before. The normal figure for A is about 60.

As modified in this way the formula gives results which usually corresponds with the blood volume changes actually observed, an increased vasomotor tone as estimated by the blood pressure changes being followed by a blood concentration. The interrelationship of the blood pressure and hæmoglobin percentage curves can then be explained. It will also be seen that in the case of diurnal variations, or patients with only slight shock (see Cases II, III, and IV), the value of A may give a graph nearly parallel with the diastolic pressure changes. On the other hand, the relationship between the value of A and blood volume changes is not obvious in certain cases, especially in cases with nitrous oxide and oxygen anæsthesia, and in cases where the blood pressure falls to a very low level, where the changes cover a big range. Probably changes in venous tone are also of great importance, since venous contraction is often induced in septic patients under nitrous oxide and oxygen anæsthesia.* It is possible, too, that the curve for the value of pulse pressures does not hold good for very low pressures. With high blood pressures the elasticity of the arteries may depend largely on the fibrous and muscular coats, while with low pressures, the elasticity may resemble much more that of an elastic rubber tube. So that, while the formula seems to hold well for pressures above 100 mm., it is very possible that the pulse pressures should be divided by $(100)^2$ and not by the (systolic pressure)^2, whenever the systolic pressure is below 100 mm. of mercury. Also, with very rapid pulse rates, it may prove necessary to take into consideration the shortening of the duration of systole.

None the less the formula seems to hold good for most conditions. It demonstrates the fact that under circumstances such as exercise and excitement, the rise of systolic pressure is accompanied by an actual lowering of

* It would seem probable that changes in the blood volume may be associated with alterations in the capacity of the arterial system, when parallel changes will be seen in the blood pressure, or with alterations in the capacity of the veins, when the blood pressure is only indirectly affected.

the average vaso-motor tone, the increased heart output more than compensating for the vaso-dilatation, and so raising the systolic pressure. This agrees with the fact that during exercise the diastolic pressure may fall.

In the curves of diurnal variations the lag of the hæmoglobin changes in the capillary blood behind the blood pressure changes is very evident, and the hæmoglobin change is therefore probably secondary. On the other hand, the concentration seen in the capillary blood immediately after a meal occurs quickly, is transient, and has no parallel in the blood pressure changes; it is probably a local and temporary change due to a local constriction of the blood vessels. By reference to the Tables of Case IV it will be seen that an estimation of the hæmoglobin of venous blood immediately after a meal showed it to be almost 10 per cent. more dilute than the capillary blood, while the capillary blood itself showed this dilution a little later. So that all the figures seem explicable, if it be assumed that any change in the hæmoglobin percentage of the capillary blood, *unless it be a transient one,* indicates a corresponding change in the blood volume. In cases where the peripheral circulation is reduced to a low level (as in Case III), a considerable degree of stasis may result, and then the change in the capillary blood may lag far behind the general circulation changes.

One case of spinal anæsthesia (Case X) is included, and though an examination of the blood changes was not possible in this case, yet the changes observed are easily explicable when analysed by the formula—the stovaine inducing a fall of blood pressure through a partial vasomotor paralysis, and this being compensated for by an increased heart output until the resistance is raised by vaso-constriction in other parts. One case (Case XII) of pure traumatic shock uncomplicated by hæmorrhage or anæsthesia is also included for comparison. In this case collapse occurred with great dilution of the blood, and this is paralleled by a calculated great loss of vasomotor tone.

This formula is therefore put forward tentatively as of value in the analysis of the circulatory changes in most clinical conditions. It is not claimed that its truth is absolute, and it can probably be improved.

In conclusion, my thanks are due to Prof. Dreyer and Prof. Bayliss for much valuable advice, to Lt.-Col. Waring, D.S.O., for the facilities he gave me to carry on this research, and to Captain Wagstaffe, F.R.C.S., for assistance in many of the cases, and for access to all his patients.

Case I.—(Not Charted.) Table of Observations and Calculations.

Gnr. F——. Penetrating wound of head. Wound evening of 23.9.17. Anæsthetic, C.E. and $CHCl_3$. Trephined. Recovery.

Date.	Time.	Remarks.	P.R.	S.P.	D.P.	P.P.	M.P.	Hb.	Visc.	M.V.	A.	Bl. Vol.	B.V. (corr.).
24.9.17	6.15 P.M.	On admission	74	135	85	50	110	92	28·2	0·203	94·5	102	102
25.9.17	2.50 P.M.	—	86	122	80	42	101	94	29	0·242	59·3	100	102
	3.5	Anæsthetised											
	3.15	Shaving	72	122	85	37	103	—	—	0·179	111		
	3.28	Shaving	—	—	—	—	—	94·5	29·2	—	—	99·5	99·5
	3.30	Operation started											
	4.7	Operation finished	—	—	—	—	—	91	28	—	—	103	85
	4.20	Rectal saline ʘi											
	4.55	In ward	120	106	70	36	86	87·7	27	0·385	26·5	107·3	92
	7.0	—	120	104	77	27	90	86·5	26·5	0·300	43·7	115·5	91
26.9.17	3 P.M.	—	100	127	86	41	106	77·3	24·3	0·255	67·1	100	100

Blood lost collected in buckets, with saline used, estimated as 782 c.c. Blood lost = 17·7 per cent. of blood volume = 760 c.c.

Case II.—Table of Observations and Calculations.

Pte. H——. Excision of knee joint. C.E. Open ether. (Shipway.) Recovery.

Date.	Time.	Remarks.	P.R.	S.P.	D.P.	P.P.	M.P.	Hb.	Visc.	M.V.	A.	Bl. Vol.	B.V. (corr.).
21.6.17	1.0 P.M.	Excited	116	145	85	60	115	64	21	0·331	57·5	—	100
	1.5	Quieter	116	138	90	48	112	64	21	0·293	72·5	—	100
		Scopolamine Morphine Atropine injection.											
	2.15	Theatre	104	140	85	55	113·5	63·5	20·9	0·292	71·8	100	100
	2.27	Anæsthetised	120	152	95	57	123·5	—	—	0·296	77		
	2.35	Operating	128	155	92	63	123·5	—	—	0·331	63·6		
	2.37	Sawing bone	128	155	90	65	122·5	61·8	20·3	0·346	56·8	101·7	98
	2.44	Stitching	132	142	78	64	110	57·2	19·5	0·418	36	110·6	100
	2.50	Dressing wound	140	145	92	53	118·5	—	—	0·353	54·4		
	3.0	Leaving theatre	136	140	85	55	112·5	61·4	20·3	0·378	44	103·2	93
	4.0	Ward	108	128	80	48	104	60·6	20	0·315	58·9	104·7	95
	5.45	Ward	100	128	80	48	104	65·3	21·2	0·292	65·9	97	87
	7.20	Ward	100	128	85	43	106·5	67·8	22	0·262	81·2	93	83
22.6.17	12.45 P.M.	—	112	135	90	45	112·5	56	19·1	0·276	86	100	100

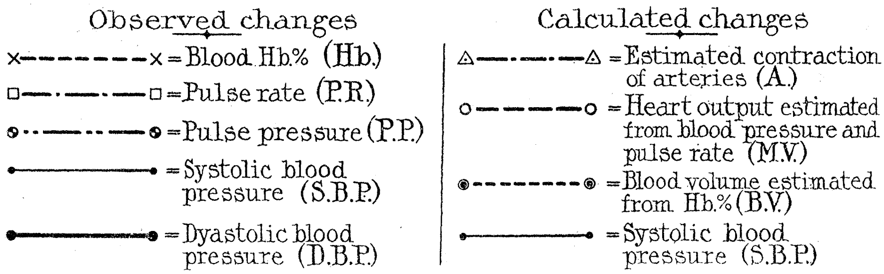
Blood lost = 12·5 per cent. of blood volume = about 480 c.c.

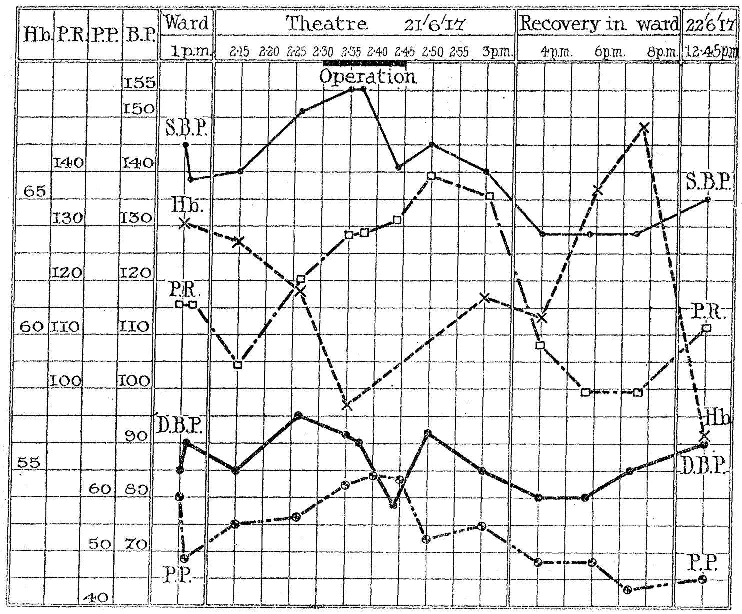
Case III.—Table of Observations and Calculations. (See Charts.) Effects due probably chiefly to cold.

Pte. B——. $CHCl_3$. Resplinting. Exposure to cold. Recovery.

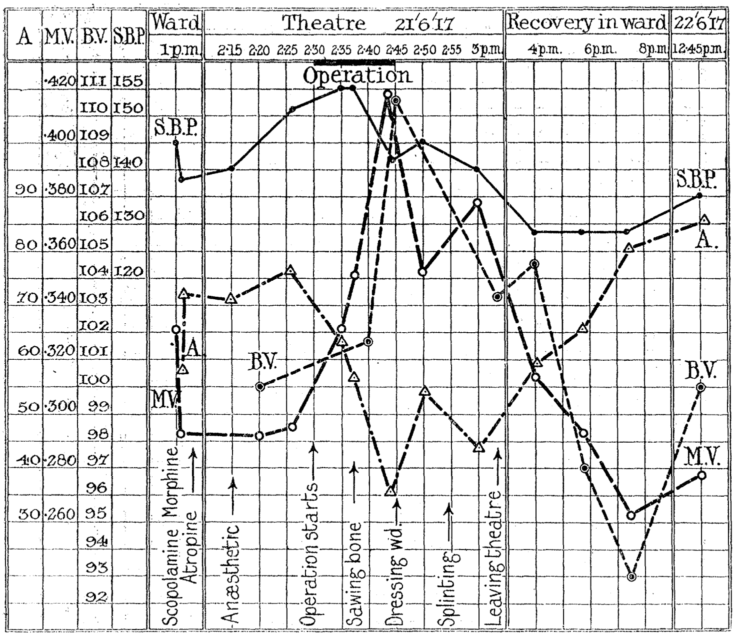
Date.	Time.	Remarks.	P.R.	S.P.	D.P.	P.P.	M.P.	Hb.	Visc.	M.V.	A.	Bl. Vol.	B.V. (corr.).
23.10.17	12.0	Ward	96	133	88	45	110	82	25·1	0·244	73·7	100	100
24.10.	1.10 P.M.	Ward (excited)	96	130	70	60	100	84	26·1	0·341	32·9	100	100
	1.55	Theatre	96	126	72	54	99	83·2	26	0·336	33·7	100·7	100·7
	2.25	Anæsthetised	80	112	76	36	94	84	26·1	0·229	63·7	99·9	99·9
	3.50	Back in ward	60	110	76	34	93	86·5	26·5	0·169	128·0	95·8	95·8
	5.25	Shivering	80	118	76	42	97	101·7	31·5	0·241	53·0	82·3	82·3
	7.20	Subnormal temperature	90	126	76	50	101	99·3	31	0·284	40·3	84·3	84·3
25.10.	11.40 A.M.	Comfortable	90	128	82	46	105	84	26·1	0·253	62·8	100	100

Blood lost—nil.

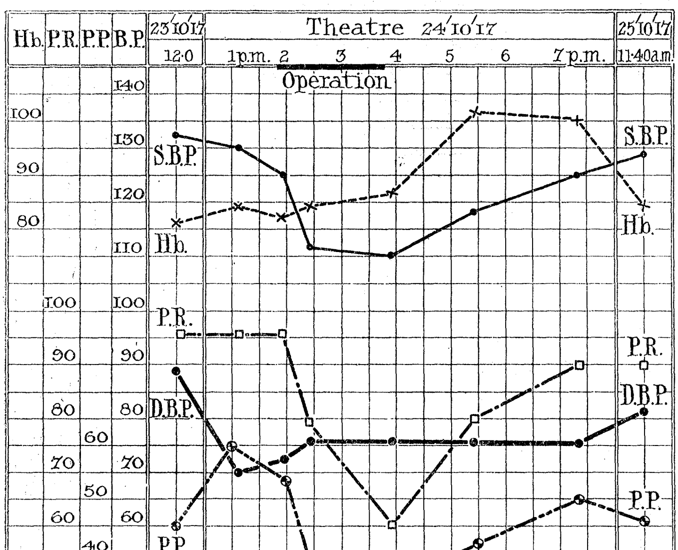

Observed changes
= Blood Hb.% (Hb.)
= Pulse rate (P.R.)
= Pulse pressure (P.P.)
= Systolic blood pressure (S.B.P.)
= Dyastolic blood pressure (D.B.P.)
Calculated changes
= Estimated contraction of arteries (A.)
= Heart output estimated from blood pressure and pulse rate (M.V.)
= Blood volume estimated from Hb.% (B.V.)
= Systolic blood pressure (S.B.P.)


Hb. P.R. P.P. B.P.
Ward
1 p.m.
Theatre 21/6/17
2·15 2·20 2·25 2·30 2·35 2·40 2·45 2·50 2·55 3 p.m.
Recovery in ward
4 p.m. 6 p.m. 8 p.m.
22/6/17
12·45 p.m.
Operation
155
150
140
130
120
110
100
90
80
70
65
60
55
60
50
40
S.B.P.
Hb.
P.R.
D.B.P.
P.P.

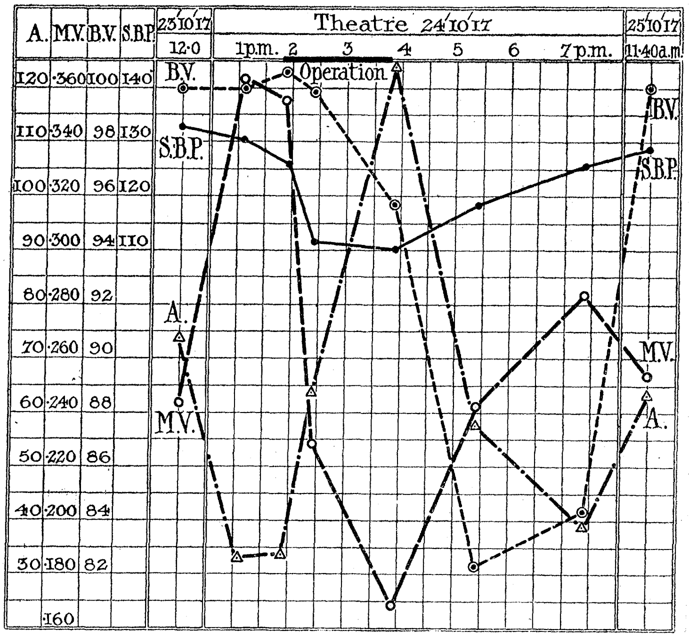
CASE II.



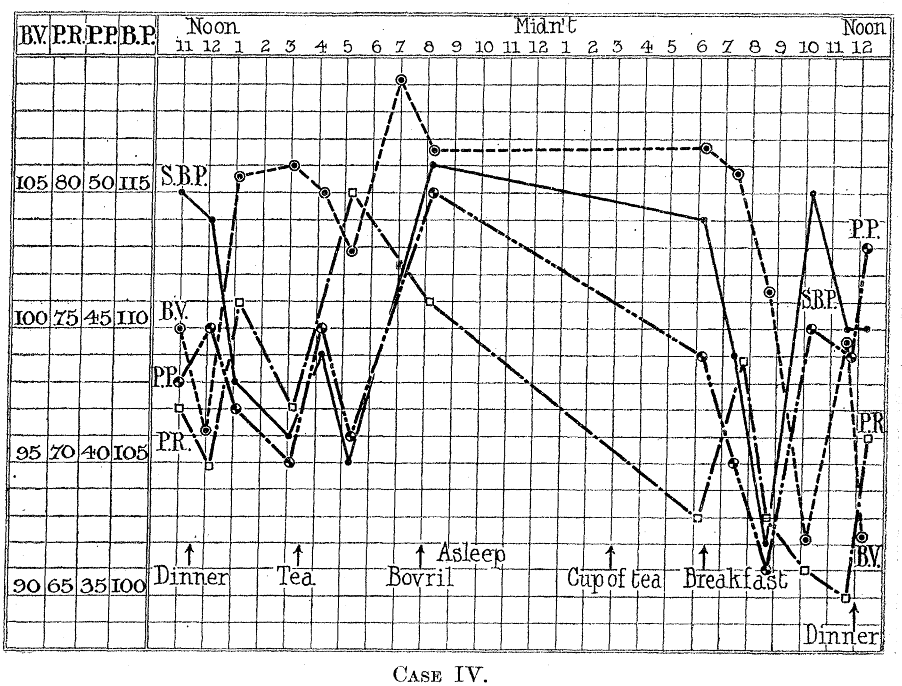
Case II (*continued*).



Case III.



Case III (*continued*).

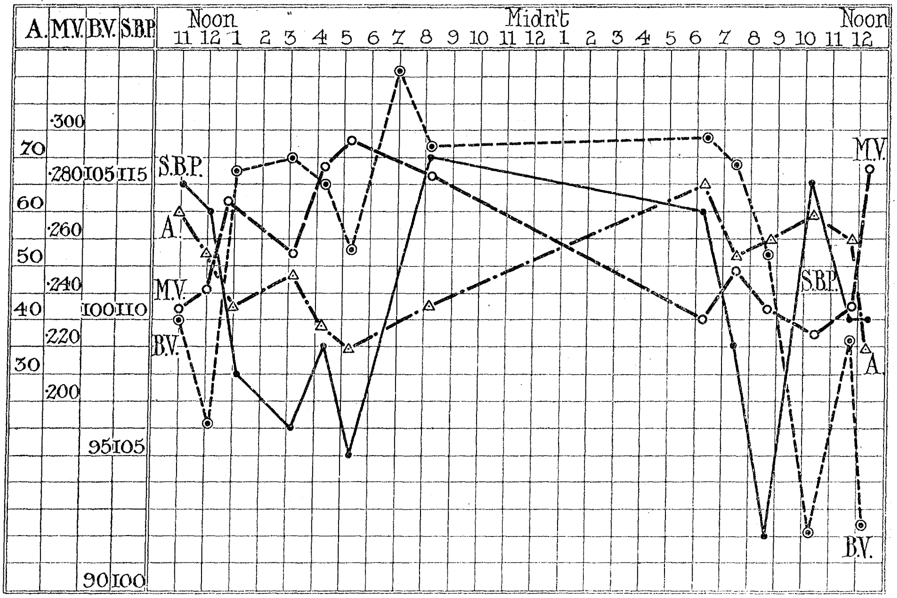


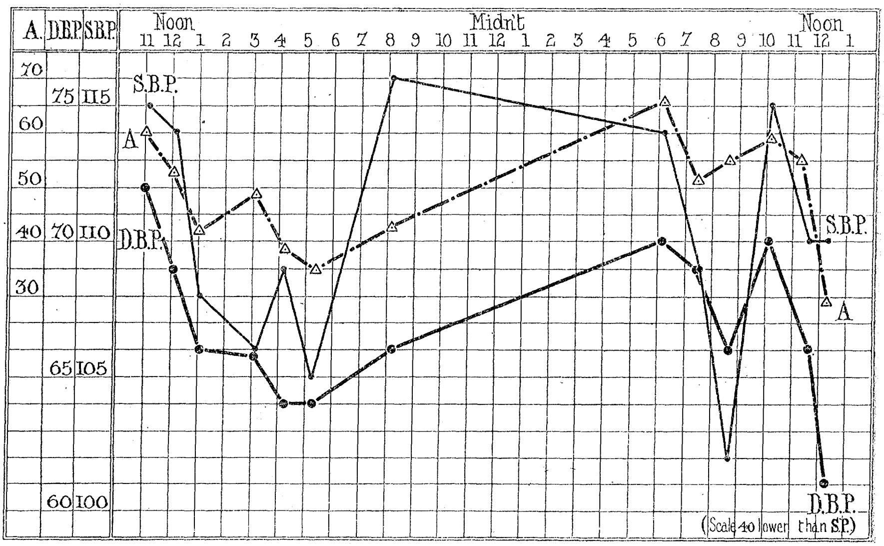
Case IV.

Case IV.—Table of Observations and Calculations.

Pte S——. G.S.W. Abdomen. Apyrexial. Diurnal Variations at Rest in Bed. Meals early. "Summer" time 20.7.17–21.7.17.

Date.	Real time.	Remarks.	P.R.	S.P.	D.P.	P.P.	M.P.	Hb.	Visc.	M.V.	A.	Bl. Vol.
20.7.17	11.5 A.M.		72	115	72	43	93 ·5	92 ·5	28 ·5	0 ·234	59 ·8	100
	11.30	*Dinner*										
	12.5 P.M.	—	70	114	69	45	91 ·5	96 ·2	29 ·6	0 ·242	52 ·8	96 ·1
	1.5	—	76	108	66	42	87	87 ·8	27 ·5	0 ·273	42 4	105 ·6
	3.5	—	72	106	66	40	86	87 ·2	27 ·1	0 ·256	48 ·4	106
	3.30	*Tea, etc.*										
	4.15	—	76	109	64	45	86 ·5	88	27 ·5	0 ·287	38 ·2	105
	5.20	—	80	105	64	41	84 ·5	90	27 ·8	0 ·297	34 ·4	102 ·7
	7.0	—	—	—	—	—	—	84 ·7	26 ·1	—	—	109 ·2
	8.15	*Bovril*	76	116	66	50	91	86 ·8	26 ·5	0 ·283	42 ·8	106 ·5
		Asleep										
21.7.17	3.0 A.M.	*Tea*										
	6.15	—	68	114	70	44	92	86 ·6	26 ·5	0 ·230	65 ·5	106 ·7
	6.20	*Breakfast*										
	7.30	—	74	109	69	40	89	88 ·5	27 ·6	0 ·249	52 ·0	105 ·8
	8.40	—	68	102	66	36	84	90 ·2	27 ·8	0 ·235	54 ·7	102 ·4
	10.15	—	66	115	70	45	92 ·5	100 ·5	31 ·4	0 ·224	48 ·7	92 ·1
	11.40	—	65	110	66	44	88	93	28 ·7	0 ·236	55	99 ·3
	11.45	*Dinner*										
	12.10 P.M.	*Blood from vein*	—	—	—	—	—	91 ·5	28 ·3			
	12.15	—	72	110	62	48	86	100 ·2	31 ·3	0 ·286	33 ·6	92 ·3





CASE IV (*continued*).

Case V.—Table of Observations and Calculations.

Pte. O——. G.S.W. Compound fracture neck of femur. Very septic. Vomiting, etc. Wound enlarged on fourth day. Gas infection probably. Died five days later of septicæmia c̄ jaundice.

Date.	Time.	Remarks.	P.R.	S.P.	D.P.	P.P.	M.P.	Hb.	Visc.	M.V.	A.	Bl. Vol.
	11.20 A.M.	Ward	128	102	75	27	88·5	70	22·5	0·332	25·7	100
	12.15 P.M.	$CHCl_3$										
	12.20	—	—	—	—	—	—	61·5	20·3	—	—	113·8
	12.35	Operation finished. Fixing splint	—	—	—	—	—	61	20·2	—	—	114·5
	12.40	Operation finished completely	—	—	—	—	—	63	20·5	—	—	111
	12.45	—	160	105	85	20	95	—	—	0·29	55·0	
	12.50	Alkaline saline infusion (hypertonic) ⊙i in 10 min. intravenously.										
	1.0 P.M.	—	—	110	85	25	97·5	—	—	? 0·32	49	
	1.5	Leaving theatre	—	—	—	—	—	57·5	19·5	—	—	121·8
	2.0	In ward	180	85	66	19	75·5	—	—	0·475	16·4	
	2.20	Rectal saline pituitrin	168	—	—	—	—	62	20·4	—	—	112·5
	3.30	Intravenous saline ⊙i										
	4.30	Sweating										
	6.15	—	132	—	—	—	—	62·5	20·4	—	—	111·5

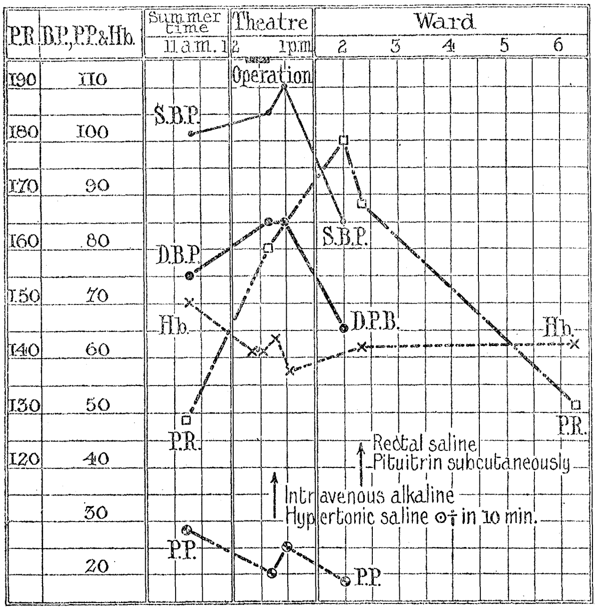
Blood lost very little, but not determined.

Case VI.—Effects probably due chiefly Hæmorrhage. Table of Observations (see Chart) and Calculations.

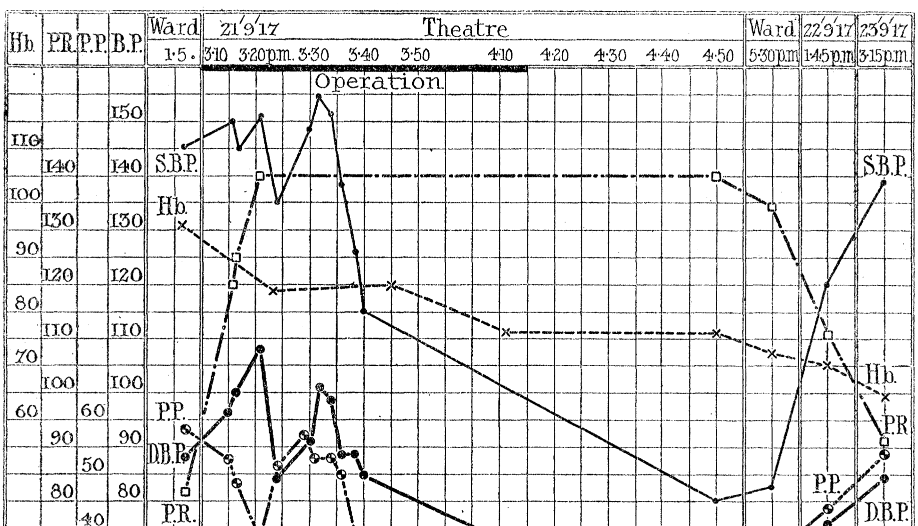
Pte. S——. G.S.W. Head. Penetrating. Hæmorrhage from middle meningeal artery and other wounds. C.E. and pure $CHCl_3$. Trephined, 21.9.17. Recovery.

Date.	Time.	Remarks.	P.R.	S.P.	D.P.	P.P.	M.P.	Hb.	Visc.	M.V.	A.	Bl. Vol.	B.V. (corr.).
20.9.17	1.25 P.M.	On admission	58	140	85	55	112	100	31·2	0·163	135	100	96·5
	2.45	Ward. Restless	58	142	85	57	113	—	—	0·164	135		
	7.15	Ward	52	146	78	68	112	100	31·2	0·166	130	100	96·5
21.9.17	1.5 P.M.	Ward	82	146	88	58	117	96·5	29·7	0·224	78·5	100	100
	3.16	Anæsthetic, 3.10	120	150	97	53	123	—	—	0·283	51·7		
	3.17	—	130	145	99	48	123	—	—	0·297	48		
	3.21	Shaving	140	146	108	38	127	—	—	0·249	69		
	3.24	—	125	135	84	51	110	—	—	0·350	30·3		
	3.30	—	128	148	92	56	120	84	26·0	0·327	43·2	115	115
	3.32	Incision	124	155	102	53	128	—	—	0·274	65·6		
	3·34	Incision	115	152	99	53	125	—	—	0·264	68·9		
	3.36	—	140	138	88	50	113	—	—	0·367	32·3		
	3.38	—	—	126	88	38	107						
	3.40	Clipping bone	—	115	85	30	100						
	3.45	First flap replaced	—	—	—	—	—	85	26·2	—	—	113·5	103
	4.12	Stitching second wound	—	—	—	—	—	75·5	23·6	—	—	128	95
	4.50	Rectal saline, 4.18	140	80	54	26	67	75·6	23·6	0·570	8·75	127·5	94·5
	5.30	—	134	82	64	18	73	72·5	—	0·358	24·2	133	97·5
22.9.17	1.45 P.M.	—	112	120	76	44	98	70	22·7	0·342	36·9	? 100	? 100
23.9.17	3.15	Sl. sepsis	92	138	84	54	111	64	21·0	0·261	77·5	? 100	? 100

N.B.—Considerable loss of blood with rapid replacement of fluid lost. Blood lost = 27·5 per cent. of blood volume or more = 1230 c.c.



CASE V.



CASE VI.

Case VII.—Table of Observed Changes and Calculations.

Sgt. D——. G.S.W. Multiple penetrating wound of knee. Amputation of leg through thigh. N_2O and O_2. Reactionary hæmorrhage. Death from sepsis a week later. Times in summer time.

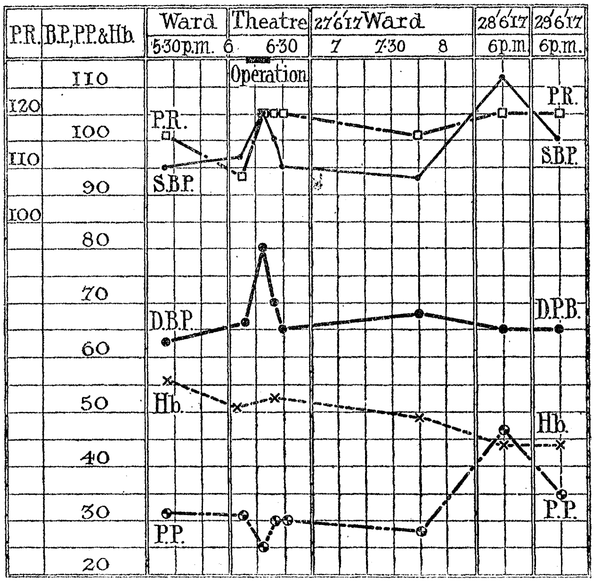
Date.	Time.	Remarks.	P.R.	S.P.	D.P.	P.P.	M.P.	Hb.	Visc.	M.V.	A.	Bl. Vol.	B.V. (corr.).
27.6.17	5.25 P.M.	Ward	116	95	63	32	79	56	19	0·412	24·6	100	100
	6.7	In theatre	108	97	66	31	81·5	—	—	0·356	25·7	—	—
	6.10	In theatre	—	—	—	—	—	51	18	—	—	109·9	109·9
	6.11	Anæsthetic											
	6.20	Operation ending	120	105	80	25	93	—	—	0·272	68	—	—
	6.25	Dressing wound	—	—	—	—	—	53	18·5	—	—	105·2	96
	6.27	—"	120	100	70	30	85	—	—	0·360	35·5	—	—
	6.30	Leaving theatre	120	95	65	30	80	—	—	0·399	27·2	—	—
	7.45	Ward. Bleeding	116	93	68	27	81·5	49	17·8	0·362	35	114·9	? 90
28.6.17	6 P.M.	Better	120	112	65	47	88·5	44	16·8	0·45	26	100	100
29.6.17	6 P.M.	Not so well	120	100	65	35	82·5	44	16·8	0·42	27·9	100	100

Case VIII.—Table of Observed Changes and Calculations.

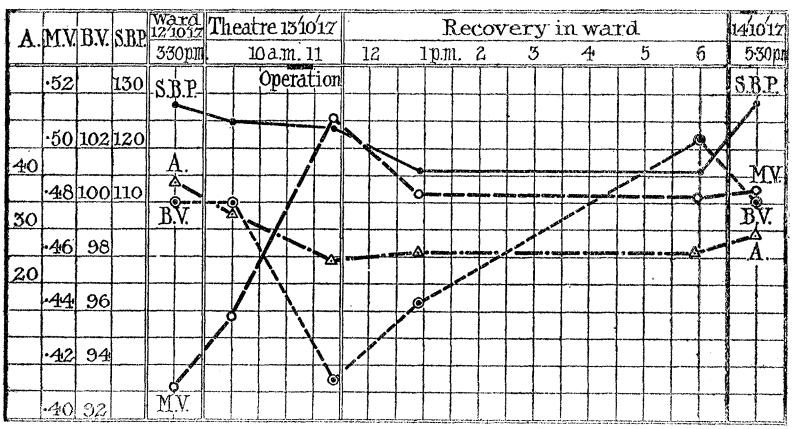
Pte. H——. Amputation through thigh. N_2O and O_2. Recovery.

Date.	Time.	Remarks.	P.R.	S.P.	D.P.	P.P.	M.P.	Hb.	Visc.	M.V.	A.	Bl. Vol.	B.V. (corr.).
12.10.17	3.30 P.M.	Ward	116	128	70	58	99	36	15·2	0·412	38·5	100	100
13.10.17	9.30 A.M.	Ward	116	125	66	59	96	33	14·7	0·438	33·9	100	100
	10.30	Operation (25 mins.)											
	11.20	Ward	140	124	68	56	96	35·3	15·1	0·510	24·5	93·5	82
	12.55 P.M.	Ward	136	116	68	48	92	34	15·0	0·484	26·3	96·3	85
	6.0	Ward	130	116	66	50	91	32·5	14·6	0·483	26·7	101·3	91
14.10.17	5.30 P.M.	—	128	128	66	62	97	29	14·0	0·484	29·6	100	100

Some symptoms of shock. Extremely septic; operation slow and moderate hæmorrhage. Blood lost 12·1 per cent. of blood volume = about 545 c.c.



CASE VII.



CASE VIII.

Case IX.—Table of Observations and Calculations (not charted).

Pte. J——. G.S.W. Compound fracture of femur involving hip joint. N_2O and O_2. Incised drained. Recovery.

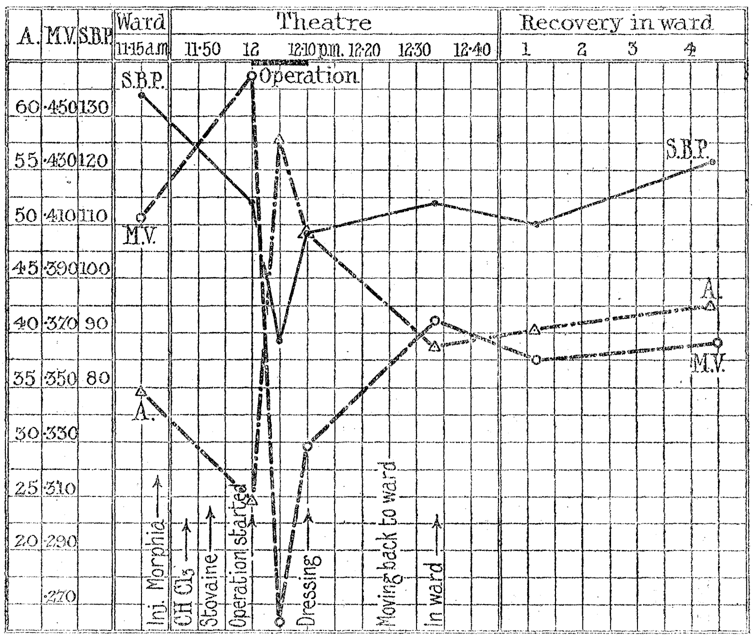
Date.	Time.	Remarks.	P.R.	S.P.	D.P.	P.P.	M.P.	Hb.	Visc.	M.V.	A.	Bl. Vol.	B.V. (corr.).
11.10.17	11.45 A.M.	Ward	128	138	100	38	119	80	25	0·256	72·6	100	100
	12.30 P.M.	Operation											
	1.30	Ward	112	138	94	44	116	83	25·5	0·259	67·8	96	88·5
	6.0	—	108	146	92	54	119	88	27·3	0·274	58·2	91	83·5
12.10.17	3.15 P.M.	—	92	130	86	44	108	74	23·5	0·239	80·5	100	100

Blood lost 7·5 per cent. of blood volume = about 350 c.c. Veins very engorged before operation; this disappeared after operation.

Case X.—Table of Observed Changes and Calculations.

Pte. F——. Amputation through thigh under spinal anæsthesia. Stovaine 0·6 grm. after a few minutes $CHCl_3$. Recovery. January, 1918.

Date.	Time.	Remarks.	P.R.	S.P.	D.P.	P.P.	M.P.	Hb.	Visc.	M.V.	A.	Bl. Vol.
1.0.18	11.15 A.M.	Ward	128	134	76	58	105	? 60	17·7 to 20	0·413	34·9	?
	11.52	Stovaine										
	12.0	Skin incision	138	114	70	44	92	?	?	0·467	24·9	?
	12.5 P.M.	—	116	88	54	34	71	?	?	0·264	57·7	?
	12.10	Dressing	128	108	78	30	93	—	—	0·329	48·2	?
	12.33	In ward	128	114	76	38	95	?	?	0·375	38·2	?
	1.10	In ward	128	110	76	34	93	?	?	0·350	40·6	?
	4.25	In ward	124	122	78	44	100	?	?	0·367	42	?


A.
M.V.
S.B.P.
Ward
11·15 a.m.
Theatre
11·50
12
12·10 p.m.
12·20
12·30
12·40
Recovery in ward
1
2
3
4
Operation
S.B.P.
M.V.
A.
60 ·450 130
55 ·430 120
50 ·410 110
45 ·390 100
40 ·370 90
35 ·350 80
30 ·330
25 ·310
20 ·290
·270
Inj. Morphia
CH Cl3
Stovaine
Operation started
Dressing
Moving back to ward
In ward

CASE X.

Case XI.—Effect on Recipient of Blood Transfusion of about 600 c.c.

L.-Cpl. P——. Blood Transfusion.

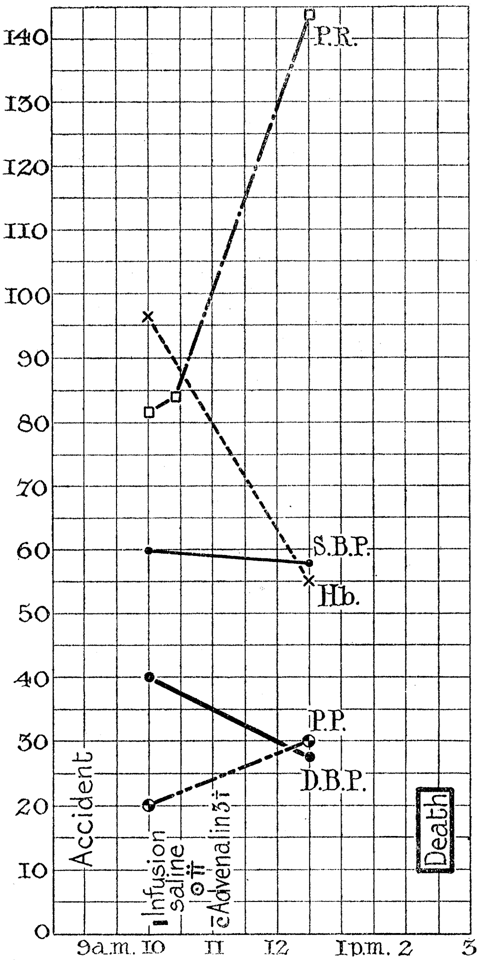
Date.	Time.	Remarks.	P.R.	S.P.	D.P.	P.P.	M.P.	Hb.	Visc.	M.V.	A.	Bl. Vol.
16.6.17	6.45 P.M.	Before transfusion	120	115	70	45	93	24	13·4	0·408	41·7	100
	7.55	After transfusion	108	128	58	60	98	33	14·5	0·396	43·2	115
17.6.17	6.15 P.M.	Very fit	104	128	75	53	102	38	15·5	0·337	57·8	100

Case XII.—Table of Observed Changes and Calculations.

Pte. W——. Railway accident. One leg torn off in thigh. Other foot and one arm crushed. No exposure to cold. No improvement with warmth.

Date.	Time.	Remarks.	P.R.	S.P.	D.P.	P.P.	M.P.	Hb.	Visc.	M.V.	A.	Bl. Vol.
	9.0 A.M.	Accident										
	10.0	In ward	89	60	40	20	50	97	30	0·444	8·4	? 100
	10.5	Intravenous saline ⊙ii c̄. ʒi adrenalin.	Slight improvement only in pulse.									
	12.30 P.M.	—	144	58	28	20	43	55·5	19	1·29	1·4	175

Death at 2.30 P.M. Patient was extremely difficult to bleed from ear at 10 A.M., but bled easily at 12.30 P.M.


140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
P.R.
S.B.P.
Hb.
P.P.
D.B.P.
Accident
Infusion saline
Adrenalin
Death
9a.m. 10
11
12
1p.m. 2
3

CASE XII.